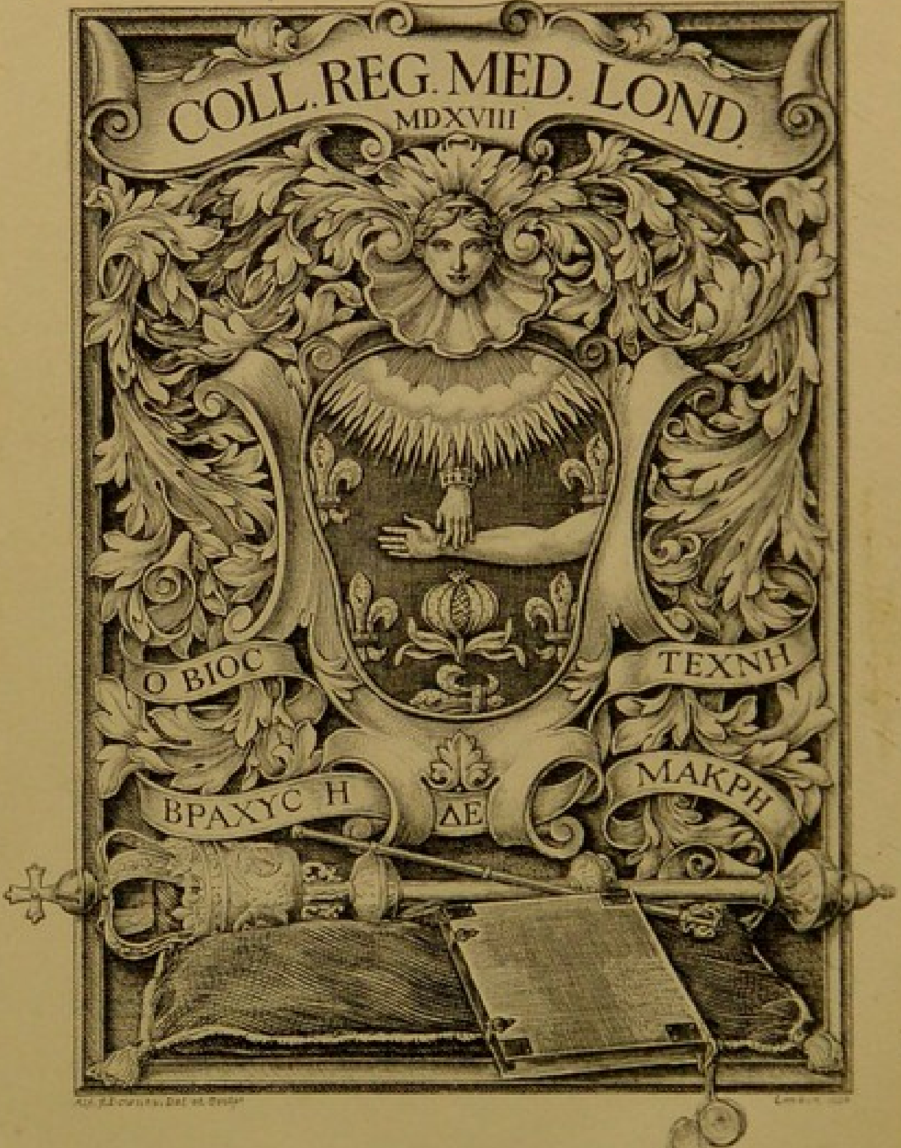
The chemical catechism : with notes, illustrations and experiments / by Samuel Parkes.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THE

CHEMICAL CATECHISM,

WITH

NOTES, ILLUSTRATIONS,

AND

EXPERIMENTS.

By SAMUEL PARKES, F.L.S. M.R.I. F.S.A.E.

MEMBER OF THE GEOLOGICAL SOCIETY OF LONDON, AND OF THE HIGHLAND AND HORTICULTURAL SOCIETIES OF SCOTLAND; HONORARY MEMBER OF THE ROYAL GEOLOGICAL SOCIETY OF CORNWALL; AND CORRESPONDING MEMBER OF THE LITERARY AND PHILOSOPHICAL SOCIETY OF MANCHESTER.

THE NINTH EDITION,

CAREFULLY CORRECTED AND ADAPTED TO THE
PRESENT STATE OF CHEMICAL SCIENCE.

LONDON:
PRINTED FOR BALDWIN, CRADOCK, AND JOY.

1819.

“ Chemical research conducts to the kno
forms the mind to philosophical enlargeme
happily than almost any other species of
intellect can be employed.”

“ Tout homme qui reçoit une éducatio
chimie parmi les objets les plus indispensab

Printed by R. and A. TAYLOR, Shoe-lane.

PREFACE.

THE following elementary treatise was undertaken many years ago for a private purpose, and without any view to publication. Finding, however, as I proceeded, that its catechetical form gave it a simplicity and plainness not usually found in works of this nature, I was led to think of the propriety of publishing it. In considering this subject, various motives presented themselves; and it very soon occurred to me, that it might be possible, and would be highly desirable, to render the promulgation of chemical science subservient to the cause of morality and religion.

To attain this end, I have endeavoured to exhibit, in a popular form, a body of incontrovertible evidence of the wisdom and beneficence of the Deity, in the establishment and modification of those chemical laws of matter which are infinitely and beautifully varied, but whose operation notwithstanding is too minute to be the object of general notice. For, I imagined if it could be proved that matter is subject to a vast variety of laws which escape common observance, and that, in the adjustment of those laws the utmost attention has been paid to our convenience and comfort,——such a detail would tend to make a more indelible impression on the young mind, than the display of the same goodness in the operation of causes which come under our daily notice and observation.

With these views it naturally occurred to me, that the work would be very incomplete, should I neglect to offer to the student some of those moral reflections which spontaneously arise in every contemplative mind, when considering the magnificent system of nature: and though such remarks may perhaps be regarded by some as irrelevant to chemical science; yet, to repeat the former apology, it may be observed that, in compiling any initiatory book, no writer, as a parent, could lose sight of the necessity of embracing every favourable opportunity of infusing such principles into the youthful mind, as might defend it against immorality, irreligion, and scepticism.

It may now also be remarked, that the catechetical form, which was first chosen for this work, has been found to possess at least all the advantages that any other mode of instructing youth in chemistry can claim, the work having been introduced with benefit into several of the most eminent seminaries in the kingdom; and that, if my original intention be followed, I have reason to believe the progressive improvement of the student will be pleasant, rapid, and correct.

I most assuredly never expected that the answers should be committed to memory *verbatim* by the pupil, nor, indeed, that the language of the questions should always be literally adhered to by the tutor; but merely that the whole should be clearly comprehended by the parent or tutor, which, with the assistance of the notes, is no difficult task, and then to allow the student to employ his *own language* to explain his ideas, and form the responses.

Several years have now elapsed since the first edition of the Chemical Catechism was published; and, from the constant and progressive improvement of the science of chemistry, each subsequent impression of the work has received many corrections and very considerable additions. During the last few years, however, so many new facts have been discovered, and the opinions of the most eminent chemists of every country so entirely changed respecting some of the more interesting branches of chemistry, that the very principles of the science have in several instances undergone a complete revolution.

Under such circumstances I felt it necessary to be prepared, whenever a new edition should be required, not only to revise every page of the work with the utmost attention, but also to make large additions of new matter to almost every chapter.

In the beginning of the last year this design was accordingly accomplished, and the changes and additions then made, were so numerous and considerable, that the greater portion of the 8th edition may be said to have been re-written.

It would be tedious and indeed useless to enumerate the whole of the alterations which the rapid progress of the science had rendered necessary; but I shall here mention a few of the most important, for the information of such persons as may not have seen the former editions of this work.

Regarding the arrangement of the metals lately proposed by M. Thenard as the most perspicuous and scientific of any I had hitherto seen, I determined to avail myself of the suggestions of that able chemist: in consequence of which I found it requisite to new-model the whole of the Tenth Chapter; especially as his classification is entirely different from that which I had previously adopted. All the new metals are now admitted; and the nature and properties of each, together with those of the whole class, have been so circumstantially described, that this part of the work has been unavoidably extended to nearly double its former limits.

All the characteristic properties of the Supporters of Combustion, the Simple Combustibles, and the Metals, as well as the Acids, Alkalies, Oxides, Earths, and Salts, which result from their mutual action upon each other, have likewise been carefully noted in the Text, under their respective heads; so that a person unacquainted with these subjects may now readily acquire a correct knowledge of the elements of chemical science, by reading only the catechetical part of the work, without attending to the Notes.

This incorporation of many of the former Notes with the Text of the last edition, while it has given more importance to that part of the work, at the same time afforded room for the introduction of those new and explanatory notes which recent discoveries and the reformed state of chemical knowledge necessarily required. In these notes, especially such as are subjoined to the respective chapters on the Earths, Acids, Salts, and Metals, a concise description of the principal minerals is given, with an account of their analysis, localities, &c.; and from the increasing taste of the public for geological pursuits, this new feature of the work will, I trust, meet with general approbation.

The chapter of ADDITIONAL NOTES has been also improved by the omission of those which the increasing knowledge of modern times had made of little value, or of doubtful authority; and others have since been introduced which the changing state of the science seemed to render absolutely indispensable.

A material revision has likewise been made of the chapter of EXPERIMENTS; and, in order to enable the student to consult this division of the work with more facility, all the experiments are now arranged under distinct heads.

Notwithstanding so great a proportion of the work was thus remodelled, so numerous have been the late discoveries in chemical science, that it was impossible to allow the present edition to pass through the press without a further revisal, and the addition of much new and important matter.

It would however be difficult to enumerate all the alterations which this impression has undergone, or to give a list of all the new matter which has been introduced: but the following may be mentioned as additions which are likely to interest the chemical inquirer; viz. the account of a new earthy substance discovered by Berzelius, called Thorina; the new alkali which has been found in the Petalite and some other minerals, called Lithia; and the four new metals which have been denominated Lithium, Thorinum, Cadmium, and Selenium. The last-mentioned of these substances is capable of forming an acid by union with oxygen; it is called Lithic acid, and may be exhibited in needle-formed crystals which are often a foot in length.

A particular account of all these new bodies will be found in the following sheets; and also a description of the apparatus for, and the method of obtaining the new gas which is now procured in abundance from common oil, and applied to the purpose of lighting dwelling-houses and other buildings.

I have only to add, that the Dictionary of Terms has been enlarged by the admission of many words not to be found in any other chemical vocabulary; and that in order to introduce so much fresh matter, without increasing the bulk or price of the volume, the page has been proportionately enlarged both in length and breadth. A new plate descriptive of a great variety of small chemical apparatus, has also been engraved purposely for this edition, to precede the chapter of amusing Experiments.

London, June 1st, 1819.

The Binder is requested to place this Slip immediately after the Preface to the NINTH EDITION *of the Chemical Catechism.*

At page viii of the Preface, line 10, for *Lithic* acid read *Selenic* acid.

A LIST

OF

THE WORKS

QUOTED IN THIS TREATISE*.

Academy.—Histoire et Mémoires de l'Académie Royale des Sciences depuis son Etablissement en 1666 jusqu'en 1790, 164 volumes in 4to. Par. 1701-1797

Academy.—Essays of Natural Experiments made in the Academie del Cimento, under the Protection of the most Serene Prince Leopold of Tuscany. Written in Italian by the Secretary of that Academy. Englished by Richard Waller, F.R.S. 4to. London 1684

Aikin.—A Manual of Mineralogy, by Arthur Aikin, late Secretary to the Geological Society. Second edition. London 1815

Allan.—Mineralogical Nomenclature, alphabetically arranged, with Synoptic Tables of the Chemical Analysis of Minerals. Second edition. Edinburgh 1814

Anderson.—An Account of the Present State of the Hebrides and Western Coasts of Scotland, &c. by James Anderson, LL.D. F.R.S. Scot., &c. 8vo. London 1785

————. Recreations in Agriculture, Natural History, Arts, and Miscellaneous Literature. By James Anderson, LL.D. F.R.S. and F.S.A. E. In six volumes, 8vo. Lond. 1799-1801

Annales de Chimie.—Annales de Chimie, ou Recueil de Mémoires concernant la Chimie et les Arts qui en dépendent. Par MM. De Morveau, Lavoisier, Monge, Berthollet, Fourcroy, &c. 99 volumes, 8vo. Paris 1789-1817

Apuleius.—Apuleius de Asino Aureo, edit. Scriverii, 24mo. Amst. 1624

Archer.—Miscellaneous Observations on Oxygen, &c. By Clement Archer, Esq. M.R.I.A. 8vo. London 1798

Ashmole.—Theatrum Chemicum Britannicum, containing several Poetical Pieces of our Famous English Philosophers, &c. Carefully collected into one volume, with Annotations thereon, by Elias Ashmole, Esq. with curious Engravings. 4to. London 1652

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* This list is given, because several readers of the Chemical Catechism had complained of being unable to find some of the passages to which they had been referred, in consequence of their not knowing what editions had been made use of.

Caledonian Horticultural Society.—Memoirs of the Caledonian Horticultural Society. 2 vols. 8vo. Edinburgh 1814-17

Cavallo.—A complete Treatise of Electricity in Theory and Practice, with original Experiments. By Tiberius Cavallo. 8vo. London 1777

————. A Treatise on Magnetism, in Theory and Practice, with original Experiments; by Tiberius Cavallo, F.R.S. &c. Illustrated with Copper-plates. The third edition, with a Supplement. 8vo. London 1800

————. Elements of Natural and Experimental Philosophy. By Tiberius Cavallo, F.R.S. &c. Illustrated with Copper-plates. 4 vols. 8vo. London 1803

Chaptal.—Chemistry applied to Arts and Manufactures. By M. I. A. Chaptal, Member and Treasurer of the French Senate, Member of the National Institute, &c. &c. Translated from the French. In 4 vols. 8vo. London 1807

Charmes.—The Art of Bleaching Piece-goods, Cottons, and Threads of every Description. Illustrated with 9 large plates in 4to. By Pajot des Charmes, Inspector of Manufactures, Member of the Lyceum of Arts, &c. Translated from the French. 8vo. London 1799

Chenevix.—Remarks on Chemical Nomenclature, according to the Principles of the French Neologists. By Richard Chenevix, Esq. F.R.S. M.R.I.A. &c. 12mo. London 1802

Clarke.—Travels in various Countries of Europe, Asia, and Africa. By Edward Daniel Clarke, LL.D. In 4 vols. 4to. London 1810-16

————. The Gas Blow-Pipe, or Art of Fusion, by burning the Gaseous Constituents of Water: giving the History of the Philosophical Apparatus so denominated; the Proofs of Analogy in its Operations to the Nature of Volcanoes; together with an Appendix containing an Account of Experiments with this Blow-Pipe. By Edward Daniel Clarke, LL.D. Professor of Mineralogy in the University of Cambridge, &c. 8vo. London 1819

Cotes.—Hydrostatical and Pneumatical Lectures. By Roger Cotes, A.M. late Professor of Astronomy and Experimental Philosophy at Cambridge. The second edition, by Robert Smith, D.D. Master of Trinity College, Cambridge. 8vo. Plates. Cambridge 1747

Cramer.—Elements of the Art of Assaying Metals. In two Parts; the first containing the Theory, the second the Practice, of the said Art. By John Andrew Cramer, M.D. Translated from the Latin. Illustrated with Copper-Plates. To which are added Notes and Observations not in the Original. 8vo. London 1741

Crawford.—Experiments and Observations on Animal Heat, and the Inflammation of Combustible Bodies. By Adair Crawford, M.D. F.R S. L. and E. &c. The second edition, with very large Additions. 8vo. London 1788

Crell.—Crell's Chemical Journal; giving an Account of the latest Discoveries in Chemistry, with Extracts from various Foreign Transactions. Translated from the German. 3 vols. 8vo. London 1791–93

Dalton.—A New System of Chemical Philosophy, Part I., by John Dalton. 8vo. Manchester 1808

———. Ditto, Part II., by the same. 1810

Darwin.—Phytologia, or the Philosophy of Agriculture and Gardening, &c. By Erasmus Darwin, M.D. F.R.S. &c. 4to. London 1800

———. Botanic Garden, with Philosophical Notes, 2 vols. 8vo. London 1799

Davy.—Chemical and Philosophical Researches; chiefly concerning Nitrous Oxide, or Dephlogisticated Nitrous Air, and its Respiration. By Humphry Davy. 8vo. London 1800

———. Elements of Chemical Philosophy. By Sir Humphry Davy, LL.D. &c. &c. 8vo. London 1812

———. Elements of Agricultural Chemistry, in a Course of Lectures for the Board of Agriculture. By Sir Humphry Davy, LL.D. F.R.S. L. & E. M.R.I. &c. 4to. London 1813

Diodorus Siculus.—The History of Diodorus Siculus, containing all that is most memorable and of greatest Antiquity in the first Ages of the World, until the War of Troy. Done into English by Henry Cogan, Gent. Folio. London 1653

Duncan.—The Edinburgh New Dispensatory. By Andrew Duncan, Jun. M.D. Regius Professor of Medical Jurisprudence in the University of Edinburgh, &c. &c. Fourth edition, corrected and enlarged. 8vo. Edinburgh 1808

Dundonald.—A Treatise showing the Intimate Connection that subsists between Agriculture and Chemistry. Addressed to the Cultivators of the Soil, &c. &c. By the Earl of Dundonald. A new edition. 4to. London 1803

Ellis.—A Voyage to Hudson's Bay in the Years 1746–7. By Henry Ellis. 8vo. London 1748

Encyclopædia.—Encyclopædia Britannica, or a Dictionary of Arts, Sciences, and Miscellaneous Literature. The third edition, in 18 vols. 4to. Edinburgh 1797

Ferber.—Travels through Italy in 1771 and 1772. By J. J. Ferber, Professor of Natural History at Mittau in Courland, &c. Translated from the German by R. E. Raspe. 8vo. London 1776

Ferguson.—Ferguson's Lectures on Select Subjects. With Notes and an Appendix, adapted to the present State of the Arts and

Sciences. By David Brewster, A.M. Second edition, in 2 vols. 8vo. with a 4to Volume of Plates. Edinb. 1806

Fourcroy.—Elements of Chemistry and Natural History. By A. F. Fourcroy. Fifth edition, with Notes by Dr. John Thomson, of Edinburgh, in three vols. 8vo. Edinb. 1800

———. A General System of Chemical Knowledge and its Application to the Phenomena of Nature and Art. By A. F. Fourcroy, of the National Institute of France, Counsellor of State, Professor of Chemistry, &c. &c. In eleven vols. 8vo. Translated from the French by William Nicholson. London 1804

———. Chemical Philosophy. By A. F. Fourcroy, Counsellor of State, Member of the National Institute, &c. Third edition, enlarged and amended. Translated by W. Desmond, Esq. 8vo. London 1807

Fulhame.—An Essay on Combustion, with a view to a New Art of Dyeing and Painting, wherein the Phlogistic and Antiphlogistic Hypotheses are proved erroneous. By Mrs. Fulhame. 8vo. London 1794

Garnet.—Observations on a Tour through the Highlands, and Part of the Western Isles of Scotland, particularly Staffa and Icolmkill. By T. Garnet, M.D. Professor of Natural Philosophy and Chemistry in the Royal Institution of Great Britain. Two vols. 4to. London 1800

Gellert.—Metallurgic Chemistry, being a System of Mineralogy in general and of all the Arts arising from this Science, &c. Translated from the German of C. E. Gellert by I. S. 8vo. London 1776

Glauber.—The Works of John Rudolph Glauber, containing a great Variety of choice Secrets in the working of Metallic Mines and the Separation of Metals. Translated into English by Christopher Packe. Folio. London 1689

———. A Description of New Philosophical Furnaces, or a New Art of Distilling, divided into five Parts. By John Rudolph Glauber. Set forth in English by J. Freind, M.D. 4to. London 1651

Gottling.—Description of a Portable Chest of Chemistry; or complete Collection of Chemical Tests. Invented by J. F. A. Gottling, Professor of Chemistry at Jena in Saxony. Translated from the original German. 12mo. London 1791

Gregory.—Lessons, Astronomical, Philosophical, &c. By Olinthus Gregory. Second edition. London 1799

Gren.—Principles of Modern Chemistry, systematically arranged by Dr. Frederic Charles Gren, late Professor at Halle in Saxony. Translated from the German. Illustrated with Plates. Two vols. 8vo. London 1800

Halhed.—A Code of Gentoo Laws, or Ordinations of the Pundits,

from a Persian Translation, made from the Original written in the Shanscrit Language. Translated by Nathaniel Brassey Halhed, Esq. M.P. 4to. London 1776

Hamilton.—Campi Phlegræi; Observations on the Volcanoes of the Two Sicilies, as they have been communicated to the Royal Society of London. By Sir William Hamilton, K.B. F.R.S. To which a new and accurate Map is annexed, with 54 Plates coloured from Nature. Three vols. royal folio. Naples 1776

Haüy.—Traité de Minéralogie, par René-Just Haüy, 4 vols. 8vo. Paris 1801

Hellot.—The Art of Dyeing Wool and Woollen Stuffs. By M. Hellot, Member of the Royal Academy of Sciences. Translated from the French, by Order of the Dublin Society, for the Use of the Dyers of Ireland. 12mo. Dublin 1767

Henckel.—Pyritologia; or a History of the Pyrites, the principal Body in the Mineral Kingdom. The whole compiled from a Collection of Samples; from visiting Mines; from an Intercourse with Naturalists and Miners; but chiefly from a Course of Chemical Enquiries. Translated from the German of I. F. Henckel, Chief Director of the Mines at Friberg in Saxony. 8vo. London 1757

Henry.—Elements of Experimental Chemistry. By Wm. Henry, M.D. F.R.S., &c. The 7th edit. in two vols. 8vo. Lond. 1815

———. The Elements of Experimental Chemistry. By William Henry, F.R.S., Vice-President of the Literary and Philosophical Society at Manchester, &c. &c. The eighth edition, in two vols. 8vo. London 1818

Heron.—Elements of Chemistry, comprehending a Variety of Facts and Views which have never before been communicated to the World. Intended for the Use of Farmers, Manufacturers, Dyers, and other Artisans. By Robert Heron. 8vo. pp. 628. London 1800

Higgins.—Experiments and Observations made with a view of improving the Art of composing and applying Calcareous Cements, &c. By Bryan Higgins, M.D. 8vo. London 1780

———. An Essay on the Theory and Practice of Bleaching, wherein the Sulphuret of Lime is recommended as a Substitute for Potash. By William Higgins, M.R.I.A. Professor of Chemistry and Mineralogy at the Repository of the Dublin Society. 8vo. London 1799

Highland Society.—Prize Essays and Transactions of the Highland Society of Scotland, vol. i. 8vo. 2d edition. Edin. 1812

———. Ditto, vol. 2, 3, and 4. Edin. 1803–16

———. Ditto, part I. of vol. 5. Edin. 1817

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Hopson.—A General System of Chemistry, Theoretical and Practical. Digested and arranged with a particular view to its Application to the Arts. Taken chiefly from the German of M. Wiegleb. By C. R. Hopson, M.D. 4to. London 1789

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Jameson.—An Outline of the Mineralogy of the Shetland Islands, and of the Island of Arran. Illustrated with Copper-plates. With an Appendix, containing Observations on Peat, Kelp, and Coal. By Robert Jameson, Member of the Royal Medical and Natural History Societies, Edinburgh; and of the Linnean Society, London. Small quarto. Edinburgh 1798

———. Mineralogy of the Scottish Isles, with Dissertations upon Peat and Kelp, &c. Illustrated with Maps and Plates. By Robert Jameson, F.R. and A.S. of Edin. &c. &c. 2 vols. 4to. London 1800

———. A Treatise on the External, Chemical, and Physical Characters of Minerals. By Robert Jameson, Regius Professor of Natural History, &c. in the University of Edinburgh, 8vo. Second edition. Edinburgh 1816

———. A System of Mineralogy. By Robert Jameson, Regius Professor, &c. Second edition, 3 vols. 8vo. Edinb. 1816

Johnstone.—An Essay on Mineral Poisons, by John Johnstone, M.B. Physician in Birmingham; of Merton College, Oxford, Fellow of the Royal Med. Soc. Edinb., &c. and late Physician to the General Infirmary, Worcester. 8vo. Evesham 1795

Journal de Physique.—Journal de Physique, de Chimie, d'Histoire Naturelle et des Arts, avec des Planches en Tailledouce. 84 vols. 4to. Paris 1777–1817

Journal des Mines.—Journal des Mines, publié par le Conseil des Mines de l'Empire François: 1796 to the present Time. 40 vols. 8vo. Par. an. iii. (1796)–1817

Journals of the Royal Institution.—Journals of the Royal Institution of Great Britain. Vol. I. 8vo. Sold at the House of the Institution, Albemarle-street. London 1802

The Journal of Science and the Arts.—The Journal of Science and the Arts. Edited at the Royal Institution of Great Britain. Published quarterly. From the 1st of April 1816 to the present Time; in 7 half-volumes, 8vo.

Kidd.—Outlines of Mineralogy. By J. Kidd, M.D. Professor of Chemistry in the University of Oxford. Two volumes, 8vo. Oxford 1809

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———. An Essay on the Analysis of Mineral Waters. By Richard Kirwan, Esq. F.R.S. &c. 8vo. London 1799

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Klaproth.—Analytical Essays towards promoting the Chemical Knowledge of Mineral Substances. By Martin Henry Klaproth, Professor of Chemistry, &c. &c. Translated from the German. 8vo. Vol. I. London. 1801. Vol. II. 8vo. Lond. 1804

Lagrange.—A Manual of a Course of Chemistry; or A Series of Experiments and Illustrations, necessary to form a complete Course of that Science. By J. B. Bouillon Lagrange, Professor in the Central Schools of Paris, and in the School of Pharmacy, &c. &c. Illustrated with seventeen Plates. Translated from the French. 2 vols. 8vo. London 1800

La Lande.—Notice sur la Vie et les Ouvrages de Lavoisier. Par Jerome de La Lande. 8vo. Paris 1797

Lambe.—Researches into the Properties of Spring Water, with Medical Cautions, illustrated by Cases, against the Use of Lead in the Construction of Pumps, Water-pipes, Cisterns, &c. By William Lambe, M.D. 8vo. London 1806

Lavoisier.—Essays, Physical and Chemical, by M. Lavoisier, Member of the Royal Academy of Sciences at Paris, &c. Volume the First. Translated from the French, with Notes, and an Appendix, by Thomas Henry, F.R.S. 8vo. Lond. 1776

———. Elements of Chemistry in a new systematic Order, containing all the modern Discoveries. Illustrated by 13 Copper-plates. By M. Lavoisier, Member of the Academies and Societies of Paris, London, Orleans, Bologna, Basil, &c. Translated from the French by Robert Kerr, F.R. & A.S.S. Edinb. Fourth edition. 8vo. Edinburgh 1799

Leslie.—An Experimental Inquiry into the Nature and Propagation of Heat. By John Leslie. 8vo. Illustrated by 9 Copperplates. Mawman, London 1804

———. A Short Account of Experiments and Instruments depending on the Relations of Air to Heat and Moisture. By John Leslie, F.R.S.E. Professor of Mathematics in the University of Edinburgh. 8vo. Edinburgh 1813

———. Elements of Geometry. By John Leslie, F.R.S.E., &c. Third edition. Edinburgh 1817

Lewis.—Commercium Philosophico-Technicum; or, The Philosophical Commerce of Arts: designed as an Attempt to improve Arts, Trades and Manufactures. By W. Lewis, M.B. & F.R.S. 4to. London 1763

Loysel.—Essai sur l'Art de la Verrerie. Par C. Loysel. 8vo. Paris, ann. viii. ou 1800

Maclure.—Observations on the Geology of the United States of America; with some Remarks on the Effect produced on the Nature and Fertility of Soils, by the Decomposition of the different Classes of Rocks; and an Application to the Fertility of every State in the Union, in reference to the accompanying Geological Map. With two Plates. By William Maclure. 8vo. Philadelphia 1817

Macquer.—Elements of the Theory and Practice of Chemistry. Translated from the French of M. Macquer, Member of the Royal Academy of Sciences, and Professor of Medicine in the University of Paris. In 2 vols. 8vo. London 1757

———.—A Dictionary of Chemisty, containing the Theory and Practice of that Science, with full Explanations of the Fundamental Principles of the Arts, Trades, and Manufactures dependent upon Chemistry. Translated from the French. The second edition. In 3 vols. 8vo. London 1777

Malkin.—The Scenery, Antiquities, and Biography of South Wales, from Materials collected during two Excursions in the Year 1803. By Benjamin Heath Malkin, Esq. M.A. F.S.A. With Plates. 4to. London 1804

Manchester Memoirs.—Memoirs of the Literary and Philosophical Society of Manchester. 7 vols. 8vo. Warrington and Manchester 1785-1813

Marsden.—The History of Sumatra, containing an Account of the Natural Productions of the Island, &c. By William Marsden, F.R.S. 4to. London 1783

Maurice.—Indian Antiquities, or Dissertations relative to the Antient Geographical Divisions of Hindostan, &c. &c. By the Rev. Thos. Maurice. In seven vols. 8vo. London 1800

Mawe.—The Mineralogy and Geology of Derbyshire; describing the Productions of the Mines, and the Position of the Strata, exhibited by Engravings, &c. &c. By J. Mawe, No. 149, Strand. 8vo. London (*no date*)

———. Travels in the Interior of Brazil, particularly in the Gold and Diamond District of that fine Country; describing the Method of working their Mines, &c. By John Mawe, Author of "The Mineralogy of Derbyshire," &c. 4to. London 1815

———. Treatise on Diamonds and precious Stones, including their History, Natural and Commercial; with coloured Plates. By John Mawe. Second edition. 8vo. London 1815

Mayow.—Tractatus quinque Medico-Physici, &c. Studio Joh. Mayow, LL.D. & Medici: necnon Coll. Omn. Anim. in Univ. Oxon. Socii. 8vo. Oxonii e Theatro Sheldoniano. An. Dom. 1674

Medical Extracts.—Medical Extracts. By a Friend to Improvements. A new edition, in 4 vols. 8vo. London 1796

Medical and Physical Journal.—Medical and Physical Journal, from Vol. 15 to the present Time. 8vo. London 1806 &c.

Medical Transactions.—Medical Transactions by the College of Physicians in London. 5 vols. 8vo. London 1785-1815

Miller.—Physical and Metaphysical Inquiries. By Walter Miller, of Perth. 8vo. London 1806

Minucius Felix.—M. Minucii Felicis "Octavius," cum integris omnium Notis ac Commentariis, novâque Recensione Jacobi Ouzelii. 8vo. Leyden 1672

Murray.—A Comparative View of the Huttonian and Neptunian Systems of Geology; in answer to the Illustrations of the Huttonian Theory of the Earth by Professor Playfair. 8vo. Edinburgh 1802

——. A System of Chemistry. By J. Murray (now Dr. Murray), Lecturer on Chemistry, and on Materia Medica and Pharmacy. In 4 vols. 8vo. Second edition. Edinb. 1809

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DESCRIPTION

OF

THE PLATES.

THE folding plate, which forms a frontispiece to the volume, is a representation of the Laboratory of the Surry Institution, at Blackfriars Bridge, London.

The upper part of the plate contains a section of the principal Furnaces, in order to show their interior construction; and the lower part represents a front view of the entire arrangement, on a smaller plan. The whole is drawn and engraved to a correct scale, which is placed beneath each compartment of the engraving.

AAA. Is a Hood or Covering extending over the whole, and communicating with two air-flues, BB, that pass through the roof of the building, and are terminated by ventilators. These flues convey away any smoke or noxious vapour from the furnaces or other apparatus, without becoming offensive to the operator.

C. A leaden Sink, plentifully supplied with water. It has a drain pipe which carries off the waste water beneath the floor.

D. A square Sand-bath, heated by a fire-place, the door and register of which are seen, in the shade, on the right.

EE. Two round Apertures closed by Stoppers, and communicating with a spare flue which is concealed in the wall of the building. These are intended to receive the iron pipes of such moveable furnaces as may be occasionally employed.

F. Is a Furnace containing an iron sand-pot calculated for distillation with a glass or earthen retort, as represented at F. in the section. This furnace is so constructed that the iron pan may be readily removed, and a copper still, an iron retort, or other apparatus, placed in its stead.

GG. A Muffle-furnace for assaying metals by cupellation, for experiments on enamelling and staining glass, and for the roasting of metallic ores, &c.

HH. A Furnace for distillation by the naked fire. In the section H. is placed a retort, the neck of which passes through an opening left in the side of the furnace for that purpose, and which is luted up during an operation. This furnace is well contrived for the distillation of phosphorus, quicksilver, oxygen gas, &c.

II. Iron Doors opening on a level with the furnace grates for the purpose of raking the fire, removing and replacing the bars, &c.

KK. Doors of the ash pits.

L. A Smelting- or Wind-furnace for the reduction of metallic ores, and other purposes requiring the highest degrees of heat. Section L. shows the interior of this furnace, with a crucible within it.

M. is an Aperture for clearing or withdrawing the bars of the grate.

N. A Reverberatory, or Annealing Furnace. This forms a chamber through which the heated air and flame of the furnace L. pass in their way to the chimney O. This addition is found to improve materially the draught of the furnace L. and is also particularly useful in heating crucibles to a proper temperature preparatory to their being used in that furnace.

PP. Moveable Covers suitable for either of the furnaces G, H, L, or N. These covers are made with fire bricks ground neatly, and bound together by a strong rim or band of iron. There is a hole in the centre of each, secured by an earthen stopper, which may be opened occasionally to inspect the state of the fire or the progress of the operation.

Q. An extended Ash-pit, covered by a moveable iron grate. This kind of ash-pit very much economizes the room in a laboratory, as it admits a large current of atmospheric air, and allows the operator to stand closer to the furnace. Throughout the whole of this apparatus, the chimneys are distinct, each furnace having its own; but being carried up within the wall of the building they cannot be described in this plan.

R. *fig.* 3, represents Mr. Knight's Table-Furnace made of wrought iron, of dimensions according to the scale annexed, the inside of which is lined with a coating of fire clay. S. a door to allow the introduction of a crucible, &c. T. another door in the cover, through which the fuel (charcoal) is to be introduced. U. an opening which serves as a chimney when the top is taken off and a sand pot is to be used; or it will admit the neck of a retort for the purpose of distilling with the naked fire: this opening is also calculated for the introduction of a muffle. X. the door of the ash-pit. WW. two apertures, opposite to each other, through which an iron, earthen, or any other tube may be passed, in order to demonstrate the decomposition of water, and for other operations which require such an arrangement.

The Plate of SMALL APPARATUS, *to precede the "Chapter on Experiments," and face page* 485, *may be thus described:*

No. 1. THE representation of Knight's Portable Furnace on the principle of Dr. Black, and which may advantageously be employed for a variety of purposes.

No. 2. Aikin's Portable Blast-Furnace, for exciting an intense heat in a short time.

No. 3. Pepys's Improved Air-Holder, with pneumatic cistern, forming a convenient apparatus for experiments on the gases. A pressure-pipe is attached to it, which renders it a most complete Hydraulic Blow-pipe.

No. 4. Pepys's Water-Bath for drying precipitates on filtering paper. This little apparatus is found extremely useful for drying explosive compounds.

No. 5. A Lamp Furnace with brass pillar and stand, sliding rings, and fountain lamp.

No. 6. An Hydraulic Blow-pipe so contrived as to enable the operator to keep up a constant blast with facility and effect.

No. 7. Pepys's Improved Ball-Blow-pipe.

No. 8. Wollaston's Apparatus for decomposing water by galvanism.

No. 9. An Apparatus for decomposing water and receiving the gases separately.

No. 10. Davy's Glass Apparatus for the analysis of earths by the disengagement of gas.

No. 11. An Iron Mortar turned smooth on the inside for reducing hard substances for analysis.

No. 12. An Air Thermometer which shows the slightest change of temperature.

No. 13. A Potassium Apparatus for decomposing the alkalies by galvanism.

No. 14. Metallic Reflector for showing Pictet's experiments on radiant heat.

No. 15. A Differential Thermometer adapted to the above.

No. 16, 17, 18, 19. Crucibles of various forms, for operative and experimental chemistry.

No. 20. A Muffle, or utensil of baked earth, for cupellation and other purposes.

No. 21. shows the form of a Retort which may be made of glass, earthenware, or porcelain.

No. 22. A Glass Receiver for holding the liquid products of distillation.

No. 23. An Evaporating Basin, which may be made either glass or porcelain.

No. 24. Dr. Hope's Eudiometer.

No. 25. Davy's Pocket Eudiometer.

No. 26. An Eudiometer graduated to cubic inches and decimal parts of an inch.

No. 27. Pepys's Eudiometer, with elastic gum bottle.

No. 28. Fontana's Apparatus for the composition of water by the electric spark.

No. 29. Davy's Spring Eudiometer.

No. 30. A bell-shaped Air Jar, with a wire and dish for deflagrating substances in oxygen gas.

No. 31. Air Jar, bell-shaped, with open neck and ground stopper adapted to it.

No. 32. Howard's Rain and Evaporating Apparatus, in two parts, with the gauge correctly graduated.

No. 33. An Hydrometer for ascertaining the strength of liquid acids.

No. 34. Wollaston's Cryophorus.

No. 35. A Glass Tube with a bulb, and drawn to a fine orifice for dropping fluids.

No. 36. A Digesting Glass Flask, with a condenser adapted to it, that prevents its bursting, or the liquor from boiling over, when heated within it.

No. 37. A Portable Argand's Lamp for chemical purposes. Another, with a fountain attached to a stand, is marked with the same number.

No. 38. Welter's Safety Tube, to be adapted to retorts or receivers.

No. 39. A Glass Digesting Flask, with a ground stopper.

No. 41. Two Test Glasses. These are sold of various forms and sizes.

No. 42. A Two-necked Glass Vessel with a bent tube for making hydrogen gas.

No. 43. Pepys's Glass Vessel with spiral tube for ascertaining the quantity of carbonic acid contained in a given quantity of calcareous earth.

No. 44. A Glass Alembic. This vessel is made for chemical purposes, to contain from half a pint to two quarts.

No. 45. A Filtering Funnel. These are made either of glass or porcelain.

No. 46. A Long-necked Funnel for firing phosphorus under water.

No. 47. A Glass Separating Vessel with stop-cock, for drawing off fluids of different specific gravities.

No. 48. A bent Funnel for filling retorts without soiling or wetting the inside of the necks.

No. 50. A Glass Evaporating Dish.

No. 51. A Vessel for separating oils or other fluids.

No. 52. A Glass Spirit Lamp.

No. 53. A Glass Globe applicable to Retorts, &c. and designed for receiving the products of distillation.

As it would have required a great deal of room to have described the whole of the above Apparatus with that minuteness which a person unacquainted with such utensils might have wished, I must content myself with referring the reader to Messrs. R. and G. Knight of Foster-Lane, Cheapside, London, who have all these articles constantly on sale.

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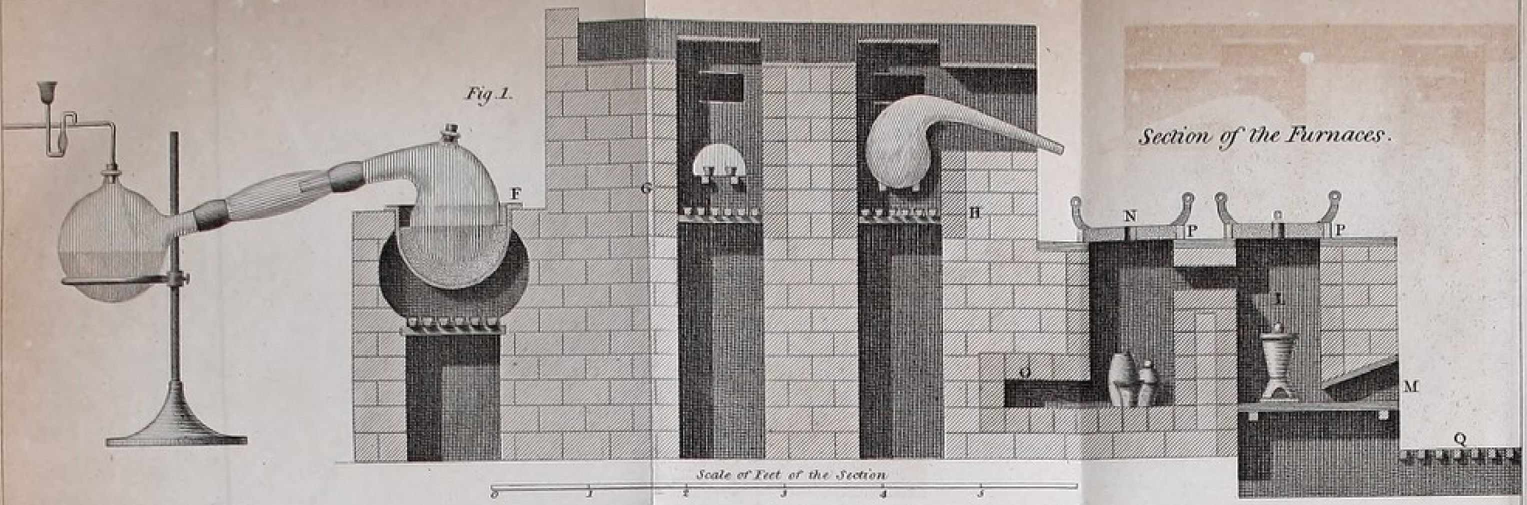
THE LABORATORY at the SURREY INSTITUTION,

Black Friars Bridge, London.

Fig. 1.

Section of the Furnaces.



View of the Laboratory. Fig. 2.

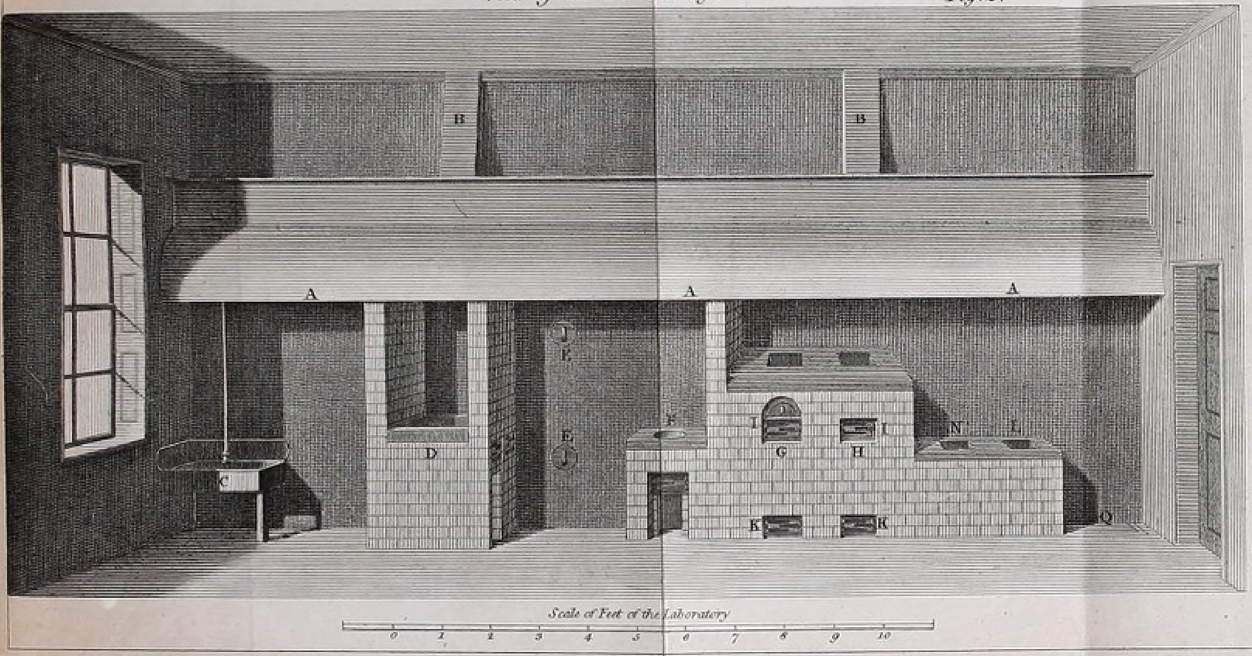
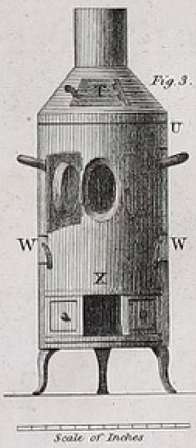


Table Furnace.

Fig. 3.



Engraved by James Davis for the New Edition of Parkes's Chemical Catechism.

London Published by Samuel Parkes as the Act directs, May 4th 1819.

Ovendon sculp.t

AN ESSAY

ON

THE UTILITY

OF

THE STUDY OF CHEMISTRY.

From the present state of chemical knowledge, and the rapid improvements which have been made in our arts and manufactures by the judicious application of its principles, it is become very desirable that every youth should be acquainted with its rudiments, and that Chemistry should be made a regular branch of education in every seminary where the sciences are professedly taught and explained.

I have therefore imagined that I should render an acceptable service to society by showing the advantages which would arise from the acquisition of this kind of knowledge; especially as a large proportion of the community is probably not apprised of its real value.

The well-informed people of France are so fully convinced of the importance of chemical knowledge, that chemistry is already become an essential part of education in their public schools.—It shall be my business in this place to endeavour to demonstrate it to be of *equal* importance to the various classes of our countrymen, that the science should be cultivated with the same ardour in these kingdoms. The branch of education we recommend to your regard, has for its objects every substance of the material world, and, therefore, is equally interesting to every civilized nation upon earth.

Is your son born to opulence,—is he the heir to an extensive domain; make him an analytical chemist, and you enable him to appreciate the real value of his estate, and to turn every acre of it to the best account.

Chemistry will teach him also how to improve the *cultivated* parts of his estate; and by transporting and transposing the different soils, how each may be rendered more productive. The analysis of the soils will be followed by that of the waters which rise upon, or flow through, them; by which means he will discover those proper for irrigation; a practice the value of which is sufficiently known to every good agriculturist.

Should he *occupy* his own estate, and become the cultivator of his own land; he must of necessity be a chemist, before he can be an economical farmer. It will be his concern not only to analyse the soils on the different parts of his farm, but the peat, the marle, the lime, and the other manures must be subjected to experiment, before he can avail himself of the advantages which might be derived from them, or before he can be certain of producing any particular effect. Besides, a knowledge of the first principles of chemistry will teach him when to use lime *hot* from the kiln, and when *slacked*; how to promote the putrefactive process in his composts, and at what period to check it, so as to prevent the fertilizing particles becoming effete, and of little value. A knowledge of the chemical properties of bodies will thus give a new character to the agriculturist, and render his employment rational and respectable*.

Are you a practitioner of MEDICINE, and have acquired great and deserved reputation in your profession,—if you are not a chemist, you must recollect many painful disappointments, and must have witnessed very unexpected results from the effects of medicine, when you have administered two or more powerful remedies in conjunction. A slight knowledge of chemistry would have informed you that many of the formulæ in the Pharmacopœia, which are salutary and efficacious, are rendered totally otherwise if given with certain other medicines,—not to say often destructive. Many instances of these chemical changes might easily be adduced.

If the profession of medicine be your son's choice, charge him, when he walks the hospitals, to pay particular attention to the Lectures on Chemistry, and to make himself master of the chemical affinities which

---

* Lavoisier cultivated 240 acres of land in La Vendée, on chemical principles, in order to set a good example to the farmers; and his mode of culture was attended with so much success, that he obtained a third more of crop than was procured by the usual method, and in nine years his annual produce was doubled.—*Lalande's Life of Lavoisier.*

subsist between the various articles of the Materia Medica. This will inspire him with professional confidence; and he will, in some measure, be as sure of producing any particular chemical effect upon his patient, as he would if he were operating in his own laboratory. Besides, the human body is itself a laboratory, in which, by the varied functions of secretion, absorption, &c., composition and decomposition are perpetually going on:—how, therefore, can he expect to understand the animal economy, if he be unacquainted with the effects which certain causes chemically produce? Every inspiration we take, and every pulse that vibrates within us, effects a *chemical* change upon the animal fluids, the nature of which requires some chemical knowledge to perceive and understand. Neither can a physician comprehend the nature of the animal, vegetable, or mineral poisons without the aid of chemistry. Many thousand lives have been lost by poison, which might have been saved had the physician been in possession of the knowledge which he may now acquire by a cultivation of chemical science. And though the operation of many of the poisons upon the system be in these days well understood, nothing but a knowledge of chemistry can enable the practitioner to administer such medicines as will counteract their baneful effects.

If we consider the MANUFACTURES of the kingdom, there is scarcely one of any consequence that does not depend upon chemistry, for its establishment, its improvement, or for its successful and beneficial practice. In order to see the connexion which subsists between chemistry and the arts, it will be necessary to take a short view of the principal trades which are carried on in these kingdoms.

One of the staple manufactures of the country is that of IRON: and it will be found that, from the smelting of the ore to the conversion of it into steel, every operation is the effect of chemical affinities. In the first place, it requires no small share of chemical knowledge, to be able to appreciate the *value* of the different ores, and to erect such furnaces for their reduction as may be contrived in the best possible manner for facilitating their fusion, and for producing good pig-iron. The subsequent processes to convert the metal into *malleable* iron are entirely chemical, and will be conducted to the best advantage only by those who have acquired a knowledge of the chemical changes which take place in these operations.

The manufacturers of utensils, &c. in *cast-iron* (called IRON-FOUNDERS) will also acquire some valuable information by the study of chemistry; as it will teach them how to mix the different kinds of metals; how to apportion the carbonaceous and calcareous matter; and how to reduce the *old* metal which they often receive in exchange; many hundred tons of which are annually sent away as ballast for ships, for want of that knowledge which would enable them to convert it into good saleable cast-iron.

The WOOLLEN, the COTTON, and the CALICO manufactures are also become of great importance to these kingdoms. In order to preserve these sources of national wealth, the utmost attention must be paid to the beauty, the variety, and the durability of their several colours. Now, of all the arts, none are more dependent upon chemistry than those of DYEING and CALICO-PRINTING. Every process is chemical; and not a colour can be imparted but in consequence of the affinity which subsists between the cloth and the dye, or the dye and the mordant which is employed as a bond of union between them. It is surely then evident how valuable a chemical education must be to that youth who is designed for either of these trades, and how necessary is that portion of knowledge which shall enable him in a scientific manner to analyse his different materials, and to determine the kind and the quantity necessary for each process. After all, his colours will be liable to vary, if he do not take into the account, and calculate upon, the changes which take place in them by the absorption of oxygen; a knowledge of which, and of the different degrees of oxidizement which the several dyes undergo, requires no small share of chemical skill; and yet this skill is absolutely necessary, to enable either the dyer or the calico-printer to produce in all cases permanent colours of the shade which he intends. Moreover, these artists must be indebted to chemistry for any valuable knowledge which they may acquire of the *nature* of the articles they use in their several processes: not to say that they are wholly dependent upon this science for the artificial production of their most valuable mordants, and for some of their most beautiful and brilliant colours.

The art of BLEACHING, which is so intimately connected with calico-printing, has also received such improvement from the science of chemistry, that no man is now capable of conducting it to the best advantage, without a knowledge of the principles on which the present practice is established.

The manufactures of EARTHEN-WARE and PORCELAIN, which were so much improved and extended by the ingenious and industrious Wedgwood, and which are become by his means a source of national wealth, and give employment to thousands of the community, are dependent upon chemistry for the successful management of all their branches, from the mixture of the materials which form the body of the ware, to the production of those brilliant colours which give a value to the manufactures by their permanency and beauty.

The sister art, that of making GLASS, is also entirely chemical, consisting in the fusion of siliceous earth with alkali and the oxides of lead. In this trade, as well as in many others, the chemical manufacturer, and the man of enlightened experience, will have many advantages. He will not only know how to analyse his alkalies, and to ascertain their exact value before he purchases, but will be enabled on chemical principles to ascertain the exact quantity necessary for any fixed portion of silica, which, to those who are ignorant of our science, must always be a matter of uncertainty, and must repeatedly subject them to losses and disappointment.

The TANNING OF HIDES is a process which was formerly carried on by persons who merely followed a routine of operations, to which they had been accustomed, without knowing the real cause of any of the changes produced. It has now, however, been well ascertained, that the whole art consists in impregnating the animal matter with that peculiar principle taken from the vegetable kingdom, called *tan* (or *tannin*), the effect of which may be explained entirely on chemical principles. It is also now known that many substances besides oak bark contain tan; and to chemistry we are indebted for the means of discovering with accuracy the *quantity* of tan which the several astringent vegetables contain. Besides, this principle having been formed *artificially* by an eminent modern chemist, it is not improbable that, whenever these manufacturers pay a proper attention to the science we recommend, they may be able to direct us how to prepare for them, in our laboratories, the article in question, so as entirely to supersede the use of oak bark. Should the chemical tanner not be fortunate enough to make a discovery of the kind just mentioned, he will at least be able to analyse the substances now in use, and to appreciate their *relative* value; a matter of no small moment to a man who operates upon a large scale.

The manufacturers of MOROCCO LEATHER, an article entirely new in the productions of this country, have the utmost reason to regret the want of chemical knowledge. Till within these twenty or thirty years, the consumers of morocco depended entirely on a foreign supply, many fruitless attempts having been made to prepare the article in this country. Later trials, with various chemical mordants, have, however, so far succeeded, that several manufactories have been established in the metropolis, where the most beautiful moroccos are now prepared at prices which have superseded the necessity of all foreign importation.

The manufacture of SOAP, an art of considerable importance, and which materially aids the revenue of the country, has in general been conducted, like many of the foregoing, without any regard to system; and yet, perhaps, there is no manufacture which can be benefited in such various ways by chemistry as this. To those who are designed for this trade, I have no hesitation in recommending the study of the science as a matter of the first importance. Many thousands per annum, now lost to the community, would be saved, if the trade were in general carried on upon scientific principles. Make a soap-boiler a good chemist, and you teach him how to analyse barilla, kelp, potass, &c., so as to ascertain the proportion of alkali in each,—the only sure guide to purchasing with advantage and profit, which with the common manufacturer is mere chance. When these articles are at an exorbitant price, he will have recourse to various residuums, which he will decompose by *chemical* means, and make use of as substitutes. He will learn, in choosing his tallows, how to avoid those which contain a large portion of sebacic acid, which require much *more* barilla than good tallow, and yet produce *less* soap. He will know how to apportion his lime so as to make his alkali perfectly caustic, without using an unnecessary quantity of that article. A knowledge of chemical affinities will teach him how, at a cheap rate, to make as good and as firm soap with *potass*, as with the mineral alkali; and how to take up the heterogeneous salts, so as to give the alkali full opportunity of forming a chemical combination with the oils, tallows, &c. And lastly, he will know how to make use of the *waste* lyes so as to decompose the salts which they contain, and convert them to good and serviceable alkali, fit for future operations.

The manufacture of CANDLES, which is often connected with the foregoing, though it is of comparatively small importance, may yet derive advantages from chemistry which would repay the study. Foreign tallows, which frequently contain a large portion of acid, rendering them inferior to the English, may be purified at the most insignificant expense by chemical means; and by the proper application of chemical agents, other brown tallows may be rendered beautifully white, and fit for the best purposes.

Where great quantities of candles are used, as in large manufactories, mines, collieries, &c., a great saving would arise from the use of carburetted hydrogen gas, which produces a beautiful intense light, much more cleanly than oil or tallow, and at little cost. A slight knowledge of the mode of managing the gases would enable the proprietor of collieries to procure this gas from the small coal, which is *trodden underfoot*, and to light up his coal-pits with it with the greatest safety, and at NO EXPENSE.

The BREWING OF FERMENTED LIQUORS, a trade of considerable consequence in the metropolis, is altogether a chemical process. To those persons whose concerns are so large that it would require a princely fortune to purchase even the *utensils*, it must surely be of the utmost importance to acquire some knowledge of the principles of bodies, and of the nature of those changes which take place in the materials upon which they operate. I would therefore say to such persons, Give your sons a chemical education, and you will fit them for conducting, in the best possible manner, the business which you have established. Hence they will learn how the barley, in the first instance, is converted to a *saccharine* substance by malting*, and how the fermentative process converts the saccharine to a *spirituous* substance. The nature of fermentation (which till lately was entirely unknown) will be studied and understood: and they will not only have learned

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* There is a valuable paper on malting in the fifth volume of the *Memoirs of the Manchester Society*, by Mr. Joseph Collier.

the means of promoting and encouraging this process, but how to retard and check it, whenever it is likely to be carried too far; so that the scientific brewer will be as sure of uniformly obtaining satisfactory results, as he would if he were operating on matter by mere mechanical means.

In like manner the DISTILLER, the MAKER OF SWEET WINES, and the VINEGAR MANUFACTURER, will all receive benefit from the cultivation of the science we are recommending. Till the promulgation of the new chemical doctrines, the making of vinegar was carried on like many other trades, in which the makers themselves had no idea of the nature of their own process. An acquaintance with chemistry will teach them many important matters: particularly how it is that the spirituous fermentation is succeeded by the acetous; and how the liquor acquires the substance necessary to produce this change. When this is once known, they will soon find by experiment how to oxygenize their wash at the least expense, and in the least possible time. Indeed, when chemical knowledge is more advanced, the process which now takes several months will probably be completed in as many days.

The REFINING OF SUGAR is also a chemical process, every branch of which depends upon laws well known to chemists. The separation of the sugar from the molasses; the granulation of the purified sugar; and the crystallization of candy; will all be conducted most economically, and with the least difficulty, by those who have studied the science with a view to the improvement of their art.

The REFINING OF GOLD AND SILVER may appear to be merely a mechanical operation; but, even in this trade, the artist cannot produce a single effect which is not attributable to the play of the chemical affinities.

The MANUFACTURERS of ALUM, of COPPERAS, of BLUE VITRIOL, and of all other SALTS, would likewise do well to become chemists, before they attempt to bring their several arts to the perfection of which they are capable. The crystallization of salts depends upon so many adventitious circumstances, that no small share of knowledge is necessary to enable a manufacturer at all times, and in all seasons, to produce the article he intends.

Even science itself is now reaping the benefit of its own discoveries. A few years ago, the MANUFACTURERS OF PAPER were apprehensive that it would be impossible to supply a quantity of that article fit for printing upon, adequate to the increasing demand. Necessity, however, often the source of new inventions, had recourse to chemistry; and in this science, of universal application, found the means of improving the colour of the very coarsest materials;—so that rags which formerly would have been thrown by for paper of the lowest description, are now rendered subservient to the progress of truth, and the promulgation of knowledge. And so easy is the application, that an immense quantity of the materials can be prepared in a few hours; and paper sufficient to print a copy of the largest work in the English language may thus be whitened at the most trifling expense.

In like manner it might be shown that the making of BREAD, SUGAR, STARCH, VARNISH, and OIL OF VITRIOL, the REFINING OF SALTPETRE, and the MANUFACTURES OF PRUSSIAN BLUE, CUDBEAR, ARCHILL, and other colours, are all dependent upon chemistry for their improvement and successful practice:—but I flatter myself that the examples already adduced are sufficient to show that chemistry is now a necessary branch of the education of youth. Even the management of a GARDEN may receive improvement from a cultivation of this science, as it explains the growth of vegetables, shows the use of the different manures, and directs the proper application of them.

The various operations of Nature, and the changes which take place in the several substances around us, are so much better understood by an attention to the laws of chemistry, that in every walk of life the chemist has a manifest advantage over his illiterate neighbour. And it may be remarked, that in case of failure or disappointment in any particular line of commercial manufacture, the scientific chemist has resources as various as the productions of the country in which he lives, to which the uneducated man has no access*.

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* A very remarkable instance of a whole nation availing themselves of advantages presented to them by chemistry, in a case of the greatest emergency, may be seen in the Chemical Catechism, Additional Notes, No. 22.

Were parents aware of this truth, that sordid maxim, *primo vivere, deinde philosophari,* would not be heard: but every youth would be instructed in the first principles of natural philosophy and chemistry, as *the means* of qualifying him for managing with advantage the concerns with which he might be intrusted. If "knowledge is power," surely the *love* of knowledge, and a taste for accurate investigation, are the most likely means of conducting him into that path which leads to opulence, respectability, and rational enjoyment.

Moreover, it is the necessary consequence of an attention to this science, that it gives the habit of *investigation,* and lays the foundation of an ardent and inquiring mind. If a youth has been taught to receive nothing as true, but what is the result of *experiment,* he will be in little danger of ever being led away by the insidious arts of sophistry, or of having his mind bewildered by fanaticism or superstition. The knowledge of *facts* is what he has been taught to esteem; and no reasoning, however specious, will ever induce him to receive as true what appears incongruous, or cannot be recommended by demonstration or analogy.

THE CHEMICAL CATECHISM.

CHAPTER I.

INTRODUCTORY AND MISCELLANEOUS.

What is Chemistry?

Chemistry[a] is the science which enables us to discover the peculiar properties of all natural bodies, either in their simple or compound state[b].

The pupil is advised to go through the catechetical part of each chapter before he attends to the notes; because the questions often arise out of the preceding answers, and therefore the connexion of the whole will be best perceived by this method, and will be most likely to be remembered.

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[a] The following definitions of chemistry have been given by some of our best writers.

"Chemistry is the study of the effects of heat and mixture, with the view of discovering their general and subordinate laws, and of improving the useful arts."—Dr. Black's *Lectures*, vol. i. page 12.

"Chemistry is that science which examines the constituent parts of bodies with reference to their nature, proportions, and method of combination."—Bergman's *Essay on the Usefulness of Chemistry*, &c. page 4.

"Chemistry is that science which treats of those events or changes in natural bodies which are not accompanied by *sensible* motions."—Dr. Thomson's *System of Chemistry*, vol. i. page 3.

"Chemistry is a science by which we become acquainted with the intimate and reciprocal action of all the bodies in nature upon each other." Fourcroy's *General System of Chemical Knowledge*.

[b] The basis of chemical science is the analytical examination of the works of nature, and the investigation of the properties of the several

How do chemists examine the properties of bodies?

The chemical examination of bodies is in general effected by producing a change[a] in the *nature* or *state* of the body under examination[b].

By what means do chemists effect a change in the qualities or states of natural bodies?

This is generally effected by means of *heat*[c], or by the *mixture*[d] of some other matter with the matter intended to be examined[e].

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substances with which we are acquainted: it should therefore be the first concern of every chemical student to receive nothing as true but what has actually been proved by experiment or deduced from analogy. Let him rely upon nothing but facts, and he will be in little danger of forming extravagant or erroneous opinions. If we "dare to investigate Nature, we must *see* her and *try* her on all sides, and be sure that she still confesses the same thing."

[a] This change is frequently effected by the addition of some other substance which can form a combination with a part of the substance under examination, and leave the other part in a detached state. On this principle re-agents, or chemical tests, are employed, the operation of which will be explained as we proceed.

[b] To the eye, many substances appear similar to other substances, though they possess different, and perhaps opposite, qualities; it therefore became necessary to discover the means of analysing these substances, and of ascertaining wherein their difference consists. These we find in chemical *re-agents*.

It may, with few exceptions, be considered as an axiom in the science of which we are treating, that *whenever chemical action takes place, a real change is produced in the substance operated upon, and that its identity is destroyed*. An example will place this in a clear point of view. If a little carbonate of lime (powdered chalk) be put into a glass of water, the chalk will sink to the bottom of the vessel. Though it should be mixed with the water, if left at rest it will soon subside. No chemical action has taken place; therefore the water and the carbonate of lime both remain unaltered. But if a small quantity of diluted sulphuric acid be added to a glass of chalk and water, a violent effervescence will commence the moment they come into contact with each other; a chemical union of the two substances will be the consequence of this chemical action; the identity of each substance will be destroyed; and sulphate of lime (a body entirely different from either of the substances employed) will be produced.

[c] Heat has a tendency to separate the particles of all bodies from each other. Hence nothing more is necessary to effect the decomposition of many bodies than to apply heat, and collect the substances which are separated by that means. The mixture of two or more compounds often produces a decomposition in each by means of chemical *affinity*, a property of bodies which will be more fully explained hereafter.

How does the application of heat and mixture enable chemists to examine the properties of bodies?

By these means we effect the *decomposition* of a compound body, and thus acquire a knowledge of the nature of its ingredients[f].

What is meant by decomposition?

In chemical language, decomposition means the art of dividing a body into its simple elements[g]. Thus water may be decomposed, and reduced into oxygen

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[d] It is owing to the laws of affinity that we are enabled to examine natural bodies by means of *re-agents*, or chemical tests. Some of these are simple, and act by *single* affinity; others, which are compound, act by producing a *double* decomposition. See chap. xiii. for further particulars.

[e] Some idea of this mode of examination may be given by the following experiment:—Put a small piece of solid camphor into a phial half filled with diluted alcohol (common spirit of wine): in a short time the camphor will be dissolved in the fluid, and the spirit will be as transparent as at first. This solution is owing to the affinity which subsists between these two substances. If water be now added (which has a greater affinity for the spirit of wine than the camphor has), the water will unite with the ardent spirit, and the camphor will be precipitated. In this way the camphor may be nearly all recovered, as at first. By distillation the alcohol may also be separated from the water, and exhibited in a separate state.

[f] This is called analysis. It is distinguished by chemists into the *simple* and the *complicated* analysis. The former is effected whenever a body is so decomposed that its elements may be exhibited in a separate state, and the body reproduced by reuniting these elements. Where the elements of a body form *new* compounds during its decomposition, and cannot be reunited to reproduce a similar substance to that which has been operated upon, it is an instance of *complicated* analysis.

In order to ascertain the exact nature of bodies, we have often recourse to *synthesis* as well as analysis. Thus, whenever the component parts of any body are reunited in order to form a similar substance, and a similar substance is actually produced, the nature of that body is said to be proved by synthesis. When a body admits of being examined in both these ways, the result is as satisfactory as can be desired.

The examination of those substances which we receive from the hand of Nature, if conducted on these principles, may sometimes be tedious, but the consequences will be pleasing; the processes may be slow, but they will be sure; and the acquisition of truth by patient investigation, and by means of our own exertion, affords to a cultivated mind the most delightful gratification.

"Nature, exhaustless still, has power to warm,
And every change presents a novel charm."

[g] Take sulphate of magnesia (Epsom salt) as an instance of the decom-

and hydrogen, which are simple substances, incapable of further decomposition.

What are the different states of natural bodies?

The matter which constitutes this lower world is usually divided by philosophical writers into four classes; viz. solid[a], liquid, aëriform, and imponderable.

What do you mean by a solid body?

Solidity is that quality of bodies whereby their parts cohere firmly[b], so as to resist impression[c].

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position and re-formation of a substance by chemical means. Dissolve some of this salt in boiling water, and pour into it a little of a solution of sub-carbonate of soda: the soda will precipitate a white powder, which on examination will be found to be carbonate of magnesia. When settled, decant the supernatant liquor, evaporate it till a pellicle rises on its surface, and set it aside to crystallize. When cold, crystals of sulphate of soda (Glauber's salt) will be found in the vessel. In this decomposition, the sulphuric acid of the Epsom salt combines with the soda to form sulphate of soda, and the carbonic acid of the soda combines with the magnesia to form carbonate of magnesia. Thus Epsom salt may be analysed, and shown to consist of sulphuric acid and magnesia. In order to prove the composition of this salt by *synthesis*, dissolve magnesia in diluted sulphuric acid, saturate the liquor, and crystallize. Epsom salt will be the result.

It may be remarked, that chemists have not only the power of decomposing natural bodies, but of producing, by certain combinations, various other substances, such as are not found in the kingdoms of Nature. Alcohol and ether are both of this class.

[a] When cohesive affinity between the particles of a body is strong, that body is a solid; when this affinity is considerably diminished by heat, the body becomes fluid; but when sufficient heat is applied to destroy the cohesion altogether, the particles of the body then begin to repel each other, and thus a vapour or a gas is formed. The ultimate particles of matter existing in these separate states escape the cognisance of our senses. They are so infinitely small, as not only to evade the scrutiny of the highest magnifying powers in glasses, but even imagination itself is incapable of forming any idea of the size of an original particle of matter. When we have reduced matter to the most impalpable powder, we are far, probably very far, from the atoms which compose that powder.

[b] The force of cohesion increases in a substance in proportion as its moleculæ are brought nearer together. Thus alumina, which has shrunk considerably in bulk by being submitted to a high degree of heat, has not only experienced much mechanical cohesion, but has thereby acquired the power of resisting acids and alkalies. See Berthollet's *Chemical Statics*, vol. i. page 3. The diamond and the adamantine spar may also be exhibited as examples of the above axiom. These are the two hardest substances we are acquainted with, and yet the chemical nature of

What are liquid substances?

Liquid substances are those whose parts do not cohere firmly, but readily yield to any impression, and have free motion among themselves[d]. They also assume, when in small masses, the spherical form, as may be observed in detached portions of mercury, and are incapable of being compressed into a smaller compass by mechanical force.

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the one is perfectly similar to that of charcoal, and the latter is constituted of the same materials as that soft body, common pipe-clay.

[c] Sir Isaac Newton has said, that the primary particles of all bodies are *hard*, whether solid or fluid; and that if the particles be so disposed or fitted to each other as to touch in large surfaces, such body will be hard; otherwise it will be soft.—Perhaps it would be more philosophical to say, that when the attraction of aggregation is strong enough to resist the motion of the particles of a body among themselves, that body will be solid, otherwise it will be soft.

Lavoisier has explained solidity thus: "The particles of all bodies," says he, "may be considered as subject to the action of two opposite powers, repulsion and attraction, between which they remain in equilibrio. So long as the attractive force remains stronger, the body must continue in a state of *solidity*; but if, on the contrary, heat has so far removed these particles from each other as to place them beyond the sphere of attraction, they lose the cohesion they before had with each other, and the body ceases to be solid."

[d] We have no reason to suppose that fluidity is an essential property of any liquid substance whatever; but rather that solidity is the natural state of all bodies; for we are able to reduce most substances to a state of fluidity by the combination of caloric. In general, bodies treated in this way expand in all their dimensions, and the attraction of aggregation is so much weakened thereby, that the particles of the body slide over each other, and are put in motion by the slightest impulse. This is the only distinguishing character of fluidity that we are acquainted with. On the contrary, the greatest number of liquid substances take a *solid* form by reduction of temperature. Thus water congeals, and forms ice. Even the gases show this disposition. Chlorine, or oxymuriatic acid gas, becomes concrete, and crystallizes at a temperature near to that at which water congeals. All the gaseous substances, when they have lost their elasticity by forming certain combinations, are disposed to assume the solid state, if the temperature allows it. Ammoniacal gas and carbonic acid gas become solid as soon as they enter into combination; and hydrogen gas, the most subtile of the ponderable elastic fluids, and 14 times lighter than the air we breathe, forms, with oxygen gas, the water which becomes ice. See this subject further elucidated in the first volume of Berthollet's *Chemical Statics*.

What are aëriform substances?

All elastic[a] fluids, usually called vapours and gases, belong to this class of matter.

What substances are they which constitute the fourth class, or the imponderable bodies?

These are four only; viz. light, caloric, electricity, and magnetism[b]. They are also sometimes denominated unconfinable, or ethereal substances.

What occasions the difference which is observable in solid and liquid substances?

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[a] These aëriform substances are called *elastic*, because they are all capable of being reduced into a smaller compass by pressure, and of expanding again to their usual volume whenever the pressure is removed. Thus atmospheric air may be so compressed that 128 volumes may be forced into a space usually occupied by *one* volume, and the greater the compression the more will its elasticity be increased. It is on this principle that the air gun is constructed. What constitutes the difference between vapour and gases will be explained hereafter.

[b] In this introductory chapter it has been found most convenient to treat only of the solid and liquid state of bodies; the aëriform and imponderable states of matter will be considered hereafter.

[c] Fluidity is owing to the matter of heat being interposed between the particles of the fluid; which heat would dissipate all fluids into the air, were it not for the pressure of the atmosphere, and the mutual attraction which subsists between those particles. Were it not for this atmospheric pressure, water would not be known in any other states than those of ice and vapour; for, as soon as ice had acquired caloric enough to give it fluidity, it would evaporate, and be dispersed into the regions of space. This may be proved by direct experiment, as will be shown in the following chapter. The constitution of the world in this respect exhibits a beautiful instance of the harmony of nature, and of the exquisite contrivance of its divine Author.

On the other hand, could we totally abstract the matter of heat from any fluid, no doubt but that fluid would by that mean be changed to a solid; the lightest vapours being nothing more than solids combined with heat. Not only fluids, but all those substances which are soft and ductile, owe these properties to the chemical combination of caloric. Metals owe their malleability and ductility to the same cause; for, in very intense artificial colds, the most ductile metals, such as gold, silver, and lead, lose their malleability and become brittle, as Van Mons has shown, *Annales de Chimie*, tom. xxix. page 300.

The following experiment will *prove* that it is caloric which converts solids to fluids:—Expose a pound of water and a pound of ice, both at 32°, in a room the temperature of which is above the freezing point. The water will arrive at the temperature of the room several hours before

Liquid substances are merely solids converted into liquids by heat[c], a certain increase of which would convert any liquid into an elastic vapour[d], similar to that fluid body which surrounds the globe, and is described under the name of atmospheric air.

Why is the air[e] *called a fluid?*

Because it flows like a fluid[f], because like a fluid it presses in every direction, and because light substances will swim in it.

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the ice is melted. The caloric, therefore, which has all the time been entering into the ice, but is not to be found in it by the thermometer, must have become *chemically* combined with it in order to give it fluidity. The caloric appears to be lost; its properties are merged in the fluid, just as muriatic acid, by union with lime, loses all its characteristic properties. See this further explained in the chapter on caloric.

[d] Take mercury as an instance. This metal is a fluid body in our climate, but by cooling it to 39 degrees below the zero of Fahrenheit's thermometer it becomes solid, and if it be heated to 660° it will be volatilized and converted into vapour.

[e] Atmospheric air is one of the permanently elastic fluids. Steam is also an elastic fluid; but atmospheric air in all states, and in all seasons, is *permanently* elastic. This elasticity arises from caloric being chemically combined with the solid substances of which it is composed. I say *solid*, because we have abundant evidence that oxygen and nitrogen are both capable of taking a solid form, and actually do, in many instances, exist in a state of solidity. Nitrogen is a component part of all animal substances, and exists in a solid state in all the ammoniacal salts. Oxygen takes the same state when it combines with metals and other combustibles: and in the composition of the nitrous salts they both take the same state of solidity. These facts surely evince that atmospheric air owes its fluidity to caloric. Indeed one of the general laws discovered by Dr. Black, and which he laid down as a chemical axiom, was, that "whenever a body *changes* its state, it either combines with caloric, or separates from caloric." The great number of natural appearances which are explained by this general law renders it important, and it ought to be remembered by all who wish to make a progress in the knowledge of the science of chemistry.

[f] The air is also known to be a fluid, by the easy conveyance which it affords to sound. In chemical laboratories a vacuum is often formed in the retorts and other glass vessels, which occasions explosions, and sometimes dreadful accidents. These are frequently produced by a torrent of cold atmospheric air rushing into these vessels. If the air did not possess the common properties of fluids, these effects could not take place. It is a property of fluids to press in all directions, upwards as well as downwards; so does atmospheric air.

What explanation do you give of bodies swimming in fluids?

All fluids upon which solids float are specifically heavier than those solids . This is an established law of nature[b]. Thus a cork swims upon water, while a stone[c] sinks in it.

Have you a clear idea of the cause which makes some substances sink and others swim in the same fluid[d]*?*

Those which swim are lighter, and those which sink are heavier, than that fluid:—thus in water, if a substance be heavier than a portion of water of *its own bulk*, it must sink[e].

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[a] This may easily be proved, even to a child at the breakfast-table, by placing a tea-cup upon a bason of water, and informing him that it swims there because the cup and the air contained in it, are together specifically lighter than a body of water of their own bulk. Water may then be gradually poured from the tea-pot into the cup; and he may be directed to observe how the cup sinks in the bason as it becomes loaded with water, until the united weights of the water and the cup are too great for the water in the bason to support, and the whole sinks.

[b] Here the pupil may be informed, that it is on this principle that ships and other vessels are constructed, and that it is this property of fluids which enables us to float a vessel from one country to another. The weight of goods in a vessel is indicated by the depth to which the vessel sinks in the water. In canal boats this is shown by graduated metallic plates affixed to them. An account of a curious method of ascertaining the tonnage of ships hydrostatically, may be seen in the first number of the *Retrospect*. It is founded on the different draught which a ship will have in salt and in fresh water, owing to the different specific gravity of the two fluids. That nautical men should be acquainted with this hydrostatical axiom, is certainly of importance: for, should a captain load his vessel with a *full* cargo at any sea-port, his vessel would inevitably sink when brought into the Thames.

[c] The pupil should be informed that *all* stones are not heavier than water, for that these natural bodies differ very much in specific gravity; that though the specific gravity of sulphate of barytes be 4.40, or nearly 4½ times as heavy as an equal bulk of water, some species of the asbestus are lighter than water. Some kinds of pumice-stone, owing to their porosity, are also much lighter than that fluid.

[d] Some of the questions in this introductory chapter may perhaps be thought trifling and insignificant; but the reader is requested to consider nothing unimportant that tends to lay a just and stable foundation for the superstructure of an interesting science. The generality of elementary writers presume too much when they suppose that what they omit

What term is made use of to express the relative *weight of bodies?*

Specific gravity.—Thus the specific gravity of one body may be much greater than that of another, though their absolute weights be the same[f].

How do you explain the difference in the specific gravity of different bodies?

When one body is larger, or takes up more room, than another of the same weight, the first is said to be *specifically* lighter[g] than the other, and vice versa.

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is universally known. Many things which they consider to be of public notoriety, are known perhaps to few who have not paid a particular attention to the subject. Hence many works which are called elementary disappoint the expectation of the student, and are laid by with distaste, for want of the first rudiments of the science being detailed with minuteness and simplicity.

[e] It is an axiom in hydrostatics, that every substance which *swims* on water displaces so much of the water as is exactly equal to its own weight; whereas, when a substance *sinks* in water, it displaces water equal to its bulk. Take a piece of hard wood, balance it accurately in a pair of scales with water, and then place it gently on the surface of water in a vessel exactly filled with that fluid, and it will displace a portion of the water, which will flow over the top of the vessel. If the wood be now taken out with care, it will be found that the water in the scale will exactly fill the vacancy left by the wood.

[f] The specific gravity of bodies is denoted in chemical writings by comparing it with the specific gravity of pure water, in decimal figures, water being always considered as 1.000. Thus the specific gravity of the strongest sulphuric acid of commerce is 1.850, or nearly nine-tenths heavier than water. Iron is 7.650, or more than 7½ times heavier than water; that is, a cubic inch of iron, if put into a scale, would require 7½ inches of water to balance it; silver is 10.478; gold, 19.300; and platinum 23.000, or 23 times heavier than water. The specific gravity of bodies is noted in the same way throughout this work

[g] The nations of antiquity were unacquainted with any method of ascertaining the specific gravity of bodies. A singular event was the cause of its being discovered by Archimedes 200 years before Christ. Having reason to believe that an unprincipled goldsmith had greatly debased the golden crown of Hiero II., king of Syracuse, he was anxious to ascertain the fact, but was perplexed by not knowing how to effect it. However, one day while bathing, the difference in the weight of his own body, when in the water and when out of it, gave him the idea that he might adopt *that* method for discovering the specific gravity of the king's crown;

What definition do you give of the atmosphere which you spoke of in connexion with this subject?

The atmosphere[a] is that very light fluid[b] which surrounds[c] us every where: it is the medium in which we live, and without which we could not exist[d].

What is the specific gravity of atmospheric air?

A pint[e] measure of atmospheric air weighs nearly nine grains, whereas a pint measure of hydrogen gas weighs

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and it is related of him that he was so rejoiced at the discovery, that he leaped from the bath in an ecstasy, and ran through the streets of Syracuse, crying *I have found it! I have found it!* It would be a pleasing, and not altogether an unprofitable employment to endeavour to recount the methematical, philosophical, and chemical truths, which tend to promote the happiness and civilization of man, and which the ancients were totally unacquainted with. It is absolutely necessary for the student to understand the nature of specific gravity, to enable him to analyse minerals, to examine the gases, and to perform a variety of other operations in chemistry. Besides, this knowledge will be of use in the common occurrences of life, and no one who wishes to have a general acquaintance with things ought to neglect to acquire it. For instance; suppose a person has a piece of silver plate which he suspects is alloyed more than it ought to be, a knowledge of specific gravity, and of the principle of bodies which sink in fluids, displacing so much of the fluid as is equal to their bulk, will enable him to ascertain its value with accuracy. He has only to weigh it in air and then in water, and calculate from the difference in its weight when weighed in these two mediums. Thus, if it weighs 46 ounces in air, and only 41½ ounces when weighed in water, its bulk of water is 4½ ounces. Now, if 46 be divided by 4½, the quotient will be 10¼; which shows that the piece of plate is 10¼ times as heavy as its bulk of water, which is about the specific gravity of standard silver. *Pure* silver is 10½ times the specific gravity of water. For an account of the other methods of taking the specific gravity of different substances, see Additional Notes, No. 1.

[a] This word is derived from the Greek language, and signifies a body of vapour in a spherical form. By this name we understand the "entire mass of air which encircles all parts of the terrestrial globe, which moves with it round the sun, which touches it in all its parts, ascending to the tops of its mountains, penetrating into its cavities, and incessantly floating on its waters. It is the fluid which we inhale from the first to the last moment of our existence."

[b] Atmospheric air, like all other elastic fluids, yields to the slightest impulse, and is put in motion with the greatest ease; but it has not the power of penetrating many substances, like oils and some other fluids.

The facility and rapidity of the motions of atmospheric air cannot be explained on any principle but its fluidity. Some of the winds move nearly at the rate of 4000 feet in a minute. This great velocity was doubtless little more than half a grain. The same measure of pure water weighs upwards of one pound avoirdupois.

If the specific gravity of water be so much greater than that of atmospheric air, how is water retained in the atmosphere?

The water which is taken up by the atmosphere is not in an aqueous state, but is converted into vapour[f] by the matter of heat[g].

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designed to produce some beneficial effects in the economy of nature, with which at present we are not acquainted. I come to this conclusion because I think we have sufficient grounds for believing that the Deity does nothing in vain.

> "His wisdom guides the rushing wind,
> Or tips the bolt with flame;
> His goodness breathes in every breeze,
> And warms in every beam." DARWIN.

[c] If the earth had no atmosphere at the time of its formation, we may easily conceive how an atmosphere might be produced. I refer the reader desirous of investigating this subject, to an interesting essay in the second chapter of Lavoisier's *Chemical Elements*.

[d] It may be remarked, that the Creator has endowed atmospheric air with the property of preserving its own equilibrium at all times, and in all places. Its elasticity is such, that, however it may be consumed by respiration or combustion, its place is immediately supplied with a new portion; and though by a mistaken policy the doors and windows of our habitations may be constructed so as to exclude it as much as possible, it *will* have admission; it forces its way through every crevice, and performs the important office assigned it, in defiance of all our exertions. If the properties which are given to the different substances in nature, and the laws by which they are governed, be thus examined, we shall find them all tending to one point, viz. the welfare and felicity of every species of animated beings.

[e] The measure here alluded to is the common *wine* pint. From this one may deduce by calculation that a cubic foot of atmospheric air weighs nearly one ounce and a quarter, and a cubic foot of water 1000 ounces, avoirdupois.

[f] It is of importance to satisfy a young person of the truth of every thing we teach him, and, whenever it can be done, it ought not to be omitted. By inverting a glass goblet over a cup of hot water, the vapour will be seen to rise into it, to condense upon the cold glass, and then to run down its inside; which will show that steam is *real* water, and can become water again.

[g] Here the pupil may be informed that water not only becomes converted into steam by heat, but that, when it is received into the atmosphere, if the air be warm it becomes so far changed by its union with the matter of heat as to be perfectly invisible. In this state it occupies

What is the immediate cause of the waters of the earth being thus vaporized?

As the rays of the sun warm the ground[a], a portion of caloric, or the matter of heat, combines with a portion of the water which has fallen upon the earth[b], and converts it into vapour.

But what causes the vapour to rise[c] *in the air?*

If a cork be placed at the bottom of a bason of

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a space 1400 times greater than its ordinary liquid state. The vapour arising from boiling water is visible only in consequence of its being partially condensed by a cold atmosphere, as may be demonstrated by causing water to boil in a Florence flask over a lamp; for in this case, the steam within the neck of the flask will be found to be entirely invisible.

An instrument has been invented for showing the relative moisture of the atmosphere, called an *hygrometer*. This instrument shows when aqueous vapour dissolves with difficulty in the atmosphere, or when vapours are about to precipitate upon the earth; but it will not indicate the real quantity of water in any given portion of atmospheric air. There is a great variety of these instruments, all made with porous substances, which contract and dilate according to the dryness or moisture of the air. Slips of whalebone, strings of catgut, and the beard of the wild oat, are the substances most commonly employed in fabricating these instruments.

[a] In winter, the earth at eighteen inches depth is warmer than the air; in summer, the air is warmer than the earth at that depth: these effects are owing to the earth being a bad conductor of heat.

[b] Bishop Watson found that, even when there had been no rain for a considerable time, and the earth was dried by the parching heat of summer, it still gave out a considerable quantity of water. By inverting a large drinking-glass on a close-mown grass plat, and collecting the vapour which attached itself to the inside of the glass, he found that an acre of ground dispersed into the air above 1600 gallons of water in the space of 12 hours of a summer's day.

The ocean loses many millions of gallons of water hourly by evaporation. The Mediterranean alone is said to lose more by evaporation than it receives from the Nile, the Tiber, the Rhone, the Po, and all the other rivers that fall into it. This water is conveyed by the winds to every part of the continents:—these it fertilizes in the form of rain, and afterwards supplies the rivers, which flow again into the sea. This is one of those continual circulations whereby all matter is made to subserve various purposes, which have been devised by the Creator for the promotion of his beneficent designs.

> "The bounteous sun
> Lifts the light clouds sublime, and spreads them thin,
> Fleecy and white o'er all-surrounding heaven."

In our climate evaporation is found to be about four times as much water, it rises immediately to the top, because it is specifically lighter than the water[d]; so vapour rises in the air, because it is specifically lighter than the air[e].

What becomes of the water which thus evaporates from the earth?

It occupies the lower regions of the atmosphere[f], and is preserved there partly dissolved[g]

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from the vernal to the autumnal equinox, as from the autumnal to the vernal. Heat facilitates all solutions; and the greater the difference between the temperature of the air and the evaporating surface, the greater will be the evaporation.

[c] That one substance swims upon another in consequence of the greater density of the fluid which supports it, should be made very clear to the apprehension of the pupil; for, till he thoroughly understands this principle, it will be impossible for him to comprehend the cause of a variety of effects which will take place during the course of his experiments. When this is understood, it may be proper to point out some of the advantages which we derive from this property of fluids. It may, however, be expedient in an early stage of his progress to inform him that this does not exactly apply to elastic fluids or gases, because they form a vacuum to each other, as I have more fully explained in the Additional Notes, No. 6.

[d] I have introduced this and other very familiar examples, because I think it of consequence that those who have the care of very young people should encourage them to inquire the *cause* of every thing which they see around them. A preceptor who is well qualified for his employment, will not think any thing too trivial which can furnish him with an opportunity of imparting useful knowledge.

[e] It is evident that water exists in the atmosphere in abundance even in the driest seasons, and under the clearest sky. There are substances which have the power of absorbing water from the air at all times, such as the fixed alkalies and sulphuric acid; the latter of which will soon absorb more than its own weight of water from the air when exposed to it.

[f] There can be no doubt but that in general the vapours occupy the lower strata of the atmosphere: that they sometimes ascend very high, is also true; for it is well known that clouds are seen forming above the tops of the highest mountains. Indeed, the clouds *begin* to form always at some considerable height.

> "At first a dusky wreath they seem to rise,
> Scarce staining ether; but by swift degrees,
> In heaps on heaps, the doubling vapour sails
> Along the clouded sky."

[g] Persons who have been in the habit of making observations on the clouds, may have sometimes noticed a cloud which appeared to be just in the act of precipitating, suddenly arrested by a warm current of air,

in air[a], and partly in the state of elastic vapour.

How is this vapour formed into clouds?

After it has remained some time in the atmosphere, it becomes in a measure condensed by causes unknown to us[b]; and the particles of water of which it is composed unite, and form small hollow vesicles, which accumulate together[c] and produce clouds.

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and entirely dissolved thereby, so as to become in a few seconds invisible. This is the same kind of solution as takes place whenever a warm breeze passes over a river or the ocean. Whenever the air is ponderous, and susceptible of holding the aqueous vapour in solution, the mercury in the barometer rises up to 30° or upwards: when lighter, and liable to suffer the vapours to coalesce, its pressure is less on the base of the barometer, and the mercury falls. See a further account of the barometer in the next chapter.

[a] By the experiments of Saussure, it appears that a cubic foot of atmospheric air will hold eleven grains of water in solution; though it usually contains from about five to ten grains in every cubical foot. From this property of the air we derive many advantages. It has a tendency to preserve every thing on the face of the earth in a proper degree of moisture. In one season of the year, in the interior parts of Africa, a wind prevails called the *Harmattan*, which is so extremely dry that household furniture is destroyed by it; the pannels of wainscots split; boarded floors are laid open; and the scarf skin of the body peels off, during its continuance. Were it not for the property which atmospheric air has of holding water in solution, this would be the case every where.

[b] The formation of clouds was formerly attributed solely to the solution of water in atmospheric air, and the production of rain to the mixture of airs of different temperatures; but there are so many difficulties attending every hypothesis, that these operations of nature are still in some measure inexplicable. It is, however, probable, that *electricity* alone is the primary cause, and that all the phenomena of nature may originate from this source.

[c] Saussure conjectures that it is the electrical fluid which surrounds these vesicles, and prevents them from dissolving in the air. These vesicles are said to be from 1.380 to 1-190th of a line in diameter.

An elaborate essay, by Luke Howard, esq. on the various forms which clouds assume, may be seen in the 16th and 17th volumes of the *Philosophical Magazine:* see also Dr. Darwin's theory of rain and dew, in notes to the *Botanic Garden*, 4to, part i. pages 114 and 169.

[d] It has before been remarked, that a portion of the water which rises in vapour is held in *solution* by the atmospheric air. When two opposite currents of air meet, of different temperatures, the vapours are some-

What further changes take place in this aqueous vapour?

By the operation of causes which are also in a great measure unknown, the clouds after a time become further condensed, and are converted into water[d], which falls again upon the earth in the form of rain, hail, or snow.

What is the use of this constitution of nature?

This principle of evaporation[e] is of very general uti-

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times condensed thereby, and rain follows. All the known gases have also the property of taking up water, and holding it in solution.

It may be remarked, that if the temperature of our atmosphere had been 212°, or upwards, rain could never have fallen upon the earth; for the water taken up by evaporation would have been converted into a *permanently* elastic fluid. It is impossible ever to contemplate the various ways in which the different operations of nature are made to correct and balance each other, without being struck with the infinite comprehension of the Divine mind, which could thus foresee the tendency of every law which it was about to establish.

[e] This principle of evaporation not only is the primary cause of all rain, mist, dew, &c., but it moderates the effects of the sun's heat, by carrying off an immense quantity of caloric in combination with the aqueous vapours. Were it not for the cold produced by evaporation, we should faint under any great bodily exertion, or die by excessive heat. But Nature, always provident, has furnished man with a fluid, which, insensibly perspiring and becoming evaporated from the surface of the body, is the vehicle which carries off the superabundant heat as fast as it is generated. Cold-blooded animals, whose temperature is regulated by the medium in which they live, never perspire; but man, who was intended to live in a variety of climates, and designed for active exertion, is thus preserved from the effects of heat, which would otherwise be destructive. The blood of an inhabitant of the torrid zone is no warmer than that of an inhabitant of the mountains of Lapland; which may be proved by placing a thermometer upon the tongue or under the arm. The various means which have thus been adopted for the promotion of our convenience and comfort, are full of instruction and highly gratifying to every reflecting mind.

The operation of this principle may be made apparent by the following experiment: Take a small tube with a little water in it, fold a little lint close round it, and having immersed it in ether till the lint is soaked through, hold it in the air for the ether to evaporate. The cold produced by this evaporation will cause the water in the tube to freeze. If the outside of the glass tube be scratched with a flint or a diamond previous to its being wet by the ether, the effect will more readily take place.

lity: it is subservient to many natural and artificial[a] processes, and is of perpetual use to man in every occupation of life[b].

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[a] The effects of evaporation are of eminent importance to the practical chemist. By this means fluids are separated from solids and one salt from another in various operations of the laboratory. Sometimes artificial and at others spontaneous evaporation is employed for these purposes. Whenever fire is used to separate the water from aqueous solutions, it is called *artificial* evaporation; when this is effected by exposing the mixture to the action of the sun and air, it is called *spontaneous* evaporation. In separating common salt from sea water, both these methods are generally adopted.

[b] A little consideration would convince any one of the importance of this principle of evaporation even in the common affairs of life. Innumerable instances of its use might be adduced: suffice it to say, that without it neither grass nor corn could be sufficiently dried to lay up for use. Our clothes when washed could not be dried; neither could a variety of the most common operations be carried on, which conduce much to our comfort and convenience.

CHAPTER II.

OF ATMOSPHERIC AIR.

WHAT are the obvious properties[a] *of atmospheric air?*

Fluidity[b], elasticity[c], expansibility, and gravity.

What do you mean by the elasticity of the air?

If atmospheric air be compressed[d] into a small compass, it has the property of recovering its former state

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[a] The habitable and cultivated parts of the earth are lavishly adorned with every thing to gratify the eye; the diversified appearance communicates pleasure, and prevents satiety; while the whole is surrounded by an atmosphere which preserves vegetable and animal life. It may be remarked, that to the *transparency* of this atmosphere we owe all the pleasure we receive from the variegated prospects which the earth affords.

[b] The fluidity of the air was considered in the last chapter. See pages 23 and 26.

[c] If a bladder be tied up with a very small quantity of atmospheric air within it, and put under the receiver of an air pump, it will be seen to inflate gradually as the receiver is exhausted, till it attains its full size, owing to the *elasticity* of the small quantity of air within the bladder, which dilates in this manner as the atmospheric pressure is removed. A wrinkled apple placed under the receiver of an air pump becomes plump and smooth, from the same cause. The elasticity of the air is such, that Mr. Boyle caused it to dilate by means of an air pump till it occupied nearly fourteen thousand times the space that it usually does. An interesting account of some of the first experiments which were made with this very important instrument, will be found in Mr. Boyle's work entitled *New Experiments Physico-Mechanical, touching the Spring of the Air*, &c. 4to. Oxford 1662.

[d] Atmospheric air may be compressed into about the 128th of its usual volume; though, if an apparatus could be procured of sufficient strength, it might doubtless be compressed to a much greater degree: but, owing to its elasticity, it would regain its original bulk the instant the pressure was removed. Saussure made use of an instrument to show the elasticity of the air, which he called a *manometer*. It was a barometer inclosed in a well luted globe. Being thus inclosed, it was only sensible to the elasticity of the air within the globe. For a further elucidation of this property of the air consult Berthollet's *Chemical Statics*.

as soon as the pressure is removed; which is called its elasticity[a].

What is meant by the expansibility of the air?

The expansibility of the air is its property of being rarefied by heat, so as to occupy a larger space than it would at a lower temperature[b].

How far does the atmosphere extend?

The atmosphere is several miles high, but it is so

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[a] It is now generally supposed that the air owes its elasticity to *caloric*; and that, if it could be entirely deprived of the matter of heat, it would lose its elastic form.

The rebounding of a common foot-ball would be a familiar instance to explain the elasticity of the air to a child; also the bubbles of air rising from the bottom of a glass of water, which will be seen to dilate as they rise to the surface, owing to the pressure of the liquor becoming less and less upon them.

The air gun and the forcing pump are constructed on this principle of elasticity. It is by this property of the air that fishes are enabled to rise and sink in the water; nature having furnished them with an *air bladder*, which they have the power of contracting or dilating at pleasure. When a fish compresses this bladder, its whole volume becomes less, and it sinks in the water: when the pressure is removed, the air within the bladder instantly expands, and then it is enabled to rise.

Mr. Gregory has remarked that, if the air were not elastic, and so fluid as to be easily put in motion, there would be an end to all the melody and harmony which now so much delight us. How admirably is every thing contrived, that it may not only administer to our wants, but be subservient to our pleasures also! That music was designed by the Deity to produce particular effects on man, might be shown very satisfactorily; for who can doubt but

> "That Heaven is pleased, when this bright power
> Dispels the clouds of earth, too apt to lower
> On every human mind, in life's precarious hour?" Hayley.

[b] If the neck of a bladder, containing a small quantity of air, be closely tied up and held to the fire, the swelling of the bladder, by the rarefaction of the air within it, will afford an idea of the *expansibility* of the air.

Mr. Robins has calculated that the air which is disengaged in the firing of gunpowder is rarefied by the heat so as to occupy a thousand times the space of the whole of the gunpowder employed.

The dilatation or expansion which bodies experience by a given elevation of temperature, is much more considerable in elastic fluids than in liquids. Atmospheric air is an instance of the truth of this chemical axiom. Whenever this expansion takes place, caloric is absorbed.

[c] If the atmosphere were of the same density throughout, its height might be known by its effect in raising a column of water or mercury; but as it increases in rarity the higher it ascends, and is probably ex-

very much attenuated[c] at considerable heights, that it cannot be ascertained how far it actually does extend.

What are the various uses of the atmosphere?

The atmosphere is necessary for the support both of animal and vegetable life[d]. It is indispensable in all the common processes of combustion[e]: it ministers to several of the pleasures which we derive from

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tremely rare in the higher regions, we cannot possibly tell how far it may extend. It was attempted to calculate the extension of the atmosphere by ascertaining its comparative rarity at different heights: but this also was found to be impracticable. Since then, it has been estimated by the length of our twilight, and supposed to be about forty-five miles high. If we had no atmosphere, we should be in total darkness at the *instant* the sun sinks below the horizon; but as the sun illuminates the atmosphere for some time before it rises, and after it has set, the light is refracted by the atmosphere to the earth. We cannot but admire the simplicity of this contrivance, to prevent the sudden transition from light to extreme darkness.

"From night to day, from day to night,
The *dawning* and the *dying* light
Lectures of heavenly wisdom read;
With silent eloquence they raise
Our thoughts to the Creator's praise,
And neither sound nor language need."

[d] It has been ascertained by experiment, that no other gaseous body with which we are acquainted can be substituted for atmospheric air. All the known gases have been tried; but they all prove fatal to the animal which is made to breathe them. Even water absorbs air when exposed to the action of the atmosphere, and thence becomes a fit element for the various tribes of creatures which inhabit it.

"The vital air
Pervades the swarming *seas* and heaving earths,
Where teeming Nature broods her myriad births;
Fills the fine lungs of all that *breathe* or *bud*,
Warms the new heart, and dyes the gushing blood;
With life's first spark inspires the organic frame,
And, as it wastes, *renews* the subtil flame." DARWIN.

It is to the presence of air that water is indebted for its agreeable taste. Boiling deprives it of the greater part of it; hence the insipidity of boiled water.

[e] I have said "common processes," because if a combustible substance be mixed with one fourth or one half its weight of nitre, or with oxygenized muriate of potass, it will burn if atmospheric air be excluded. But even this is owing to oxygen being afforded by these salts. See chap. xii. on Combustion.

our senses[a]; it gives buoyancy to the clouds, and enables the feathered creation to transport themselves with ease from one part of the earth to another[b].

But what is the use of the atmosphere being extended so far above the surface of the earth?

It is this great extension of the air which occasions its *weight*; and the pressure of such a weight

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[a] Were it not for atmospheric air, we should be unable to converse with each other; we should know nothing of sound, nor of smell, nor of the pleasures which arise from the variegated prospects which now surround us. It has been well remarked, that, if the Deity had intended only to give us existence, and had been indifferent respecting our happiness or misery, all the necessary purposes of hearing might have been answered without harmony; of smell, without fragrance; of vision, without beauty.

Perhaps nothing tends to give so satisfactory an assurance of the goodness of the ALMIGHTY, as the consideration of the various *uses* to which the different substances in Nature may be applied. With this view I copy what an elegant French writer has said on this important elastic fluid. "In the use of atmospheric air, *man* is the only being who gives to it all the modulations of which it is susceptible. With his voice alone he imitates the hissing, the cries, and the melody of all animals; while he enjoys the gift of speech denied to every other. To the air he also sometimes communicates sensibility; he makes it sigh in the pipe, lament in the flute, threaten in the trumpet, and animate to the tone of his passions even the solid brass, the box-tree, and the reed. Sometimes he makes it his slave: he forces it to grind, to bruise, and to move for his advantage an endless variety of machines. In a word, he harnesses it to his car, and obliges it to waft him over the stormy billows of the ocean."

[b] Messrs. Robertson and Saccharoff, who ascended with an air balloon from Petersburgh in June 1804, took some live pigeons with them. At different heights they gave liberty to their birds, who seemed not very willing to accept it. The poor animals were so terrified with their situation, that they clung to the boat till forced from it; when it appears their fears were not groundless; for, on account of the rarity of the air, their wings were nearly useless, and they fell towards the earth with great rapidity: the second struggled with eagerness to regain the balloon in vain: and the third, thrown out at the greatest elevation, fell towards the earth like a stone, so that they supposed he did not reach the earth alive. *The Retrospect*, vol. i. page 94. This relation affords a fresh instance of the harmonies of Nature, and of the suitableness of every creature to the medium in which it was designed to live. The density of the air near the surface of the earth, we see, is exactly what was requisite for the residence of the feathered race: and the specific gravity of every in-

produces many important effects in the economy of nature[c].

What are the effects of the weight of the atmosphere?

It is owing to the weight of the atmosphere that we are enabled to raise water from beneath the surface of the earth by the common pump[d], and to perform many other useful operations.

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dividual of every species is just sufficient to enable it to occupy that element, and to move within it at all times with ease and safety. The most acute fatalist would surely be puzzled to account for these congruities. Let us attribute them to the contrivance of that Being, who never bestows existence but for the sake of conferring felicity, and we are at once in possession of the most satisfactory solution.

[c] The pressure of the atmosphere may be shown by a very simple experiment. Place a card on a wine-glass *filled* with water; then invert the glass, and the water will not escape; the pressure of the atmosphere on the outside of the card being sufficient to support the water.

The same thing may be shown by a different experiment. Invert a tall glass jar in a dish containing a little water, and place a lighted taper under it. As the taper consumes the air in the jar, its pressure becomes less on the water immediately under the jar; while, the pressure of the atmosphere on the water *without* the circle of the jar remaining the same, part of the water in the dish will be forced up into the jar, to supply the place of the air which the taper has consumed. Nothing but the pressure we are speaking of could thus cause a part of the water to rise within the jar, above its own level.

Again, the reality of atmospheric pressure may be explained and demonstrated by a common barometer, merely by showing how it acts upon that instrument.

> " In tubes of glass mercurial columns rise,
> Or sink, obedient to the incumbent skies."

It is this action of the atmosphere which enables the limpet to attach itself to the rocks. It forms a vacuum in its pyramidal shell, and the pressure of the atmosphere supports it where it wishes to remain, without any further exertion of its own.

[d] In this operation the atmosphere presses equally upon the whole surface of the water in the well, until the rod of the pump is moved; but, by forcing the rod down, the bucket compresses the air in the lower part of the pump tree, which being elastic forces its way out of the tree through the valve; so that, when the bucket is again raised, that part of the pump tree under the bucket is void of air; and the *weight of the atmosphere* pressing upon the body of water in the well, forces up a column of water to supply its place; the next stroke of the pump rod causes another column of water to rise; and so long as the bucket fits the pump tree close enough to produce a vacuum, a constant stream of

What other advantages do we derive from this extension of the atmosphere?

If we had little or no atmosphere, we should have no cold water; for the waters on the face of the earth would all evaporate at a very inferior temperature[a]: besides, the arterial vessels of all organized beings would be so constantly distended, that animal and vegetable life would be endangered.

How are waters and other fluids preserved to us by the weight of the atmosphere?

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water may be drawn from below. See Additional Notes, No. 12. By cutting a piece of pasteboard in the form of a valve, and fixing it in a glass tube of a large bore, it will be no difficult thing to explain how the successive columns of water force up the valve in the pump tree, and how that valve supports the water when raised, and prevents its return.

> "Press'd by the incumbent air, the floods below,
> Through opening valves, in foaming torrents flow,
> Foot after foot in lessen'd impulse move,
> And rising seek the vacancy above." DARWIN.

A common syringe (which may be bought for a few pence) will show the action of atmospheric air in pumping. When a child sucks at the breast, it forms a vacuum with its mouth, and the milk flows on the same principle. In like manner the boy forms a vacuum between a piece of wet leather, tied to a string, and a pebble stone; and, by means of the pressure of the atmosphere, is enabled to lift the pebble from the earth, and carry it about suspended by the leather. The common syphon is also indebted to this pressure for its action.

[a] On the tops of very high mountains, water will boil much sooner than on the plains, where the atmosphere is heavier; at the top of Mont Blanc it has been known to boil at the temperature of 187° of Fahrenheit; and it has been observed that many spirituous liquors, such as ether and spirits of wine, lose the best part of their qualities when exposed at such heights. See some interesting experiments in the first chapter of Lavoisier's *Elements of Chemistry*, also the Additional Notes (at the end of this volume), No. 3.

The quick evaporation which would take place if we had no atmosphere, may be shown by a common instrument, invented by Dr. Franklin, called a pulse-glass. It is a small tube with a bulb at each end, exhausted of its air, and containing a small quantity of spirits of wine. If this instrument be held sloping, with one end in the palm of the hand, the heat of the hand will quickly cause the spirit to boil; but the vapour rising to the other end becomes condensed as soon as it comes in contact with the cold glass. This is a very cheap and simple experiment, and shows that a very small degree of heat would be sufficient to evaporate most of our fluids, if we had no atmosphere. This instrument is also calcu-

The weight of the atmosphere, pressing on the water, binds it down as it were, and prevents the usual heat of the sun from converting this and all other fluids on the face of the earth into vapour[b].

How does the weight of the atmosphere operate so as to be beneficial to the animal and vegetable creation?

The uniform pressure of the atmosphere on the *exterior* of all organized beings counterpoises the

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lated to show that evaporation produces cold; for the instant that the spirit begins to boil, a sensation of sudden cold is felt on that part of the hand where the bulb rests.

It is the principle of *evaporation producing cold* that occasions the injury which persons sustain by sitting in wet clothes. In these circumstances, it is not the water that hangs *upon* them which produces the mischief, but the sudden loss of a large portion of caloric, which is carried off from the body by the evaporation of this water. If a healthy person were closely covered up with his wet clothes, so that no evaporation could take place, he would probably sustain no injury.

[b] That the waters on the face of the earth would be dissipated in vapour by a small degree of heat, if we had no atmosphere, may be shown by the following easy experiment:—Procure a common oil flask, let this be about one third filled with water, and heat it over a lamp. When the water boils remove the flask, cork it closely so as to exclude the air, and plunge it for a moment into cold water, nearly up to the mouth of the flask. This will not only cool the hot water in some measure, but it will entirely condense the vapour which occupied the upper part of the flask, and occasion so great a vacuum, that the water which had been thus partially cooled, will be seen to recommence its boiling with great violence. This effect can be attributed to nothing but the vacuum which has been formed in the upper part of the flask, and to the cork preserving the water from the pressure of the atmosphere. In like manner, water which has been cooled many degrees below boiling will begin to boil again, if placed under the receiver of an air pump, as soon as we begin to exhaust the receiver of its air. Under the pressure of the atmosphere water boils at 212°, but in vacuo it boils when heated only to 67°. On the contrary, if additional pressure be given to water by a Papin's digester, it may be heated to 400°, without ebullition. Lead has often been melted by the water heated in these digesters.

At the boiling fountain in Iceland the water is thrown to the height of 90 feet, and is still boiling-hot when it falls to the ground. This water, therefore, must have been much hotter, in its reservoir, than the boiling point of water. See Troil's *Account of Iceland.*

If a small metallic cup be half filled with good ether, and placed within a large watch-glass half filled with water, and both be put under the receiver of an air pump, when the air is exhausted the ether will *boil*, and the water will be *frozen*. The cause of these opposite effects may be *internal* pressure of the circulating fluids, and preserves the vessels in due tone and vigour[a].

What is the weight of the atmosphere?

Each square foot of the earth's surface sustains about 2160 pounds of atmospheric air. A column of air an inch square weighs about fifteen pounds[b].

What other advantages do we derive from this immense atmosphere?

The great density of the atmosphere gives a proper

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thus explained—When the pressure of the atmosphere is removed by the air pump from the surface of the ether, its own latent caloric occasions its expansion, and, absorbing caloric from the water, it becomes converted into gas; and the water having lost its caloric of fluidity, becomes *ice*.

The best elucidation of the nature of the pressure of the atmosphere which I have seen, is in Brisson's *Physical Principles of Chemistry*, sect. 31, &c.

[a] Were it not for the pressure of the atmosphere constringing the vessels in animals and vegetables, the elastic fluids contained in the finer vessels would inevitably burst them, and life become extinct. Count Zambeccari and his companions, who ascended with a balloon to a great height on the 7th of November 1783, found their hands and feet so swelled, that it was necessary for surgeons to make incisions in the skin. They ascended to so great a height, that the pressure of the atmosphere was not sufficient to counterbalance the pressure of the fluids of the body.

Persons who have delicate constitutions need not wonder that they are generally much affected by a change in the atmosphere, when they learn that often in the course of a few hours there is an increase or diminution of one hundred weight, and from that to half a ton weight, of atmospheric pressure, on each individual, while the *internal* pressure of the circulating fluids remains the same. Supposing a man's body to contain fifteen square feet of surface, (which is near the truth,) he will sustain a body of air of upwards of fourteen tons weight. But it is necessary to remark that the air presses upwards, downwards, and sideways, in every direction; and that it is owing to this equal pressure that we are not injured by the vast weight of the atmosphere; for the equal pressure on all sides resists as much as it is resisted.

Whenever I hold my hand out in this fluid, I feel no weight upon it, because the pressure under and above my hand is equal: but if I lay my hand on a hollow cylinder of glass, placed on the plate of an air pump, and exhaust the cylinder of air, I become immediately conscious of something that presses it so forcibly to the glass, that I cannot release it. The prop is now gone; I have no pressure under my hand; a column of air 45 miles high forces it down by its weight, and I must let in the air under it before the hand can be withdrawn. Mr. Cotes computed that the weight of the air which presses upon the whole surface of the earth, is equal to that of a globe of lead sixty miles in diameter. See Cotes's *Hydrostatical and Pneumatical Lectures*.

temperature to the rays of the sun: it also reflects those rays so as to give a lucid brightness to every part of the heavens[c], and is the cause of those dews and rains which make the earth fruitful[d].

What is the real nature[e] of the air which forms the atmosphere of this earth?

This immense atmosphere is composed of oxygen and nitrogen, two different airs[f], which are intimately mixed in certain definite proportions[g].

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[b] A column of air of the height of the atmosphere, when greatest, is equal to a column of water 35 feet high, or a column of mercury of the same size 30½ inches high. Hence water will not rise in a pump more than 35 feet, nor mercury in a barometer stand higher than 30½ inches. See Additional Notes, No. 12. A quart measure of atmospheric air weighs about seventeen grains and a half.

[c] If there were no atmosphere surrounding the earth, only that part of the sky would appear light in which the sun was placed; and if a person should turn his back to the sun, he would directly perceive it as dark as night; for in that case there would be no substance to reflect the rays of the sun to his eyes. It is owing to refraction that the sun enlightens the earth some time before it rises, and some time after it sets. This is explained with perspicuity by Gregory in his *Astronomical Lessons*, page 78—82.

[d] The atmosphere is the cause of evaporation; it is the atmospheric air which holds the aqueous vapours in solution, and preserves them in a gaseous state till they are condensed again into rain.

[e] For the discovery of the composition of atmospheric air we are indebted to Scheele, whose genius when very young enabled him to break the trammels of a dependent situation, and whose subsequent investigations of Nature have immortalized his memory.

[f] Although atmospheric air is said to be composed of two gaseous substances only, it is perpetually intermixed with a variety of adventitious exhalations from the earth's surface. "The atmosphere is a vast laboratory, in which Nature operates immense analyses, solutions, precipitations, and combinations: it is a grand receiver, in which all the attenuated and volatilized productions of terrestrial bodies are received, mingled, agitated, combined, and separated. Notwithstanding this mixture, of which it seems impossible for us to ascertain the nature, atmospheric air is sensibly the same with regard to its intimate qualities, wherever we examine it."

According to Sir Humphry Davy, the air of Europe, Asia, Africa, and America, differs very little in the proportion of its ingredients. *Journal Royal Instit.* vol. i. page 48. By submitting to a careful analysis the contents of a glass balloon that had been filled with air at the height of 20,000 feet from the earth, it was found similar in every respect to that taken from the surface. Nicholson's *Journal*, vol. x. page 286.

[g] Atmospheric air is a mixture of two distinct substances, viz. oxygen

Are oxygen and nitrogen the only substances which enter into the composition of the atmosphere?

No; atmospheric air contains also about one part in every thousand[a] of carbonic acid gas[b], and several adventitious substances.

What other substances are found in atmospheric air?

Besides carbonic acid gas, it holds a portion of

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and nitrogen, rendered aërial by the expansive power of caloric: it likewise contains a portion of carbonic acid gas. See Additional Notes, No. 6. Oxygen was discovered by Dr. Priestley on the 1st of August 1774, and was certainly the most brilliant of all his discoveries. He named it dephlogisticated air.

Oxygen and nitrogen, combined in various proportions, form also no less than four other well known compounds, viz.

Nitrous oxide gas, which is composed of . . .	2 volumes, or measures, of nitrogen gas, and	1 volume of oxygen gas.
Nitrous gas, of	2 volumes of ditto, and	2 vol. of do.
Nitrous acid gas, of . . .	2 volumes of ditto, and	4 vol. of do.
Nitric acid gas, of	2 volumes of ditto, and	5 vol. of do.

Or, if estimated by weight,

Nitrous oxide gas is composed of	100 parts of nitrogen gas, and	57 parts of oxygen gas.
Nitrous gas, of	100 parts of ditto, and	114 pts. do.
Nitrous acid gas, of . . .	100 parts of ditto, and	228 pts. do.
Nitric acid gas, of . . .	100 parts of ditto, and	285 pts. do.

Upon an examination of the above statement, it will be perceived that these compounds of nitrogen and oxygen are not formed by the union of accidental and unlimited quantities of the two gases, but that they are combined in certain definite proportions (see Additional Notes, No. 45); so that the quantity of oxygen which is required by a definite proportion of nitrogen for the formation of one compound, will be found to be either an exact multiple or divisor of the quantity which enters into the composition of either of the others; the gradation being in the order of 1, 2, 4, and 5.

Moreover, if the component parts of these various compounds be estimated by *weight* instead of by *volume*, exactly the same results will be obtained. Thus, if the 57 parts of oxygen gas which combine with 100 parts of nitrogen to form *nitrous oxide gas*, be multiplied by 2, the multiple will be 114; and it will be seen by the above tabular representation, that this is the exact quantity which the before-mentioned proportion of nitrogen requires to form *nitrous gas*. In like manner 57×4=228, which is found to be the exact quantity of oxygen gas required to form the third compound, viz. *nitrous acid gas*; and lastly 57×5=285, which is the proportion of oxygen gas that actually enters into the composition of *nitric acid*. For some further elucidation of the above tables, see Additional Notes, No. 10.

water in solution[c]; and sometimes contains hydrogen and carburetted hydrogen gases.

What are the sources of these other gases?

Carbonic acid gas is constantly formed by the respiration of animals and by combustion[d]: and hydrogen and carburetted hydrogen gases arise from various sources, particularly from marshes, stagnant pools, &c., all which are prejudicial to the animal creation.

The respirable part of atmospheric air has been called oxygen, on account of its acidifying principle: the other part has been termed azote, from its known quality of killing all animals that are obliged to breathe it, when separated from oxygen. The terms are taken from the Greek language. I have in this work adopted *nitrogen* in preference to azote, because it is the base of nitric acid, and it agrees in termination with oxygen and hydrogen.

It should be remarked, that oxygen requires *light* as well as caloric in order to convert it into oxygen *gas*. During combustion, the vital air gives out this light in every direction.

[a] The proportion of carbonic acid gas in atmospheric air was formerly calculated at one per cent.; but Mr. Dalton has lately demonstrated that it does not amount to more than one part in a thousand. *Manchester Mem.* N. S. vol. i. page 254.

[b] If a pure alkali be exposed to the atmosphere, it will gradually absorb carbonic acid. This is also the case with several of the metallic oxides.

Carbonic acid gas is found to exist in the atmosphere, not only near the surface of the earth, but at the greatest heights. Saussure found it at the top of Mont Blanc, which is esteemed the highest point of the old continent. However, it is probable that the proportion of carbonic acid is not so large at great heights as it is near the earth; for the unfortunate philosophers who attended La Perouse in his last voyage could not detect it in the atmosphere at the summit of the peak of Teneriffe. See La Perouse's *Voyage*. On the constitution of the atmosphere, see Additional Notes, No. 6.

[c] Upon an average, atmospheric air contains about 1 per cent. of water in the state of elastic vapour. For calculations respecting its pressure on the earth, see *Manchester Memoirs*, N. S. vol. i. page 253.

It is remarkable, that whenever aqueous vapour is united to atmospheric air, an augmentation of volume is the consequence, and damp air is always specifically lighter than dry air.

[d] The quantity of carbonic acid which is daily formed by these processes is so great, that it must have increased rapidly, had not the Almighty provided means for its being as rapidly decomposed. The wisdom and goodness of this appointment must be apparent to those who know that whenever atmospheric air becomes charged with one tenth of this gas, it is unfit for promoting combustion, and is fatal to most animals that are obliged to breathe it.

If carbonic acid air and carburetted hydrogen air are prejudicial to animal life, how are they corrected in the atmosphere?

These airs, which would cause the death of any animal obliged to breathe them[a], are the proper nutriment of vegetables, and nature has endowed them with organs for their decomposition.

You have spoken of different gases; what do you mean by gas?

When solid substances are rendered permanently

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[a] Every chemist must be aware that a large quantity of *carburetted hydrogen gas* is perpetually evolved at the surface of the earth; he must also know that this gas is fatal to animal life. I could adduce a melancholy instance of a gentleman who inhaled it by mistake, and died almost immediately in consequence of it. How, then, has the all-wise Artificer of the world contrived to protect its inhabitants from the baneful influence of that immense quantity with which the atmosphere is perpetually contaminated? The means are as simple as they are important.—Vegetables are so constituted that carbon and hydrogen are the necessary food of plants, and conduce to the support of vegetable life: their vegetating organs seize the carbonic acid gas which comes within their reach, and while they appropriate the *carbon* to themselves, the *oxygen* is thrown off to renovate the atmosphere by its union with the nitrogen rejected by animal respiration. As all vegetables are in want both of carbon and hydrogen, there can be little doubt but that by their means the atmosphere is divested of carburetted hydrogen gas also. Thus, what is noxious to man is rendered beneficial to vegetables; and the oxygen which vegetables are not in want of, is separated by them in its utmost purity for the use of man. The wisdom, the simplicity, and the beneficence of this arrangement are so striking, and address us with so much effect, that the mind of the reader may be left to its own reflections. See Additional Notes, No. 37.

[b] Van Helmont was the first chemist who made use of this term to denote an elastic fluid. He gave fixed air the name of *gas*.

All the gases are compounds of solid matter and caloric. It is caloric which separates the particles, and gives to the whole a gaseous form. In order to produce any of the gases, heat is generally made use of, though sometimes we have recourse to the acids for this purpose.

The simple gases are elastic, transparent, and permanently aëriform, unless condensed by chemical combinations. Few of them possess any colour.

The permanency of the gases appears to be owing to the strength of the affinity existing between caloric and their bases, which affinity resists every reduction of temperature.

When gases are produced by distillations, or by chemical mixtures, aëriform by heat, the air thus produced is called a *gas* [b], to distinguish it from those aëriform substances which return to the solid or fluid state when the heat is removed [c].

Is there any chemical means of analysing atmospheric air?

By the operation of different agents, the several gases may be separated from each other, and the quantity of each ascertained [d].

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the radical of the gas is not merely heated by caloric, but caloric is chemically *combined* with it, and forms one of its necessary component parts. Some of the gases, such as muriatic acid gas, nitrous acid gas, &c., may be condensed by water; but in this case a new combination is formed by the acid and the water, and the caloric is disengaged in the form of sensible heat.

For directions how to proceed in weighing gases, consult Additional Notes, No. 1.

For an account of the method of collecting gases, and of transferring them from one vessel to another, consult Berkenhout's *First Lines of Philosophical Chemistry*, page 204, or the Additional Notes to this volume, No. 47.

The pneumatic trough, which is used for these purposes, was invented by Dr. Priestley. A common tub, with a shelf fixed in it, was what he first used; afterwards he was furnished with a very elegant apparatus which the amiable duke of Rochefoucault sent him from Paris.

[c] By heating water we convert it into steam, but when the heat is abstracted it returns again to the state of water. In like manner if *iodine* be heated it will assume a beautiful purple colour and an elastic form, but as soon as it becomes cooled it returns to the solid state. Mercury and sulphur also assume an elastic form on being sufficiently heated, and yet none of these substances are classed with the gases, but they are known by the name of vapours. Thus we say aqueous vapour, vapour of iodine, vapour of mercury or vapour of sulphur; while those substances which are *permanently* elastic, such as oxygen, hydrogen, &c. are called gases.

[d] If a measure of atmospheric air be confined over a portion of sulphuret of lime, it will soon be decreased nearly one fourth of its volume; its oxygen will be absorbed by the sulphuret, and the remaining air will be found to be incapable of supporting combustion. A piece of phosphorus will decompose atmospheric air in like manner.

The gases have been divided by some writers into two classes, viz. those that are *respirable*, and capable of maintaining combustion, and those that are *not respirable*, and incapable of maintaining combustion. It is remarkable, that if we attempt to breathe any of the non-respirable gases, they stimulate the muscles of the epiglottis in such a manner as to keep it perfectly close, and prevent, in opposition to our exertions, *Do you know the proportions of the different gases in atmospheric air?*

There are about 21 parts of oxygen gas, and 79 of nitrogen gas, in every 100 measures of atmospheric air, or nearly 23¼ of the former and 76¾ of the latter, if the calculation be made by weight[a].

Is there much difference in the nature of these gases?

Yes: they are of different and opposite qualities[b].

What are the properties of oxygen gas?

The oxygen gas in atmospheric air is the principal supporter of combustion[c], and the vehicle of heat[d]; and is, as was before mentioned, absolutely necessary for the support of animal life[e].

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the smallest particle of gas from entering into the bronchia. Some modern atheists have asserted, that the members of the animal body have acquired their adaptation to the wants of the individual by habit, and that they have been gradually formed to what we see them by repeated use from generation to generation: but here is an instance of the parts *refusing action*, for the preservation of the animal. This peculiar faculty, therefore, as a celebrated writer has remarked in another instance, could not have grown out of the use of the parts, though it had had an eternity to grow in. It can only be attributed to that beneficence of contrivance which in so many instances excites our gratitude and admiration.

[a] The pupil may be satisfied of the truth of these proportions in various ways;—the following is the easiest: A lighted taper will not burn in nitrogen gas a moment; if immersed in oxygen gas, it burns with a splendour too great for the eye to endure; but if four measures of nitrogen gas and one of oxygen gas are put into a jar inverted over water, and a lighted taper put into such mixture, it will burn exactly the same as it does in atmospheric air.

[b] These gases are of such opposite qualities, that the one is sometimes called *vital* air; while the other, from its causing the death of those who breathe it, is by the French chemists (as has before been remarked) called azotic gas.

[c] The necessity of oxygen for supporting combustion may be shown by the following simple experiment. Pour a little water on a flat dish, place two or three lighted wax tapers of different lengths in the water, and invert a tall glass jar over them. The flame of the different tapers will soon be seen to grow smaller, and at length will be extinguished in succession. That which is highest will be extinguished first, and the shortest taper the last, owing to the purer air occupying the lower part of the jar.

What is the nature of oxygen gas, when in a separate state?

Pure oxygen gas has the property of accelerating the circulation of all the animal fluids, and occasions the most rapid combustion of all combustible substances; so that it is the most energetic and powerful agent that we are acquainted with.

What is the specific gravity of oxygen gas?

Oxygen gas is a little heavier than atmospheric air[f], and about 750 times lighter than water.

What are the principal properties of nitrogen gas?

Nitrogen gas, or azote, is chiefly distinguished by certain *negative* qualities, such as its being incapable of supporting combustion and animal life[g]. It is un-

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[d] Dr. Higgins having caused a young man to breathe pure oxygen gas for several minutes, his pulse, which was at 64, soon rose to 120 beats in a minute. By abstracting a part of the oxygen from atmospheric air, the pulse may likewise be lowered at pleasure. See Additional Notes, No. 8.

[e] It has been asserted by Mr. Hassenfratz, that oxygen is necessary to promote the vigour of plants as well as that of animals.

> "LEAVES, LUNGS, and GILLS, the vital ether breathe
> On earth's green surface, or the waves beneath."

A collection of experiments on the effects of oxygen on animal and vegetable life may be seen in Archer's *Observations on Oxygen*, 8vo, 1798.

[f] At the temperature of 60° when the barometer stood at 30° it was determined by Messrs. Allen and Pepys that 100 cubical inches of oxygen gas weigh 33.82 grains. Sir Humphry Davy states it at 34 grains.

Oxygen gas is plentifully procured from nitre, or from the black oxide of manganese. Four ounces of nitre melted with a little slacked lime produced Mr. Ingenhousz 3000 cubic inches of vital air. See Additional Notes, No. 7.

[g] Nitrogen was discovered by Dr. Rutherford in the year 1772: but it was known to Mayow more than 100 years before this time. See Dr. Yeats's *Observations on the Claims of the Moderns to some Discoveries in Chemistry and Physiology*, page 48. From some late experiments it seems probable that nitrogen is not a simple substance. See *Phil. Magazine*, vol. xxxiii. page 173. Indeed the experiment of Dr. Priestley, by which he procured several portions of nitrogen from the same distilled water by repeatedly freezing it, seems to confirm this opinion. See Nicholson's *Journal*, quarto, vol. iv. page 137. But the novel experiments

inflammable, and somewhat lighter than atmospheric air[a].

Seeing that nitrogen gas is injurious to animal life, what is the use of so large a quantity of it in atmospheric air?

Nitrogen gas has the effect of neutralizing, in some measure, the properties of oxygen gas, and rendering it fit for respiration and combustion[b].

How is this change effected by nitrogen gas?

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of Sir Humphry Davy are more to the purpose. From these it would appear that nitrogen is a compound of hydrogen and oxygen. See *Phil. Trans.* for 1809. Priestley conceived it to be a compound of oxygen and phlogiston. See his pamphlet entitled *Experiments and Observations relating to the Analysis of Atmospheric Air,* &c. 1796, page 11.

Nitrogen forms a part of all animal substances. It is also the base of ammonia, and of the nitric acid. It appears to be favourable to plants, as they grow and vegetate freely in this gas. It seems to be the substance which nature employs in converting vegetables to animal substances, and to be the grand agent in animalization. See Fourcroy's *Philosophy of Chemistry,* chap. xi.

When nitrogen gas is required for experiments, it may be thus procured :—Take a few iron filings, mix them with a little sulphur, and moisten the mass with water. Put this mixture into a large glass jar, and cork it close. In a few days the oxygen will be absorbed by the mixture from the air which was previously in the glass, and the residuum will be found to be nitrogen gas. It may be procured also by digesting pieces of flesh or the muscular fibre in very dilute nitric acid.

[a] One hundred cubical inches of nitrogen gas weigh 29.55 grains.

[b] According to Trousset, the gas emitted by the skin is pure nitrogen. *Annales de Chimie,* tome xlv. page 73.

Dr. Lambe has remarked that " if the proportions of oxygen and nitrogen were reversed in atmospheric air, the air taken in by respiration would be more stimulant, the circulation would become accelerated, and all the secretions would be increased; the tone of the vessels, thus stimulated to increased action, would be destroyed by over-excitement; and, if the supply from the stomach were not equal to the consumption, the body must inevitably waste and decay."

" From Nature's chain whatever link you strike,
Tenth, or ten thousandth, breaks the chain alike."

[c] The necessity of atmospheric air, for the support of life, was exemplified by a melancholy accident which happened to two men in the bay of Dublin, who went to visit a wreck in a diving-bell. Two barrels of fresh air were to be alternately sent down to them, and the contaminated air was to be let out by a stopcock at the top of the bell. But, by the contraction which ropes suffer in being wet, the bell turned round in its

By the union of nitrogen gas with oxygen gas: the latter is so diluted and modified as to prevent combustion from being too rapid and respiration too stimulating; and by the due proportions in which these gases constitute the atmosphere, the compound possesses properties so different from either of them as to be admirably fitted for every purpose for which it was designed.

How does atmospheric air support life[c]?

By giving out its oxygen and caloric to the blood[d].

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descent, and entangled the strings by which the divers meant to ring bells, and indicate their wants to the people on board the ship from whence they were lowered. Waiting too long for these signals, the bell was raised, and the divers were both found dead. They were not *drowned*, but died, like the unhappy people in the hole at Calcutta, for want of a supply of pure air.

[d] Dr. Priestley has shown, by a variety of experiments, that the blood perpetually receives oxygen gas (or what he calls dephlogisticated air) from the atmosphere, by the agency of the lungs. See his Experiments on Air.

The blood is *purple* when it arrives at the lungs: but having there thrown off hydrogen and charcoal, it imbibes the vital air of the atmosphere, which changes its dark colour to a brilliant red, rendering it the spur to the action of the heart and arteries; the source of animal heat; and the cause of sensibility, irritability, and motion.

Black venous blood, exposed to the air, becomes red on its surface; and air, remaining confined over venous blood, loses its oxygen, so that what remains is found to be unfit for combustion. These facts prove that the vermilion colour of the blood is owing to the inhalation of oxygen gas.

"The internal surface of the lungs, or air vessels, in man, is said to be equal to the external surface of the whole body: it is on this *extended* surface that the blood is exposed, through the medium of a thin pellicle, to the influence of the respired air." See Additional Notes, No. 8.

"'Tis surely GOD
Whose unremitting energy pervades,
Adjusts, sustains, and *agitates* the whole.
HE ceaseless works alone: and yet alone
Seems not to work: with such perfection framed
Is this complex stupendous scheme of things." THOMSON.

By the rise of the breast-bone in man, and the descent of the diaphragm, room is afforded for 42 cubic inches of atmospheric air at every drawing in of the breath. A deeper inspiration will give room for more than twice this quantity.

What do you mean by caloric?

Caloric is the name which modern chemists have given to fire, or the matter of heat; a large portion of which is intimately combined with atmospheric air[a].

Is the caloric which is combined with the air we breathe, sufficient of itself to keep up the necessary heat of the body?

Animal heat is preserved chiefly by the inspiration

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[a] This name was given by the framers of the new nomenclature to the matter of heat, which they always distinguish from the effect. Caloric is applied to fire, or the substance which produces the sensation we call heat, but never to the sensation itself, or the effect produced by fire. In this case it is said that caloric raises the temperature of bodies, or, on the contrary, that the temperature is lowered by the loss of caloric.

[b] Dr. Menzies ascertained that the blood in its passage through the lungs gains more heat than is equivalent to one degree of Fahrenheit's thermometer. See Dr. Menzies *on Respiration.* The temperature of the human body is generally 98°; but birds, which breathe more air in proportion than man in a given time, have a temperature of 103° or 104°.

Dr. Crawford instituted a series of experiments, with a view to discover the cause of animal heat. In the course of his inquiry, he found that blood contains a much greater quantity of *absolute* heat than the elementary substances of which it is composed, and that in its change from venous to arterial blood it acquires a greater *capacity* for caloric; by which admirable contrivance, any rise of temperature in the lungs which would be incompatible with life, is prevented. Nothing can afford a more striking proof of creative wisdom, than this provision for the preservation of an equable animal temperature. By the decomposition of atmospheric air, caloric is evolved, and this caloric is taken up by the arterial blood, without its temperature being at all raised by the addition. When it passes to the veins, its capacity for caloric is diminished, as much as it had before been increased, in the lungs: the caloric therefore, which had been absorbed, is again given out; and this slow and constant evolution of caloric in the extreme vessels over the whole body, is the source of that uniform temperature which we have so much occasion to admire.

This same chemist has ascertained that whenever an animal is placed in a medium the temperature of which is considerably high, the usual change of arterial into venous blood does not go on; consequently, no evolution of caloric will take place, and the animal heat will not rise much above the natural standard. How pleasing is it to contemplate the arrangements which the Deity has made for the preservation and felicity of his creatures, and to observe that he has provided for every possible exigency!

According to Lavoisier, a man generally consumes 32 ounces troy of oxygen gas in 24 hours; that is, the lungs separate this quantity of oxygen gas from the air which he respires in that time.

of atmospheric air. The lungs, which imbibe the oxygen gas from the air, impart it to the blood; and the blood, in its circulation, gives out the caloric to every part of the body[b].

How do clothes conduce to preserve the heat of the body?

As the temperature of the atmosphere in this climate is always inferior to the animal temperature[c],

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The blood, in passing through the lungs to take up oxygen gas, throws off charcoal; for there is a larger portion of carbonic acid gas given out in every respiration than could be furnished by the atmosphere.

Lavoisier has shown that, in respiration, there is a constant combination of the oxygen of the atmosphere with the hydrogen and carbon of the blood. See Additional Notes, No. 9.

> "Thus LIFE discordant elements arrests,
> Rejects the *noxious*, and the *pure* digests;
> Combines with heat the fluctuating mass,
> And gives awhile solidity to gas." DARWIN.

See a good Memoir on Respiration, and the Production of Animal Heat, by Armand Seguin, in the 6th volume of the *Monthly Magazine*, page 94: but this subject is treated more at large by Dr. Bostock, of Liverpool, than any other writer: to his work I would refer the reader.

[c] Those animals which do not breathe, such as fishes and insects, have a bodily temperature but little superior to the medium in which they live. The temperature of all animals is in proportion to the quantity of air which they breathe in a given time. Man, quadrupeds, and the whale tribe have a heart, and breathe through lungs; in consequence of which structure heat is evolved during the circulation of the blood. They are therefore called warm-blooded animals. In the severest winter, or in the coldest regions that man or any quadruped can inhabit, the temperature of the body is hardly a degree lower than in the warmest summer, or in the torrid zone. A thermometer with its bulb under the tongue, or buried in a wound in any fleshy part of the body, always indicates a heat of 97° or 98°, be the temperature of the air what it may. This astonishing effect is produced by the decomposition of atmospheric air, as explained in the preceding notes. A postulatum has been assumed by some atheists, that the organs of the body have been formed by what they call *appetency*, i. e. endeavour perpetuated, and imperceptibly working its effects through a long series of generations: but I would ask any man of common understanding, whether he would like to assert that he believes this to have been the way in which the lungs acquired the faculty of decomposing atmospheric air; and that this hypothesis is sufficient to account for *the composition of this air*, which so exactly suits the operation of these lungs, and which contains that exact portion of caloric which the animal economy requires! It is worthy of remark, that

clothes[a] are necessary to prevent the sudden escape of that heat from the surface of the body[b] which the lungs have separated from the atmosphere.

What becomes of the nitrogen which was combined with oxygen in atmospheric air?

The greatest part of the nitrogen is thrown out of the lungs at every respiration[c]; and being somewhat lighter than atmospheric air, it rises into the atmosphere to await fresh combinations.

What provision has nature made for restoring the vast quantity of oxygen which respiration and combustion are perpetually taking from the atmosphere?

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cold-blooded animals, which are not furnished with this breathing apparatus, are so constituted that their temperature changes with every change of the temperature of the surrounding medium. Frogs have been absolutely frozen so as to chip like ice, and yet when carefully and gradually thawed have been completely reanimated.

[a] Clothes keep the body warm in consequence of the air which they infold within them; all confined bodies of atmospheric air being non-conductors of heat. It is on this principle that double windows preserve the warmth of apartments at an equable temperature. In like manner double lids for boilers, formed so as to hold a sheet of air, are found to be very effectual for preserving the heat of the liquor with a very small portion of fuel.

On this principle it is that light spongy substances, such as furs and down, afford the warmest clothing. Hence it is that the carpet of snow which covers the earth in winter, is spread out by nature with so light a hand, that it might hold an abundance of atmospheric air within its interstices, to preserve the warmth of those innumerable tribes of vegetables which it is destined to protect.

[b] We clothe ourselves with wool, because it is a bad conductor of heat, and retards its escape from the body. The inhabitants of Russia clothe themselves in fur, because fur is still a worse conductor of heat than wool. Sheep are natives of a temperate climate; but the bear and the ermine of the coldest. The provident care of the Creator is evidently conspicuous in this appointment, and discovers the same undeviating attention to the comfort of all his creatures: hence the clothing of animals in the torrid zone is hair, in the temperate zones wool, in the frigid thick fur.

[c] It is not simple nitrogen which is thrown out, but *nitrogen gas*; and it has been imagined, that when atmospheric air is decomposed by the lungs, part of the disengaged caloric is required for the nitrogen, to preserve it in the form of gas: but it is a curious fact, that nitrogen gas and

The leaves [d] of trees and other vegetables give out during the day a large portion of oxygen gas [e], which, uniting with the nitrogen thrown off by animal respiration, keeps up the equilibrium, and preserves the salubrity of the atmosphere.

Is this perpetual renovation of the atmosphere owing to a fortunate concurrence of circumstances, or is it the effect of design and contrivance?

When we recollect the various processes of nature and art, which concur with respiration and combustion in depriving the atmospheric air of its oxygen; and that, notwithstanding the atmosphere uniformly con-

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carbonic acid gas, both which are thrown off in the act of respiration, have less capacity for caloric than any other gaseous substance. It is a general characteristic of the gases, that they absorb a large portion of caloric to preserve them in a gaseous form. Yet one of these gases has less capacity for caloric than many liquids, and the other (nitrogen gas) less capacity than even ice. Could any thing possibly have been better contrived for the preservation of that portion of caloric, which is necessary to keep up the animal temperature! See Dr. Bostock's *Essay on Respiration*, Oct. 1804.

It may be remarked, that the interval which there is between every inspiration seems to have been designed, to allow time for the nitrogen gas which is thrown out of the lungs to mount in the air above the head, in order that a fresh portion of air might be taken in, and that the same air might not be repeatedly breathed. How provident has the Almighty been, in thus foreseeing the operation of those laws which were designed to promote the welfare of every species of animated beings!

[d] The *upper* side of the leaf is the organ of respiration: hence some vegetables (as they give out oxygen only in the day) close the upper surfaces of their leaves during the night. The multiplicity of the leaves of trees indicates the importance of transpiration to a vegetable. I believe this fact was first announced by Dr. Priestley. He had observed that the plant called a *conferva* which exists in pools of water, when exposed to the rays of the sun, is covered with minute globules of water filled with air, and when he inverted a glass filled with water over the slender filaments of this plant, he obtained the gas collected in the upper part of the glass and found it to be pure oxygen gas, which he proved by the difference there was in the burning of a lighted taper when immersed in this gas and in atmospheric air.

[e] To show the production of oxygen gas from the leaves of plants, fill a glass bell with water, introduce some fresh leaves under it, and place the bell inverted in a flat dish of water. Expose the apparatus to the rays

tains every where the same proportion of this gaseous substance[a], we can attribute the renovation to nothing but design, and perceive in it a proof that the laws of nature must be referred, not to blind chance, but to unerring intelligence combined with infinite goodness[b].

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of the sun, and very pure oxygen gas will be disengaged, which will displace the water in the jar, and occupy its place. In like manner a sprig of mint, corked up with a small portion of carbonic acid air, and placed in the light, will absorb the carbon and render the air again capable of supporting life. The plant purifies what the animal had poisoned.

All the oxygen however is not given out by plants; part must be retained to form the sugar and acids which are found in vegetables. Mr. Cruickshank has shown by experiment, that oxygen is absolutely necessary for the conversion of mucilage into sugar.

[a] It has been found that the air of the most crowded cities contains as much oxygen gas as that of other places. This was demonstrated by Priestley soon after he became engaged in making experiments with his eudiometer.

[b] All kinds of vegetables, when assisted by the rays of the sun, have the power of decomposing water; during which decomposition the hydrogen is absorbed, and goes to the formation of oil and resin in the vegetable; while the oxygen combines with part of the caloric received from the sun, and is given out in the form of oxygen gas; so that this *one operation* of nature gives nourishment and provides materials of growth to the vegetable world, and at the same time renovates that vital principle in the atmosphere which is necessary for the support of the animal creation. Surely nothing short of consummate wisdom could have conceived any thing half so beautiful in design, or extensively and superlatively useful in effect. See Additional Notes, No. 18.

CHAPTER III.

OF CALŌRIC.

What is heat?

Heat is the well-known sensation which we perceive on touching any substance whose temperature is superior to that of the human body[a].

What name is given to the matter of heat?

Chemists have agreed to call the matter of heat *caloric*[b], in order to distinguish it from the sensation which this matter produces[c].

What are the principal uses of caloric[d]*?*

Caloric is every where indispensable to the existence of man. " It is with fire that, in every country, he

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[a] The sensation of heat and cold arises from the tendency which caloric has to diffuse itself equally amongst all substances that come in contact with it. If the hand be put upon a hot body, part of the caloric leaves the hot body, and enters the hand: this produces the sensation of *heat*. On the contrary, if the hand be put upon a cold body, part of the caloric contained in the hand leaves the hand to unite with the cold body: this produces the sensation of *cold*.

Some of the methods of producing artificial cold may be seen in Mr. Walker's papers in the *Philosophical Transactions*, for 1795 and for 1801, and in Watson's *Chemical Essays*.

[b] In answer to the question, What is the *cause* of caloric? it may be necessary to state, that philosophers have differed in their opinions on this subject. Some have considered it merely the consequence of a peculiar motion among the particles of bodies, and that it has no existence independent of motion, any more than sound has. Others have supposed that it is really a distinct substance, which exists independent of every other. The latter is the general opinion at present.

[c] In order to give precision to chemical language, it was necessary to find a term to distinguish the matter of heat from its effect; for, whenever caloric becomes fixed in a body, it loses its property of affording heat. Nothing can be more evident than that caloric may exist in many substances, without producing any of the effects which arise from the agency of fire.

[d] Many of the uses of fire will immediately occur to every individual, whenever the importance of this subtile fluid is alluded to; though per-

prepares his food, that he dissôlves metals, vitrifies rocks, hardens clay, softens iron, and gives to all the productions of the earth the forms and combinations which his necessities require."

What are the sources of caloric?

There are six sources from whence we procure caloric; viz. from the sun's rays, by combustion, by percussion, by friction, by the mixture of different substances[a], and by means of electricity and galvanism[b].

Which of these is the principal source of caloric?

The sun is the chief, and, probably, the original fountain which furnishes the earth with a regular

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haps the wisdom of the Deity, in giving the use of it to man only, has not been often noticed. Why has this powerful agent been solely intrusted to man? Why was every fowl of heaven, and every beast of the field, impressed with an unconquerable dread of approaching it?—If it were at the disposal of animals, which of our possessions, or even of our lives, would be safe for a single moment!

[a] These are the chief sources of caloric with which we are acquainted; but there are instances of *spontaneous* combustion on record, which are unaccountable. The most remarkable case that I have seen, is related in the *Philosophical Magazine*, vol. xvi. page 92. See also an interesting memoir on this subject, vol. xviii. page 346.

[b] The student may acquire a competent knowledge of electricity by studying the following esteemed works on the subject: viz. Dr. Priestley's *Familiar Introduction to the Study of Electricity*, 8vo. with plates, London 1786.—*A complete Treatise of Electricity in Theory and Practice*, by Tiberius Cavallo, Esq. 8vo.—And Dr. Priestley's *History of Electricity, with original Experiments*, in quarto, with many plates, London 1775.

[c] Caloric comes to us from the sun at the rate of 200,000 miles in a second of time*; but Dr. Herschel has proved, that the solar rays which occasion heat, are distinct from those which illuminate and produce vision. Such investigations have a tendency to impress us with the most sublime ideas of the economy of the universe, and to convince us of the infinite resources of its Divine Author.

> "Great source of day! for ever pouring wide,
> From world to world, the vital ocean round,
> On Nature write, with every beam, His praise."

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* See Additional Notes, No. 59.

supply[c], and renders it capable of supporting the animal and vegetable creations[d].

How is caloric furnished by combustion?

The oxygen gas of the atmosphere is *decomposed* by combustion; and caloric, one of its component parts, is set at liberty[e].

How is caloric produced by percussion?

The heat produced by percussion is generally occasioned by the *compression* of the particles of the body, which compression forces out a portion of its latent caloric[f].

How is caloric produced by friction?

It is not known how friction produces caloric[g],

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[d] According to the laws of nature, animal and vegetable life are both very much influenced by the temperature in which they exist; we therefore find different kinds of vegetables, and a different race of animals, appropriated to the different climates of the earth.

That caloric is as necessary for the support of vegetable as it is for that of animal life, may be proved by direct experiment. If in the midst of winter a hole be bored in a tree, and a thermometer put into it, it will be seen that the tree is many degrees warmer than the atmosphere.

[e] We are indebted to Lavoisier for the discovery that caloric is disengaged from atmospheric air by combustion: it was he who pointed this out as a general law of nature, "that in all cases of combustion, oxygen combines with the combustible, during the act of combustion." For a further explanation of this phenomenon, consult the chapter on *Combustion*, in this volume.

[f] As evaporation produces cold, condensation always occasions heat: that is, caloric is always evolved from those bodies which have undergone any degree of condensation. In one case caloric is absorbed, in the other it is set at liberty.

By the collision of flint and steel so much caloric is disengaged, that the metallic particles which are struck off are actually melted thereby. This is evident, from their being always found in a spherical form. See note[e], page 59.

[g] Mr. Thomas Wedgwood took a piece of common window-glass, and held the edge of it against the edge of a revolving grit-stone, and the part in contact with the stone became red hot, and threw off hot particles which fired gunpowder. The stone and the glass being both incombustible substances, it remains to be explained how caloric was produced. *Philosophical Transactions* for 1792.

The original inhabitants of the New World, throughout the whole extent from Patagonia to Greenland, procured fire by rubbing pieces of hard unless we suppose it to be a succession of percussions.

In what way can heat be produced by means of electricity or galvanism?

By the discharge of an electrical battery, or by the galvanic apparatus, a more intense degree of caloric may be obtained than by any other means whatever[a].

How is caloric produced by mixture?

When heat is produced by the mixture of two or more substances, it is owing to the fluid part of the mixture taking a more solid form[b]; for neither water nor any other fluid can acquire an increase of

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wood against other very dry pieces, till they emitted sparks, or kindled into a flame. Some of the people to the north of California had the method of inserting a kind of pivot in the hole of a very thick plank, and by its circular motion produced the same effect.

Instances have occurred, where whole forests have been burnt down, by fires kindled from the violent friction of the branches against each other by the wind.

[a] By means of an electrical battery metals may be suddenly fused, and gases united; but if fine metallic wire be made part of a powerful galvanic circle, it will be melted in an instant, and give out the most beautiful coruscations of light, of various colours, according to the nature of the metal employed. In like manner gold and silver leaf, when submitted to galvanic action, burn with the greatest splendour, and afford spectacles extremely beautiful. If a piece of charcoal, from hard wood, be inflamed by galvanism, the light produced seems to vie with that of the sun, being too intense for the eye to endure.

With Mr. Pepys's apparatus, charcoal has been deflagrated by the galvanic power, after passing through 16 persons with wetted hands joined. But the effects produced by the immense battery of the Royal Institution, and which consists of two thousand double plates, making a surface in the whole of 128,000 square inches, far surpass any thing before seen. The plates are arranged in cells of porcelain, and when the cells were filled with diluted nitric and sulphuric acids, quartz, the sapphire, magnesia, lime, &c. all entered into fusion, and platina became fluid as readily as wax would melt in the flame of a taper. Davy's *Chemical Philosophy*, vol. i. page 152.

[b] Whenever two gases or liquids unite *chemically*, the compound has greater density than the mean density. Thus the vapour of water, at the heat of ebullition, occupies much less space than the hydrogen gas and oxygen gas, which compose it, would have occupied at the same temperature. Nitrous gas has a specific gravity greater than that of the

density without giving out a portion of its latent caloric[c].

You speak of latent *caloric; is there any difference in the nature of caloric?*

No: we have reason to believe that caloric is uniform in its nature; but this term is necessary, because there exist in all bodies two portions of caloric, very distinct from each other[d].

How are these two portions of caloric distinguished?

The one is called *sensible* heat, or free caloric; the other *latent* heat, or combined caloric[e].

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simple mixture of its two elements: it is the same with ammoniacal gas; and this latter, though its elements are already greatly condensed, experiences a new condensation when it combines with muriatic acid gas; which is even so considerable, that both take a solid form. This subject is treated more at large in Berthollet's *Chemical Statics.*

[c] Sulphuric acid and water experience this condensation by mixture, which is proved by the measure of the fluids, before and afterwards, and by the heat that is evolved. If four parts of the former be mixed with one of the latter, the mixed fluids will quickly acquire a temperature higher than that of boiling water. It is necessary to be cautious in making this experiment.

If iron filings and sulphur be mixed into a paste with water, a sulphuret of iron will be formed, which decomposes the water and absorbs oxygen so rapidly that the mixture takes fire, even though it be buried under ground.

Mixture does not uniformly produce heat. The mixture of some substances produces an intense cold. But the cause of both effects is easily explained. Whenever substances become more condensed by mixture, heat is evolved; when they expand, cold is produced; or, in other words, the compound has a greater or less capacity for caloric than the separate ingredients. The mixture of crystallized muriate of lime and snow produces the greatest degree of cold yet known.

[d] How the same substance may exist in a body in two distinct states, may easily be explained by the familiar example of a piece of common bread which has been dipped in water. This bread will contain two portions of water very distinct; one of them is in a state of combination, and forms a constituent part of the bread; the other is only interposed between the particles of the bread, and may again be forced out by pressure.

[e] The difference which there is in the effects of caloric, in the two states in which caloric exists, may be shown by a variety of experiments.

What do you mean by free or sensible caloric?

Sensible caloric is the matter of heat disengaged from other bodies, or, if united, not *chemically* united with them[a].

What is latent caloric?

Latent caloric is that portion of the matter of heat which makes no *sensible* addition to the temperature of the bodies in which it exists[b].

What substances contain latent caloric?

Caloric in a latent state exists in all substances that we are acquainted with[c].

Wrought iron, though quite cold, contains a large portion of *latent* caloric; and if it be briskly hammered for some time on an anvil, it will become red hot by the action of this species of caloric, which by the percussion of hammering is now evolved and forced out as *sensible* heat. While chemically combined with the iron, it only tended to give it malleability and ductility, without affecting its temperature.

If a little sulphuric acid be mixed with about an ounce of the strongest nitrous acid, and the mixture be poured into oil of turpentine, the whole will burst into flame. This is owing to the compound having less capacity for caloric than these separate fluids. The phial containing the mixed acids should be fixed to a rod, and its contents poured at arms-length and as quickly as possible upon the oil in a cup. The cup containing the oil of turpentine should be placed in the open air, or under a large chimney, to prevent any accident from the sudden combustion.

The reverse of this may be shown by hanging a pan of snow over a large fire. The snow will receive a great accession of caloric from the fire without being at all sensibly warmer. The caloric as it enters the snow, becomes chemically combined with it, and the fire will not in the least alter its temperature, till the whole becomes fluid.

[a] Some writers have called the matter of heat when in this state *interposed* caloric.

[b] We owe to Dr. Black the discovery of *latent* heat. The train of thought and series of experiments which convinced him of this fact may be seen amply detailed in the *preface* to his *Lectures*. "By this discovery we now see (as his editor expresses it) heat susceptible of fixation—of being accumulated in bodies, and, as it were, laid by till we have occasion for it; and are as certain of getting the stored-up heat, as we are certain of getting out of our drawers the things we laid up in them."—Black's *Lectures*, by Robison. He might have added, that whenever caloric quits its latent state, how long soever it may have lain dormant and inactive, it always resumes its proper qualities and character, and affects the thermometer and the sense of feeling as if it had never been latent.

Do all substances contain the same quantity of latent caloric?

No: caloric combines with different substances[d] in very different proportions; and for this reason one body is said to have a greater *capacity* for caloric than another[e].

Is this capacity for caloric uniformly the same in the same bodies?

The same bodies have at all times the same capacity for caloric, unless some change takes place in the state[f] of those bodies.

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[c] Caloric pervades all bodies; this is not the case with any other substance we know of—not even light. It lies hid in every thing around us. It is a substance which we are ever in want of; it is therefore deposited on every side, and is ready for every exigency.

[d] Caloric, as it penetrates bodies, frequently forms a chemical combination with them, and becomes essential to their composition. This is always the case when a solid is converted to a liquid, or when a liquid passes to a gaseous state. But if caloric be superadded to a body when it is in a state of saturation, it merely traverses its surface, and passes from it, in the form of sensible heat, to some of the adjacent bodies.

It is the opinion of Dr. Irvine and some other chemists, that the absorption of caloric, which accompanies liquefaction and vaporisation, is owing not to its entering into chemical combination, but to the enlarged capacity which the body acquires by a change of form. To those who wish to investigate this subject I would recommend the perusal of Murray's *System of Chemistry*, first edition, vol. i. page 409, &c. or second edition, page 398, &c. See also the Additional Notes to this work, No. 36.

[e] The propriety of this term may be shown to a pupil by dipping a lock of wool and a piece of sponge in water, and directing him to observe how much more water the sponge is capable of taking up than the wool. Hence sponge may be said to have a greater *capacity* for water than wool has.

[f] The nature of the combination of a substance with caloric was first placed in a clear light by Dr. Black. He discovered that all matter is subject to the following law, viz. that "whenever a body changes its chemical state, it either combines with, or separates from, caloric."

If muriate of ammonia be dissolved in hot water, the temperature of the water will be found to be much lowered by the solution of the salt. When the salt takes again a solid form by crystallization, it will part with the caloric which it combined with in the act of solution, and a rise of temperature will be the consequence. The cold which is produced by the solution of this and other crystallized salts, is owing either to the water, which was combined with them in a state of solidity, suddenly

Can you adduce instances of a change of this kind?

When gaseous substances become liquid, or liquid substances become solid, they lose in a great measure their capacity for caloric: accordingly, when solid bodies become liquid or gaseous, their capacity for caloric is proportionately increased[a].

How does this property of bodies operate?

Whenever a body has its capacity for caloric thus increased, it requires a larger portion of the matter

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taking a liquid form, and absorbing caloric to preserve it in a state of fluidity, or to an increased capacity for caloric.

If when the air is at 22° we expose to it a quantity of water in a tall glass, with a thermometer in it and covered, the water gradually cools down to 22° without freezing, though 10° below the freezing point. Things being in this situation, if the water be shaken, part of it instantly freezes into a spongy mass, and the temperature of the whole rises to the freezing point; so that the water has acquired 10° of caloric in an instant. Now whence came these 10°? Is it not evident that it must come from that part of the water which was frozen, and consequently that water in the act of freezing gives out caloric?—Water in a solid state has less capacity for caloric than it has when in a state of fluidity, although it then occupies a greater space.

The evolution of caloric which is occasioned by the combination of the condensable gases with water during several kinds of distillation, must be very familiar to those who have been accustomed to superintend chemical operations. In some cases, this evolution of caloric is so considerable as to raise ice-cold water almost to the state of ebullition.

[a] The freezing of water, and the cooling of melted lead, may be adduced as familiar examples of the former; and the absorption of caloric in the melting of salts will sufficiently exemplify the latter. By the solution of some salts water may be deprived of so large a portion of its caloric as to be frozen in the midst of summer. An account of several cheap and powerful frigorific mixtures may be seen in the *Philos. Trans.* for 1787, 1788, 1789. See also Watson's *Chemical Essays*, vol. iii. 139, and one of the tables at the end of this volume. The heat which is given out during the slaking of quick-lime escapes from the water in consequence of its changing from a liquid to a solid form by its union with the lime. The same effect is produced in making butter. When the cream changes from a fluid to a solid, a considerable degree of heat is produced. Bodies which have the greatest density have generally the least capacity for caloric, while those which have the least specific gravity possess the greatest capacity for heat. This is the case with the gases, and especially with hydrogen gas, which is the lightest of all ponderable bodies.

of heat to raise it to a given temperature, than another body does which has a less capacity for caloric[b].

Can you exemplify this curious property of matter?

If equal quantities, by weight, of water and mercury, cooled down to the same point, be afterwards separately heated to the heat of boiling water, the water will be found to have required more than three times the quantity of caloric that the mercury did to bring it to that temperature[c].

If equal weights of water at 32° and at 212° be mixed, the mixture will acquire the mean temperature of 122°; but if 1 lb. of *ice* at 32° and 1 lb. of water at 212° be mixed, the temperature of the mixture will be only 52°.

Chlorine or oxymuriatic acid gas becomes a *liquid* at a temperature somewhat below 40°, and at 32° forms solid crystals. Ammoniacal gas condenses into a liquid at —45°.

When water is poured upon dry pulverized plaster of Paris, in order to form cornices for rooms, great heat is produced by the mixture. This is owing to the water giving out its caloric of fluidity as it becomes solidified in the plaster.

Whenever caloric becomes active, it produces heat; when it passes into a latent state, it produces cold.

[b] The difference in the capacity which different bodies have for caloric, is owing to one substance having a chemical affinity for caloric superior to that of another. See this fully explained by Dr. Henry in the fifth volume of the *Manchester Memoirs*.

[c] This property may be shown more readily by the following experiments:—Take 1 lb. of water at 100°, and mix it with 1 lb. of water heated to 200°, the mixture will be found to give the exact mean temperature of 150°; but 1 lb. of mercury at 100°, and 1 lb. of water at 200°, will produce a heat much higher than the mean temperature: mercury has not therefore so great a *capacity* for caloric as water.

A metal plunged into an equal weight of water of a higher temperature, gains more degrees of thermometric heat than the water loses; and this takes place, in different proportions, for each species of metal. —Berthollet's *Chemical Statics*.

Whenever two kinds of substances of different temperatures are mixed, the capacity of each for caloric may be known by observing the temperature of the mixture; for the capacity of each will be in the inverse ratio of the change of temperature. But it is necessary, in order to justify this calculation, as Fourcroy has remarked, that the bodies themselves should not act chemically upon each other; and it is also necessary to prevent a portion of their caloric from being carried off by the vessels in which the experiment is made.

What term is made use of to denote the quantity of caloric thus required?

The portion of caloric necessary to raise a body to any given temperature is called the *specific* caloric of that body[a].

Is there any method of ascertaining the specific caloric of different bodies, and comparing the relative capacity of each for caloric?

An instrument called a *calorimeter*[b] is used for this purpose. The substances to be tried are heated to the same temperature, and then placed in this machine surrounded with ice[c]. By observing how much ice each of them melts in cooling down to a given

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[a] This term is always used in a *comparative* sense, expressive of the relative portions of caloric contained in equal weights or measures of different bodies at the same temperature, or the comparative quantity of caloric which can produce the same effect. Thus, if the specific caloric of mercury be said to be 1, that of water may be said to be 3, as noted in an experiment just related.

[b] The calorimeter was first suggested by M. Laplace, and contrived by Lavoisier. A drawing of the machine, with an accurate description of it, may be seen in Lavoisier's *Elements of Chemistry*. Though this instrument be capable of measuring what is called the *specific* caloric of bodies, no method has yet been discovered of ascertaining the *absolute* quantity which bodies contain. It is therefore unknown at what point a thermometer would stand, if it were plunged into a substance entirely deprived of caloric. According to the experiments and calculations of Crawford, Irvine, and others, the real zero is at least 1200 degrees below the freezing point of water.

[c] Ice has the property of absorbing all the caloric with which it comes in contact, and communicates no part of it to the surrounding bodies till the whole of the ice is melted: therefore the specific caloric of bodies may easily be calculated by its means.

[d] The thermometer was invented by Sanctorius, an Italian physician, about the beginning of the 17th century; but it was improved, and rendered useful, by Mr. Boyle and Sir Isaac Newton.

Thermometers are made by putting mercury into small glass tubes with bulbs, and heating these bulbs till the mercury boils. This ebullition forces out the air, and the tubes are hermetically sealed while the mercury is boiling; which preserves the vacuum. They are afterwards graduated by a correct scale.

Thermometers filled with alcohol are useful for ascertaining very low point, the specific caloric which each of them contained is determined.

What do you call the instrument which is in common use to measure the temperature of bodies?

It is called a thermometer[d]. It consists of a glass tube containing a portion of mercury, with a graduated plate annexed to it. The tube is hermetically sealed, to preserve the metal from the pressure of the atmosphere[e].

Do you understand how a thermometer is affected by the temperature of bodies?

When a thermometer is brought in contact with any substance, the mercury expands or contracts till it acquires the same temperature[f]; and the height at

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temperatures in which mercury would be frozen,—as alcohol preserves its fluidity in the most intense colds that have ever been observed.

For very delicate experiments *air* thermometers are used, in which, as the air is expanded or contracted, a coloured liquor is made to fall or rise, which marks the degree of expansion, and consequently the variation of temperature. They are called *thermôscopes.*

[e] Though mercury has a capacity for caloric inferior to that of many liquids, it has such an attraction for it that it absorbs sufficient to keep it in a fluid state in the common heat of our atmosphere. Owing to this affinity it expands very readily by every addition of the matter of heat. It is also equally affected by equal increments of heat at every temperature between its freezing and boiling points; which is not the case with some other fluids, such as water, ardent spirit, &c.: hence it is the most proper substance for thermometers.

To measure the degrees of heat in high temperatures, Mr. Wedgwood contrived a very useful instrument, which he called a pyrometer, including a range of nearly 32,000 degrees of Fahrenheit; a description of which may be seen in the 72d volume of the *Philosophical Transactions.* Since Mr. Wedgwood's death, the method of making the pieces of clay for these pyrometers has been lost.

[f] The absolute necessity there was for an instrument of this kind may be shown by the following simple experiment. If the bulb of a thermometer be immersed in a mixture of snow and common salt, the mercury will fall to at least 32° below the freezing point of water;—and if the instrument be then removed from that mixture and put simply into a mass of snow, the mercury will be so much heated by the change, as to rise 32 degrees; so that snow which appears to the hand to be totally void of all heat contains sufficient to raise the thermometer many degrees.

which the mercury then stands in the tube, indicates the exact temperature of the substance to which it has been applied[a].

Will the thermometer show the quantity of caloric in all bodies[b] *?*

No: it will not show that portion which is latent, or chemically combined with any body: for instance, fluids require a certain portion of caloric to keep them in a state of fluidity; which portion is not indicated by the thermometer[c].

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[a] Fahrenheit's thermometer is universally used in this kingdom. I it the range between the freezing and boiling points of water is divide into 180°; and as the greatest possible degree of cold was supposed t be that produced by mixing snow and muriate of soda, that was mad the zero: thus the freezing point became 32°, and the boiling point 212°

The centigrade thermometer of France places the zero at the freezin point, and divides the range between it and the boiling point into 100° This has long been used in Sweden under the name of Celsius's thermometer.

Reaumur's thermometer divides the space between the freezing an boiling of water into 80°, and places the zero, like the centigrade thermometer, at the freezing point.

De Lisle's thermometer is used in Russia. The graduation begins a the boiling point, and increases towards the freezing point. The boiling point is marked 0, and the freezing point 150°.

In Wedgwood's pyrometer the zero corresponds with 1077° of Fahrenheit's, each degree of which is equal to 130° of Fahrenheit. Therefore 180° F.=100° C.=80° R.=150° D. L.=$\frac{18}{13}$ W.

For an easy method of reducing the degrees of one thermometer t the scale of another, consult Dr. Duncan's *Elements of Pharmacy*; c Lavoisier's *Elements of Chemistry*, page 560, fourth edition. A table temperatures, according to the different thermometers, at the end this volume, will enable a person to form a tolerably correct idea of th difference there is in the scales of each.

[b] The property which we call the temperature of bodies does not sho the measure of their caloric, but merely the degree of dilatation, whi the caloric they contain in a disengaged state is capable of producing the substance of which the thermometers are formed.

[c] Every substance requires its own quantity of caloric to raise it to given temperature; but when raised to that temperature, every *furth* addition of caloric is precisely shown by the thermometer.—See Add tional Notes, No. 4 and 36.

If a quantity of snow be placed in a bason before a fire, and a therm meter be plunged in it, the thermometer will stand at 32°; if the the

Is the thermometer, then, of no use in ascertaining the temperature of fluids?

Yes: all fluids operate upon the thermometer in the same manner as solids; for, whatever sensible caloric be contained in any liquid, that portion is accurately shown by the thermometer[d].

What do you call that portion of caloric which is a necessary part of fluids?

It is called the caloric of fluidity; but different

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mometer be removed, and the snow suffered to remain before the fire some time longer, and then tried by the thermometer, it will still indicate the same temperature, though it has all along been receiving an accession of caloric; but the moment that the *whole* of the snow is melted the thermometer will begin to rise. In like manner, suppose a piece of ice cooled 20° below the freezing point be exposed to a fire with a thermometer stuck in it; the thermometer will rise very uniformly till it comes to the freezing point 32°, and there make a full stop till the ice is all liquefied, as though the fire had lost its faculty of heating: but the instant that all the ice is melted the thermometer will begin to rise again, and will continue to rise gradually till the water becomes heated to 212°, the boiling point. See Additional Notes, No. 4. These experiments show that the heat which snow and ice receive while melting is necessary to give them fluidity, though it does not increase their temperature; and that ice contains much less absolute caloric than water at the same temperature. Were this not the case, all cold countries would be subject to dreadful inundations; for, whenever the atmosphere became warmer than 32°, the ice and snow would be melted *in an instant*, and the sudden deluge of water would sweep down every thing before it. It is pleasing to observe how careful the great Author of nature hath been in providing for every exigency. To this goodness every clime and every season bear testimony;

> "The tokens of HIS friendly care
> Open, and crown, and close the year."

[d] Nature is uniform in all her results; for, if we plunge a thermometer ever so often into boiling water, it will always stand at the same point, provided the pressure of the atmosphere be the same. Melting snow will always show the same degree upon the thermometer, in whatever state the atmosphere may be,

> "In tubes of glass mercurial columns rise
> Or sink, obedient to th' incumbent skies;
> Or, as they touch the figured scale, repeat
> The nice gradations of circumfluent heat." DARWIN.

This subject is further elucidated in Additional Notes, No. 36.

fluids require different portions of it to preserve them in the state of fluids[a].

What are the effects of caloric upon bodies?

The *general* effects of caloric are to increase the bulk of the substances with which it unites, and to render them specifically lighter than they were before[b];

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[a] This may he made evident by the following striking experiments:—If four parts of sulphuric acid and one part of ice, both at the temperature of 32°, be mixed together, the ice melts instantly, and the temperature of the mixture rises to 212°, the heat of boiling water. But if four parts of ice and one of the same kind of acid at 32° be mixed, the temperature sinks to about—4°. In the first of these experiments, as the ice and acid combine, they become more dense than their *mean* density; consequently, they both give out a part of their caloric of fluidity, and retain only the caloric of fluidity which is necessary for the new compound. In the other case, the ice, assuming a liquid form, requires a large dose of caloric to give it fluidity; and the sudden fall of the thermometer is owing to the suddenness with which the ice absorbs the caloric from the acid, and which it requires before it can take a liquid form. See note, page 78.

According to Dr. Irvine, the caloric of fluidity of

Water . . . is . . .	140°
Spermaceti	145
Bees Wax	175
Tin	500

Bishop Watson has remarked, that nitrous acid mixed with snow water excites a very great degree of heat, but when mixed with snow produces the greatest cold that he had ever yet observed. *Chemical Essays*, vol. iii. page 142.

Our power of producing cold is at present very limited when compared with that of exciting heat. No one that we read of has ever yet been able to sink the temperature of any substance below —90° of Fahrenheit, or 122° below the freezing point of water; but Mr. Wedgwood constructed an air furnace in which he raised a heat equal to 185 degrees of his pyrometer, or 25127° of Fahrenheit; and by means of a mixture of oxygen and hydrogen gases, more intense heats than even this have been produced.

[b] In order to be convinced that solids increase in bulk by combination with caloric, procure a piece of iron wire, of an exact length, to slip lengthways within a ring, or within some metallic box: then if the wire be heated it will be found increased in length so as not to pass through the ring or box.

From the experiments of General Roy, in the 75th volume of the *Philosophical Transactions*, it appears that the expansion of a steel pendulum of a clock is such, that every four degrees of the thermometer will cause a variation of a second per day; and that the difference be-but in whatever quantity it is accumulated in bodies, it never adds to their absolute weight.

What are the PARTICULAR *effects of caloric on bodies?*

It favours the solution of salts[c], and promotes the union of many substances[d]. In other cases it serves to separate bodies already united[e]; so that in the

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tween the going of a clock in summer and winter will be about six seconds per day, or one minute in ten days, owing to the metallic pendulum varying in length with every change of temperature. A knowledge of this circumstance gave rise to Harrison's self-regulating time-piece, which, by the different expansion of *different* metals, accommodates its movements to every change of season or climate.

The expansion which heat gives to liquids may be shown by that of the spirits in a spirit thermometer: or fill a Florence flask with water to about the middle of the neck, mark the place to which it rises, and then immerse it in boiling water; when it will be seen to expand in the flask till it nearly runs over its neck.

The effect of heat on atmospheric air has been shown in page 34. The converse of this (viz. that the denser bodies are, the less caloric they contain), may be exemplified thus:—Add one measure of water to four measures of sulphuric acid, and the temperature will rise to 300°, which is 88° above boiling water. If the mixture be now measured, it will be found to measure less than it did; consequently it must have become much denser than the medium of the two separate liquors. If 28 measures of water be mixed with 4 measures of sulphuric acid, only 29 measures of mixture will be produced instead of 32.

The best collection of facts respecting the expansion of *wood* by heat, will be found in a memoir by Dr. Rittenhouse, in the *Transactions of the American Philosophical Society*.

Some bodies are much more dilatable by heat than others; thus iron is more dilatable than wood, and wood is more dilatable than a stone. Of the metals, platina dilates the least, and lead and zinc the most, by increase of temperature.

[c] If two ounces of sulphate of soda (Glauber's salt), in powder, be put into a tea cup of cold water, the water will dissolve only a portion of it; but if heat be applied the whole will be dissolved. If the liquor be left to cool, the salt will be seen to shoot again into crystals. This little experiment will also have its use as an example of crystallization.

[d] Sulphur and mercury may be mixed without any apparent change; but if caloric be added, and the heat properly regulated, they combine so intimately as to form vermilion. Charcoal seems to have no attraction for oxygen in the atmospheric temperature, but if heated it unites to it with great eagerness.

[e] This is the case in distillation, whereby the most subtil parts of a compound body are dissolved by caloric, and separated from the mass in the state of gas or vapour. Every kind of distillation may be per-

hands of chemists it is the most useful and powerful agent we are acquainted with[a].

Can you recollect any other particular effect that caloric has upon bodies?

It is the cause of fluidity in all substances which are capable of becoming fluid, from the heaviest metal to the lightest gas[b].

How does caloric act upon hard bodies to convert them into fluids?

It insinuates itself among their particles, and invariably separates them in some measure from each

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formed in a common retort, with common receivers attached to it. For strong heats, Wedgwood's retorts are preferable to glass. Some important directions for the conducting of different kinds of distillation may be seen in a paper of the thirteenth volume of the *Repertory of Arts*, which gives a very particular account of the management of these processes at Petersburgh. When the product of distillation is collected in a *solid* form, the process is called *sublimation*.

Caloric also promotes the decomposition of bodies, by reason of its counteracting the attraction of cohesion which exists in all bodies.

[a] For a more particular explanation of the effects of caloric in chemical processes, consult the article *Repulsion* in chapter xiii. of this volume.

Mr. Watt mentions a strong analogy between *solution* and *fusion*: viz. that ice and soda have no more action on each other than soda and silica: but raise the temperature of the ice, and it unites to the soda. A sufficient increase of temperature will unite the silica also to the soda. Potass and silica if mixed have no action whatever on each other; but if submitted to a great heat the potass melts, and attracts the silica, which melts with it into a substance that may be dissolved in water; or if the silica be in proper proportion, the compound will be glass.

[b] For an account of the expansion of gaseous bodies by heat, see a detail of Mr. Dalton's experiments in the 5th volume of the *Manchester Memoirs*, page 595; and in several papers in Nicholson's *Journal*. For a method of estimating the changes of volume in gases, consult Sir H. Davy's Memoir in the original *Journals of the Royal Institution*.

The expansion of volatile bodies by heat may be shown by the following experiment: Put a little ether into a small retort, tie a bladder to the beak of it; and hold the retort over a lamp. The ether will quickly boil, and the gas which arises from it will soon occupy the bladder, and distend it to its full size. If the bladder be then held in water, the gas will be condensed by the loss of its heat, and the bladder will collapse. In order for this experiment to succeed, it is necessary previously to warm the bladder to 80 or 90 degrees, to prevent the gas from being condensed in the first instance.

other[c]. Thus ice is converted into water, and by a further portion of caloric into steam[d].

How are those substances distinguished which are capable of being thus rendered fluid by caloric?

We have reason to believe that every solid substance on the face of the earth might be converted to a fluid, or even a gas, were it submitted to the action of a very high temperature in peculiar circumstances[e].

You say the sun is the great source of caloric:—how is caloric transmitted from the sun to us?

Caloric is transmitted to us accompanied by light:

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[c] From this general effect upon bodies, caloric has been considered as the only agent in insensible repulsion. It has been called the *repulsive power*, which constantly acts in opposition to the power of attraction, or chemical affinity.

[d] Though the temperature of steam be no more than that of boiling water, or 212°, yet it has been demonstrated by some very ingenious experiments of Mr. Watt, that it contains near 1000° more caloric; and that this keeps it in the form of steam. Here the caloric must be in a state of chemical combination with the water, or it would be indicated by the thermometer. It is owing to this principle (viz. the necessity of a large quantity of caloric being combined with fluids, to convert them into vapour or gas,) that profuse perspiration is so cooling to labouring men, and that all evaporation produces cold. A person might be frozen to death in summer by being repeatedly sprinkled with ether. See Additional Notes, No. 36.

In Spain this principle is so well understood, that every family is provided with a utensil for cooling water or wine by *evaporation*. It is merely a piece of very porous earthenware which they fill with water; and as a small quantity is perpetually oozing through every part of the vessel, a constant evaporation from the outside is kept up, which cools the water within. The vessels are called *acarrazas*, and are now in common use in this country.

"In India and China the wealthy have their rooms open on all sides, the roof being supported on pillars, and the intervals hung with curtains. Servants without doors scatter water on these curtains continually; its evaporation absorbs a vast deal of heat, and makes the apartments cool and refreshing."

[e] The late experiments of Sir James Hall have thrown considerable light upon this subject. It appears that many substances which were deemed infusible, were so only in consequence of the decomposition they suffered in the usual way in which they were submitted to the action of caloric; but by means of a pressure sufficiently strong to prevent the escape of the volatile parts of the substance, such as the carbonic acid

both are perpetually thrown off from that immense body with astonishing velocity, in every direction[a].

If caloric passes with such velocity, how is it retained by those substances which receive it?

It is retained by its affinity for those bodies[b], or rather their mutual affinity for each other.

Do bodies in general possess a very strong chemical affinity[c] *for caloric?*

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from calcareous earth, &c., he succeeded in fusing limestone, chalk, marble, and even common coal. These effects were produced, in several instances, at a temperature much lower than would have been imagined. See Sir James's very interesting papers in the *Edinburgh Philosophical Transactions*.

[a] Since the discoveries of Dr. Herschel, we have reason to believe the sun to be an *opaque* body, probably a habitable world; and that the light and heat we receive from it are owing to an atmosphere which it has, of elastic fluids of a phosphorescent nature, by the decomposition of which, light and heat are evolved. (*Philosophical Transactions* 1801, page 265.) Aristotle conjectured that the sun was not a body of fire. *Pursuits of Literature*, second edition, part iv. page 96.

"Hail to that orb, from whose rich fountain flow
Beams that illume and glad the world below!
Unseen by thee, had nature mourn'd;
No smile her Æthiop cheek adorn'd;
Pale Night had spread her spectred reign,
And death-like horror ruled the scene." Dr. Walcott.

See an interesting paper on the nature and construction of the sun and fixed stars, in *Philosophical Transactions* for 1794.

When we require a very intense heat, it is procured by collecting the sun's rays by means of a double convex lens, or a concave mirror. This way of administering heat is particularly useful in operations on the gases. For a more detailed account of the uses of burning glasses, see my *Chemical Essays*, vol. i. pages 181—190.

[b] As caloric (like light) moves at the rate of 200,000 miles in a second, it never could be accumulated in any body, were it not retained by its *affinity* for that body, but would pass through it with the rapidity of lightning, and leave not a trace behind.

The rays of the sun seem to afford heat, only when they meet with an *opaque* substance, and not when they pass through a transparent one, as air or water; or when they are reflected by a white or polished one. The air is not heated immediately by the rays of the sun passing through it; but on their meeting with an opaque body, as the earth for instance, heat is elicited, and is thence gradually communicated to the surrounding atmosphere. Hence, the further we remove from the earth's surface the greater is the degree of cold.

No: it is one of the weakest of all known affinities[d], which is evident from the facility with which heated bodies part with their caloric to all surrounding bodies[e].

Is this universally the case?

Yes; it seems to be one of the laws of nature, that heated bodies should give out *part* of their free caloric to the neighbouring bodies at a lower temperature,

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The Swiss peasants, when they want to sow their seed, spread black cloths on the surface of the snow, to absorb the sun's rays and facilitate its melting. The late Dr. Franklin, in order to exemplify the effect that different colours have in absorbing heat, covered snow with pieces of cloth of different colours at a time when the sun was shining fully upon the snow. Having done so, he observed that the snow under the black cloth was melted first, then that under the blue, then under the brown, and that under the white cloth the melting was very inconsiderable.

[c] Before a youth can have an accurate idea of chemical attraction, the nature of philosophical attraction should be explained to him, by means of a magnet and iron filings; by globules of water, of mercury, &c.

It would be difficult to explain the nature of chemical affinity to a youth without assisting his conception by experiments. Some of the plainest, and which may be performed without difficulty, may be seen in Additional Notes, No. 11.

[d] It is worthy of remark, that this was wisely and kindly ordered by the Creator; for, owing to this, organized bodies have no difficulty in separating a sufficient quantity of caloric from the substances around them, and of securing to themselves the quantity necessary for their wants. It is obvious how dreadful would have been the consequences, if caloric had had as strong an affinity for bodies, as some simple substances have for each other. A small deviation from the present order of things would probably occasion infinite mischief.

"By some curious experiments Mr. John Hunter discovered that the living principle in fish, in vegetables, and even in eggs and seeds, possesses a power of resisting congelation." It appears from hence that these must have some peculiar attraction for caloric, in its free state.

[e] The facility with which caloric passes from one body to another may be owing to the repulsion which is known to exist among the particles of caloric. This repulsion gives it a tendency to fly off in every direction.

Count Rumford has asserted that fluids are non-conductors of heat; but Mr. Murray of Edinburgh has demonstrated the contrary by experiment. See his papers in Nicholson's *Journal*, vol. i. 8vo, 165—241. That heat descends through fluids very *slowly*, may however be demonstrated by many experiments. It is owing to this circumstance that in boiling large vessels of water, such as dyers' kettles, by passing steam into them, it is always necessary for the steam to enter at the *bottom* of the vessel.

The motion of caloric through bodies is of two kinds: through some till the whole become of an equal degree of temperature[a].

Give me an instance of the operation of this law of nature.

When the temperature of the atmosphere is reduced below 32°, water gives out its superabundant caloric

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bodies it moves with the same rapidity as through free space; through other bodies it moves with a remarkably slow motion. In the first case it is said to be *transmitted* through the body, in the latter *conducted* through it.

[a] Some bodies give out their superabundant caloric much sooner than others. Iron is a quicker conductor of caloric than glass, and glass is a better conductor than wood. Hence the use of wooden handles to metallic tea-pots and other utensils.

I take a piece of iron in one hand, and a piece of wood in the other; the iron feels cold, the wood warmer, though the thermometer shows that their temperature is the same. How is this? The iron has a stronger affinity for caloric than wood, and conducts it from the hand much swifter than the wood, and hence gives me a more lively sense of cold. From the property of radiating which heat possesses, it has been determined that metallic vessels which are intended to retain their heat should always be kept highly polished; and that pipes for warming rooms by steam or heated air should be covered in those parts which enter the apartments, with some radiating substance, such as soot, or black paint that is destitute of a shining surface. See my *Chemical Essays*, vol. i. pages 279, &c.

Some of the earths are very slow conductors of heat. Sand is eminently so. "The red hot balls, employed by the garrison of Gibraltar to destroy the Spanish floating batteries, were carried from the furnaces to the bastions in *wooden* barrows with only a layer of sand interposed; and this was found sufficient to prevent the balls, though in a high state of incandescence, from setting fire to the wood."—Tilloch's *Philosophical Magazine.*

The necessity of one body being endowed with a greater power to conduct caloric than another, is apparent in many instances; but perhaps the nature of snow in this respect renders us a more important service than any other substance. Owing to the distance of this globe from the sun, and to the vast mountains of ice at the poles, the atmosphere over a large portion of the earth is at times reduced to so low a temperature, that, were it not for a wise provision of nature, all vegetable life must be destroyed. Caloric has always a tendency to equilibrium; therefore, if the temperature of the air be lowered, the earth cools in proportion: but, when the atmosphere is reduced to 32°, the water which it held in solution becomes frozen, and precipitates in the form of snow upon the earth, covering it as with a carpet, and thereby preventing the escape of that caloric which is necessary for the preservation of those families of vegetables that depend upon it for their support and maturity. Be by degrees, till at length the cold atmosphere robs it of its caloric of fluidity also, and it becomes ice[b].

If water be changed into ice by parting with its caloric, how comes it to pass that ice swims upon the surface of water?

Because, by the change which it undergoes, it becomes specifically lighter than the subjacent water[c].

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the air ever so cold, (and in the northernmost parts of the Russian empire it is sometimes 70 degrees below the freezing point,) the ground, thus covered, is seldom reduced below 32°, but is maintained equably at that temperature for the purpose above mentioned. How multiplied are the means which Nature has adopted for the preservation of all her productions!

The constant tendency of caloric to the state of equilibrium is very clearly expressed by Dr. John Thomson of Edinburgh. "When a mercurial thermometer," says he, "is immersed in water, the caloric of the water makes an effort to diffuse itself through the mercury, and the caloric of the mercury makes an effort to diffuse itself through the water. If the tendencies to expand be equal in these two quantities of caloric, both quantities will remain at rest. But when the tendencies to expansion are unequal, the caloric is impelled from the substance where it had existed in the state of the greatest tension, into the substance where it had existed in the state of the least tension. When this happens, the degree of the dilatation or contraction of the mercury is said to indicate the *temperature* of the substance to which it is applied." *Notes on Fourcroy*, vol. i. page 178. For a further elucidation of this subject, consult Dr. Thomas Thomson's *System of Chemistry*, vol. i. page 335; and *Philosophical Transactions* for 1802, page 403.

[b] The quantity of heat given out in freezing, occasions the progress of congelation to be extremely slow. The constant emission of caloric from the freezing substances operates favourably; for thus the severity of the frost is mitigated, and its progress retarded. This accounts for its often feeling warmer after a great fall of snow. On the other hand, if the return of caloric to the frozen body of water were not equally slow, what sudden inundations would be occasioned, in those countries where large masses of ice are collected, at the first approach of summer! as has before been remarked. That the melting of ice produces cold, is seen in many operations. By melting ice with common salt, confectioners produce cold much greater than that of the original ice.

[c] Ice is lighter than water, owing to air-bubbles produced in the ice while freezing: but Monsieur de Mairan attributes the increase in the bulk of water in freezing to a different arrangement of its particles; ice being a crystallization composed of filaments, which are found to be uniformly joined at an angle of 60°, and by this disposition occupy a greater volume than if they were parallel. See Dr. Black's *Lectures*, vol. i.

That ice contains a large portion of air, may be seen by the following

Did you not say that all substances become more dense by the loss of caloric?

They usually do; but the freezing of water is a striking *exception*[a] to this general law of nature, and

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experiment. Drop small pieces of ice into a tall glass full of hot water; as the ice melts, bubbles of air will be seen to rise from it, and burst at the surface of the water.

[a] We are acquainted with a few other exceptions. Saline solutions expand in cooling as crystallization takes place: and more perfect castings of iron may be had than of almost any other metal, in consequence of iron always enlarging as it cools, and filling the most minute parts of the mould into which it may be poured when in a fluid state; but we know of no fluid that has a *maximum* of density like water, and that expands whether heated above or cooled below that temperature.

In general, all bodies, whether solid or fluid, contract their dimensions and become of more specific gravity in cooling. This axiom has been long known and acknowledged; but WATER affords a remarkable and striking exception. Water as it cools below 42°.5, instead of contracting and becoming of greater specific gravity, actually becomes increased in bulk, and its specific gravity continues to lessen as it cools. Count Rumford noticed this fact some years ago in one of his early essays. His remarks, if I mistake not, are accompanied with some ingenious calculations, to which I refer the reader. Sir C. Blagden has, from actual observations, made a table of the specific gravity of water of different temperatures between 30 and 40 degrees.

40———1000.54 bulk
37———1000.55
36———1000.56
35———1000.58
34———1000.60
33———1000.63
32———1000.66
31———1000.70
30———1000.74

Since these experiments, Mr. Dalton has discovered that the expansion of water is the same for any number of degrees above or below the maximum of density. Therefore the density of water at 32° and at 53° is precisely the same. The bulk of water at 5° is equal to the same bulk of water at 80°. *Manchester Memoirs*, vol. v. page 374.

From these experiments, we see that water becomes of less specific gravity, whether it be heated *above* or cooled *below* 42°5; a fact too astonishing ever to have been discovered or imagined *a priori*. The wisdom and goodness of the GREAT ARTIFICER of the world will manifest itself in this arrangement, if we consider what would have been the consequences had water been subject to the general law, and, like other fluids, become specifically heavier by the loss of its caloric. In winter, when the atmosphere became reduced to 32°, the water on the surface of our rivers would have sunk as it froze; another sheet of water would have is a memorable instance of the wisdom and provident care of the Almighty, when he established the laws of the universe.

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frozen immediately, and sunk also: the ultimate consequence of which would have been, that the beds of our rivers would have become repositories of immense masses of ice, which no subsequent summer could unbind; and the world would shortly have been converted into a frozen chaos. How admirable the wisdom, how skilful the contrivance, that, by subjecting water to a law *contrary* to what is observed by other fluids, the water as it freezes becomes specifically lighter, and, swimming upon the surface, performs an important service by preserving a vast body of caloric in the *subjacent* fluid from the effects of the surrounding cold, ready to receive its own accustomed quantity upon the first change of the atmosphere! I shall not regret having subjoined these remarks, should they but afford

> "One ray of light in this terrene abode,
> To prove to man the goodness of his God." DARWIN.

CHAPTER IV.

OF WATER.

What is water?

Water is a compound consisting of hydrogen and oxygen.

In how many states do we find water?

In four: solid or ice; liquid or water; vapour or

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[a] Ice at 32° must absorb 140° of caloric before it can become fluid; or such a quantity as would raise a body of water of equal bulk with itself from 32° to 172°. This may be made very evident to a youth who has been taught the use of a thermometer, by the following directions:

"Take any quantity by weight of ice or snow at 32°, and mix it with an equal weight of water heated exactly to 172°. The snow instantly melts, and the temperature of the mixture is still only at *thirty-two* degrees. Here the water is cooled 140°, while the temperature of the snow is not increased at all; so that 140° of caloric have disappeared. They must have combined with the snow; but they have only melted it, without increasing its temperature. Hence, it follows irresistibly that ice, when converted into water, absorbs and combines with 140° of caloric. Water then, after being cooled down to 32°, cannot freeze till it has parted with 140° of caloric; and ice, after being heated to 32° (which is the exact freezing point), cannot melt till it has absorbed 140° more of caloric. This is the cause of the extreme slowness of these operations. There can be no doubt, then, but water owes its fluidity to its latent caloric, and that its caloric of fluidity is 140°." Thomson's *System of Chemistry*, vol. i. page 365, &c.

The advantages which we derive from the slowness of these operations, and the inconveniences we should have suffered had it been otherwise, are numerous and obvious. See notes pages 66, 67 and 76; and Additional Notes, No. 5.

[b] However long we boil water in an open vessel, we cannot make it in the smallest degree hotter than its boiling point. When arrived at this point, the vapour absorbs the heat, and carries it off as fast as it is generated. Yet by continued heat, united with additional compression, both the expansibility and temperature of steam may be greatly increased; and some constructors of steam engines have lately availed themselves of this property, to augment the power and diminish the expense. See note page 39; also Additional Notes, No. 3 and 4.

Those who have an air-pump may easily see that water requires a vast portion of caloric to convert it into steam; for if a cup of *hot* water steam; and in a state of composition with other bodies.

Which is the most simple state of water?

That of ice; because water contains a larger portion of caloric[a].

How do you define vapour?

Vapour is water, combined with a still greater quantity of caloric[b].

What are the properties of vapour?

Vapour, owing to the large portion of caloric which is combined with it, takes a gaseous form, acquires great expansive force[c], and a capability of supporting

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be put under the receiver, and the pump be set to work, the water will soon begin to boil furiously, and the receiver will be covered with vapour. If the receiver be now taken off, the water will be found barely lukewarm, owing to the vapour having carried off the greatest part of its heat. Water, in being converted into vapour, combines with more than five times the quantity of caloric that is required to bring ice-cold water to a boiling heat, and occupies a space 800 times greater than it does when in the form of water.

Owing to the quantity of caloric that liquids require to convert them into vapour, all evaporation produces cold. It has been remarked before, that an animal might be frozen to death in the midst of summer, by repeatedly sprinkling ether upon him. Its evaporation would shortly carry off the whole of his vital heat. Water thrown on hot bodies acts in the same way; it becomes, in an instant, converted into vapour, and thus deprives these bodies of a great portion of the caloric they contain.

The most striking example that I have seen, of the production of cold by rarefaction, is given by Dr. Wolfe in his account of the fountain of Hiero, at the mines of Chemnitz in Hungary. In this curious machine, of which he has given a plate, the air is compressed by a ponderous column of water, 260 feet high; it therefore happens, that whenever the stop-cock is opened, this compressed air rushes out with great vehemence, becoming immediately much expanded. The consequence of this sudden rarefaction is, that the moisture the air contained is not only precipitated, but congealed; a part of which falls down in a shower of snow, and the other part forms icicles which adhere to the nosle of the cock. *Philosophical Transactions*, vol. iii.

[c] The expansive force of steam is found by experiment to be much greater than that of gunpowder. Some volcanic eruptions and earthquakes, it is supposed, owe their terrible effects to this power of steam; the water of the sea finding its way to subterraneous fires. See an account of the dreadful effects of the earthquake at Catania, in the his-

enormous weights[a]; whence it has become a useful and powerful agent for raising minerals of all kinds, and even water itself, from deep pits, and for other very important purposes[b].

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torical notes to Madame de Genlis's *Tales of the Castle*, vol. ii. page 241; or in Sir William Hamilton's splendid *Survey of the Two Sicilies*.

In boiling oil, the workmen are very careful to prevent any water coming near it; for a single drop coming among it would instantly, by the excessive heat of the oil, be converted into vapour, and would force part of the oil over the sides of the boiler.

It is to the expansive force of steam that the well-known motion in water, called boiling, is to be ascribed. The vapour is first formed at the bottom of the vessel, and, passing through the water, causes that motion in it which we call ebullition.

[a] The invention of the steam engine was a vast acquisition to the arts. There is reason to believe that, in time, steam may be applied to many useful purposes of which at present we have no idea. In America vessels have long been navigated by steam, and of late years such vessels have become very common in some districts of England.

> "Soon shall thy arm, unconquer'd steam! afar
> Drag the slow barge, or drive the rapid car,
> Or on wide waving wings expanded bear
> The flying chariot through the fields of air." DARWIN.

The steam engine, approaching to the nature of a *perpetuum mobile*. or rather an animal, is incapable of lassitude; it procures for us coals; it works metals; moves machines; and is certainly the noblest drudge that was ever employed by the hand of art. Thus we "put a hook in the nose of the leviathan; play with him as with a child; and take him for a servant for ever;" thus we subdue nature, and derive aid from the elements of earthquakes.

The steam engine is brought to such perfection, that one bushel of coals will raise 6,000 hogsheads of water ten feet high, and do the work of ten horses. Where there is no waste of steam, this work may be performed continually with the consumption of only one bushel of coals per hour. Some of the engine chambers in London and elsewhere are now fitted up with great taste, and are kept with the utmost neatness; in these one may spend hours without being annoyed by the escape of the most minute portion of steam.

Dr. Black calls the steam engine the masterpiece of human skill, and the most valuable present that was ever made by philosophy to the arts. The account of the introduction of the first steam engines into South America for the purpose of draining the Peruvian Mines, is extremely interesting. It will be found in a memoir by Henry Boase, Esq. printed in the *Transactions Roy. Geol. Soc. of Cornwall*, vol. i. p. 212.

[b] Steam is now employed in a vast variety of ways in the different manufactories of this kingdom. It is used with much economy of fuel in a great number of dye-houses in various parts of Great Britain. It

In what proportions are oxygen and hydrogen[c] *combined to form water?*

Water is composed of 88 parts by weight of oxygen, and 12 of hydrogen[d], in every 100 parts of the fluid.

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should however be remembered, that whenever it is intended to heat water by means of steam, the steam must not be thrown in upon its surface, but must be conducted to the *bottom* of the cold liquor before it be disengaged, or the effect will not be produced, water having but little power of conducting heat *downwards*.

Messrs. Gott and Co., of Leeds, boil 30 large coppers by the steam of one boiler. It is employed elsewhere in drying malt, linen, coffee, paper, &c., and might be used with peculiar advantage in drying gunpowder. Dr. Black remarks, that steam is the most faithful carrier of heat that can be conceived, as it will deposit it only on such bodies as are colder than 212°.

Water heated to 220 degrees or upwards is found to be very effectual in bleaching linen goods. This method is coming into practice in the North of England. The necessary pressure is given by means of large chambers constructed of massy stone; and in these chambers the linen is submitted to the action of the condensed steam. In the boilers of some of the high pressure steam engines water has been heated to nearly 300° of Fahrenheit; and what appears very extraordinary is, that the workmen have no fear of coming in contact with the steam thus heated, as it occasions no unpleasant sensation; though at 212°, the usual temperature of steam, it would scald dreadfully. Of this curious fact I have never been able to obtain a satisfactory explanation.

[c] Both these terms are derived from the Greek language; the former signifies to *generate acids*, the latter to *generate water*.

[d] Hydrogen appears capable of uniting with oxygen only in one proportion, and water is the result of the composition.

Of all the known substances, there is not any of which an equal weight can combine with so large a portion of oxygen, covering at the same time its characteristic properties, as hydrogen; and losing also all those which characterize itself:—it requires rather less than 2 of hydrogen to saturate 15 parts of oxygen to this point, that is, to form water.

As water does not permit any property of oxygen or hydrogen to be perceived, it may be concluded that these two substances are combined at the point at which the reciprocal affinity exercises the greatest effect; and that they are in a state which may be compared with that of a neutral salt, in which the acid and alkaline properties have equally become latent. It should however be remembered, that although water may be considered as being formed of 1 part hydrogen and $7\frac{1}{2}$ parts oxygen by *weight*, it is constituted of 2 parts hydrogen and 1 of oxygen by *measure*. Therefore if water be considered to be formed of an atom of oxygen and an atom of hydrogen, the size of the atom of hydrogen must be to that of the oxygen as 2 to 1, though its weight when compared with the atom of oxygen be as 1 to $7\frac{1}{2}$.

How is it known that water is a compound substance[a] *?*

Several methods have been contrived whereby wate may be decomposed, and the exact proportion of it constituent parts ascertained[b].

Do you know any of the methods of decomposing water

Yes, there are several: it may be done by forcin it through a tube over red-hot charcoal[c], by passin repeated electrical shocks through it, and also b means of the galvanic apparatus[d].

Does nature decompose water in any of her ope rations?

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[a] This was discovered by Mr. Cavendish, in the year 1781. D Priestley had previously combined the two gases by combustion; b Mr. Cavendish was the first who drew the proper conclusion from t Doctor's experiment. The benefit which the world has derived fro the labours and communications of such men is incalculable. "Nature says an elegant French writer, "in order to unite mankind by reciprocal communication of knowledge, has given to each individu his particular ignorance; and has placed science as a common stock render us necessary and interesting to each other."

From a passage in Virgil's *Georgics*, lib. ii. 325, one might imagi that the ancient chemists of Egypt had discovered the composition water. See the notes in Darwin's *Botanic Garden*, book i. 136.

[b] A history of the discovery of the composition and decomposition water, with the curious facts relating thereto, may be seen detailed a familiar and pleasing manner by Dr. John Thomson, in his valua *Notes on Fourcroy*, vol. i. page 237, &c. The operation of electric or galvanism, in uniting the two gases to form water, is explained Mr. Murray, with great perspicuity, in the notes to his *System Chemistry*, vol. i. page 25.

[c] "Water cannot be decomposed without a combustible body," or t agency of electricity or galvanism, "as the hydrogen requires a ve large dose of caloric to put it in a gaseous state. This appears fr the lightness of hydrogen gas compared with water. A cubic foot water weighs 62½ pounds, whereas a cubic foot of hydrogen gas weig less than 40 grains." See Additional Notes, No. 13.—When wate decomposed by means of galvanic electricity, it is separated into t volumes by measure of hydrogen and one volume of oxygen.

[d] When two wires from the opposite extremities of a galvanic batt are placed in a tube containing water, so that they are distant fr each other ¼ or ½ an inch, a stream of gas issues from each wire—fr the positive wire oxygen, from the negative, hydrogen gas; and th are in the proportions which when exploded, either by galvanism

Certainly, by many: particularly by means of every living vegetable; all vegetables having the power of decomposing water, by a secret operation peculiar to themselves[e]. Fish in general, and all cold-blooded amphibious animals, we have reason to think, are endowed also with the same faculty[f].

For what purpose are vegetables endowed with this power of decomposing water?

They combine part of its hydrogen, as well as of its oxygen, with the carbon of the atmosphere and of the soil, to form the vegetable compounds oil[g], wax[h], gum,

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electricity, re-form water. See more on this subject in Murray's *System of Chemistry*, vol. ii. page 172.

Some French aëronauts decomposed water by the galvanic pile at an elevation of nearly three thousand metres from the earth. *Philosophical Magazine*, vol. xix. page 374.

The decomposition of water by electricity or galvanism, which produces an intense heat, seems to prove that there is a degree of temperature at which water cannot exist, but in which it is reduced to its two original elements.

Water is often partially decomposed by being kept for a long time in casks, especially on long voyages. The wood combines with its elements, forming, amongst other impurities, carburetted hydrogen. Hence the disagreeable taste and smell which are observable in such water. If the cask be charred on the inside, it will not operate in this way.

[e] See the latter part of chap. ii. and Additional Notes, No. 18.

[f] Among other cases, we read of a fish that was kept three years in a vessel and fed only with water, and that at last it became too large to live any longer in the vessel. Whence this increase of animal substance, if we deny it the power of decomposing water? Rondelet *de Piscibus*, lib. i. cap. 12.

[g] It should always be recollected that the oil found in vegetables is produced by this process of vegetation. The oils, bitumens, &c. in minerals, must all have had a vegetable origin.

In the duchy of Modena, mineral oil is separated from bituminous coals by a natural subterranean distillation. The inhabitants of the district, by piercing the sides of a particular rock, at different distances from its summit, obtain oil of different kinds, thickening, and growing deeper-coloured, as the channels through which they flow approach to the surface of the earth. See Bp. Watson's *Chemical Essays*.

[h] In Louisiana and Pennsylvania, the *myrica* is cultivated solely for the *wax* which it produces. In China, vegetable wax is extracted from plants by maceration in boiling water, and employed in the manufacture of candles.

Bees' wax is doubtless a vegetable product. The bees extract it unresin, sugar, &c.; while the superfluous oxygen is abundantly evolved by the leaves;

> "Killing infectious damps, and the spent air
> Storing afresh with elemental life [a]."

Can you recapitulate what has hitherto been detailed of the nature of oxygen?

Yes: oxygen is the basis of vital air, as well as one of the constituent parts of water [b]; it is the chief support of life and heat; and performs an important part in most of the changes which take place in the mineral, vegetable, and animal kingdoms [c].

What is hydrogen, the other constituent part of water?

Hydrogen is the base of that gas which was formerly called inflammable air, and is, when in the aëriform state, the lightest of all ponderable things [d].

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altered from the leaves of trees, and other vegetables. They seem, however, to mix it with some of the pollen of flowers. The comb which these insects form with the wax, is a collection of hexagonal cells closely fitted to each other. It may be remarked that no other geometrical figure could have been chosen for them, that would have been equally capacious, without any loss of room; so that the operation of creative wisdom is apparent even in the impression of that instinct whereby these little animals are directed to fabricate their cells in that particular form, and in no other.

[a] When a living vegetable is moistened with water and the sun shines upon it, two very important operations are performed at the same time by the decomposition of the water which the sun's rays enable the plant to effect, viz. the plant is nourished by the hydrogen, and the atmosphere is purified by the restoration of its oxygen.

[b] Nature, in economizing the primary materials of the universe, has constituted *oxygen* the basis both of the atmosphere which surrounds the earth, and of the water which forms its seas and oceans:

> "For mark how oxygen with azote gas
> Plays round the globe in one aërial mass,
> Or, fused with hydrogen in ceaseless flow,
> Forms the wide waves which foam and roll below."

We see in this and other instances, by what simple means the most beneficial effects have been produced.

[c] Some idea may be formed of the importance of oxygen, by attending

Has any method been discovered of composing *vater by a mixture of oxygen and hydrogen?*

Yes: there are several ways of doing this[e]; so that he composition of this fluid is now ascertained beyond ll doubt[f].

Do you know any of the methods which have been mployed to form water by a mixture of its constiuent parts?

If a mixture of oxygen and hydrogen gases, in proper

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o the analysis which Lavoisier made of the materials necessary for fer- nenting 100 pounds of sugar.

	lbs.				lbs.	oz.
Water	400	Oxygen of the water			340	0
Sugar	100	Ditto of the sugar			64	0
Yeast	10	Ditto of the yeast			7	12¼
	510				411	12¼
		Hydrogen of the water . .	60	0		
		Ditto of the sugar . .	8	0		
		Ditto of the yeast . .	1	6		
					69	6
		Carbon of the sugar . .	28	0		
		Ditto of the yeast . .	0	12½		
					28	12½
		Nitrogen in the yeast			0	¾
					510	0

It appears from the above analysis that more than four-fifths of the hole is oxygen. See a further account of oxygen in chap. x.

[d] Hydrogen gas, from its great levity, has generally been used to fill ir balloons. One hundred cubical inches of it weigh only about 2 grains nd one quarter. The following is the best way of procuring it: Put a uantity of filings of zinc into a vessel which has a glass tube adapted o it; then pour upon them sulphuric acid diluted with 6 or 8 times its uantity of water, an effervescence will immediately take place; the ater will be decomposed, the oxygen of it will become united to the etal, and the hydrogen gas will be disengaged, and may be conveyed y the glass tube into any proper receiver. This gas can be procured ure only from water, which in all cases must suffer a decomposition. See further account of hydrogen and its compounds in chap. ix.

[e] An ingenious and simple apparatus for the re-composition of water as been invented by Mr. Cuthbertson. A drawing and description of may be seen in Nicholson's *Journal*, vol. i. 4to. page 235.

[f] The decomposition of water and its subsequent re-formation may be

proportion, be fired, the inflammation will unite the bases of the two gases, without separating the whole of their caloric, and water will be the product[a].

Is there any reason to suppose that water is thus formed in any of the great operations of nature?

Yes: it is probable that the torrents of rain which generally accompany thunder storms, may arise from a sudden combustion[b] of hydrogen and oxygen gases.

How is the atmosphere furnished with this hydrogen gas?

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shown by the following easy experiment: Add gradually one ounce of sulphuric acid to four ounces of water in a large phial containing a few iron filings. The temperature of the mixture will be so much raised by the union of the water with the acid, as to enable the iron to decompose a part of the water. If a hole be neatly made through a cork which fits the mouth of the phial, and a piece of tobacco-pipe with a very small orifice be fitted into it, and the whole cemented into the phial with a mixture of resin and bees' wax, the hydrogen gas as it is separated from the water will pass in a continued stream through the pipe, and may be set on fire by the flame of a candle brought in contact with it. The gas will continue to burn with a blue lambent flame, as long as the decomposition goes on. This shows that the gas is really hydrogen, and that it arises from the decomposition of the water.

That water may be re-formed by the combustion of this gas, may be shown by holding a glass bell over the flame of the gas: as the hydrogen burns it unites with the oxygen of the atmosphere, and the union of the two gases produces water, which will soon be seen to deposit itself like dew on the inside of the glass. *It is advisable to fold a cloth round the bottle to prevent any injury from the fragments of glass, in case of an explosion, which sometimes will happen during this experiment, if atmospheric air be left in the phial: or let the gas burn for a moment, before the cork and pipe are fixed into the neck of the bottle.* These two experiments prove the compound nature of water in the most satisfactory manner. Again: if water be decomposed by a galvanic apparatus, the separate gases may be collected and measured; and then if the gases thus produced be united by an electric spark, water will be re-formed in an instant.

[a] In Lavoisier's *Elements of Chemistry*, a copper-plate print of an apparatus for composing water may be seen, with a full and satisfactory description of the method of making use of it. See Additional Notes, No. 13.

M. Biot has succeeded in forming water from hydrogen and oxygen, by *compression* only, independently of the electric spark. The compression, by bringing the particles of gas into intimate union, makes them throw out heat sufficient to set the hydrogen on fire; and the product of the combustion is water.

It here occurs, that the affinity of hydrogen for oxygen may be exem-

Hydrogen is continually emanating from, and is the consequence of, every species of vegetable and animal decay or putrefaction; and it is also evolved from various mines, volcanoes, and other natural sources[c].

What is the specific gravity of water?

A wine-pint measure of water weighs rather more than one pound[d]; and a cubic foot of water weighs about 1000 ounces, or $62\frac{1}{2}$ lbs. avoirdupois. It is 825 times heavier than atmospheric air[e].

What change does water undergo in order to be converted into ice?

The atmosphere, when its temperature is sufficiently low, deprives the water of a certain portion of

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lified by the large portion of oxygen which all combustible bodies containing much hydrogen require in combustion; affording water as the product. Thus, one pound of highly rectified spirits of wine on being burnt will produce more than its own weight of water. See Additional Notes, No. 16.

[b] Some recent speculations of Sir H. Davy seem to involve the conclusion that water is not a compound body, but the ponderable base, both of oxygen and hydrogen gases, assuming either of these forms according to its electrical states. See his paper in the *Phil. Trans.* for 1808.

[c] Hydrogen gas is only one-thirteenth of the weight of atmospheric air, and occupies a space fifteen hundred times greater than it possessed in its aqueous combination; although in that combination it is always united to 85 per cent. of oxygen.

The ignis fatuus, or will-o-wisp, originates from decayed vegetables, and the decomposition of pyritic coals: it consists generally of hydrogen combined with carbon; and, perhaps, occasionally with phosphorus or sulphur.

> "Thus heat evolved from some fermenting mass
> Expands the kindling atoms into gas."

Dr. Shaw in his *Travels in Palestine* has given a curious account of an ignis fatuus which he observed there.

[d] It is very necessary for the student to bear in mind the specific gravity of water, because this is always taken for unity in the measure of the specific gravity of every other substance. An accurate wine-pint holds 7272 grains of distilled water, which is 272 grains more than one pound avoirdupois.

[e] This estimate is agreeable to the last experiments made by Sir Geo. Shuckburgh, when the barometer is at 30 inches, and the thermometer between 50° and 60°.

its caloric—crystallization then ensues, and the water solidifies and becomes ice[a].

What do you mean by crystallization?

By crystallization is understood the concretion of certain substances into regular forms, occasioned by the loss of a portion of their caloric.

To what substances is the term usually applied?

The term is generally applied to compound bodies

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[a] Water in freezing crystallizes in filaments, which are uniformly joined at angles of 60 and 120 degrees. The word *crystal* originally signified ice.

It is owing to the *expansion* of water in freezing, that rocks and trees are often split during intense frosts. According to the calculations of the Florentine academicians, a spherule, or little globe of water, only one inch in diameter, expands in freezing with a force superior to the resistance of 13½ tons weight. See *Essays, &c. of Experiments in Academie del Cimento,* 4to. 1684. Major Williams also attempted to prevent this expansion; but during the operation the iron plug which stopped the orifice of the bomb-shell containing the freezing water, and which was more than two pounds weight, was projected several hundred feet with great velocity; and in another experiment the shell burst. The imbecility of man never appears so conspicuous as when he attempts to counteract the operation of laws which were designed by infinite beneficence for his preservation and comfort. The law in question is eminently important, and nature has made it unalterable.

This property of water is taken advantage of in splitting slate. At Colly Western the slate is dug from the quarries in large blocks; these are placed in an opposite direction to what they had in the quarry, and the rain is allowed to fall upon them: it penetrates their fissures, and the first sharp frost freezes the water, which, expanding with its usual force, splits the slate into thin layers.

It was necessary for the preservation of the world, that water should in this instance be subjected to a law different from that of other substances which change from fluid to solid. For an account of this important deviation from a general decree of nature, see the last notes in chap. iii.

It may be remarked, that though fresh water freezes when reduced to the temperature of 32°, sea water does not freeze till cooled down to 28.5°. Was not this designed by nature to keep the ocean open at all seasons, that there might be no impediment to that general intercourse among nations which eminently promotes their civilization and refinement?

> "For this the ship, in floating balance held,
> By earth attracted and by seas repell'd,
> Directs her devious track, through climes unknown,
> That leads to every shore and every zone." FALCONER.

[b] Crystallization is a kind of precipitation, in which the salt as it separates from the solvent assumes peculiar determinate forms. Mr. Smith-

of the saline kind, and to their separation in regular and peculiar figures, from the water in which they were dissolved[b].

You have said that ice is the most simple state of water;—do you then imagine that water is naturally solid?

Near the poles water is eternally solid: there it is similar to the hardest rocks[c], and may be formed by the chisel of the statuary, like stone[d].

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on has shown that crystallization cannot take place while solution subsists, and that the only requisite for this operation is a freedom of motion in the masses which tend to unite. *Phil. Trans.* for 1803, page 27.

[c] There happen cracks at certain times in the ice mountains of Switzerland, which have shown the great thickness of the ice; some of these cracks have measured 300 or 400 ells deep. Near Hudson's Bay there are islands of ice which are immersed above 100 fathoms beneath the surface of the sea, and which measure three or four miles in circumference. *Phil. Trans.*

" There can be no doubt but that the quantity of ice at the north pole is the principal source of the coldness of our winters, and that it is brought thither by the regions of air blowing from the north."

" Where, for relentless months, continual night
Holds o'er the glittering waste her starry reign."

The ice at each pole of the earth forms an immense cupola, the arch of which extends some thousand miles over the continents; the thickness of which, beyond the 60th degree of latitude, is several hundred feet. Navigators have assigned to detached masses, which are met with floating at sea, an elevation of from 1500 to 1800 feet. See Ellis's *Voyage to Hudson's Bay.*

There can be no doubt but that the thickness of these cupolas of ice is much greater nearer the poles; for astronomy sometimes presents in the heavens so vast an image of them, that the rotundity of the earth seems to be considerably affected thereby. Captain Cook could never approach nearer the south pole, where there is no land, than the 70th degree of latitude; that is no nearer than 1500 miles, though he had coasted round it for a whole summer; and it was only under favour of a day that he was permitted to advance even so far. St. Pierre's *Studies of Nature*, vol. i. 129—132.

From a late memoir by Mons. Perron, there is reason to believe that these mountains of ice at the poles, which have hitherto impeded the progress of European navigators, have been detached from the depths of the sea, to float at the surface. All the results of observations made by him and other navigators, concur in proving that the temperature of the sea decreases according to the depth; and that the deepest gulfs of the sea are continually covered with ice, even under the equator. A translation of this interesting memoir may be found in the 21st volume of the *Philosophical Magazine.*

[d] " It is related that at the whimsical marriage of Prince Gallitzi, in

Is this great solidity of ice at the poles, owing to its being frozen in such large masses?

The great solidity of ice at the poles is occasioned by the very low temperature of the circumambient air[a]; for in very cold countries ice may be ground so fine as to be blown away by the wind, and will still be ice.

Is ice the only instance of water existing in a state of solidity?

No: water becomes still more solid in the composition called mortar and in cements, (see the note on the properties of lime, chap. v.) having parted with more of its caloric in that combination than it does in the act of freezing[b].

1739, the Russians applied ice to the same purposes as stone. A house consisting of two apartments was built with large blocks of ice; even the furniture of the rooms was made with ice; and the icy cannon, which were fired in honour of the day, performed their office more than once without bursting." Bishop Watson's *Chemical Essays.*—See Additional Notes, No. 17 and 55.

In the most northern part of the Russian territory, the temperature of the atmosphere is sometimes sufficiently low to freeze mercury, or 71 degrees below the freezing point of water. It is so intense in some seasons, that the poor inhabitants cannot venture out of their miserable huts but at the hazard of their lives.

> " There, through the prison of unbounded wilds,
> Barr'd by the hand of Nature from escape,
> Wide roams the Russian exile. Nought around
> Strikes his sad eye, but deserts lost in snow,
> And heavy-loaded groves, and solid floods,
> That stretch athwart the solitary vast
> Their icy horrors to the frozen main."

See the Additional Notes, No. 17.

[a] Though water be converted to ice by the loss of caloric, there is reason to suppose that ice, notwithstanding, contains more caloric than is disengaged between the state of vapour and that of congelation. For although mercury requires to be cooled 71° below the freezing point of water before it will congeal, frozen mercury must still contain a portion of the matter of heat, because there are other fluids which cannot be rendered solid even by reducing them to that low temperature.

I have been informed by some intelligent workers in iron and steel, that they have great difficulty in making tools hard enough to cut ice in extremely *cold* winters; and that in such seasons the workmen are under the necessity of having their instruments very frequently repaired.

What other instances are there of water taking a solid form?

Water is also combined in a state of solidity in many alkaline, earthy and metallic salts[c], both natural and artificial; and most of these when deprived of it, lose their transparency and also their crystalline form.

What are the general and more obvious advantages which we derive from water?

Water is a necessary beverage for man and other animals; is perpetually used as a solvent[d] for a great variety of solid bodies[e]; acts an important part in con-

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[b] Though water takes a solid form in its various combinations, such as with lime, saline crystals, &c. we know of no method of compressing it when in a fluid state. The Florentine academicians filled a globe of gold perfectly full of water, and submitted it to a very powerful press; but could not perceive that they were able to make it occupy less space than it did at first. They gave it such a degree of pressure, that at length the water exuded through the pores of the metal.

[c] Most stones and salts lose their solidity and transparency by being deprived even of a part only of the water which they contained, and generally become pulverulent. It is by a combination with water that some of the gases are rendered liquid substances, and that some liquids acquire the property of becoming fixed. This may be satisfactorily shown by boiling a few copper filings in concentrated sulphuric acid, with a small portion of nitric acid, till the copper is dissolved; then adding water, and leaving the mixture to cool gradually; when beautiful crystals of blue vitriol will be found, as hard as some minerals. It is the water which gives them their solidity;

> "That chief ingredient in Heaven's various works,
> Whose flexile genius sparkles in the gem,
> Grows firm in oak, and fugitive in wine." ARMSTRONG.

If water be thrown on quick-lime, it will be retained by it with such force that nothing less than an intense *red* heat will separate it. In its combination with lime it becomes much more solid than when in the state of ice; which may be proved by direct experiment. Calcined plaster of Paris, in a pulverulent state, becomes quickly solid by mixing it with water. Saussure has proved that alumina, when mixed with water, retains a tenth of its weight of that fluid at a heat which would melt iron.

[d] It should be remembered, that all bodies which are soluble in water, form, during their solution, a chemical combination with the water, and that solutions in water are not mere mechanical mixtures.

[e] Water is not only employed as a solvent for many solid substances,

veying nourishment to the vegetable world[a], and giving salubrity to the atmosphérical regions[b]; and lastly, by its accumulation in the ocean[c], affords a ready communication with distant countries;—the whole of which evidently teaches how provident the great AUTHOR of nature has been in his attentions to the comforts and conveniences, as well as to the wants, of his numerous creatures.

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but has important uses in a variety of compounds. Besides imparting solidity to the classes of salts, it gives energy to the action of many of the acids, and is even necessary in their formation. Muriatic acid and nitrous acid gases are condensed so as to form liquid acids, merely by their union with water.

[a] For an account of several modern experiments on the growth of vegetables in water, see Additional Notes, No. 57.

[b] See notes chap ii. page 54.

[c] The immense quantities of marine productions found at very great heights above the present level of the sea, seem to indicate that there has been a prodigious recession of the ocean. While water was conceived to be a simple and indestructible substance, innumerable conjectures were afloat as to the channels which had been found for such an immense body of water. The new chemical doctrines have however afforded a clue by which to unravel this mystery, and fresh motives for admiring the exquisite contrivance of the great Author of all things.

See this subject further investigated in the Additional Notes, No. 18, 'On the recession of the ocean.'

I cannot resist making an extract from Mrs. Charlotte Smith's observations on the ocean: "There are people," she says, "who think nothing but the human character deserves their study, and pass over the great works of God as unworthy the trouble of contemplating. But I wonder any being who affects *taste* would venture to assert that this immense body of water presents only sameness and monotony. To me it seems, that even the colours and sounds are little less varied than those we see or hear in the midst of the most luxuriant landscape."

"Ah! wherefore do the incurious say,
That this stupendous OCEAN wide
No change presents from day to day,
Save only the alternate tide?
Show them, its bounteous breast bestows
On myriads life; and bid them see
In every wave that circling flows,
Beauty, and use, and harmony:
Works of the Power Supreme who pour'd the flood
Round the green peopled earth, and call'd it good."

CHAPTER V.

OF EARTHS.

What are the principal characters of the earths?

The earths are incombustible bodies, and in general are unalterable in the fire. Till lately they were thought to be unsusceptible of decomposition[a]; they are insoluble in water, or nearly so, when combined with carbonic acid[b]; and are of a specific gravity never exceeding five times that of water.

How many earths are there?

There are nine distinct earths known at present, viz. silica, alumina, zirconia, glucina, yttria, barytes, strontites, lime, and magnesia[c]. The four which I have enumerated last are generally called alkaline earths.

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[a] Baron Born, many years ago, was of opinion that the earths were compound bodies. Sir H. Davy has now succeeded in decomposing most of them; and from his experiments we have reason to suspect that they are all metallic oxides.

[b] Bergman classes all substances, except metals, with the earths, which require more than one thousand parts of water for their solution. We have, however, another test to distinguish them, when held in solution by acids, viz. the prussian alkali. Prussiate of potass, and indeed prussiates in general, have the property of precipitating all metallic oxides from their solutions; yet, excepting yttria, it has no effect on any of the earths.

[c] To a cursory observer the earths appear to be infinitely diversified; so much so, that he would probably think the different kinds are innumerable. However, notwithstanding the varied appearance of the earth under our feet, of that of the furrows of the field, and of the mountainous parts of the world, whose diversified strata present to our view substances of every texture and of every shade, the whole is composed of only nine primitive earths; and as three of these occur but seldom, the *variety* which is produced by the other *six* becomes the more remarkable. This may fairly be adduced as one instance of the infinite skill of the Deity, as it "bespeaks an artist master of his work, acquainted with his materials."

To give a still greater variety to the works of Nature, these earths

Why are some of these earths called alkaline earths?

Barytes, strontites, and lime[a], are called alkaline because they agree with the alkalies in taste, causticity, solubility in water, and in their effect upon vegetable colours[b]. Magnesia agrees with the alkalies in the latter property only.

What is the nature of silica; and what are its chie properties?

Silica[c], or pure flint, is a white, inodorous and insipid earth; it is insoluble in water[d], and in every acid

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are endowed with an affinity for acids and metallic oxides, whence aris the spars, gems, and precious stones of every colour and ever species.

> "The unfruitful rock itself, impregn'd by thee,
> In dark retirement forms the lucid stone."

[a] Barytes, strontites, lime, and magnesia, are found in nature alway combined with acids. None of the combinations are very hard, as eithe of them may be scratched with a knife. The acids, which are foun united by nature with these alkaline earths, are generally the carbonic the sulphuric, the fluoric, the boracic, and the phosphoric.

[b] Barytes, strontites, and lime, differ from the alkalies, in thei infusibility by fire, in forming insoluble compounds with carbonic acids and in being insoluble in alcohol. As these are the common propertie of the earths, we have sufficient reason to reject the proposal of som of the French chemists, who are desirous of transferring these substance from the earths to the class of alkalies.

[c] *Pure* silica may be procured, by fusing common flint stones wit three or four times their weight of potash, dissolving the product i water, and then taking up the alkali by the addition of an acid, whic will precipitate the silica, which is to be well washed for use. Th siliceous stones should be previously heated red in a crucible, an plunged in that state into cold water. This will render them brittle, s that they may easily be reduced to powder before they are mixed wit the potash.

Sir H. Davy has not yet succeeded in exhibiting the base of this eart in a separate state, though from the result of his experiments there i great reason to believe that silica, like the other earths, is a metalli oxide. *Elem. Chem. Philos.* part i. page 362.

[d] We cannot by any means dissolve silica in water:—Nature, howeve by some wonderful and unknown process, contrives to dissolve it, eve copiously, so as to form stalactites and other incrustations. In Icelan there is a boiling fountain which spouts water 90 feet in the air, an deposits in falling so great a quantity of siliceous earth, that it form around its base a sort of solid cup, which surmounts and envelops i

except the fluoric; it endures the strongest heat without alteration[e]; but, when mixed with soda or potash, becomes fusible in a strong fire into glass. Its specific gravity is 2.65.

In what state is silica found native?

Silica is found in almost all solid mineral substances, particularly in gravel, sand, quartz, and flint, of which it forms nearly the whole substance[f]. It is also the chief ingredient of those rocks which constitute the most bulky material of the solid parts of our globe[g].

See note, page 39. This earth has also been found in solution in the Bath waters, and in some other spring water.

[e] According to Saussure, quartz or silica may be fused by heat equal to 4043° of Wedgwood; but this is a temperature so far above any heat that can be procured by common means, that I have not thought it necessary to alter the text. Mr. Hare also fused it by means of a stream of oxygen and hydrogen gases. Dr. MacCulloch has published a paper on the sublimation of silica in the *Trans. Geol. Soc.* vol. ii. page 275.

It is a curious fact, that if three parts of barytes be fused with one of his earth, the compound will be soluble in all the acids, even in common inegar.

Sand sets into a less bulk when wet, and does not afterwards contract y heat. This property may be taken advantage of in constructing everberatory furnaces, &c.

[f] Dr. Kirwan, in his *Geological Essays*, relates, that about the year 1760 he Emperor of Germany, being desirous to know the length of time ecessary to complete a petrifaction, obtained leave from the Sultan to ake up and examine one of the timbers that supported Trajan's bridge over the Danube, some miles below Belgrade. The outer part of this imber to the depth of half an inch was found to be converted to an *agate*; the inner parts were slightly petrified; and the central were still wood. The agate is a mineral composed of silica and alumina, but chiefly silica.

Agate is brought from Germany in blocks. It is cut by means of diamond powder into leaves, for making caps for the pivots of mariners' needles to run in, and other purposes. Might it not be used advantageously for the balances of watches, instead of iron, which is liable to be ltered by magnetic influence, by oxidizement, and other causes?

[g] "A granite mountain, about 30 miles from the Cape of Good Hope, called the PEARL DIAMOND, rises out of the ground to the height of 400 feet, being half a mile in circumference, and formed of a single block of granite."—Parkinson's *Organic Remains of a former World.*

Silica also constitutes two thirds of the asbestus, so valued by the ancients for wrapping up the bodies of the dead before they were committed to the funeral pile. They discovered methods of drawing the fibres of the mineral into thread, and afterwards weaving it into cloth. In con-

What are the chief uses of silica?

Silica is the most durable article in the state of grave for the formation of roads; it is a necessary ingredien in earthen-ware, porcelain, and cements; is the basi of glass[a], and of all vitreous substances[b]; and is ar indispensable article in many of our chemical furnace and utensils.

What is the use of silica in glass-making?

Silica is the chief ingredient in glass. It is rendere

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sequence of its incombustibility, it preserved the ashes of the body fro mixing with those of the wood, upon which it was laid to be burnt. Th practice was, however, probably confined to the families of the opulen So late as the year 1702 a funeral urn was discovered at Rome, in whic were a scull and other remains of a human body wrapped in a cloth amianthus or flexible asbestus. The whole was deposited in the Vatica library.

This mineral might be manufactured into paper: and, for documen of great importance, it might perhaps be worth while to be at the e pense of preparing this incombustible paper, and of writing upon it wit indelible ink. The methods of making it into paper or cloth, and preparing proper ink for writing upon it, may be seen in Dr. Rees's *C clopædia.* The mineral is found in Corsica; in the isle of Elba; in Swede and in Cornwall and the isle of Anglesea, in England.

The Chinese form furnaces with this mineral. They grind it, mix up with some kind of mucilage, and introduce it into moulds, the for and polish of which it assumes. These furnaces are very portable, an indestructible by fire. What kind of mucilage they employ is not know but it is said that the mucilage of gum tragacanth answers this purpos completely.

[a] The manufacture of glass was known very early; but glass perfect transparent was reckoned so valuable, that Nero is said to have given sum equal to 50,000*l.* for two glass cups with handles. When the e cavations were made in the ancient city of Pompeii, which was buried b an eruption of Vesuvius A.D. 79, the windows of some of the hous were found glazed with a thick kind of glass, not perfectly transparen In others isinglass was substituted, split into thin plates.—Miss Starke *Letters from Italy.*

The best book on glass-making, which I have seen, is an octavo volum by H. Blancourt, with plates, 1699. But a scientific work, published Paris by Loysel in 1800, entitled "*Essai sur l'Art de la Verrerie,*" is, I b lieve, the best modern work on this subject. It gives a detailed accou of the different processes in this manufacture, and treats of each chem cally. Dr. Merret's translation of Neri's *Art of making Glass,* 12m 1662, contains much curious matter, but this book is now very rarely be met with on sale.

fusible by a due mixture of alkali, which acts as a flux to the silica, and renders the whole transparent[c].

Are these the only articles necessary to form glass?

In Holland, and some other parts of Europe, glass is manufactured with alkali and sand only; but in England, flint-glass is made by a mixture of red lead[d] with those substances; which gives the glass great weight, and makes it more useful for all common purposes.

The manufacturing of *pastes*, or artificial gems, is a branch of the art of glass-making. The basis of these is a very hard and pure silica, obtained by melting pounded quartz with an alkali, with the addition of borax, nitre, and oxide of lead, different metallic oxides being added to imitate the colour of the different gems.—See *Journal de Physique*, tom. xxviii. page 502.

[b] I would recommend to the perusal of the young reader, Fourcroy's account of the various uses of silica, in vol. ii. of his *System of Chemistry*, page 190. It is beautifully written, and cannot fail to interest and instruct the pupil.

[c] Glass cannot be made without great heat, as the alkali retains the last portions of carbonic acid and water with singular obstinacy, and it is only at a very high temperature that the alkali fuses, and then it prefers the silica; for it is one of the laws of nature, (to which there are few exceptions,) that, in order that two bodies may become *chemically* united, one of them must be in a state of fluidity. All the information which I have been able to collect respecting this very curious manufacture will be found in my Essay on Glass, vol. iii. of the *Chemical Essays*, page 377—518.

[d] Metallic oxides have the property of making glass more fusible. The oxide of lead is serviceable in this way when mixed with glass. Plate and crown glass contain no lead, but the former has generally some lime combined with it.

The common bottle-glass is made with a large portion of the ashes of vegetables, or soap-boilers' waste ashes, instead of pure alkali. The portion of iron, which is generally found in vegetable substances, gives it the green colour.

For the best flint glass, rather more alkali is used than is necessary to flux the sand; and when the whole is in fusion, the fire is continued so as to volatilize the superabundant quantity. If an excess of alkali be left in the glass, it will attract water from the atmosphere, and in a short time assume a fluid state.

Professor Seigling, having left a bottle of *liquor silicum* undisturbed eight years, found transparent *rock crystal* formed in it, hard enough to give fire with steel. See an account of a similar result in Nicholson's *Journal*, vol. i. page 217.

What are the chief properties of alumina?

ALUMINA, or pure clay, is soft to the touch; adhesive to the tongue; emits a peculiar odour when moistened; forms a paste with water; has great affinity for colouring matter; will unite with most acids[a]; and acquires great hardness, and contracts in the fire[b]. Like silica, it is soluble in caustic potash, or soda. Its specific gravity is 2.

In what state is alumina found native?

Alumina is distributed over the face of the earth in the form of clay, and from this circumstance acquired the name of *argil;* it is found also in a state of crystallization in the sapphire, and other precious stones[c], and is united to the oxides of iron in the ochres. It obtained the name of *alumina* from its being the base of the salt called alum.

What are the chief uses to which alumina has been applied?

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[a] Alumina is soluble in every acid, and in solutions of the caustic fixed alkalies. Sir Humphry Davy has made many attempts to decompose this earth: and though there are reasons to believe that he has succeeded in part, the experiments were not so decisive as they were with the other earths. *Elem. Chem. Philosophy*, page 355.

[b] Alumina is completely fusible *per se* into a very hard vitreous kind of substance, hard enough to scratch glass; but sufficient heat cannot be procured to effect its fusion without oxygen gas. Saussure found that it required 18.900° of Wedgwood to fuse it; but when mixed with certain proportions of silica and lime, it fuses readily.

Pure alumina may be procured by decomposing common alum with carbonate of ammonia. It has not been found native in a state of purity any where, except at Halle in Germany.

Common clay is a mixture of alumina and silica. It frequently contains metallic oxides, chalk, and other earths. Alumina united to the oxides of iron is plentifully procured in Staffordshire and Derbyshire; in which state it is called raddle, an article very useful in colour-making. Fuller's earth is alumina combined with very fine silica. It is owing to the affinity which alumina has for greasy substances, that this article is so useful in scouring cloth. Hence pipe-clay is frequently used for the same purpose.

[c] According to the best analyses, the beryl contains 15 per cent. of

Alumina, on account of its aptitude for moulding[d] nto different forms[e], and its property of hardening in he fire, is employed in various ways, such as for ma- ing bricks, earthen-ware, porcelain[f], crucibles, &c.; ut the alumina which is made use of for these pur- oses is always impure, as it is employed in the state f clay, and often as it is taken from the bowels of he earth, without any previous preparation what- oever.

Is alumina employed in forming any direct chemi- al combinations?

Aluminous earth is employed for various purposes y the dyer and the calico-printer, especially in its ombination with acetic acid as a mordant for fixing nadder reds and some other colours on calico; and pon the continent it is artificially combined with ulphuric acid, in order to form alum[g]; but we pos-

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umina, the emerald 16, the garnet 22, the tourmaline 40, the topaz 50, e automalite 60, the ceylanite 68, the spinel 82, and the sapphire, though it is the hardest substance in nature, except diamond, contains 2 per cent. of this earth. Chalcedony is found to be a compound of 84 rts silica and 16 of alumina, with a slight admixture of iron. On e vegetable remains which are frequently found preserved in chalce- ny consult Dr. MacCulloch in *Trans. Geol. Soc.* vol. ii. page 510; and l. iv. page 398.

[d] Earthen-ware, according to the Old Testament, was known at an rly period to the Jews; and the potter's wheel, there spoken of, was obably the same simple machine as is used at the present day to form und vessels with plain surfaces. The making of porcelain has long en known in China and Japan; but it was accidentally discovered in rope by a chemist, in the beginning of the 18th century. It was so teemed by the Romans, that, after the taking of Alexandria, a porcelain ssel was the only part of the spoil retained by Augustus.—Dr. Thom- n, vol. ii. page 286.

[e] Alumina is of inestimable value for securing the bottoms and sides canals and reservoirs of water, and composes in a great measure those nacious earths called *arable* soils.

[f] The beautiful colours which are seen upon porcelain and earthen re are given by metallic oxides. Purple is given by gold; red by the ide of iron; yellow by the oxide of silver; green by copper; blue by balt; and violet by manganese.

[g] Alum is generally made artificially in France. Chaptal, a chemist

sess the compound, or alum-slate, ready formed, in abundance[a].

Why do potters employ a mixture of alumina and silica for earthen-ware?

In making earthen-ware a due proportion of both these earths is necessary; for if alumina[b] alone were used, the ware could not be sufficiently burnt without shrinking too much, and even cracking; and a great excess of silica would lessen the tenacity, and render the ware brittle.

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of some eminence, formed a considerable establishment for the manufacture of this very useful article, and erected immense buildings for preparing sulphuric acid by the combustion of sulphur, totally different from those usually appropriated to such purposes in England. See *Annales de Chimie*, tome ii. page 86.

[a] In England it is not necessary to form alum by art, as the native alum-slate is easily obtained. It is procured on the sea-coast of the north-east part of Yorkshire, from Whitby to Stockton, a distance of about 50 miles. The slate, when taken from the bed, is broken to pieces by the aid of fire, and afterwards further acidified, by being frequently moistened, and by exposure to the air. When the efflorescence has taken place, it is put into lixiviating vessels for the extraction of the salt. The saline liquor is then boiled down to the proper strength for crystallization; previous to which is added a portion either of sulphate or muriate of potash. Indeed alum cannot be made without ammonia or potash, as it is a triple salt. All alum is either a sulphate of alumina and potash, or a sulphate of alumina and ammonia. Urine is generally used in Scotland, and sulphate of potash or muriate of potash in Yorkshire.

I have been informed, by one of the most considerable manufacturers of alum, that the account of the English alum-works published by Danie Colwall, Esq. so early as the year 1678, corresponds exactly with the present practice. This paper may be seen in the 12th volume of the *Philosophical Transactions*, page 1052.

The first English alum-work was established at Gisborough in York shire, in the reign of Queen Elizabeth, by Sir Thomas Chaloner, wh engaged workmen from the Pope's alum-works to superintend it; an kept those workmen till his manufacture was brought to perfection notwithstanding the bulls and anathemas which His Holiness issued i abundance against him.

One of the most ancient manufactories of alum was at Roche, a cit of Syria; whence the name of Roche-alum. See Additional Notes No. 24.

[b] For making pottery, or earthen-ware, the clay is beaten in water by which the fine parts are suspended in the fluid, while the coarse sink to the bottom of the vessel. The thick liquid is further purifie

What is the nature of that very hard species of pottery called stone-ware?

STONE-WARE, like other pottery, is chiefly composed of alumina and silica, but a certain quantity of old pottery finely ground is generally introduced into its composition. The difference however between this and common earthen-ware, chiefly consists in the burning and glazing; stone-ware being always submitted to a much higher degree of heat, and in its being glazed with muriate of soda instead of the oxide of

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by passing it through hair and lawn sieves of different degrees of fineness; and is afterwards mixed with another liquor of about the same density, consisting of ground flints. This was the composition of the *white stone ware*, about 40 years ago the staple manufacture of the potteries of this kingdom; and it is also that of the finer earthen-wares at present in use, though in different proportions, and with various improvements, introduced by the ingenuity of succeeding manufacturers. This mixture is then dried in a kiln, and, after being beaten to a proper consistence, becomes fit for being formed by the workmen into dishes, plates, bowls, &c. The fine white and cream-colour earthen-wares now made in England are fired twice; the first time to give them the requisite hardness; and in that state they are called *biscuit:* they are then dipped in a vitrifiable composition, and, being subjected to a second burning, acquire a coating of true glass, thence called a glaze. If they are finished with painting in enamel, it is necessary to pass them a third time through the fire. One of the ingredients of this glass (see Note[d] page 97) being oxide of lead, the workman, whose hands are constantly immersing in the mixture, is subject to *paralysis*, unless due precaution be taken. To prevent it, the more respectable manufacturers have of late years assigned to such men a *varied* employment about their ovens, and furnish them with a dress to wear at the glazing tub, and throw off when they leave it, and a water cistern, soap, and towels near them, that they may be more certain, when employed in the glazing, to wash their hands before they go to their meals. It is feared, however, that an unhappy opinion of the efficacy of spirituous liquors does more mischief to this class of workmen than any other circumstance; for, attributing to the effect of lead whatever slight disorder occurs, they have recourse, in the first instance, to them as specifics, in such cases, and thus acquire the habit of an immoderate use of what probably affords them a temporary relief, but does not fail to produce a permanent and destructive disease. This is, I believe, the sole opprobrium which falls upon the potter's art; yet even this may be greatly diminished, if not entirely removed, by the precautions above mentioned: however, as it is desirable to preclude the use of lead altogether, the Society for the Promotion of the Arts has offered a premium for a substitute for this lead[a]. On account of the superior strength of stone-ware, its very compact texture, and the wholesome nature of its glaze, it is greatly to be wished that its use were considerably extended, and that every article for culinary purposes were to be manufactured with it[b].

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glaze, or for a mode of using it which would not subject the men to these dangers. An account of several new glazes, as substitutes for *lead*, will be found, in my *Chemical Essays*, vol. iii. page 193—376.

[a] The *white* and the *brown stone wares* are passed only once through the fire; for at a certain period of the heat, they are made to undergo a partial vitrification at the surface, by the fumes of muriate of soda; this salt being thrown into the oven, and the pieces of ware so disposed as to receive the fumes of it on every part of their surfaces. This method of glazing earthen-ware with salt was introduced into England by two brothers from Holland, of the name of ELERS, about the year 1700. They settled in the neighbourhood of the Staffordshire potteries; and it is remarkable, that the alarm occasioned by the fumes which spread over the country obliged them to leave it. The son of one of these artists was afterwards an active magistrate of the county of Oxford; and *his* son is at present a very respectable English barrister. A similar manufactory was, however, soon after established, at Shelton in the Potteries, by one of their workmen, named *Astbury*, who had possessed himself of their secret; and as it became of great utility, it was readily tolerated by the inhabitants; and at length, on the common day of glazing, (Saturday,) the thick offensive fumes from fifty or sixty manufactories filled the valleys and covered the hills of a district of country extending many miles.

There is no doubt that potteries had been established in this part of Staffordshire, which abounds with *coal*, for many centuries: at some depth indeed below the surface strong indications have been found of the site of *Roman* potteries; but down to the epoch I have been speaking of, the productions and the condition of the potters were in much the same rude state as when *Plot* made his survey of the county.

The Messrs. Elers had also the merit of introducing into this country a red unglazed porcelain, which they made from a clay found in the estate they had settled upon in Staffordshire, called *Bradwall*; but it was only the *brown* stone ware, (of the same kind as that now made by the Lambeth potters,) in the composition of which no flint is used, which they glazed in the manner above described. The *white* stone ware, and the use of ground flints in pottery, were discoveries of later years, and owe their origin to the following curious incident:—About the year 1720, a potter (believed to be the *Astbury* above mentioned) travelling to London on horseback, had occasion, at *Dunstable*, to seek a remedy for a disorder in his horse's eyes; and the ostler of the inn by burning a flint stone reduced it to a fine powder, which he blew into them. The potter, observing the beautiful white colour of the flint after calcination, *What constitutes the difference between earthen-ware and porcelain?*

Porcelain is not esteemed good, unless it be very compact, quite white, and semi-transparent[c]; indeed, it is chiefly the last quality that constitutes the principal difference, for *earthen-ware* is always opaque.

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instantly conceived the uses to which it might be applied in his art; and then introducing into use the white pipe-clays found in the south side of Devonshire, instead of the irony clays of his own country, he readily produced the *white* stone ware. At first the burned flints were reduced to *powder*, to the great annoyance and injury of the health of the persons employed: but the immortal *Brindley*, in the early part of his life, rendered a most important service to this class of manufacturers, by contriving the mills that are at present in use for grinding them in a *moist* state.

About the year 1750 commenced the inventions and improvements of the late Mr. Wedgwood, who, by combining science with the art, and having the advantage of a highly cultivated taste, not only greatly extended the uses of English pottery, and turned the tables upon the *French* and *Dutch*, who had hitherto exclusively supplied Europe with fine earthen-wares, but rendered it an object of admiration, and deserving a rank among the fine-arts of the age. This inestimable man has left us an admirable example of what may be effected by cultivated talents and persevering industry. Such investigations as those to which he was accustomed, bring with them their own reward. Such experimentalists

> "Exult in joys to grosser minds unknown,
> A wealth exhaustless, and a world their own."

[b] It appears to me that this is a desideratum of considerable importance; that in endeavouring to attain this object, a new field is open for the display of taste and elegance; and that the potter who should succeed in this attempt would obtain considerable emolument and acquire also a lasting reputation.

[c] Porcelain is an artificial compound of great durability. When good, it is of so compact a texture that it would probably endure for ages. There is an octagon tower at Nan-king in China, called the Porcelain Tower, which is entirely covered with the most beautiful china. It is a building of nine stories, nearly 300 feet high, and each story decreases in breadth as it rises in height. This singular and elegant edifice still retains its original beauty, though it has sustained the continued action of the sun and weather for more than four hundred years.

An interesting account of the processes which are carried on in the great French manufactory of porcelain at Sevres has been published by Brongniart, who superintends it. See *Philosophical Magazine*, vols. xiii. and xiv.

The Chinese are said to let their clay remain exposed to the atmosphere at least twenty years before they use it in making porcelain.

What is zirconia[a] *?*

ZIRCONIA is a peculiar earth, which has been found only in a mineral called zircon and in the hyacinth of the island of Ceylon[b].

What are the properties of zirconia ?

Zirconia, when separated from the precious stones in which it is found, has the form of a fine white powder, destitute of taste and smell. It is insoluble in water, though soluble in the acids and the alkaline carbonates[c], but not in pure alkalies. Its present scarcity prevents our employing it to any useful purpose.

Whence do we procure glucina ?

GLUCINA has been found only in a beautiful mineral called euclase, and in the emerald and beryl, precious stones procured from Peru and from the mountains of Siberia[d].

Some tile-makers in England, who are curious in the articles they manufacture, never use their clay till it has lain a year or two in the open air.

[a] There are reasons for believing that zirconia, like the other earths, is a metallic oxide. Sir Humphry Davy submitted it to the action of galvanism, and obtained results which indicated decomposition ; but the appearances were not decisive.

[b] Zirconia was discovered by Klaproth in the year 1793. The stone from which he procured it came from Ceylon : but the same stone has since been found in various parts of Europe, and also in the three other quarters of the world.

A fossil from Greenland, called *compact* hyacinth, has been lately analysed, and found to contain 10 per cent. of zirconia.

[c] If zirconia be heated to whiteness, it is not afterwards soluble in the acids. If kneaded with water, and gradually dried, it will take the semi-transparent appearance of horn.

[d] The ancient Romans, who highly esteemed the emerald, are said to have procured theirs from Æthiopia and Upper Egypt. The beryl is now found in various parts of the earth. Its inferiority in colour to that of the emerald is thought to be owing to its want of the oxide of chrome which always occurs in that beautiful precious stone. The emerald contains 13, the euclase and beryl 14 per cent. of glucina.

[e] *Glucina* is derived from the Greek word *glycys* (*sweet*) ; which is very appropriate to this earth, as it gives a saccharine taste to all the acids with which it combines. In operating on this earth by means of galvanism, Sir Humphry Davy met with the same success as in the

What are the properties of glucina?

Glucina[e], when separated from the stones which ontain it, is a soft, light, white powder, without taste nd smell; adhesive to the tongue like alumina[f]; nfusible by heat; but soluble in the acids, with which t forms soluble sweet-tasted salts[g], slightly astringent. This earth is not very plentiful, nor has it yet been mployed in the arts[h].

From what source is yttria obtained?

Yttria is a peculiar earth[i] found in a black mineral called gadolinite, and also in the mineral called ttrotantalite, both of which are found at Ytterby, ear Roslagen in Sweden[k].

How is yttria to be distinguished?

Yttria, when separated from the mineral, is in the orm of a fine, insipid, white powder[l]. It forms sweet

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rocess with zirconia; but further experiments will be necessary in rder to ascertain the nature of its base.

[f] Glucina is insoluble in water, and soluble in pure liquid alkalies, in hich it further resembles alumina; it also agrees with that earth in eing insoluble in pure ammonia, though soluble in carbonate of mmonia, which alumina is not.

[g] From the sweet taste of the salts of glucina, we have reason to elieve that Nature, who forms nothing without its use, has endowed his earth with properties which will some time or other render it eminently serviceable to the animal economy.

[h] Vauquelin is of opinion that hereafter this earth will be useful as a nordant in dyeing, and that it may be serviceable in medicine when it omes to be discovered in greater plenty. Lelievre announced some ime ago, that he had discovered the emerald in stones used for repairng the roads near Limoges in Guienne. From this source a large uantity of glucina might be procured.

[i] This earth was discovered by Gadolin, a Swedish chemist, in a mineral found at Ytterby in that kingdom. From this circumstance the ossil has been called Gadolinite, and the earth Yttria.

[k] There is some reason for supposing that yttria may be a metallic oxide. A foreign chemist has lately announced, that when muriate of ttria is heated to redness it gives out oxygenized muriatic acid. I ave not heard that any one has hitherto succeeded in decomposing this arth, so as to exhibit its base in a separate state.

[l] The specific gravity of yttria is 4.842, which is greater than that of ny other earth.

and coloured salts with the acids, is insoluble in water or in the caustic alkalies, but easily dissolved in a solution of carbonate of ammonia[a].

What is the origin of barytes?

BARYTES[b], in combination with sulphuric acid, was discovered by Scheele in a mineral called ponderous spar, afterwards terra ponderosa. It is chiefly found in this state in England, and in other parts of the globe.

Does this earth occur in any other states?

It has also been found, combined with carbonic acid[c], in several parts of the British empire, particularly in Northumberland, Cumberland, and Lancashire;

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[a] Though yttria is insoluble in the alkalies, and infusible when alone, it may be fused when mixed with borax, (sub-borate of soda,) in which state of combination it forms a white glass.

[b] Barytes was discovered by Scheele in 1774. It is always found united either with the sulphuric or the carbonic acid. The best method of procuring this earth pure for chemical purposes, is, to dissolve the carbonate of barytes in very weak nitrous acid, by which means the carbonic acid will be expelled, and then in the usual way, by proper evaporation, crystals of nitrate of barytes will be formed. By exposing this salt to a strong heat, the nitric acid will be dissipated, and pure barytes will be left in the crucible. See Fourcroy and Vauquelin's memoir in the *Annales de Chimie*, tome xxi. page 276. Sulphuric acid is the best test for the presence of this earth.

Bergman gave it the name of *barytes* from the Greek word *barys* (*heavy*), this being the most ponderous of all substances except the metals, and the earth called yttria.

Sulphate of barytes is very plentiful in the Derbyshire lead-mines: the workmen call it *cauk*.

A method of crystallizing this earthy salt artificially was pointed out by Withering, in the *Philosophical Transactions* for 1784.

Casciarole, an Italian shoe-maker, discovered that if sulphate of barytes be calcined in a peculiar way, it will acquire a phosphorescent quality, and will shine even in water. It is known by the name of Bologna phosphorus. For the method of making it, consult Bouillon La Grange's *Manual of Chemistry*, vol. i. page 188; or Nicholson's *Chemical Dictionary*. See also *A Series of Experiments on the Subject of Phosphori*, by R. Wilson, F.R.S. quarto, London, 1776.

Several of the natural gems and fossils exhibit phosphorescent properties by attrition. In the tremolite this property is so abundant, that the slight friction of a feather is of itself sufficient to excite it.—Murray's *System of Chemistry*. For an account of the Tremolite of Cornwall, nd in France, in combination with the oxide of manganese.

What are the properties[d] of barytes?

Barytes when pure is of a grayish white colour; like he alkalies[e] it changes the vegetable blues to a green; as a pungent caustic taste; has the property of nabling oil to unite with water; and is in all its com-inations a violent poison. It is a non-conductor of lectricity; and may be known from the other earths y its solubility in water[f], by its forming an insoluble ompound with sulphuric acid[g], and by its imparting to ame a yellow colour. Its specific gravity is 4.00[h].

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onsult a paper by the Rev. W. Gregor in the *Trans. Geol. Soc.* vol. iii. age 399.

[c] Carbonate of barytes was first discovered by Dr. Withering of Bir-ningham, in the lead-mines of Alston Moor, Cumberland; and for a ng time afterwards it was found only there and at Anglesark, three iles to the east of Chorley in Lancashire. See Dr. Withering's paper n the *Philosophical Transactions* for 1784: also an original communication especting the mines at Anglesark in my Treatise on 'Barytes,' in the *hemical Essays*, vol. ii. pages 202—221. Some remarks by Mr. Arthur ikin on the Witherite of Shropshire will be found in the *Trans. Geol. oc.* vol. iv. page 438

[d] Pure barytes changes quickly when exposed to the air; it swells ke quick-lime, and like it falls into a white powder, but this slacking is uch more violent and speedy than that of lime. It combines intimately ith water, and the water becomes solidified in the barytic earth.

[e] Barytes is also similar to the alkalies in changing *red* vegetable co-ours to a violet or blue, and *yellow* vegetable colours to a brown; in endering oil miscible with water; in forming glass with silica; in its olubility in water; and in the readiness with which it shoots into rystals.

[f] Barytes is soluble in about 20 parts of water at the temperature of 0°; but boiling water will dissolve half its weight of this earth, part of hich will crystallize on cooling.

[g] The most singular property of this earth is the tenacity with which holds the sulphuric acid when combined with it. It has such an ffinity to it, that it will not part with it even to pure alkalies. Hence ure barytes will decompose sulphate of potash or sulphate of soda.

[h] Sir Humphry Davy in 1808 decomposed this earth, and separated om it a peculiar metallic substance which he has named *Barium*. It s of the colour of silver, and sinks if dropt into sulphuric acid. If ex-osed to the air, it is instantly tarnished, and the whole is soon re-con-

What are the uses[a] of barytes?

Barytes forms some of the most useful chemica tests[b], whether in its pure state, dissolved in water, o combined with particular acids[c]: in muriatic acid i is also employed as a medicine. It is capable of makin a very tenacious cement, but has not yet been use much in the arts, except by limners as a most excel lent water colour[d].

What is the origin of strontites?

STRONTITES was discovered by Dr. Hope about th year 1787 in a mineral brought from the lead-min of Strontian in Argyleshire. That mineral, which is *carbonate* of strontites, has been found but in smal quantities in any other place[e].

Does this earth occur in any different state o combination?

Strontites is more abundantly produced by Nature

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verted to barytes in a pulverulent form. *Elem. Chem. Philos.* part page 339.

[a] Barytes has been proposed as a medium for decomposing muriat of soda in a cheap way. The method of using it may be seen in th *Annales de Chimie*, tome xix. See also a memoir of Vauquelin's on th subject in *Journal de Phys.* 1794, page 297.

[b] The solution of this earth in water, and in various acids, furnish excellent tests for chemical analysis. The muriatic acid is often pr ferred, especially for medical purposes, such as scrophulous and som other chronic diseases. Though this earth has been accounted highl poisonous, yet Dr. Johnstone says that he has seen a delicate female tak thirty drops of a saturated solution of muriate of barytes *repeatedly* in th course of a day, without even nausea. He therefore concludes that would require at least 2 or 3 drachms to do mischief.—*Essay on Poison* page 143.

[c] Muriate of barytes is often used for the purpose of examining th purity of vinegar, and sometimes has occasioned erroneous conclusions because acetic and some other vegetable acids will precipitate baryte There is however this difference: If the precipitation be occasioned b sulphuric acid, it will be permanent; if not, a larger portion of the v getable acid will re-dissolve it.

[d] Many years ago Mr. Hume discovered the method of making a co lour from this earth. It is the only *white* for water painting, that neve

when in union with sulphuric acid; particularly near Bristol; where it is in such quantity as to be employed in the repairs of the neighbouring roads[f].

What are the properties of strontites?

Strontites, when separated from its acid, is considered to be a pure earth, and, like barytes, is then soluble in water; it is of a grayish white colour[g]; its taste is acrid and alkaline, but less so than barytes or the alkalies. It is not poisonous; and its solution in water is capable of crystallization[h]. It gives a purple colour to flame[i], which, together with the form of its salts[k], are the chief characteristics that distinguish it from barytes.

What are the uses of strontites?

Though strontites combines readily with all the acids, and possesses alkaline properties, it has not hitherto been employed for any useful purpose[l]. Hereafter it

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changes. It has another peculiar advantage, it may be mixed with any other colour without injury. It is sold under the name of "Hume's Permanent White."

[e] See Pelletier's memoir on this earth in the *Annales de Chimie*, tome xxi. page 113; and in Nicholson's *Journal*, 4to, vol. i. page 518. For a history of the discovery of strontites see Add. Notes, No. 66.

[f] Nicholson's *Journal*, vol. iii. page 36. Sulphate of strontites is also found in great plenty on the roads near Paris, and in the State of Pennsylvania in America.

[g] In order to procure this earth in a state of purity, carbonate of strontites may be treated in the same way as carbonate of barytes is treated to procure pure barytes.

[h] Strontites is not soluble in less than 200 parts of cold water; hot water dissolves it much easier; it then crystallizes on cooling, and is similar to barytes in many of its habitudes.

[i] If moisture be present in the mixture of strontites with inflammable bodies, the flame will be of the colour of carmine. Thus, if this earth, or the salts formed with it, be dissolved in alcohol, the spirit will burn with a flame of this colour. This distinguishes it from barytes.

[k] Muriate of barytes crystallizes in rhomboidal plates, whereas muriate of strontites gives slender hexagonal prisms.

[l] It will be adviseable for the preceptor to procure specimens of this and other minerals, that the pupils may learn how to distinguish them.

may be found to possess valuable properties[a], for it exists in abundance, and the Author of nature has formed nothing in vain.

How is lime to be distinguished from the other earths[b]*?*

Lime is of a white colour, and of a hot caustic taste; it forms peculiar salts with acids[c], which is perhaps the most decisive proof that can ever be obtained to identify this or any other earth: it changes vegetable blues to a green; it is incapable of fusion; it solidifies

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Mr. Mawe in the Strand, Messrs. Knights in Foster-lane, or Mr. Heuland No. 25 King-street St. James's, London, will furnish any specimens that may be desired.

[a] Sir Humphry Davy has succeeded in decomposing this earth and extracting its metallic base, whose properties, as far as can be ascertained, are very similar to the base of barytes. He has named this metallic substance *Strontium.—Elem. Chem. Philos.* page 343.

[b] The specific gravity of pure lime is 2.3. It is soluble in about 400 parts of water. Sir Humphry Davy in the year 1808 decomposed this earth, and separated its metallic base, to which he has given the name of *Calcium*. It has the colour and lustre of silver, and if heated in atmospheric air it takes fire, burns with an intense white light, and quicklime is regenerated. Lime, therefore, is an oxide of calcium, consisting of 20 parts of the metal and about 7.5 of oxygen; and the hydrate o lime consists of 55 lime and 17 water.

[c] Lime forms with sulphuric acid a compound soluble in water to a certain degree; so that this earth is easily distinguished from barytes and strontites, whose sulphates are insoluble.

[d] Quick-lime has such an affinity to water that it will absorb one-fourth of its weight of that fluid, and yet remain perfectly dry. The water becomes solidified and identified with the earth. The heat therefore that is evolved in the process of slacking lime, proceeds from the water as it passes to the solid state, and not from the earth as is sometimes supposed.

[e] The effect of carbonic acid upon lime may be shown by the following experiment: Add gradually a very small quantity of water impregnated with carbonic acid, to a jar about one-fourth filled with lime-water. A milkiness will ensue, because the carbonic acid forms with the lime an insoluble compound. On adding more of the carbonated water, and shaking the jar as these additions are made, the milkiness at last disappears, and the whole precipitate becomes re-dissolved. Hence it appears that lime with a *small* quantity of carbonic acid is insoluble, and soluble with a *larger* quantity.

It is thus that Nature dissolves and deposits calcareous masses. When the waters, by their exposure to the air, lose that quantity of carbonic

vater[d], when sprinkled with that fluid, occasioning it
o give out a great quantity of caloric; it absorbs
noisture and carbonic acid[e] when exposed to atmo-
pheric air; but is itself very sparingly soluble in
vater, and possesses the peculiar property of dissolv-
ng more copiously in cold than in hot water.

In what state is lime found in nature?

Lime is never found pure; it is always in a state of
ombination, generally with an acid, and more fre-
uently with the carbonic acid, as in chalk, marble,
mestone, &c.[f] It is found also in vegetables, and

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cid which favoured the solution of the lime, deposits are formed; and
ence the stalactites and incrustations found in caverns, and even the
liaceous calcareous strata of rocks; which, without doubt, have in some
eriod been held in solution. When these waters *suddenly* lose the acid
hich was essential to the solution, there is an *irregular* precipitation:
ence those tender calcareous cellular stones, and perhaps also the
oongy tufts; but if the evaporation of the carbonic acid takes place
owly, it produces crystallizations, such as stalactites, &c. When lime
crystallized by nature in combination with acids, it is called *spar*.
ith fluoric acid it forms the beautiful Derbyshire spar, called *blue*
ohn; with carbonic acid, the dog-tooth spar, the Iceland crystal, &c.

[f] The vast mountains of calcareous earth which occur in different parts
the world, owe their origin, in general, it is supposed, to the destruc-
on of marine testaceous animals, which in long process of time formed
ese extensive and accumulated heaps:

> "For in vast shoals beneath the brineless tide,
> On earth's firm crust, testaceous tribes reside:
> Age after age expands the peopled plain,
> The tenants perish, but their cells remain;
> Whence coral walls and sparry hills ascend
> From pole to pole, and round the line extend." DARWIN.

ourcroy, in his *Chemical Elements*, has given a beautiful account of this
rocess of Nature, to which I refer; as I am persuaded every reader of
ste must be charmed with its perusal. See Dr. John Thomson's edi-
on, part iii. chap. 7. sect. 1.

According to Captain Cook, there are in the Southern Ocean perpen-
cular coralline rocks, formed entirely of sea-shells, which are of such
agnitude as to render the navigation of those seas extremely dangerous.
The shells of some testaceous animals in the South Sea are of a vast
ze. The *kemo* shell on the coast of Sumatra is frequently found three
four feet in diameter, and as white as ivory. See Marsden's *History*
the Island of Sumatra, page 10.

It may be remarked, that while *testaceous* shells are formed with car-is the basis of animal bones. It occurs likewise in the waters of all springs and rivers[a].

How is pure lime procured from these minerals?

Carbonate of lime, by whatever name it is called whether chalk, marble, limestone, oyster-shell, &c is broken into convenient pieces, and piled in alternate layers with coal, furze, or other fuel, in prope kilns, where it is kept for a considerable time in a *white* heat. By this means the carbonic acid and water are driven off, and tolerably pure lime is the product[b].

What are the chief uses of lime?

Lime united with the acids is applied to variou

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bonate of lime, the shells of *crustaceous* animals and the shells of birds eggs contain also a portion of phosphate of lime. Its use in the forme is not known; but the design of Nature in furnishing the shells of egg with phosphoric acid is very apparent. The body of the egg contain neither phosphoric acid nor lime: it was necessary therefore that Natur should provide means of furnishing both these substances, which it doe at the expense of the shell; which becomes thinner and thinner durin the whole time of incubation, till the living embryon hath appropriate a sufficient quantity for the formation of its bones. Part of the albumen combines with the shell for this purpose, and another portion form feathers.

One thousand parts of egg-shells are composed of

Carbonate of lime .	896
Phosphate of lime .	57
Gluten and moisture .	47
	1000

If fowls are kept in a state of confinement where they cannot get a any calcareous earth, they lay their eggs without shells.

[a] This earth is dissolved in such quantities in the waters of Tuscany that the artists there are said to form *basso-relievos* of very considerabl hardness, merely by frequently filling their moulds with the waters.

[b] *Pure* lime should always be kept in well stopped bottles, if for nic experiments; for, without this precaution, it would soon absorb carboni acid, and become carbonate of lime. If lime-water be exposed to th air, it will soon be covered with a pellicle of carbonate of lime, from th same cause. In like manner, if a little lime-water be put into a glas siphon, and the legs of the siphon be held upwards so that a perso might blow through it without the liquor running out, the breath wil

useful purposes, and, next to silica, forms a material portion of the solid fabric of the terrestrial globe. In its pure state it is used in many of the arts[c], particularly in making mortar for buildings. It is employed by the farmers as a manure; also by bleachers[d], tanners, sugar-bakers, soap-boilers, iron-masters[e], and others, in their several manufactories, and in medicine.

How do you explain the operation of lime in forming mortar?

Pure lime has, when united to a certain portion of water, a very strong affinity for silica, another most essential ingredient in all mortar and cements; for without this it never hardens,—but when mixed in proper

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e found to give a milky colour to the lime-water, and carbonate of lime ill be seen forming at the bottom of the liquor, which will effervesce ith acids, and have every chemical quality that it had when in the arry. This change is owing to the absorption of carbonic acid from e lungs.

Bishop Watson found by experiment, that upon an average every ton limestone produced 11 cwt. 1 qr. 4 lbs. of quick-lime, weighed before was cold; and that when exposed to the air it increased in weight ily at the rate of a hundred weight per ton for the first five or six days er it was drawn from the kiln. This fact is worth the notice of those rmers who fetch their lime from great distances.

In the *Journal de Physique* for 1775, page 311, are a plan and description of a kiln for calcining limestone *after* it has been reduced to powder, order that it might be used quite hot without the necessity of its being cked by water. For some purposes this is found to be very advantageous.

[c] Lime is used in the manufacture of glue. The design of it is to event its becoming flexible by the absorption of moisture, and to add its strength. Some persons use alum for the same purposes.

[d] Quick-lime was used by the ancients for bleaching. Theophrastus, disciple of Aristotle, and who wrote more than 300 years before rist, states that it was used for this purpose. He relates an instance a ship, which was loaded in part with linen and in part with quick-e, having been set on fire by water that was accidentally thrown over latter, which fired the linen, and occasioned the destruction of the sel.

[e] The iron ores that are wrought in this country contain a large porn of alumina and silica: in order therefore to flux these earths, and re effectually separate the iron, a quantity of lime is usually mixed h the ore in the furnace; lime having the property of rendering the er earths more fusible.

proportions, the gradual absorption of carbonic acid from the atmosphere occasions it in a series of years to become as hard as unburnt limestone[a].

How does lime act so as to be of use as a manure for land?

The use of lime in agriculture may be attributed to the property which it possesses of hastening the dissolution and putrefaction of all animal and vegetable matters[b], and of imparting to the soil a power of retaining a quantity of moisture necessary for the nourishment and vigorous growth of the plants, corn,

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[a] When lime is made into mortar, it takes a long time in acquiring the portion of carbonic acid which it possessed in the quarry; but the mortar hardens as this absorption takes place. This accounts for the great strength of some ancient buildings, in which the mortar is found to have a greater degree of firmness than even limestone itself. See Dr. Higgins's *Experiments on calcareous Cements.*

The nature of the sand which is mixed with lime to form mortar or cement, is of the utmost consequence; the harder and sharper the sand the better, for if this matter be of a friable nature like chalk, the mortar must be weak. See Additional Notes, No. 20.

[b] When quick-lime is spread upon arable land, it destroys by its causticity the organization of all animal and vegetable matters remaining in the soil, and thus renders them a fit pabulum for the future crop. In like manner the lime would also burn up the tender shoots of the fresh plants and sterilize instead of fructify the ground; but Nature has so ordered it, that as the lime falls to powder upon the land it should graduall absorb carbonic acid from the atmosphere, which deprives it of its causticity and converts it into chalk. For a further explanation of this chemical process, and for an illustration of the use of *chalk* upon land, se Anderson's *Essays on Agriculture*, Dundonald's *Treatise on Agriculture* or Sir Humphry Davy's *Lectures on Agriculture.* An ingenious theor to explain the operation of gypsum upon land, will be found in M Maclure's *Observations on the Geology of the United States of America* page 78.

[c] Hence lime and chalk are found to be particularly useful on sand soils. Marle is a mixture of carbonate of lime and clay. See Additiona Notes, No. 20. Marles are useful in agriculture only in proportion t the calcareous earth they contain. Unless they contain more than 3 per cent. of lime, they are of no value to the farmer. Of all the modes o trial, the one best suited to the unlearned farmer is, to observe how muc *fixed air* the marle gives out; and this he will learn by dissolving a littl of it in diluted muriatic acid, and observing what portion of its weight i loses by the escape of this air. Thus, if an ounce loses only from 40 t

&c.[c]: for there is no good soil that does not contain a certain portion of lime, though always, without exception, combined with carbonic acid.

What is the use of lime in the operation of tanning leather?

Lime is used by the tanner in a state of solution; in this the hides are immersed in order to dissolve the gelatinous part of the skin, and to facilitate the removal of the hair[d].

How is lime used in refining sugar?

By boiling the sugar in lime-water the manufacturer

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44 grains, he may conclude that the ounce of marle contained only 100 grains of calcareous earth, and that it would be his interest to pay seven times as much for a load of lime as he must pay for a load of marle at the same distance.

Every farmer should ascertain the *nature* of his lime before he uses it in agriculture, as there are many extensive districts in England where the lime contains magnesia, which renders it injurious to the growth of vegetables. See Mr. Tennant's memoir on this subject in the *Philosophical Transactions* for 1799. The limestone of Breedon in Leicestershire contains half its weight of magnesia. That of Humbleton hill near Sunderland, 45 per cent. of carbonate of magnesia.—Thomson's *Annals of Philosophy*, vol. iv. page 417.

Magnesian limestone is generally of a fawn colour, but it may be known by its being much longer in dissolving in an acid than common limestone. This is the lime which the Yorkshire farmers call *hot* lime. Common lime soon becomes mild after it is spread upon the land; and hence it cannot injure the young plants, as explained in a former note: but where there is a large portion of magnesia in the lime it is otherwise, because the magnesia does not absorb carbonic acid with the same facility as lime, and therefore does not readily acquire that degree of mildness which is necessary for the safety of the young crop. See a paper on the magnesian limestone and red marle of the neighbourhood of Bristol, by Dr. Gilby, in the *Trans. Geol. Soc.* vol. iv. page 210.

[d] The theory of tanning is shortly this: After the impurities of the skins are removed, they are steeped in an infusion of oak-bark, which consists of two distinct substances, viz. the gallic acid, and the tanning principle; the latter of these combines chemically with the gelatine and albumen of the skins, and forms leather. See Seguin's paper on the improved modes of tanning in Nicholson's *Journal*, quarto, vol. i. page 271; also Sir Humphry Davy's paper on this subject in the *Philosophical Transactions*, vol. xciii. page 233.

deprives it of a certain uncombined acid[a] which prevents its crystallization[b].

What is the use of lime in the manufacture of soap?

Lime is mixed with the alkali in order to deprive it of carbonic acid. The alkali is thus rendered what is called *caustic*, and by this means is fitted to combine with the oil or tallow which is thereby converted into soap[c].

We have hitherto spoken only of lime and of carbonate of lime:—Is lime found in any other state of combination?

Yes: lime occurs in combination with sulphuric acid forming gypsum[d]; with the fluoric acid consti-

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[a] Lime is frequently used by chemists in processes where there is a superabundant and injurious quantity of acid. The lime seizes the acid, and frees the solution from it, by forming with it a neutral salt.

[b] For the process of refining sugar in England, see Rees's *Cyclopædia*—article *Sugar*. The account may be relied on, as I know it was written by a gentleman engaged in the business. The method of refining in the French South American colonies is described in Fourcroy's *Elements of Chemistry*, vol. vii. page 215.

Dr. Roxburgh has published a minute account of the Hindu method of cultivating the cane, and manufacturing the sugar, in the *Asiatic Annual Register* for 1802

[c] As differen talkalies require different proportions of lime to render them perfectly caustic, every soap-maker should be acquainted with a test by which he may precisely ascertain the necessary quantity.

We have no *English* work on soap-making, and I believe there is nothing in any language worth reading on this subject, except the "Report on the Fabrication of Soaps, made by Darcet, Lelievre, and Pelletier, by Order of the Committee of Public Safety," in the 19th volume of the *Annales de Chimie:* but as the French make use of articles which our soap-makers cannot avail themselves of, a great part even of that paper is not applicable to the practice in this country.

[d] Gypsum, or, as it is also called, selenite or sulphate of lime when crystallized, is composed of about 33 lime, 46 parts of sulphuric acid, and 21 water.

[e] Lime combined with the fluoric acid forms those beautiful fluor spars which are brought from the mines of Derbyshire. The most usual colour of this mineral is that of a deep purple; but by exposing it to the rays of a hot sun, or to different degrees of artificial temperature, the artist has found the means of forming a suit of colours of great variety and

tuting fluor spar[e]; with the phosphoric acid in a mineral called *apatite*[f], and in some precious stones[g].

What is magnesia?

MAGNESIA is a very soft, white, light earth[h], with little taste or smell[i]; unalterable in the fire[k], and almost insoluble in water. Nevertheless it absorbs a considerable portion of water when that fluid is poured upon it, and heat is evolved. It dissolves in alkaline carbonates, but is not soluble in the caustic alkalies.

How is magnesia procured?

Magnesia is never found in a state of purity, but always in combination with some acid. It is generally

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beauty. I am indebted to Mr. Mawe, in the Strand, who is the first manufacturer of these articles, for the knowledge of this fact.

[f] The bones of all kinds of animals are formed of lime and phosphoric acid in the proportion of 48.5 parts of that earth and 51.5 of phosphoric acid.

The best test for the presence of lime is oxalic acid, which forms with it an insoluble precipitate. Oxalate of ammonia is generally used for this purpose.

[g] According to analyses which may be depended upon for their accuracy, the emerald contains 1½ per cent. of lime, the precious garnet 3, the green tourmaline 4, the chrysoberyl 6, the common garnet from 8 to 18, and the cinnamon stone 31 per cent. of this earth. A pleasing account of these and other gems will be found in Mr. J. Mawe's *Treatise on Diamonds and Precious Stones*, 8vo, London, 1815.

[h] Sir Humphry Davy has demonstrated that this, like the other earths, is a metallic oxide. It was with considerable difficulty that he was enabled to separate its base, but he effected it by means of quicksilver and the agency of galvanism. "It sunk rapidly in water, producing magnesia, and quickly changed in air, becoming covered with a white crust, and falling into a fine powder, which proved to be magnesia." The metallic base was named *magnium*, but he now calls it *magnesium*.

[i] Magnesia converts vegetable blues to a green. In this respect it resembles the alkalies. It was formerly confounded with carbonate of lime. Hoffman was the first who distinguished it from all other earths.

[k] Though this earth is infusible of itself, it assists the fusion of every other body. It requires 2000 times its weight of water to hold it in solution: notwithstanding this it has the property of rendering camphor, opium, and resins, soluble in water. Its specific gravity is about 2.33.

procured from sulphate of magnesia[a], which exists with the muriate of this earth in sea-water, and in many springs. Magnesia is also a component part of several minerals[b].

What are the uses of magnesia?

Pure magnesia, as well as the sulphate and carbonate, has important uses in medicine[c]. It is also required in some chemical processes, and is employed by the manufacturers of enamels and porcelain[d]. Calcined magnesia is also the most effectual antidote in case of poison by the mineral acids[e].

We have spoken of each of the earths separately, but are there not instances in nature of the earths entering into combination with each other[f]*?*

Yes: minerals are found in every part of the world,

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[a] Sulphate of magnesia (the Epsom salt of commerce) is found in several mineral waters. The *bitter* saline waters generally owe their taste to this salt. That which is found in the shops is generally procured from the mothers which remain after the separation of common salt from sea-water, by subsequent evaporation and crystallization. All the salts formed with this earth are bitter, and generally very soluble.

The magnesia used in medicine is prepared thus: A solution of carbonate of potash or soda is poured into a heated solution of sulphate of magnesia, when a double decomposition and combination take place. The sulphuric acid of the sulphate of magnesia seizes the alkali, and the carbonic acid of the alkali combines with the magnesia. Thus carbonate of magnesia and sulphate of potash or soda result from the process.

[b] Inverary-House is built with a stone called *lapis ollaris*, which contains 16 per cent. of magnesia. Magnesia is found also in talc, steatites, asbestus, fossil cork, and other minerals. The stones which contain a large portion of this earth have generally an unctuous feel, a fibrous texture, and a silky lustre. Some specimens of serpentine contain more than 40 per cent. of magnesia.

[c] When magnesia is taken as an aperient, it ought to be in the state of carbonate of magnesia, or what is called mild magnesia. When as an absorbent to correct acidities, calcined or caustic magnesia is most proper. On several accounts it is of consequence to attend to this distinction.

[d] It is probable that some of the most esteemed of the porcelain clays may owe their estimable properties to an admixture of magnesia. In Nicholson's *Journal*, vol. xii. we read of a porcelain earth, hitherto considered pure clay, having been analysed, and found to consist only of carbonate of magnesia and silica. Magnesia, I understand, is of use in

in which the earths are combined in different proportions by processes unknown to us, which nature employs to produce that endless variety of what, in common language, we call rocks, stones, gems[g], &c.

Is the design of Nature in forming so many distinct earths very apparent?

The earths have several properties in common; yet as every earth possesses different and specific properties[h], it is evident that Nature designed them for different and distinct purposes of utility[i].

You have enumerated the separate uses of most of the earths:—Can you recollect the collective advantages which arise from this class of bodies?

The uses of some of these earths are not yet discovered; but the benefits which we derive from lime,

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porcelain, by lessening the degree of contraction to which all kinds of earthenware and porcelain are liable, by the process of burning.

[e] If putrid water be agitated with a small quantity of magnesia, it will lose its bad taste and smell in a few minutes. Proust, *Journal de Physique*. Might not this method be sometimes of use at sea, on long voyages?

[f] Alumina and silica are the earths which have the greatest affinity; they are found in nature oftener united than any other. Some of the hardest stones are formed of these two earths.

[g] Potter's clay is a mixture chiefly of silica and alumina; the colouring earths used as pigments are mixtures either of clay and the oxides of iron, or clay and charcoal; garden mould is a mixture extremely various, sometimes containing silica, alumina, magnesia, iron, lime, and carbon; the common mill-stone is generally composed of alumina and silica; and the crumbling sandstone is a mixture of iron and silica: it is, however, impossible to enumerate the endless diversity of substances which Nature offers ready formed for the use of man; for the mixtures of the earths which are found *naturally* combined comprehend most of the varieties of clays, slates, stones, gems, rocks, crystals, zeolites, quartz, flints, &c.

[h] The student may acquire much information on this subject from Weaver's Translation of Werner's *External Characters of Fossils*, 8vo.

[i] A few short directions for analysing stones are given in Mr. Parkinson's *Chemical Pocket-book*, last edition, page 216.—There is an excellent paper on this subject in vol. iv. of Dr. Thomson's *System of Chemistry*, page 128. Fourcroy's directions are more concise, but they are worth the perusal of those who are not accustomed to this kind of analy-

clay, silica and magnesia, are very various and important.

In order to impress your memory, and to finish the consideration of this class of bodies, endeavour to recollect some of the more important uses of those earths with which you are best acquainted.

LIME, then, has an extensive and important use in agriculture[a]; it is employed in building, &c., and adds much both to the neatness and durability of our dwellings. SILICA is the basis of all mortar and cements, and is a necessary ingredient in earthen-ware, porcelain, and glass. BARYTES is employed in chemical laboratories as a re-agent. MAGNESIA, besides being the basis of several salts, is of great use in medicine; and ALUMINA, by a due mixture with silica, is capable of forming vessels for chemists that will resist the action of the most concentrated acids; it is the material of which the bricks are formed which construct the walls of our habitations, and is also spread out by the great Author of nature in strata within our hills and mountains[b], to arrest the progress of subterraneous

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sis. Further information may be had by consulting the 1st volume o Kirwan's *Mineralogy*.

The minerals which are generally the subject of analysis are formed with different proportions of the nine earths and the metallic oxides such as oxide of iron, copper, nickel, manganese, chrome, &c.

[a] "The goodness of a soil depends upon its being able to retain the quantity of moisture which is proper for the nourishment of vegetables and no more. Now the retentive power of a soil increases with the proportion of its alumina, lime, or magnesia; and diminishes as the proportion of its silica increases." The *Essay on Soils*, by Dr. Alderson o Hull, is, perhaps, the best paper that has yet appeared on this subject.

[b] Some have imagined that the earth would have had more beauty and would have been much more convenient, if the whole had been a plane surface; and have adduced the mountainous parts of the world a a proof of the imperfection of the works of Nature: but surely such persons were not aware that, independent of the beautiful *variety* they pro

waters, and to produce those springs that fertilize the valleys, and which take such diversified courses upon he surface of the globe.

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duce, the crystal spring and the meandering river owe their origin ntirely to these eminences dispersed over the earth's surface.

> "I see the rivers in their infant beds!
> Deep, deep, I hear them, lab'ring to get free!
> I see the leaning strata, artful ranged;
> The gaping fissures to receive the rains,
> The melting snows, and ever-dripping fogs.——
> Strow'd BIBULOUS above, I see the sands,
> The pebbly gravel next, the layers then
> Of mingled moulds, of more retentive earths,
> That, while the stealing moisture they transmit,
> Retard its motion, and forbid its waste." THOMSON.

CHAPTER VI.

OF ALKALIES.

WHAT is the nature[a] *of an alkali?*

The alkalies[b] have an acrid and peculiar taste; the
change the blue juices of vegetables[c] to a green, an
the yellow to a brown; and have the property of render
ing oils miscible with water. They are incombustible
but may be rendered volatile by great heat. They ar
soluble in water; form various salts by combinatio
with acids[d]; and act as powerful caustics[e] when ap
plied to the flesh of animals[f].

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[a] To a person who has not had an opportunity of examining an alkal
no written description that can be given will convey any correct idea
the taste or properties of this class of bodies: let the pupil therefo
procure a specimen of each kind, before he enters upon this chapte
The juice of the gooseberry and the lemon, and many other vegetab
substances, will remind him of the general properties of the acids: b
having met with nothing analogous to the alkalies, it will be necessa
for him to *taste* and examine one of these bodies in order to acquire a
thing like a just idea of their nature. Let him form potash or soda in
a neutral salt by saturating it with one of the acids, and he will percei
still more of the nature of these bodies.

[b] The word alkali is of Arabian origin, and signifies the "dregs
bitterness."

[c] Although this effect of alkalies on the blue juices of vegetables
almost universal, we know of one exception. Tincture of litmus, a
litmus paper, are always rendered more intensely *blue*, by the additi
of alkalies.

[d] Potash becomes comparatively mild by its union with carbonic aci
and the most caustic soda, if united to corrosive muriatic acid, for
muriate of soda, our mild table-salt.

[e] It seems that causticity depends on chemical affinity, and that t
caustic substance corrodes the matter to which it is applied, in cons
quence of its tendency to *unite* with that matter; and that it continu
to act upon it until it has saturated itself by the combination. Thus t
most caustic alkalies may be combined so as to form insipid salts.

[f] If a piece of animal flesh be put into a strong solution of potash

How many alkalies are there?

There are three alkalies[g]; two of which have been alled *fixed* alkalies, the other the *volatile* alkali.

Which are the fixed alkalies?

The fixed alkalies are potash[h] and soda[i].

Why have they been called fixed[k] *alkalies?*

Because they will endure a great heat without being olatilized; and yet in a very high temperature they re dissipated in vapour.

What substances enter into the composition of these lkalies?

Till lately the fixed alkalies were considered to be *mple* substances, no one having been able to decomose them; but they are now found to be *compound* odies[l].

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da, it will immediately be acted upon by the alkali, and soon be entirely ssolved.

The alkalies have a great affinity for water: it is therefore probable at their causticity is owing to this circumstance, water being so abunnt in animal bodies. If the alkalies be dissolved in a large portion of ter, their caustic qualities are diminished, though not in any measure stroyed thereby.

[g] The French chemists have classed barytes, strontites, lime, and agnesia among the alkalies, on account of their possessing some kaline properties; but as they bear a greater resemblance to e earths than the alkalies, I adhere to the *old* classification of these dies, particularly as a new one will probably soon become necesry.

[h] This alkali was formerly procured by burning vegetables in large on pots; hence it acquired the name of *pot*ash.

[i] Soda acquired its name from the plant *salsola soda*, which grows on e Spanish coast, and is burnt for its preparation.

[k] Mr. Chenevix objects to the name *fixed* alkalies; but as the term used in many modern chemical writings, and as I conceive that it may useful to assist the memory of beginners, I have retained it in this ork. These alkalies have surely some claim to the title of *fixed*, for ey require a red heat to dissipate them; whereas the other alkali comes volatile at a very low temperature.

[l] It will be recollected, that, in the *first* edition of the *Chemical Cateism*, written ten years ago, I offered this opinion of the compound ature of the alkalies. The galvanic experiments of Sir Humphry Davy ave confirmed the truth of this conjecture, and proved beyond all doubt

Have we any historical account of the discovery these substances?

Potash was known to the ancient Gauls and Ge mans[a]; and soda was familiar to the Greeks a Hebrews. This latter substance was known to the ancients by the name of *nitrum*[b].

What is the origin of potash?

Potash is chiefly procured by lixiviation from t ashes of burnt wood, and other vegetable substances

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that potash and soda are both metallic oxides. See Experiments, N 248 to 255, and Additional Notes, No. 67.

At the great explosion of the iron furnace at Colebrook Dale by t bursting of the dam of the river, on the 7th of September 1801, its wh contents were thrown into the air, and it is said nothing was found aft wards but potash, soda, and prussiate of potash.

It has been ascertained by experiment, that potash is formed in wh are termed nitre-beds, or collections of the materials from which nitre procured, though it could have pre-existed in none of them. How t takes place we are at present quite ignorant.

[a] These people were probably the *inventors* of soap, as we are told Pliny that they made soap with the ashes of vegetables and tallow. soap-boiler's shop with soap in it was discovered in the city of Pomp overwhelmed by Vesuvius A.D. 79. See Miss Starke's *Letters from Ita*

[b] This substance is found native in Egypt, and is there called *natro* a name not much unlike that which it bore among the Jews and Gree

[c] A table of the quantities of alkali procured from different kinds wood, may be seen in a valuable memoir on the fabrication of potash, *Annales de Chimie*, tome xix. page 157. Directions, by Vauquelin, burning vegetables in a proper manner for this purpose, will be found the same volume, page 194.

Potash is prepared in large quantities in wine countries, by the in neration of wine-lees and must. This article is known in France by t name of *cendres gravelées*.

[d] Potash has been discovered in the pumice-stone; in some miner of the zeolite family; and in the leucite, a mineral of the siliceous ki The later contains 21 per cent. of this alkali. It has also been found the aluminous ores of La Tolfa; and in felspar, a mineral which con tutes a great portion of the granites; and as granite is always class with the primitive mountains of the globe, this circumstance will aff room for much speculation. The various felspars contain from 3 to per cent. of potash. The *elaolite*, a mineral of the same family, was fou by Klaproth to contain 18 per cent. of this alkali.

[e] It has been said, that potash cannot be procured from vegetab without burning them *previously* to their being lixiviated, or treating th with nitrous acid, or by some process capable of furnishing oxygen a nitrogen; and indeed it has been found, that if vegetables be soak for some time in water and then burnt, they will afford no potash.

t as it exists in minerals and earths[d], there is rea-
n to believe that plants receive it from the earth
ring vegetation[e]: hence it may be proper to discard
e word *vegetable* entirely, when speaking of this
bstance .

What is the origin of soda?

Soda is generally procured from the ashes of *marine*
ants[g]; but its great depository is the ocean, soda
ing the base of sea-salt[h]; or muriate of soda.

Potash was called the vegetable alkali, because it was supposed to
st only in vegetables, though it is now found in some minerals. Soda
s called mineral alkali, because it exists in mineral salts. Soda, as
tinguished from potash, has been known but of late years; and yet
ne of the properties of soda were known in times of remote antiquity.
Hebrew writer speaks of washing with natron. *Jeremiah* ii. 22.

The *salsola soda*, which grows among the cliffs on the sea-coast, is
l to be endowed with the property of decomposing sea-salt, and that
some process of vegetation it separates the muriatic acid and absorbs
soda. Hence it acquired the name of *saltwort*. This plant is col-
ed by the Spaniards with great care, and burnt for the manufacture
ARILLA, which is a considerable article of commerce. Thus Nature
providently furnished the inhabitant of the otherwise barren coast
h a source of employment, and has enabled him to supply the interior
h an article of indispensable necessity, for ages before the science of
mistry could afford him other means of decomposing muriate of
a.

> " The *saltwort's* starry stalks are thickly sown,
> Like humble worth, unheeded and unknown."
>
> CHARLOTTE SMITH.

Most of the peasantry in the Shetland Isles and in the Highlands of
tland are supported by collecting sea-weeds, and burning them into
LP, an article which produces great revenues to the lairds of those
ricts. Many of the wretched inhabitants of those dreary regions
e nothing to depend upon for subsistence, but a miserable pittance,
ich they acquire in this employment.

> " The kind impartial care
> Of Nature nought disdains; thoughtful
> Her lowest sons."

The best account of the manufacture of kelp will, I believe, be found
Jameson's *Mineralogy of the Scottish Isles.* See also Dr. Anderson's
ount of the Hebrides; and my 'Prize Essay on Kelp' in the 5th volume
he *Transactions of the Highland Society of Scotland*, page 65—122.

Soda, combined with carbonic acid, is found mixed with the common
th in Hungary, Bohemia, and Switzerland: also in China, Syria,
sia, and India.

Soda is procured also by chemical processes from sea-salt, which is

How is it that marine plants give out soda, whi those which grow in the interior of the country affor potash ?

This has been accounted for by supposing tha these marine vegetables have the power, during vegetation, of decomposing sea-salt, and retaining th soda in their constitution.

Is soda found in any other state ?

Soda combined with carbonic acid is found in grea plenty in the natron beds of Egypt[a], and in the Eas

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found in immense masses under the earth's surface in many countrie particularly in Poland, Hungary, Spain, and England.

An interesting memoir on the decomposition of this salt, publishe by order of the Committee of Public Safety, may be seen in the *Annal de Chimie*, tome xix. page 58. It occupies 98 pages, and contains detailed account of several effective processes. It may perhaps be th means of saving some individuals from loss and disappointment, if inform them, that I have myself repeated most of those processes in reverberatory furnace, built for that particular purpose, capable of pr ducing an intense heat, and sufficiently capacious to allow some hundre weights of the materials to be operated upon at once ; and that I am opinion that none of the means there directed can be profitably emplo ed in this country during the present high price of salt. The decon position by potash, or by the oxides of lead, presents the fewest difficu ties ; but even these methods cannot be lucrative, unless at a time whe potash and lead are at moderate prices. More information respectin the alkalies may be obtained from the 'Treatise on the Alkalies' in th 3d volume of my *Chemical Essays*, page 121—190.

[a] The natron lakes of Egypt annually produce a large quantity mineral alkali. In summer the water of these lakes is evaporated b the sun, which leaves a bed of natron generally two feet thick ; and th is broken up by wedges, and packed for the European markets.

Berthollet formed an *artificial* natron bed in one of the gardens of th National Institute, by the mixture of carbonate of lime, silica, and muriat of soda. After a time, a partial decomposition was effected, which wa evident from the incrustation on the surface changing the colour of te paper.

[b] Natron in large quantities is frequently sold at the English Eas India Company's public sales. It is brought by their vessels from Chin and other parts of the East.

[c] There is a native combination of boracic acid and soda in the sa called borax. Soda occurs also in abundance in muriate of soda, whic is our common culinary salt. In the kingdom of Valencia in Spain ther is a mountain of this salt called *Cordona*, 500 feet high, and near three miles in circumference. The mine of Cracow in Poland is con

ndies[b]: it occurs also in various other parts of the vorld, though never in a state of purity[c], and enters nto the composition of the *sodalite* and of several ther minerals[d].

What are the distinguishing properties of these wo alkalies?

The fixed alkalies are very similar in their general roperties[e]; but are easily distinguished by the variety f salts which they form with the acids; and by potash eing more deliquescent than soda.

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uted to hold salt enough to suffice the whole world for many thousands f years. For a particular account of the salt mines of Cordona, I refer e reader to some observations by Dr. Traill in the *Trans. Geol. Soc.* ol. iii. p. 404.

I copy the following extract from a letter received by a friend of mine om the Rev. Dr. Allison, dated Borden-Town, New Jersey, Dec. 3, 803:—"There has lately been discovered on the Missouri in Louisiana, mountain of pure rock salt of the best quality, 80 miles long, 45 wide, nd of an immense height. The surface is barely covered with earth, nd there is not a tree or shrub growing on it. This is established as a ct, and some of the salt has been sent to Marietta on its way to Washgton city. Various caves of saltpetre are found in its vicinity."

[d] Soda has also been found in the *cubicite*, in common whinstone, and volcanic lava. The *cryolite* of Greenland, which is an insoluble uate of alumina, contains 36 per cent. of soda.—Klaproth's *Analytical ssays.*

Soda is one of the substances found in the bile of animals. Whenever is alkali occurs native, it is always in a *mild* state; and as it cannot ombine with oils to form soap, unless it be *caustic*, this causticity is iven it for these manufactories by artificial means. It is worthy of emark, that Nature has furnished the bile with soda in a state of *caus-city*, which gives it the property of combining with and saponifying e fat or oily substances taken into the stomach, and rendering them luble in the other animal fluids. What account can be given of this eviation from the usual course of nature, but the important purpose hich it serves in the animal economy?

[e] When the fixed alkalies are in a state of purity, it is impossible by spection to distinguish them from each other; and yet they form, by nion with the *same* acid, salts very opposite in their appearance and line properties. Thus the sulphuric acid and soda form a salt very luble in water, which crystallizes in long separate six-sided prisms, floresces in the air, and undergoes watery fusion by the action of heat; hereas, the same acid and potash form a salt extremely difficult of sotion, which crystallizes either in dodecahedrons with triangular faces,

Is there any chemical test by which you can distinguish these two alkalies?

There are many; but a solution of the ore of platina in nitro-muriatic acid will answer this purpose most completely[a].

What are the chief uses of these alkalies?

The fixed alkalies have various uses in surgery and medicine: they are the bases of several salts; are employed much in the arts[b]: and are of great importance to the analytical chemist[c].

How are the fixed alkalies employed in the arts?

The fixed alkalies are used in large quantities by

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or in short hexahedral prisms terminated by hexahedral pyramids, is not affected by the action of the air, and decrepitates in the fire.

The oxalic acid has been used as a test to distinguish the mineral from the vegetable alkali. With the latter it forms a very soluble salt, but, with the former, one of difficult solubility.

The acetic acid is one that may be employed, as it forms a *crystallizable* salt with soda, and a *deliquescent* salt with potash. Potash may also be known from soda by supersaturating it with tartaric acid, with which it forms a salt very *insoluble* in water.

The alkalies, when combined with carbonic acid, form very *soluble* salts, while the earthy carbonates (or earths combined with a similar acid) are nearly *insoluble* in water.

[a] If a little of any alkaline solution be poured into a solution of the ore of platina in nitro-muriatic acid, a yellow precipitate will be seen, if the alkaline solution contains potash; but if it contains only soda, no precipitate will occur. The peculiar advantage of this test consists in its ready application; whereas the old tests required time to ascertain the nature of the salts formed by their means.

[b] The greatest consumption of the fixed alkalies in this country is in the manufacture of soap. They are also largely employed in bleaching, and in the manufacture of glass. Soda and potash are also both used in washing, and for other domestic purposes; as they powerfully unite with all greasy substances, which they render soluble in water.

[c] See an account of the uses of the fixed alkalies as re-agents in note page 132.

[d] Soda has the property of fusing silica with more facility than potash; hence it is preferred by those glass-makers who have made trial of both these alkalies.

Sub-carbonate of soda is preferred to sub-carbonate of potash in most the glass-maker[d], the dyer, the soap-maker, the colour-maker, and by various other manufacturers.

In a former chapter we noticed the use of fixed alkali in making glass:—What is the use of it to the dyer?

The alkalies are known to have the property of altering the hue of most colours[e]; they are therefore employed with this view by the persons who are engaged in this trade.

Why are the alkalies employed in making soap?

An alkali is an essential ingredient in soap, as it is the only article capable of converting tallow or oil into a saponaceous substance, and enabling it to combine with water[f].

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f the manufactures, because it is much less acrid, and does not attack r weaken the texture of linen goods, nor corrode and destroy utensils f wood, metal, &c. as potash does.

It is curious to observe that the alkalies combine with *transparent* ive oil, and produce *opake* soap; and that they unite with *opake* sand form *transparent* glass. How various are the properties that have een impressed upon those primary materials of the universe, that were trusted to man for the promotion of his convenience and comfort!

[e] The fixed alkalies are also employed to facilitate the extraction of e colouring matter from a few of the foreign woods, and in some processes to precipitate the colours from metallic salts.

[f] To make soap, it is necessary to employ a fixed alkali in a *caustic* ate. In this country the business is usually conducted in the following manner: Spanish barilla or Scotch kelp is broken in pieces, or coarsely round by a horse-mill: and, when mixed with a sufficient quantity of ick-lime to absorb the carbonic acid, the whole is thrown into large ooden or iron vats, and covered with water. In great works, these vats e generally of cast iron, and sufficiently capacious to hold 3 or 4 tons alkaline ashes. At a proper time, the water, impregnated with the ustic alkali, is let off into iron receivers below, and the vats are covered ain with water, which, after standing a sufficient time, is let off as fore. This liquor is called soap-boilers' ley. When a sufficient quan- y of this is prepared, Russian or English tallow is put into a large iron iler, and melted with a portion of the above-mentioned alkaline ley. first the tallow appears liquid like oil, but during its boiling it ac- ires by degrees consistence as it saponifies. When the alkali is uni- mly combined with the tallow, the weak liquor is pumped from beneath e soap, and fresh leys are added in their stead. These are boiled as fore, till the soap exhibits certain appearances well known to the ma- facturer: it is then cooled down, and poured into deep wooden frames

Why are the fixed alkalies employed in makin colours?

Many colours are now manufactured in this countr which cannot be made without an alkali: thus, anima matters are always incinerated with an alkali to form Prussian blue; a fixed alkali is also employed as a flu in the formation of the potter's blue from cobalt; an what are called French and mineral greens are mad by precipitating copper from its solutions by mean of these alkalies.

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15 inches wide and 45 inches long; where it remains till it has acquire a sufficient degree of solidity to be cut up for sale. It is the *alkali* whic gives soap its detergent quality, and which renders it soluble in wate The tallow serves to moderate the sharpness of the alkali, and to pr vent its injuring the hands of those who use it.

In making yellow soap, resin is used in the proportion of about 1 part 3 or 4 parts of tallow. The resin makes the soap more detersive, and e ables the manufacturer to sell it cheaper. Common fish oil, when i price permits, is also used in yellow soap.

Potash is the alkali used for soft soap, the manufacture of which is distinct and separate trade in this country. A solution of this alkali in caustic state is boiled with fish oil; and when the oil is sufficiently sap nified, and a complete union of the materials formed, the *whole* is pour into small casks for sale; the water having combined with the oil as w as the alkali.

[a] Alum, which is a triple compound, cannot be perfect without t addition of a portion of potash or ammonia. For this purpose the B tish manufacturers generally use kelp (which contains a quantity potash as well as soda), or black ash, which is an article made from t waste leys of the soap-boilers, and which, with other salts, generally co tains a portion of muriate and sulphate of potash. Putrid urine is som times used, on account of the ammonia which it affords. For the proc of alum-making, see page 99.

[b] The design of using alkali in bleaching, is to loosen and carry that particular substance in the cloth which occasions its brown colo and which Dr. Home says is a kind of heavy oil. See Dr. Home's *E periments on Bleaching*, 8vo, 1756. For further information cons Pajot des Charmes's *Treatise on Bleaching*.

[c] The soda of Spain is procured from the *salsola*, as has been notic and also from the *basis maritima*, a species of samphire. The Si barilla which is imported into this country is chiefly made by the incine tion of the *zostera maritima*. These plants must be endowed with so very peculiar organization; or why does not sea wrack (the *Fucus* Linnæus) of the British shores, and other sea plants, that are burnt kelp, yield a proportionate quantity of soda? Whenever I have had

What are the other uses of these alkalies?

They are employed in making alum[a]; in bleaching linen[b]; in scouring wool; and in many other processes too various to be enumerated.

From whence is this country supplied with these articles?

The greatest part of the potash used in this country comes from America and Russia; but the *kelp* of our own coasts, and the *barilla* of Spain[c] and of the islands of Teneriffe and Sicily, furnish us with most of our mineral alkali[d].

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asion to lixiviate ordinary kelp, especially Irish kelp, I have not failed o observe that the neutral salts which precipitate from the solution, are ot muriate of soda, as might have been expected, but *muriate of potash*. And this salt is so abundant, that I have often had many hundred weights f it from a single ton of kelp. From this circumstance I am induced o believe that marine plants (excepting those that are cultivated for arilla) yield *potash* by incineration, and not *soda* as has generally been nagined; and that the soda which occurs in kelp is produced by the peration of the potash on the sea-salt in the vegetable, or on that which thrown into the mass by the burners to increase its weight; for a solution of carbonate of potash, poured into a boiling solution of sea-salt, ways produces an immediate decomposition, the result of which is rbonate of soda and muriate of potash.

[d] As we are indebted to foreign countries for most of our fixed alkalies, would be a great national benefit if some ingenious chemist could disover an expeditious as well as economical mode of recovering the alkalies ter they have been used for manufacturing or domestic purposes. The aste liquor might be evaporated; and if the residuum were calcined, the otash or soda would be recovered entire, and endowed with all the luable properties which it originally possessed; as it is by nature inestructible. The desideratum is, how to divest it of its impurities, and egenerate it at a small expense.

By examining 'The Report of the Committee of the House of Comons appointed to inquire into the Laws relating to the Salt Duties,' ind that from the 5th of January 1800 to the 5th of January 1801 the llowing quantities of alkali were imported into Great Britain.

	Cwt.	*Declared Value.*		
Barilla . . .	172,454	362,153*l.*	18*s.*	6*d.*
Pearlash . . .	44,401	128,765	2	6
Potash . . .	135,401	284,342	3	6

More extensive tables of this kind will be found in my late publication titled *Thoughts on the Laws relating to Salt.* London, 1817.

Are these alkalies sold in a state of purity?

No: both potash and soda always contain carbonic acid[a] and water; and are often contaminated with earths, sulphur[b], and other impurities.

Have alkalies any peculiar affinity for sulphur?

Both potash and soda, as well as ammonia, have a strong affinity for sulphur; they combine by trituration or heat, and form *sulphuret* of alkali[c], formerly called *hepar sulphuris*, or "liver of sulphur."

What is the nature of sulphuret of alkali?

Its colour is similar to that of the liver of animals; its taste is acrid and bitter; and it has the property of decomposing water[d].

How are the alkalies of commerce purified for the use of the chemist or manufacturer?

Potash or soda is generally mixed with a portion of quick-lime to divest it of carbonic acid, and then lixi-

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[a] The potash and soda of commerce contain nearly one-fifth of thei weight of carbonic acid, beside lime, silica, and other impurities.

[b] An ash which contains 20 per cent. of pure alkali is capable of takin up 15 parts of sulphur. Such ashes may be desulphurated by three processes:—by calcining them in an open furnace exposed to a rapid blas of air; by saturating them with any vegetable acid; or by exposing then in a situation to imbibe carbonic acid. See a paper on this subject in th *Irish Philosophical Transactions* for 1789.

[c] If equal parts of sulphur and pure potash be triturated together i a mortar, the sulphur will soon acquire a green colour, the temperatur of the mixture will be raised, and a *sulphuret of potash* formed. Carbonate of potash or soda will answer for this purpose as well as the pur alkalies, if heat be employed.

[d] Sulphuret of potash or soda is similar in colour to the liver of animals; it cannot exist but in a *dry* state, for it decomposes water whe dissolved, and then sulphuretted hydrogen is produced.

[e] The different methods which have been followed to purify the fixed alkalies, are detailed at length by Dr. John Thomson in his *Notes o Fourcroy*, vol. i. page 373. Another method has been proposed b Lowitz, which may be seen in Nicholson's *Journal*, vol. i. page 4. Bu Sir Humphry Davy has shown that the potash obtained by alcohol is no a pure alkali as had been imagined, but a compound of potash and water containing between 17 and 18 per cent. of water.

viated in proper vessels to obtain a solution of the caustic alkali, free from other impurities. When it s required *perfectly* pure for nice purposes, the alkali s dissolved in alcohol, and purified by a peculiar process[e].

Are the fixed alkalies ever used in a state of combination with carbonic acid?

Carbonic acid gives potash and soda the property f crystallizing readily[f]: it also renders them mild[g], nd fit for purposes in which caustic alkali would be mproper[h]; hence carbonate of potash is employed in medicine, and carbonate of soda for washing and other omestic uses.

What is the chemical name of the volatile *alkali?*

It is called ammonia.

What are the properties of ammonia?

Ammonia when uncombined with water, or any

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[e] Dr. Henry has suggested that the fixed alkalies may be purified from lphate of potash, which generally contaminates them, by means of rytes. His method consists in rendering the alkali first perfectly caustic quick-lime, and then adding to the clear solution a warm solution of re barytic earth till the precipitation ceases. The barytes seizes the lphuric acid, and leaves the alkali pure; which may be afterwards sa-rated with carbonic acid. During its restoration to a mild state, any rytes that may remain in excess is precipitated.

[f] Carbonate of soda crystallizes readily, and often in crystals of a ge size. The potash of commerce is a sub-carbonate, which does not ily crystallize. However, if this be saturated with carbonic acid, cry-ls may readily be produced.

[g] Caustic soda, like pure potash, is so corrosive that it will affect glass sels in which it is kept, and render them brittle, like earthen-ware f burnt.

[h] Carbonate of soda and carbonate of potash are of use in chemical oratories as *re-agents*, being employed for purposes which could not ffected by the *caustic* alkalies. Thus the two fixed alkaline carbonates l precipitate barytes, strontites, lime, magnesia, manganese, and iron, n their solutions, by means of double affinity. But when these re-nts are employed to precipitate either of the three latter substances, o much be used the precipitate will be *re-dissolved:* some nicety refore is requisite in separating magnesia, manganese, and iron, from ir solutions by this means.

other substance, exists in the state of gas[a], and is then so extremely volatile as to exhale at all known temperatures. Its volatility is diminished in some degree by combination with water, still more so by combining with carbonic acid, and most when combined with the mineral acids[b]. In the gaseous state it has a remarkably pungent smell, it instantly extinguishes flame, and would be fatal to any animals that were obliged to breathe it. It is lighter than atmospheric air i the proportion of 6 to 10.

As this alkali is a gaseous substance, how can i be applied in the arts ?

Ammonia has an affinity for water[c], with which i

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[a] Ammoniacal gas is lighter than atmospheric air, and, like it, i elastic and invisible.

[b] Ammonia has another peculiar property, that of reducing the oxide of metals to a metallic state. Ammonia being composed of hydroge and nitrogen, the hydrogen seizes the oxygen from the metal and form water, while the nitrogen escapes in a gaseous form. Some metals ar oxidized and dissolved by liquid ammonia.

[c] Water is incapable of dissolving either hydrogen or nitrogen, an yet when these are united in ammonia their nature is so changed th they become very soluble in water ; that fluid having the power of takin up and condensing nearly 670 times its own bulk of ammoniacal gas and when thus saturated, the solution is lighter than an equal volume water in the proportion of 875 to 1000.

[d] It is owing to the levity of ammonia, that water becomes specifical lighter in proportion to the quantity of gas it contains. Next to hydroge and carburetted hydrogen, ammonia is the lightest of all the gaseo bodies. Its specific gravity compared with hydrogen is as 8 to 1. O hundred cubical inches of it weigh rather more than 18 grains.

[e] By the following process ammonia may be formed, so as to becon evident to the senses in a short time. Take some filings of tin or zin pour on them some moderately diluted nitrous acid. After a short tin stir into the mixture some quick-lime, or caustic alkali, and a very stro pungent smell of ammonia will be produced. For the rationale of th experiment consult Higgins on *Ammonia*, and a curious paper by D Milner in the *Philosophical Transactions*, vol. lxxix. page 300.

[f] Various methods have been adopted for proving the composition ammonia. The following appears to me to be decisive : When two me sures of ammoniacal gas are decomposed by electricity, four measu of gas are produced, consisting of three measures of hydrogen and o of nitrogen ; showing, that when hydrogen and nitrogen gases unite these proportions they become condensed by combination into half th

readily combines, and forms *liquid* ammonia; in which state it is generally used[d].

What is the composition of ammonia?

Ammonia is a compound of hydrogen and nitrogen, in the proportion of about one part of the former, and four parts of the latter[e], when calculated by weight, or of one measure of nitrogen and three of hydrogen if calculated by volume[f].

Is this alkali capable of being decomposed?

Yes: ammonia may be decomposed by the electric spark. Oxygen gas will also decompose it by the assistance of heat, and then nitrous acid and water will be the result[g]. If passed over red-hot charcoal, it will com-

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original volume, and the produce is ammonia. Again: if the specific gravity of the two simple gases be compared with that of the resulting compound, a satisfactory confirmation of this statement will be obtained; for according to the experiments of Biot and Arago, 100 cubical inches of nitrogen gas weigh 29.55 grains, and 300 cubical inches of hydrogen gas weigh 6.69 grains, amounting together to 36.24 grains; and as the 400 measures become condensed into 200 measures to form ammonia, the one half, or 100 measures, ought to be 18.12 grains. Now on looking to the specific gravity which has been assigned to ammoniacal gas by some of the most able experimental chemists, I find that Sir H. Davy has stated 100 cubical inches at 18 grains, Allen and Pepys at 18.18, and Kirwan at a temperature of 61° and 30 inches of barometrical pressure at 18.16. The mean of these, 18.113, and which comes within one $\frac{7}{1000}$dth part of a grain, is probably very near the actual weight of 100 measures of ammoniacal gas at a medium temperature and pressure; especially as it so exactly agrees with the principle assumed by Gay Lussac and Thenard, from a series of careful experiments, that 200 volumes of this gas are reducible by decomposition into 300 of hydrogen and 100 of nitrogen. Dr. Henry supposes that 136 measures of hydrogen combine with 47 measures of nitrogen to form ammonia; which is very near the proportions of Gay Lussac and Thenard, as stated above. Mr. Dalton assigns this alkaline gas a specific gravity of 18.6: and the agreement which there is in all these statements is very satisfactory, as none of them differ more from each other than by the small fraction of a grain.

[g] Dr. Priestley was the first chemist who decomposed ammoniacal gas; indeed he was the first who procured it in a state of purity; but I believe Berthollet was the first who proved its composition by synthesis as well as analysis.

The decomposition of ammonia may be shown by the following expecombine with part of the charcoal, and form *prussic acid.*

What is the effect of galvanism on ammonia?

A very different result may be obtained if ammonia be decomposed in contact with mercury, by means of galvanism; for in this case a metallic substance of a very uncommon nature may be separated from this alkali[a].

How is ammonia procured?

All animal and vegetable substances, when in a state of putrefaction[b], will furnish ammonia: this

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riment: Fill four-fifths of a long glass tube with strong oxygenized muriatic acid, and the remaining fifth with water strongly impregnated with ammonia, and invert it in a saucer of water. When the tube is inverted, the ammonia, on account of its lightness, will pass through the oxygenized muriatic acid; but by its passing a strong effervescence is produced, and a decomposition ensues. When the effervescence has ceased, a portion of nitrogen gas will be found in the tube.

In this experiment the oxygen of the oxygenized muriatic acid combines with the hydrogen of the ammonia, and forms water; while the other component part of the ammonia, nitrogen, becomes disengaged in the form of gas. When the oxygenized muriatic acid is thus reduced to common muriatic acid, it unites with another part of the ammonia, and forms with it muriate of ammonia. But if the oxymuriatic acid be a simple undecomposable substance, then we should say that it is the hydrogen of the ammonia uniting with the oxymuriatic acid that in this experiment converts it to common muriatic acid.

[a] This experiment was first made in the year 1808 by Dr. Zeobeck of Jena, and also about the same time by MM. Hissinger and Berzelius of Stockholm. Mercury, by combination with about one twelve-thousandth part of its weight of new matter, is thus rendered a solid, and at the same time so expanded in volume that its specific gravity is reduced from 13.5 to less than 3; while all its metallic characters of colour, lustre, opacity, and conducting powers, remain unimpaired. See Additional Notes, No. 67.

[b] As the quantity of ammonia obtained from different substances corresponds with the quantity of nitrogen which they contain, and knowing that ammonia is one of the products of putrefaction, it has occurred to me that a manufacture of volatile alkali might be established with advantage on any part of the coast where herrings, pilchards, &c. arrive in such shoals as to be employed in manure for land. Besides, as fish bones contain more phosphoric acid than those of quadrupeds, the bones might be advantageously employed afterwards in the manufacture of phosphorus, &c.

lkali is, however, generally procured in England by dry distillation of bones, horns, and other animal ubstances[c].

What are the uses of ammonia?

In a liquid state ammonia has various uses in our anufactories[d], and in medicine; it is a valuable re- gent to the chemist; and when combined with car- onic acid it takes a concrete form and a beautiful hite colour, being then the article known in com- erce by the name of *volatile salts*[e].

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[c] Ammonia is also found in mineral waters. According to Dr. Austin, mmonia is formed whenever iron rusts in water which has a free com- mication with the air. *Philos. Trans.* vol. lxxviii. page 379.

For chemical experiments ammoniacal gas may be procured thus: x one part of powdered sal-ammoniac with two parts of powdered ick-lime in a retort, and apply the heat of a lamp, which will disengage gas in abundance. On account of its affinity for water, this gas must received over mercury.

Ammoniacal gas may be procured also by heating strong liquid ammo- , and collecting the gas as before.

Muriatic or acetic acid are the usual tests employed to discover the sence of ammonia. If either of these be held over any thing evolv- ammonia, white fumes will appear, which are owing to the ammonia ting with the acid, and forming a visible cloud, which is a true neutral t in vapour.

Ammonia is of use in making archil, an article in great demand h dyers. A Florentine merchant about the year 1300, having acci- ntally observed that stale urine, which contains ammonia, imparted ery fine colour to a certain species of moss, he made experiments, l learned to prepare archil.—Berthollet's *Elements of the Art of eing.*

It is said that this alkali will give to *new* brandy all the qualities of t of the oldest date. The method consists in pouring five or six drops qua-ammonia into each bottle of brandy, and shaking it well, that it y combine with the acid, on which the taste and other qualities of the v liquor depend. *Bib. Phys. Econ.*

When ammoniacal gas is passed into carbonic acid gas, the two es become condensed, and a crystallization of carbonate of ammonia, ilky fibres or fine powder, takes place upon the internal surface of vessel. This is a beautiful experiment; but it must be made over rcury, and not upon water, as water would absorb the ammoniacal . Carbonate of ammonia is composed of about 50 carbonic acid, 39 monia, and 11 water.

Are there any other uses[a] *to which ammonia is applied?*

Ammonia is serviceable in dyeing, and in staining ivory; but its principal use is in making the muriate of ammonia, of which it is the basis.

How is ammonia formed into muriate of ammonia?

Muriate of ammonia is formed by combining ammonia with muriatic acid. It is known in commerce by the name of *sal-ammoniac*[b].

Muriate of ammonia being formed by two gaseous substances, how does it acquire solidity?

It may appear surprising that the union of two gases should produce a hard ponderous body; but this may be attributed to their loss of caloric. The bases of these gases having a greater affinity for each

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[a] Nearly 20 years ago it was discovered that ammonia is useful in vegetation. See Dr. Darwin's *Phytologia, or, Treatise on Agriculture and Gardening.* ☞ Lately the waste ammoniacal liquor from the gas establishments has been tried upon land as a manure, and produced surprising effects.

Muriate of ammonia has been found native in the neighbourhood of volcanoes, in some of the mountains of Tartary and Thibet, and in the waters of some lakes in Tuscany.

[b] In this country liquid carbonate of ammonia is saturated with sulphuric acid, which forms sulphate of ammonia. This is decomposed by muriate of soda, from which result muriate of ammonia and sulphate of soda. The former is sublimed into cakes, and the latter crystallized for Glauber's salt.

In France a very considerable manufactory of sal-ammoniac was established a few years ago, on a plan very different from the usual practice. Leblanc de Franciade was the author of the process. He covered the brick floor of an oven heated to redness, with common salt, and poured thereon sulphuric acid. The muriatic acid gas which arose was conducted by a brick gutter into a large leaden chamber, where it met with a stream of ammoniacal gas, conducted thither from animal matters burning at the same time in three iron cylinders, placed in a furnace beside the former. These gases condensed by mixtnre, which was hastened by an eolipile heated by the same furnace. A full account of the process may be seen in *Annales de Chimie*, tome xix. page 61: it will, however, be better understood by examining a drawing of the apparatus in the 2d volume of the *Journal de Physique* for the year 1794: or by other than they have for caloric, they combine intimately whenever they come in contact; and the compound having less occasion for caloric than the separate ingredients, the caloric is given out, and a solid is produced[c].

What are the uses of sal-ammoniac?

Sal-ammoniac is employed in many of our manufactories, particularly by dyers, to give a brightness to certain colours[d]; also by braziers, tin-plate workers, and others; and in medicine.

From whence was sal-ammoniac procured before it was made in this country?

Sal-ammoniac was formerly brought from Egypt sufficient for the supply of all Europe[e]; but it is now made in various parts of Great Britain, particularly in

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referring to my *Chemical Essays*, vol. iv. page 339—395, where the various processes for preparing sal-ammoniac are described, accompanied by an engraving of the apparatus above mentioned.

Sal-ammoniac is very profitably formed in France also by the distillation of animal substances, and mixing the aqueous product with the mother-waters of the saline springs of La Meurthe, Mount Blanc, &c., which contain muriate of lime and muriate of magnesia. By this mixture a double decomposition takes place; and the carbonate of lime and magnesia, being insoluble, precipitate, while the muriate of ammonia remains dissolved. The latter solution is then evaporated to dryness, and the salt sublimed for sale. See *Annales de Chimie*, tome xx. page 186.

[c] This mixture may be considered one of the most striking chemical combinations with which we are acquainted. Ammoniacal gas, and muriatic acid gas, are two of the most pungent and volatile substances known; they are so volatile and gaseous, that when in a state of purity neither of them can be condensed; and yet these gases are no sooner thrown together than they form a solid and inodorous substance, void of volatility, and of little taste.

[d] Sal-ammoniac is used also by some dyers in what they call composition, to prevent the tin from precipitating. In tinning metals it is of use to cleanse the surfaces, and to prevent them from oxidizing by the heat which is given to them in the operation. This salt is employed also in the assay of metals, to discover the presence of iron.

[e] Sal-ammoniac acquired its name from the Temple of Jupiter Ammon, it being first made in the neighbourhood of that temple. According to

Scotland, where it is formed by a peculiar process from soot; and also from a variety of refuse animal matter.

Is ammonia capable of entering into any other combinations?

Yes: ammonia is capable of forming salts with most if not all of the acids[a].

Can you recapitulate the origin of the different alkalies?

The volatile alkali is procured from bones and other animal matters; potash or vegetable alkali from the ashes of weeds and burnt wood; and soda or mineral

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Pliny, there were large inns in the vicinity of this famous temple, where the pilgrims, who came to worship, lodged; and who usually travelled on camels. The proprietors of these stables had some contrivance for preserving and concentrating the urine of these beasts, and the salts which it produced were afterwards sublimed in glass vessels for sale.—*Plinii Historia Naturalis*, lib. xxxi. cap. 7.

[a] If ammoniacal gas be brought in contact with either of the acid gases, both lose their aëriform appearance, and a solid salt is produced. These salts are called *ammoniacal* salts. For an account of their properties consult the chapter on Salts.

[b] Soda may be readily procured from muriate of soda, (common salt,) by methods alluded to, page 125. As the act of parliament which imposes the tax upon salt, allows it to be used duty free for the separation of mineral alkali, to be consumed in making glass, a manufacture of soda has within these few years been established for that purpose at Wormbridge near Wellington, in the county of Salop. I understand that at this place considerable quantities of martial pyrites are found intermixed with coal, and that the sulphuric acid obtained from this mineral is used in the decomposition. I have found by operations in the large way, that if muriate of soda can be converted by any means to a *sulphate*, carbonaceous matter alone, at a red heat, will finish the decomposition; that is, it will convert the sulphate to a sulphuret, and then by exposure to atmospheric air carbonic acid is absorbed and the sulphur separated.

Near the town of Wednesbury in Staffordshire, and Dudley in Worcestershire, there are masses of coal on fire, which have been burning for ages, owing probably to the decomposition of pyrites. In some cases where the sulphurous vapour meets with aluminous earth, alum is formed upon the surface. An account of these subterranean fires may be seen in Plot's *History of Staffordshire*. We read also of a combustible ground of this kind, near Baku in Persia, where the followers of Zoroaster perform their devotions. The carburetted hydrogen gas that arises from this ground is so abundant, that the priests have conducted alkali from the ashes of some marine plants, also from sea-salt or muriate of soda[b].

What is the natural inference from a consideration of the nature and production of the alkalies?

The reflection which naturally arises from a consideration of this subject is, that the original organization of matter, whereby the effete recrementitious parts of animals and vegetables are made capable of producing useful and powerful substances, evinces, that infinite Power and Wisdom, united with consummate Beneficence, can effect the most *important* changes, by the most *unlikely* agents; and can convert to valuable purposes, substances which to us appear totally useless and inert[c].

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it by hollow canes into one of their temples, where it burns continually, and is looked upon to be "the sacred flame of universal fire." Mr. William Maclure relates, that in America, near the mouth of Elk river, there are constant streams of carburetted hydrogen gas issuing from the ground, which when once lighted will burn for several weeks. Maclure's *Observations on the Geology of the United States of America*, page 57.

[c] The following is not an inapt illustration of this economy of Nature.

> "Organic forms with chemic changes strive,
> Live but to die, and die but to revive;
> IMMORTAL MATTER braves the transient storm,
> Mounts from the wreck, unchanging but in form."

CHAPTER VII.

OF ACIDS.

What is an acid[a] *?*

Most of the acids are substances which produce that sensation on the tongue which we call *sour;* but some substances are classed with the acids which have not this characteristic—though they possess some of the other properties of acids.

What are the properties of acids?

Acids[b] change the blue, green, and purple juices of vegetables to red[c]; and combine with alkalies, earths,

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[a] The acids differ from each other in their appearance and properties as much as any class of bodies we are acquainted with: it is therefore difficult to give a definition of an acid. In general they are liquids, but some of them take a solid, and others a gaseous form; some are mild, others corrosive; some are pungent and volatile, others are fixed and inodorous.

[b] It is desirable as soon as possible to give the chemical student correct ideas of the properties of the acids and alkalies. To this end, let him be early instructed in the use of chemical tests. If he be accustomed to carry a few test papers in his pocket-book, it will be a very rational amusement to try the succulent vegetables which he will meet with in his walks, many of which will be found to contain acids of different kinds. The hope of making an important discovery will furnish an additional zest to this employment. Litmus paper is a good test for acids; and the same paper when reddened by vinegar, and afterwards dried, is a proper test for alkalies. Should litmus not be at hand, common writing-paper rubbed over with the rind of the radish will answer every purpose.

[c] This is so general, that we know of only one exception. Indigo may be dissolved in concentrated sulphuric acid, and yet its original blue colour will be preserved.

[d] From some late galvanic experiments by Sir Humphry Davy, it appears that acids combine with alkalies and metallic oxides in consequence of their being in opposite states of electricity,—that is, the acids are naturally negative, and the metals and the alkalies positive,—and that hence an union would take place between them, independently of any other power than electricity. He has also demonstrated, that, if an acid be put in a state of positive electricity, it refuses to combine with

or metallic oxides[d], so as to form those compounds called *salts*.

What is the origin of acids?

Most of the acids owe their origin to the combination of certain substances with oxygen[e], which has been called the acidifying principle.

How is it known that oxygen imparts acidity?

This is built upon analogy; for it is found that most of the acids contain oxygen, and that they lose their acidity exactly in proportion to the quantity of oxygen which is taken from them[f].

Are there any other means of ascertaining this?

Yes: some acids may be decomposed, and deprived of their oxygen, and others may be formed by a direct combination of oxygen with certain radicals[g].

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an alkali, and that, when an alkali is made negative, it refuses to combine with acids, as may be seen in his very interesting paper in the *Philosophical Transactions* for 1807, page 1. A brief abstract of the experiments will be found in the Additional Notes to this volume, No. 558. However, since the publication of this paper, Sir Humphry Davy has said that "he does not suppose that chemical changes are OCCASIONED BY electrical changes, but that these are *distinct* phenomena, produced by the *same power*, acting in one case on masses, in the other case on particles." See Davy's *Elements of Chemical Philosophy*, vol. i. page 165.

[e] The substances which are combined with oxygen to form acids are (in all the decomposable acids) *combustible* substances. Indeed several of the acids are the *product* of combustion:—witness the sulphuric, the phosphoric, &c. Five of the metals, and the other simple combustibles, hydrogen not excepted, are all convertible into acids.

It is proper to remark that some of the acids are the productions of art, and are not known to exist in nature. This is the case with the mucous, the suberic, &c.

[f] Many of the acids may be decomposed, and deprived of their oxygen, by combustible bodies. Any combustible body, that has a greater affinity for oxygen than oxygen has for the radical of the acid, will decompose that acid. Charcoal, when made red-hot, will in this way decompose sulphuric acid.

[g] This is shown by the somposition of sulphuric acid, which for experiment may be formed thus: Mix a little sulphur coarsely powdered with one-eighth of its weight of ground nitre. Put the mixture upon a small tile, and place the tile upon a low stand in the middle of a flat glass or

Do the same radicals always combine with an equa portion of oxygen?

No: some of these acidifiable radicals combine wit different proportions of oxygen, and consequently produce different states of acidity[a].

How is this difference distinguished?

When two acids have the same radical, but contai different quantities of oxygen, they are distinguishe by their termination[b]. The name of that which contains most oxygen ends in IC, the other in OUS. Thu we say *sulphuric* acid, and *sulphurous* acid; *phosphoric* acid, and *phosphorous* acid.

What substances are capable of being acidified b oxygen?

The mineral, the vegetable, and the animal king

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earthen dish. Then pour a small quantity of water into the dish, an procure a large glass jar to invert over the brimstone, so that its edge shall dip into the water, which must be deep enough to form a wate lute. Things being thus prepared, the brimstone is to be set on fire i several places, by means of a red hot iron, and immediately covered wit the jar. The sulphur will burn with great rapidity, and will be chiefl converted into sulphuric acid, which may be concentrated by evaporatin the superfluous water. In this process the sulphur unites with the oxygen of the atmospheric air within the jar, at the same time that the hea and light, which are unnecessary in the new compound, are evolved, an become sensible to our feelings: the result is a new substance widel different from either, viz. sulphuric acid. The use of the water is t absorb the gas, and render it liquid.

[a] The first portion of oxygen converts some bodies into oxides, as i the case with carbon, forming carbonic oxide; and sulphur, forming oxid of sulphur: the second into that class of acids of which the specifi names drawn from their particular bases terminate in *ous*, as the sulphurous acid: the third degree of oxygenizement changes some of thes into that division of acids which are distinguished by the termination i *ic*, as the sulphuric acid, &c. In like manner we have oxide of phosphorus, phosphorous acid and phosphoric acid. For an account of th four distinct combinations of nitrogen with oxygen, see the tabular representation at page 42.

[b] The term OXYGEN is derived from the Greek words *oxys geinomai* signifying *that which produces or generates acids:* but as Sir Humphr Davy has discovered that this substance is necessary also to the production of the alkalies, some other term, surely, should be found that would be more applicable to this wonderful invisible agent! Had the framers

oms, all furnish bases or radicals, which become acid y their union with oxygen[c].

Do all the acids owe their acidity to the presence f oxygen?

The greater number of the acids are evidently in-ebted to oxygen for their acidity, but there are sub-ances that possess acid properties which contain no xygen[d]. Until lately, there were also three acids hose composition was unknown[e].

How are the acids classed by chemists?

The acids were formerly divided into three classes, z. the mineral, the vegetable, and the animal acids; it the more useful and scientific way of dividing the ids is into two classes only.

How are the acids now divided[f]?

The undecomposable acids, and those which are

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the new nomenclature happened to have called it *hydrogen*, no objec-ı, that I can perceive, could have been made to it, as it is undoubtedly of the component parts of water.

The mineral acids are generally formed with a peculiar base and gen; the vegetable acids, with carbon, hydrogen, and oxygen; while animal acids are composed of the same substances united with ogen.

ome of the mineral acids are decomposable, as already mentioned, harcoal heated to redness. Some of the vegetable acids are also omposed, and reduced into water and carbonic acid, by leaving them n exposed situation to the action of their own principles: others may hanged into different acids, by imparting or abstracting a portion of gen.

he animal acids are of all others the most liable to decomposition. n elevated temperature the carbon and oxygen unite to form carbonic , and the hydrogen and nitrogen combine to produce volatile alkali.

Sulphuretted hydrogen has all the properties of an acid without gen. And it has not yet been proved that prussic acid contains any gen. Iodine and chlorine also are capable of forming distinct and liar acids by combination with hydrogen.

Those acids were, the muriatic, the fluoric, and the boracic; these, ever, have lately yielded to the power of voltaic electricity, and their s have been separated.

Those acids of the first class, which are formed with two principles , are composed of oxygen and some other substance which is called r radical. The acids of the second class are composed chiefly of formed with two principles, are comprised in the first class; while those acids which are formed with more than two principles compose the second class[a].

Can you enumerate the acids of the first class?

The sulphuric and sulphurous acids; the muriatic and oxygenized muriatic acids; the nitric, the carbonic, the phosphoric and phophorous, the fluoric, the boracic, the arsenic and arsenous, the tungstic, the molybdic and molybdous, the telluric and the chromic acids.

Enumerate the acids of the second class.

The acetic, the oxalic, the tartaric, the citric, the malic, the lactic, the gallic, the mucous, the benzoic, the succinic, the camphoric, the suberic, the laccic, the prussic, the sebacic, the uric, the amniotic, and the fluoboric acids.

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oxygen, hydrogen, and carbon; though some of them contain a portion of nitrogen, as mentioned in a former note.

[a] Fourcroy, in his last work entitled, *Philosophie Chimique*, divides the acids into four classes: 1st, those with known radicals; 2d, unknown ditto; 3d, single ditto; 4th, compound ditto: but I conceive that the above division is better calculated for an elementary treatise.

In the first class we have also the hyperoxygenized muriatic acid; but as this acid has never been properly exhibited in a separate state, its properties are very little known. In the second class we have also the mellitic acid; but as this acid has been found only in a very rare mineral, its properties are likewise very little understood. Besides these, Berzelius and some other foreign chemists speak of the antimonic and antimonous acids; of the boletic, the ferro-prussic, the ferruretted chyazic, the moroxylic, and the rosacic acids: but as the properties of these are little known, and no value whatever is attached to them, I have thought it most adviseable to content myself with a simple enumeration of them.

[b] This acid was formerly drawn from green vitriol (sulphate of iron): hence its name. It has been remarked that the old name *oil* conveys an erroneous idea of the composition of this acid, and that on this account it ought to be entirely dropped. Oil is a compound of carbon and hydrogen; but sulphuric acid contains neither of these substances.

[c] The pupil may be satisfied that sulphuric acid is really produced by the combustion of sulphur, by burning a little sulphur in a glass jar of oxygen gas inverted over water, as directed in page 143. He may see that sulphuric acid has actually been formed, by adding a few drops of a solution of muriate of barytes to the water; for as this is the proper reagent for discovering the presence of sulphuric acid, it will not fail in

What is the SULPHURIC *acid?*

The sulphuric acid is a combination of sulphur and xygen. It is commonly called oil of vitriol[b].

How is the sulphuric acid obtained?

Sulphuric acid is procured by burning sulphur, in ontact with oxygen; by which process the sulphur ombines with the oxygen, and becomes acidified[c].

If sulphuric acid is nothing more than sulphur and xygen, what is it that occasions its fluidity?

Sulphuric acid, at the instant of its formation, is in a aseous state; therefore the manufacturers find it neces- ry to condense the gas by means of water. Hence the lphuric acid of commerce is always in a fluid state[d].

What are the properties[e] *of sulphuric acid?*

The sulphuric is a very ponderous[f], corrosive acid,

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is case to precipitate the barytes.—An account of the different methods making sulphuric acid from the time of its first preparation to the esent day, will be found in my paper on that subject in the *Chemical says*, vol. ii. page 375—483.

[d] In the large manufactories for making sulphuric acid (called oil vitriol works) the sulphur is mixed with $\frac{1}{8}$th of its weight of dried re, and burnt in very large leaden chambers, according to the plan of . Roebuck, to whom we are indebted for this process. The floor of chamber is covered with water, that the sulphuric acid gas may be ndensed as it is formed. An indeterminate quantity of water is poured o the chamber; and when the manufacturer finds that this water is ome sufficiently impregnated, the weak acid is drawn off, and con- ntrated by boiling. It is then removed to glass retorts, where it re- ves a greater heat to drive off a further portion of the water. It is nsidered fit for sale when it is brought to the specific gravity of about 45. By keeping it in the retorts for a long time, and in a little lower nperature, it may be somewhat further concentrated; but it is never ught to a higher specific gravity for general sale than that above ntioned.—For an account of the present theory of the formation of phuric acid, see Nicholson's *Journal* for May 1807.

[e] When sulphur is combined with a smaller portion of oxygen, it forms olatile acid of a penetrating smell called *sulphurous* acid; a larger tion of oxygen gives what we call *sulphuric* acid, which on the con- ry is very ponderous, and destitute of smell. These acids are consti- ed in the following manner:—*Sulphurous* acid consists of 100 parts sulphur and 100 of oxygen; while *sulphuric* acid is composed of 100 ts of sulphur and 150 parts of oxygen.

[f] Sulphuric acid will sometimes freeze, and endanger the bursting of

destitute of colour and smell, and has a very strong acid taste. It has a great attraction for water[a], and, when combined with the alkalies, the earths, or the metallic oxides, forms with them those salts called *sulphates*[b].

What is the SULPHUROUS *acid?*

The sulphurous acid, like the sulphuric, is a combination of sulphur and oxygen, but with less oxygen, or, we may say, with more sulphur, than the latter[c].

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the carboys in which it is contained. Whenever this happens, it is a proof that the manufacturer has not sufficiently concentrated it. If it be brought only to the specific gravity of about 1.780, it will freeze much sooner than water. Mr. Keir first pointed this out in the *Philosophical Transactions* for 1787.

[a] Sulphuric acid and water combine so intimately that the compound gives out a large portion of caloric. Four pounds of this acid mixed with one pound of water will raise the thermometer to 300° of Fahrenheit.

The sulphuric acid of commerce is never perfectly pure; it always contains a portion of sulphate of lead and sulphate of potash. The former comes from a partial dissolution of the lead of the chamber in which it is made, and the latter from the nitre which is always used in the process.

Concentrated sulphuric acid does not act upon lead unless by the assistance of heat. It acts slowly upon iron; but if diluted it dissolves iron with great rapidity. Excepting iron and zinc, most of the metals are insoluble in diluted sulphuric acid.

[b] Sulphuric acid is a test for barytes: a single drop poured into any solution of this earth instantly causes a white precipitate. It is also a good test for lead. I know, however, of *one* case where this acid cannot detect the presence of barytes, and that is when sulphuric acid is contaminated with this earth. Mr. Hume has shown that sulphate of barytes is completely soluble in sulphuric acid. See the *Philosophical Magazine*, vol. xiv. page 357.

[c] Sulphurous acid gas is produced by the *slow* combustion of sulphur. Its specific gravity compared with hydrogen is as 30 to 1. 100 cubical inches of it weigh 67.5 grains. If sulphur be burned in 100 cubical inches of oxygen gas, the weight of which is 33.75 grains, it will be found, when the apparatus is cold, that there are still 100 measures of gas, but that it is increased to double the original weight, being now 67.5, which shows that sulphur combines with exactly its own weight of oxygen to form sulphurous acid. If this gas be received in water, the gas will combine with it, and liquid sulphurous acid will be the result. Water at 40° absorbs one-third of its weight of sulphurous acid gas, and acquires a specific gravity of about 1.0513.

Sulphurous acid gas may also be procured by the following process:—Put into a glass retort two parts of sulphuric acid and one of mercury, *What are the properties of sulphurous acid?*

Sulphurous acid in the gaseous state is invisible like air, but of a strong suffocating smell[d]. It is readily absorbed by water, and then forms liquid sulphurous acid. It is capable of uniting with various bases, and forms the salts called *sulphites*.

What is the MURIATIC *acid?*

The muriatic is a peculiar acid obtained from sea-salt[e].

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and apply the heat of a lamp; the mixture effervesces, and a gas issues from the beak of the retort, which may be received in glass jars filled with mercury and standing in a mercurial trough. In this process the mercury in the retort combines with a part of the oxygen of the sulphuric acid; and the sulphuric acid, having lost a certain portion of its oxygen, is converted into *sulphurous* acid.

Any combustible substance will decompose sulphuric acid, by combining with a portion of its oxygen, and sulphurous acid gas will be evolved. On the contrary, if 10 cubical inches of sulphurous acid gas be dissolved in water, and then exposed over mercury to the action of 5 cubical inches of oxygen gas, the oxygen will be absorbed, and the liquid sulphurous will be converted to sulphuric acid. This combination, however, will not take place without the intervention of water.

[d] Sulphurous acid gas is very abundant in the environs of volcanos. It was the vapour of sulphurous acid which suffocated Pliny the naturalist, in that eruption of Vesuvius by which Herculaneum was swallowed up in the year of Christ 79. Anxious to observe the effects of the eruption, he staid in the house of a friend too long, and paid for his temerity with his life.

Sulphurous acid gas is used by manufacturers in bleaching straw and silk. A slow combustion of sulphur is promoted in a close chamber, and the goods are exposed to the gas as it is produced. Thus, silks which are dyed by archil of a dark lilac are brought to a beautiful flesh-colour by the fumes of this gas. Flesh-coloured silk stockings are also coloured in this way.

Sulphurous acid possesses very slight acid properties. Instead of changing vegetable blues to a red, as acids generally do, it invariably renders them white. In like manner, if a red rose be held in the fumes of a brimstone match, the colour will soon begin to change, and at length the flower will have become white. By the same process, fruit-stains or iron-moulds may be removed from linen or cotton cloths, if the spots be previously moistened with water.

[e] Glauber was the first who procured muriatic acid from sea-salt by means of sulphuric acid; ground tiles, clay, or alum, having till then been used as the medium of distillation. It is also remarkable that this able chemist employed a series of receivers for the process, similar to those now in use; and adapted them to each other *exactly* in the manner directed by Mr. Woulfe. This inestimable apparatus, which Woulfe has given to the public as his own, was actually drawn and described

Until lately, the radical or base of this acid was e tirely unknown[a].

What method is made use of to collect and p serve the muriatic acid?

Muriatic acid is distilled from sea-salt by mea of sulphuric acid, and collected in appropriate ceivers, where it is condensed in water, for which has a very powerful affinity[b].

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by John Rudolph Glauber more than a hundred years before Mr. Wo was born. See plate 1. to the *Treatise on Philosophical Furnaces.*

Muriatic acid was known only in a liquid state until Dr. Pries taught us how to procure it perfectly pure in a gaseous form.

[a] The decomposition of muriatic acid was a desideratum with the chemists of Europe for many years. Berthollet imagined that it w compound of nitrogen, hydrogen, and oxygen, and Dr. Lambe suppo that its base was sulphuretted hydrogen; but nothing satisfactory said upon the subject until Sir H. Davy favoured us with the resul his experiments. According to this illustrious philosopher, muri acid is a compound of hydrogen and oxymuriatic acid. The facts f whence he drew this conclusion are fully detailed in the *Philosoph Transactions* for 1810.

[b] Muriatic acid is disengaged from muriate of soda in the state of by a process similar to that for drawing the nitric acid. It prese its gaseous state even in the coldest temperature, unless it com contact with water; and if thrown upon ice it melts it in an inst It is nearly double the specific gravity of atmospheric air. It may be remarked that all acids contain water as an essential part of t composition, and that the whole of the water cannot be separated f any of them without occasioning the destruction of the acid.

Liquid muriatic acid, or water saturated with this gas, is about spec. grav. 1.196. The muriatic acid of commerce varies from a 1.120 to about 1.164.

Bergman says that 100 parts of muriate of soda contain 52 part muriatic acid and 6 of water. That this statement is erroneous, one may satisfy himself by experiment. I have frequently tried i the large way, and could never procure more than 45 or 46 parts of from 100 parts of dried muriate of soda. When pure, this salt cont no water. I calculate that in distilling muriatic acid 100 pounds of muriate of soda yield 36,000 gallons of muriatic acid gas, and that wine gallon of this gas weighs only 90 grains. This accounts for great heat which is evolved during the operation.

[c] Muriatic acid gas may be obtained for chemical experiments pouring one part of sulphuric acid upon two parts of dry muriate of in a tubulated retort, and collecting the gas, as it becomes disenga over mercury in a pneumatic apparatus. This gas may also be colle by heating the muriatic acid of commerce in a glass retort.

Retorts are not always of glass; they are sometimes made of st

What are the properties of muriatic acid?

This acid in the gaseous state[c] is invisible like air; and has a pungent suffocating smell[d]. With water it forms the liquid muriatic acid, which preserves the smell of the gas, and gives out white fumes when exposed to the atmosphere. This acid is much employed in the arts[e], and in chemical laboratories. With various bases it forms the salts called *muriates*[f].

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ware, or iron. They are of various sizes, from eight ounces to eight or ten gallons. The best stone-ware retorts are made by Messrs. Wedgwoods. Glass ones may be had at the large glass-warehouses in London, and elsewhere. A great variety of those which are proper for philosophical experiments are sold by Messrs. Knights, in Foster-lane, Cheapside.

[d] Sulphuric, phosphoric, nitric, and other acids may be decomposed by charcoal; muriatic acid is unalterable by any of the combustibles with which we are acquainted.

Muriatic acid will decompose the carbonates, and some other salts; but it is itself generally expelled in its turn by the sulphuric acid.

[e] Muriatic acid is the best test for silver. If a single drop be poured into any solution containing this metal, a copious precipitate will immediately follow, owing to the affinity of this acid for silver, and the insolubility of muriate of silver.

[f] Sir H. Davy supposes that, in all cases where muriatic acid is employed to dissolve the metals, hydrogen is separated from the acid so as to convert it to the oxymuriatic acid, or chlorine; and that the products are not muriates, but real oxymuriates of such metals as may have been dissolved.

Muriatic acid attacks oxide of iron with more rapidity than the sulphuric. It dissolves tin and lead. At a boiling heat it oxidizes copper.

Muriatic acid removes the stains of common ink, but it does not affect printers'-ink. It is therefore recommended for cleaning old books and prints. Half an ounce of red lead being added to three ounces of common muriatic acid, will render it fit for this use. Where writings have been effaced for fraudulent purposes with this acid, sulphuret of ammonia and prussiate of potash will revive the writing, and discover the artifice. Very old writing may be revived in this way. If indigo and oxide of manganese be added to common ink, it will prevent its being effaced by oxymuriatic acid.

The citric acid is proper for removing ink-stains from linen, but they are best removed when recent. If they remain long on the cloth, the iron of the ink acquires that degree of oxidizement which renders it insoluble in acids. When ink-stains are thus become what are called *iron-moulds*, they may be removed by oxalic acid, or by first washing them with a solution of sulphuret of potash to absorb the oxygen, and then applying the citric acid as usual.

What is the OXYMURIATIC *acid?*

It is now a prevailing opinion that the oxymuriatic acid, or chlorine as it is usually called, is a simple substance[a]. It is known in the gaseous state, and in combination with water: but in the latter form it is more commonly used in the arts.

What are the properties of oxymuriatic acid?

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[a] Oxymuriatic acid, or chlorine, is a peculiar gaseous body which was discovered by Scheele in 1774; he deemed it a simple substance, and called it dephlogisticated marine acid; Berthollet however pronounced it to be a compound of common muriatic acid and oxygen, and gave it the name of oxygenated muriatic acid. It is procured by the distillation of a mixture of manganese, common salt, sulphuric acid and water, as I have fully explained in my *Chemical Essays*, vol. iv. page 68. The oxymuriatic acid resulting from this distillation was always supposed to be a compound of muriatic acid and oxygen; but if it be true, as Sir Humphry Davy asserts, that common muriatic acid is a compound of chlorine and hydrogen, and that these are both simple undecomposable substances, a different explanation must be given of the operation of the manganese in producing oxymuriatic acid; and we can account for its production in no other way, than by supposing that the oxygen gas decomposes the muriatic acid, and absorbs its hydrogen, and that both these gases unite in the proper proportions to produce water.

If oxymuriatic acid be exposed to light, it will soon be converted to common muriatic acid. See note on Light, chap. 12.

Oxymuriatic gas may be obtained for chemical experiments by the following method: Put into a retort a little black oxide of manganese in powder; and pour upon this double its weight of strong muriatic acid; connect the retort with the pneumatic trough, and receive the gas over water. When the ascension of the gas slackens, apply the heat of a lamp, and it will be disengaged in abundance. Its specific gravity is to that of hydrogen, nearly as 34 to 1.

If a small quantity of liquid oxymuriatic acid be wanted for experiment, it may readily be formed by dissolving a few grains of oxymuriate of potash, and adding the solution to an ounce of common muriatic acid. It is of a yellowish green colour, which was the cause of its being called *chlorine*, a name given to it by Sir Humphry Davy.

Accounts have been received from Spain, that in the midst of the dreadful contagion which reigned in that country, the inhabitants of those houses where fumigations of oxymuriatic acid were used, had no attacks of the sickness, and enjoyed the best health.

[b] The death of the ingenious and indefatigable Pelletier was occasioned by his inhaling by accident a large portion of this gas. A consumption was the consequence, which in a short time proved fatal.

[c] Acids in general change blue vegetable colours to red; but this

The oxymuriatic acid gas is so suffocating, that it cannot be breathed without great injury[b]; yet it will support combustion. This gas discharges vegetable colours[c]; it burns all the metals[d], and is the only acid that will dissolve gold and platina[e]: with various alkaline and earthy bases it forms salts, called hyper-oxymuriates[f].

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destroys colour. Instead of considering it as one of the acids, it would be more proper to call it an acidifying principle, for it possesses few properties which characterize that class of bodies. Its taste is not acid but astringent; and unlike the acids it combines very sparingly with water. It has not been decomposed either by electricity or galvanism; which is a presumptive proof of its being a simple substance.

The great use of oxymuriatic acid is in bleaching. A full account of the methods of applying it may be seen in my Essay on Bleaching in the th volume of the *Chemical Essays*. The manufacturer might also derive considerable advantage from the perusal of Mr. Rupp's paper on the use of this acid, in the fifth volume of the *Memoirs of the Manchester Society*. See also Charmes *on Bleaching*, 8vo. Robinsons, 1799. C. Potel of the Academy of Dijon has shown that the fears of those who suppose this process *burns* the cloth are groundless; and that, if the operation be performed by a careful workman, it preserves the texture of the cloth instead of injuring it. *Philosophical Magazine*, vol. xiv.

[d] Metals beaten into thin leaves, or reduced to powder, inflame when thrown into a vessel filled with this gas, provided the temperature be not lower than about 70°, and present a kind of shower of fire. The following is a pleasing and instructive example:

Prepare a jar of chlorine (oxymuriatic gas), and suspend in it a piece of Dutch metal, or copper-foil; it will immediately inflame, and the combustion will continue till the whole is consumed, affording a very striking spectacle. It will however soon subside in the jar, and form a substance exactly similar to the native muriate of copper brought from Peru. In this experiment the evolution of heat and light is no absolute proof of oxidizement; for this may be attributed to the intensity of the action of the acid and the metal on each other.

[e] Nitro-muriatic acid, it is true, will dissolve gold; but this is probably owing to the muriatic acid having been converted to oxymuriatic acid.

Mr. Humboldt has found that seeds which do not commonly germinate in our climates, or in our hothouses, and which of course we cannot raise for our gardens, or hope to naturalize in our fields, become capable of germinating when immersed for some days in a weak solution of oxymuriatic acid. This interesting discovery has been turned to advantage in some botanic gardens.

[f] For an account of these salts see the next chapter.

What other compounds may be formed by mea of chlorine or oxymuriatic acid?

Chlorine will combine with oxygen[a], with h drogen[b], and with nitrogen[c]; also with carb retted hydrogen[d], and with the carbonic oxide some of which combinations possess very curio

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[a] Chlorine and oxygen do not unite by simple mixture; but if hyp oxymuriate of potash be distilled by a gentle heat in a glass retort w diluted muriatic acid, a gas will be set at liberty which consists chlorine and oxygen. If this gaseous compound be received over m cury, it will be found to possess a brighter colour than chlorine, m inclining to yellow; and its smell will be different, being like that burnt sugar. Sir H. Davy, who discovered this compound in Janua 1811, has named it *euchlorine*. This elastic substance should, howev be always examined with great care, and in very small quantities a time, as a very trifling heat will sometimes occasion it to explode w great violence. About four years after the discovery of euchlorine, H. Davy announced another new compound of chlorine and oxygen, c taining more oxygen than euchlorine, and of a much more brilliant col than that gas. For particulars consult the *Phil. Trans.* for 1815, part

[b] Hydrogen and chlorine unite readily. If equal measures of each mixed and exposed to the light of day, the two gases will gradua combine without condensation, and the result will be muriatic acid g In making this experiment the mixed gases must not be submitted the action of the sun's rays, as this would occasion them to explode.

[c] Nitrogen does not unite with chlorine by simple mixture, but t compound may be formed by passing chlorine gas into a solution nitrate of ammonia. By this process the salt is decomposed, and p of its nitrogen unites with the chlorine to form the compound in qu tion, called *chloride of azote*. This singular substance, which appe first as a thin film on the surface of the saline solution, has the appe ance of oil, and detonates with so small a degree of heat, and with su violence that it is not safe to operate upon a quantity exceeding that a grain of mustard-seed. The discoverer of this singular compou M. Dulong, was not at first aware of its properties, and being unguard he lost an eye and a finger by its explosion. Sir H. Davy also sustai an injury in the face by repeating one of M. Dulong's experiments. Chloride of azote possesses also the following singular properties: I small quantity of any oleaginous substance come in contact with detonation will take place without the intervention of heat. It is mo over one of the most dense fluid substances we have, its specific grav being 16.53. It is decomposed by detonation into its original elemen which, according to Sir H. Davy, are four volumes of chlorine and o of nitrogen; or if taken by weight, of

Chlorine . . .	91.2
Nitrogen . . .	8.8
	100.0

properties, as may be seen by a reference to the notes.

Those you have now mentioned are all gaseous substances; does chlorine form any other combinations?

By peculiar management chlorine may likewise be combined with sulphur[f], with phosphorus[g], and

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This compound of chlorine and nitrogen has been submitted to a powerful freezing mixture composed of snow and muriate of lime, but it appeared unchanged, and was uncongealed in a temperature low enough to solidify mercury.

[d] The mixture of carburetted hydrogen with chlorine has been treated on by Dr. John Davy in the *Philosophical Transactions* for 1814, and the following are some of its most remarkable properties: When three or four parts of chlorine were mixed with one of carburetted hydrogen, and suffered to stand over water exposed to the light of the sun, they exploded; and the water being partially decomposed, carbonic acid gas was produced. In another experiment, when the gases were perfectly dry and no water was present, muriatic acid gas was furnished by the detonation, and charcoal was precipitated:—a strong presumptive proof this of the compound nature of muriatic acid.

[e] Carbonic oxide and chlorine when united by peculiar management form a singular compound, which the discoverer, Dr. John Davy, has named *phosgene gas.* This compound gas has a very peculiar and remarkably pungent odour; it is the heaviest of all the known gases, 100 cubical inches of it weighing nearly 112 grains, which is almost four times as much as an equal volume of atmospheric air. It is readily decomposed by water, and the resulting gases, as might be expected, are muriatic and carbonic acid gases.

[f] When sulphur is heated in contact with chlorine, a red fuming fluid is obtained of the specific gravity of 1.60. The peculiar properties of this compound have been described by Dr. Thomson in Nicholson's *Journal,* 8vo. vol. vi. to which I refer. It has not yet been found to be of any use in the arts.

[g] When phosphorus in a state of vapour is passed through heated corrosive sublimate, which is a chloride of mercury, a liquid compound will be formed consisting of 20 parts of phosphorus and 67 of chlorine. It is a fluid as clear as water, of the specific gravity of 1.45, and by exposure to the air becomes acidulous. Its discoverer, Sir H. Davy, has named it *phosphorane.* But when phosphorus is introduced into chlorine gas, the phosphorus inflames, and as it burns a white substance condenses on the sides of the vessel, which is found to be a compound of 20 phosphorus and 134 chlorine. Its properties are very peculiar. It is a solid snow-white substance; very volatile at a temperature much below that of boiling water; is fusible when submitted to pressure, and on cooling crystallizes in transparent prisms. It has been named *phosphorana.*

with the metals[a], including also the metals of the earths and alkalies[b].

What effect has chlorine upon charcoal?

Chlorine has no action whatever upon charcoal, even though the charcoal be intensely hot when plunged into it. Some intelligent chemists consider this fact to be a decisive proof that chlorine contains no oxygen.

What is NITRIC *acid?*

Nitric acid is one of the constituent parts of nitre or saltpetre[c]. It is a compound of oxygen and nitrogen[d], in the proportion of about 26 parts by weight of nitrogen, to 74 of oxygen[e].

How is nitric acid obtained?

Nitric acid is obtained by distilling two parts of nitre and one part of sulphuric acid in a glass retort,

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[a] Chlorine is capable of combining with all the metals, and in many cases the combination is accompanied with inflammation, those metals which are most readily oxidized burning with the most brilliancy: but for an account of each of these compounds I must refer the reader to the respective Notes in the chapter on the metals.

[b] By heating potassium or sodium in chlorine gas, compounds may be formed resembling those which result from heating those metals in common muriatic acid gas. Ten grains of potassium or sodium absorb about eleven cubic inch measures of chlorine: but the combination is accompanied with a more brilliant combustion than when these alkaline metals are burnt in oxygen gas.

[c] Nitric acid was known to Raymond Lully in the thirteenth century; but it was Mr. Cavendish who discovered its component parts, in the year 1785. See his paper in the *Philosophical Transactions* for that year.

[d] If a proper mixture of these gases be made in a glass tube, and a number of electric explosions passed through the mixture, the gases will unite, and *nitric acid* will be the product. As nitric acid is formed of the same substances with atmospheric air, we have no difficulty in accounting, as far as regards the acid, for the natural production of saltpetre. Indeed by repeatedly passing electric shocks through atmospheric air, it may be converted to nitric acid. This fact was first demonstrated by the late Dr. Priestley.

[e] These proportions refer to nitric acid in the state of gas or dry nitric acid, when in a state of combination. According to Sir Humphry Davy the specific gravity of this gas, when compared with hydrogen, is about

collecting the fluid in proper receivers[f]. This d, which at first contains nitrous gas, and is thereby de of a deep red colour, is in a great measure deved of it, and rendered transparent and colourless, the application of heat in a subsequent process.

What are the properties of nitric acid?

Pure nitric acid is clear and colourless, like water; smell is pungent, its taste exceedingly acid, and its ion on animal substances very corrosive. It has property of permanently staining the skin yellow. as a great affinity for water[g]; is capable of oxidizing st of the metals[h], and with various bases forms the s called *nitrates*.

What constitutes the acid of commerce, called ROUS *acid?*

Nitrous acid, improperly so called, is in fact nitric

1; and 100 cubical inches of it weigh 65 grains. *Elements of Che-* *l Philosophy*, page 262.

is curious that the gases which compose atmospheric air, so neces- to our existence, should, in different proportions, produce also one e most corrosive acids.

parts by weight of oxygen,
mixed with
parts of nitrogen
} form atmospheric air.

parts of oxygen, with
parts of nitrogen,
} when chemically combined and condensed by water, form nitric acid, or aquafortis.

rely none but Deity could have conceived an idea of the production ch *different* substances from the *same* principles!

The manufactories of this acid are commonly called AQUAFORTIS KS. The acid is drawn of different strengths, according to the pur- s for which it is designed. It is used in dyeing, in refining gold, in icine, and in a great variety of manufactories. For more on this ect, see Additional Notes, No. 65.

Nitrate of barytes, which is so soluble in water, is perfectly *insoluble* tric acid. This was first noticed by Mr. Hume. See his observa- on barytes, in the 14th volume of the *Philosophical Magazine*.

If nitric acid be poured on iron filings, on copper, or on some other acid impregnated with variable portions of nitrous acid gas[a].

What are the properties of nitrous acid?

Nitrous acid is somewhat similar to *nitric* acid in its properties[b]; but its colour varies according to the proportions of nitrous acid gas which it has absorbed, and the water that it contains[c].

What is CARBONIC *acid?*

Carbonic acid[d] is a combination of carbon and oxygen. It was formerly called fixed air, on account of its being so intimately combined in chalk, limestone[e], magnesia, &c.

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metals, the acid will in part be decomposed; its oxygen will render the metal soluble, and the nitrous gas will be thrown out in copious red fumes.

[a] Dr. Priestley having separated nitrous gas from nitric acid, by means of iron, he received the gas under an inverted vessel filled with water, and found it a transparent *colourless* gas, resembling air; whence it appears that it is red or coloured, only when combined with atmospheric air. To Dr. Priestley we owe the discovery, that nitrous gas is converted into nitrous acid by its union with oxygen and water. See Priestley's *Experiments on different Kinds of Air.*

On the principle that oxygen gas is necessary to convert nitrous gas to nitrous acid, Dr. Priestley invented his eudiometer, to discover the degree of purity of atmospheric air.

[b] Nitrous acid is generally used for purposes of manufacture and experiment. The *nitric* acid is principally employed in medicine. Two parts of either nitrous or nitric acid, and one of muriatic acid, form aqua regia, or nitro-muriatic acid, the true solvent of gold. It is curious that aqua regia has less specific gravity than either of the acids from which it is composed.

[c] The changes which take place on the addition of water to strong nitrous acid exhibit very curious phenomena. Different portions change its colour to a blue, a green, a yellow, &c. while the vapours which rise from it preserve their original flame-coloured red. It is proper to remark that the salts which have been called *nitrites* cannot be formed by the union of any alkaline or metallic base with *nitrous* acid, because the acid becomes partially decomposed by the operation, losing exactly that quantity of nitrous gas which is sufficient to reduce it to the state of *nitric* acid; so that the resulting salt will always be a *nitrate* and not a *nitrite*, whether *nitric* or *nitrous* acid be employed in its formation.

[d] It is to Dr. Black we owe the discovery of carbonic acid gas. Mr. Keir was the first who suspected it to be an acid; and Dr. Priestley afterwards announced that this gas formed a part of atmospheric air.

What are the properties of carbonic acid?

Carbonic acid is invisible when in the state of gas, l unfit for combustion[f], or respiration[g]. Water, pressure, may be made to absorb three times its k of this gas; by which it acquires an agreeable dulous taste[h]. Carbonic acid in the proportion in ich it exists in atmospheric air is favourable to the wth of vegetables, but in a large proportion is highly urious[i]. This acid enters into combination with alkalies, with earths, and metallic oxides; and forms h them those salts called *carbonates*[k].

Carbonic acid is composed of about 28 parts carbon and 72 oxygen; ch has been ascertained by analysis as well as synthesis. Mr. Ten- t was the first who decomposed this acid. This he effected by the owing means: He burnt phosphorus in a close vessel, in which was rtion of carbonate of soda. The phosphorus absorbed the oxygen n the carbonic acid, and the carbon was separated in the form of a k powder.

If this gas be poured from a wide-mouthed jar upon a lighted candle, ill be as effectually extinguished as by water. Its superior gravity tmospheric air may also be shown by pouring a common glass-full his gas into another tall glass, containing a short taper burning in it.

Carbonic acid gas is positively noxious to animals independently of essening the proportion of oxygen in atmospheric air; for it has been d that an animal will live longer in a confined atmosphere from nce the carbonic acid is removed as fast as it is generated, than in in which that acid gas is suffered to remain.

Carbonic acid gas is found in abundance in many natural waters. se of Pyrmont, Spa, and Seltzer, are instances: the last, particularly, ighly impregnated with this acid. These waters are so pleasant and tary, that various imitations of them, made in this country, are sold er the names of single and double soda water. They are manu- ured by several houses in London, equal in every respect to the ral waters imported from the continent. For instructions how to mine such waters, an excellent work may be consulted entitled n *Essay on the Analysis of Mineral Waters*," by Richard Kirwan, . F.R.S. &c.

M. Saussure jun. has found by experiment that an atmosphere con- ing even an eighth part of carbonic acid aids the growth of vege- es, but that when in a larger proportion it is injurious.

The earthy carbonates are insoluble in water. Hence, breathing into ial of lime-water renders it turbid. Owing to this, lime-water is a d test for the presence of carbonic acid.

What is PHOSPHORIC *acid?*

Phosphoric acid is a compound of oxygen and a peculiar substance called phosphorus[a].

How is phosphoric acid procured?

Formerly phosphoric acid was procured only by burning phosphorus in oxygen gas; but, since it is known that this acid is a component part of animal bones[b], we now procure it at a much cheaper rate from that source.

What are the properties of phosphoric acid?

Phosphoric acid is very soluble in water; the solution

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[a] During a great part of the last century, phosphoric acid was supposed to be a modification of the muriatic acid. This error originated with Stahl. In 1743 Margraff distinguished it from all other acids, and in 1772 Scheele discovered that it was a component part of animal bones.

[b] When animal bones are divested of their oil and jelly, the earth which remains is chiefly lime, united with phosphoric acid, and this phosphate of lime is often employed for the preparation of the medicinal salt called phosphate of soda. But Mons. Chaptal jun. son of the Count Chaptal, employs bones in Paris, as I am informed, in a very different manner. Having a large establishment for the preparation of soda, in which process a larger quantity of muriatic acid is afforded than can be consumed in the ordinary way, he employs persons to collect bones from all parts of the city, and digests them in this spare muriatic acid. The acid dissolves the phosphate of lime and leaves the gelatine. The latter is made into soup, and sold in every district of Paris.

It is worthy of notice, that phosphate of lime is found in abundance also in milk. This seems to indicate, as Fourcroy beautifully remarks, "that Nature thought fit to place in the first nourishment of animals a quantity of osseous matter, with a view to the necessary celerity of the formation and growth of the bones in the earliest stage of their lives." This fact is probably unknown to some who study natural history, and is one of the numerous instances of the beneficence of the Creator, exemplified by the science of chemistry. The more we know of the minutiæ of matter, and of the laws by which it is governed, the greater occasion shall we have to admire the excellence of contrivance and the benevolence of intention of the Omnipotent Artificer. Let the advocates for chance consider the aforesaid fact, and say, if they can, that phosphate of lime is found in animal milk, in consequence of *fatality*, and that it occurs by *accident* where it performs so important an office in the animal economy. It is also a remarkable fact, that the nearer the female approaches to the period of parturition the more is the milk charged with this calcareous phosphate; and that it is not till the digestive organs of the infant are sufficiently strengthened to answer the purposes and is colourless; it has a strong acid taste[c]; by evaporation the solution becomes very dense[d] and of an oily consistence. This acid may be evaporated to dryness, and even submitted to a white heat, without suffering any change, or being volatilized. It forms by its union with earthy, alkaline, and metallic bases, that variety of salts which we call *phosphates*, and occurs in nature combined with lime, oxide of lead, and other bases[e].

What is the PHOSPHOROUS *acid?*

This acid contains a smaller proportion of oxygen than the phosphoric acid. It is procured by the *slow* combustion of phosphorus[f]; for when phosphorus is

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he work of animalization, that this earthy salt disappears from the milk of the mother. See Nicholson's *Journal*, 4to. vol. i. page 205.

[c] Pure phosphoric acid obtained, without the addition of water, by burnng phosphorus in oxygen gas, has the form of white, snowy, light flocks, f a very strong acid taste. By exposure to the air it attracts humidity, nd becomes a *fluid* acid. One hundred parts of dry phosphoric acid onsist of about 46½ phosphorus and 53½ oxygen.

[d] Phosphoric acid may be concentrated until it be of greater specific ravity than sulphuric acid; but though the taste is very acrid, it does ot possess a causticity sufficient to burn organic substances, like the atter, whose oxygen is retained with less obstinacy.

If phosphoric acid be exposed to heat, it gradually becomes thick and lutinous; and if the heat be continued it acquires more consistence, nd at last melts into a solid transparent glass. This phosphoric glass ust be preserved from the action of the atmosphere, or it will be graually dissolved again into liquid phosphoric acid. If the phosphoric cid be fused in an *earthen* crucible, it will act upon and combine with e earth of which the crucible is composed, and then it will not be deliuescent nor soluble in water.

[e] Phosphoric acid is found in large proportion in the *apatite*, in the *sparagus stone*, in the *phosphorite*, and in some metallic combinations, uch as lead, iron, manganese, copper, &c. The earthy phosphates hich occur abundantly in Spain and elsewhere, contain from 30 to nearly 0 per cent. of phosphoric acid. The bog iron ore is said to contain only per cent. of this acid, whereas the blue iron ore is found to hold 32 er cent.; the native phosphate of manganese 27, the phosphates of lead om 8 or 9 to 19 per cent.; and the compact phosphate of copper, which laproth procured from Firneberg on the Rhine, he found to consist of xide of copper 68.13, and phosphoric acid 30.95.

[f] Phosphorous acid is generally prepared by exposing sticks of phoshorus to the action of atmospheric air, in a glass funnel, and receiving e acid, as it forms, in a bottle placed underneath. Two or three pieces

heated it burns *rapidly*, and the product is phosphoric acid.

What are the properties of phosphorous acid?

Phosphorous acid is a dense, viscid liquid, with an acid taste, and emits the smell of garlic when heated. This, like the phosphoric acid, may be decomposed by charcoal, but cannot be obtained in a concrete state. It has not yet been applied to any use. The salts formed with it are called *phosphites*.

What is FLUORIC *acid?*

The fluoric is an acid of a very peculiar nature[a], found in the fluor spar[b], which is a natural production, composed of fluoric acid and lime. This acid is found also in nearly the same proportion in the *cryolite*, a

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of broken glass placed in the neck of the funnel to support the phosphorus, and a small quantity of distilled water put into the receiving bottle complete this simple apparatus. The pieces of phosphorus should b placed so as not to touch each other. Phosphorous acid consists of abou 20 phosphorus and 15 oxygen.

[a] Fluoric acid is obtained by pouring sulphuric acid upon the powdere spar in a leaden retort, and applying a gentle heat. The sulphuric aci expels the fluoric, and unites with the lime in its stead. This acid ha been discovered also in the enamel of the human teeth, and in ivory Vauquelin has found it likewise in the *schorlite*, &c.

Fluor spar requires two or three times its own weight of concentrate sulphuric acid to disengage the fluoric acid gas, which must be co densed in water to form liquid fluoric acid. To preserve the liquid acid it should be kept in vessels of lead or platina.

[b] Fluor spar is found in many parts of Europe, particularly in Derb shire. It is employed in the manufacture of ornamental vases, &c. I is constituted of about 67 per cent. of lime and 33 of fluoric acid.

[c] This acid has somewhat of the smell of muriatic acid, but is muc more corrosive. It exceeds all other acids in its saturating power, in a much as it neutralizes a larger quantity of any base. It acts so powe fully on silica that it is impossible to use glass vessels for its distillatio A glass retort would be destroyed before a pound of the gas could b obtained. It combines with the siliceous earth of the glass, and carri it over with it in distillation.

Its action on glass may be shown by strewing some powdered flu spar on the surface of a pane of glass, and pouring a little sulphuric ac upon it. The sulphuric acid will disengage the fluoric acid from th spar, which will act upon the glass immediately as it becomes disengage and destroy the polish.

rare mineral brought from West Greenland. The topaz likewise contains fluoric acid, though in a less proportion.

What are the properties of fluoric acid[c] *?*

In the state of gas it is invisible like air. Water rapidly absorbs it, and forms liquid fluoric acid[d]. It has an acid taste, and the peculiar property of corroding silica[e]. With the alkalies and earths it forms salts called *fluates*. Though it has been decomposed, the nature of its radical is not yet known.

What is the use of fluoric acid?

Fluoric acid has been used for etching upon glass[f]; also in various cases for destroying the polish upon glass, so as to render it nearly opake. It appears that

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[d] Fluoric acid has of late years been decomposed by the agency of galvanism, and is supposed to consist of hydrogen united to a peculiar base called *fluorine*; but as this base has not yet been exhibited in a separate state, very little is known respecting it.

[e] If a small animal or reptile be exposed to the vapour of this acid, drawn in glass, the animal moisture will absorb the acid, and the silica will be precipitated, so as to give it the appearance of a real petrifaction, or an animal covered with stone.

[f] It has been a fashionable employment for young ladies to etch landscapes and other drawings on glass by means of this acid. They cover he surface of the glass with wax, and trace any kind of drawing upon by cutting out the wax with proper instruments. The piece is then ut into a leaden receiver, and the gas, disengaged from the fluor spar y means of an Argand's lamp, is thrown in upon it In this way drawngs of great beauty are made, as imperishable as the glass itself. A omplete apparatus may be had of Messrs. Knights Foster-lane, for bout four guineas: it is so contrived, that a lady may operate with it a sitting-room with great safety; and by varying the process, the full ffect of light and shade may be given to the drawings: for, if *liquid* uoric acid be used, the lines will be transparent; whereas, if it be aplied in the state of *gas*, they will appear dark and opake. Great caution, owever, should be observed in the employment of the liquid fluoric cid, as it quickly destroys the skin and produces tedious wounds. The frontispiece to the third edition of this work, I have reason to beeve, exhibits a more favourable specimen of printing from glass etched y fluoric acid, than any that has hitherto been produced. In France, arometers, thermometers, and other glass instruments, are graduated y means of this acid. It might surely be very usefully employed for ngraving labels on glass bottles designed to hold the corrosive acids.

it was employed for the first-named purpose so early as in the seventeenth century[a].

What is meant by silicated fluoric gas?

This is a compound gas of great specific gravity, and is merely fluoric acid holding a large portion of silica in solution[b].

What is fluoboric gas?

A compound of the fluoric and boracic acids, neither interesting nor useful.

What is BORACIC *acid?*

The boracic is a peculiar acid separated from a substance called borax[c]. Until lately the nature of its radical was unknown[d].

What are the properties of boracic acid?

Boracic acid is in the form of thin scales[e], slightly

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[a] Henry Swanhard, an artist of Nuremberg, having discovered the corrosive nature of this acid by observing its effect upon his spectacles, on which some had accidentally fallen, applied it to the purposes of engraving on glass so early as 1670.

[b] Pure fluoric acid has never been obtained in the state of gas, and yet when combined either with silica or boracic acid it is capable of assuming that form. If fluor spar be mixed with half its weight of pulverized glass and then treated with an equal weight of sulphuric acid, silicated fluoric gas may be separated by distillation and collected over mercury. This gas being already saturated with silica, has no action whatever on glass, and therefore may be received in vessels of that substance. According to Dr. John Davy, who has carefully analysed this gas, the fluoric acid has the singular property not only of combining with more than 1½ of its own weight of silica, but of converting that compact earth into a gaseous form. According to his experiments, this curious gas is composed of 61.4 per cent. of silica and 38.6 of fluoric acid.

[c] The boracic acid was discovered by Homberg in 1702. It may easil be procured by dissolving refined borax in hot water, and adding sulphu ric acid till the solution has a slight acid taste. This is then to be left t cool and crystallize. The crystals contain more than 40 per cent. of water

[d] See an account of Crell's experiments for the decomposition of thi acid in *Annales de Chimie*, tome xxxv. page 202. Sir H. Davy has suc ceeded in decomposing it by the agency of galvanism, and calls its bas *boron*. It is an opake, dark olive-coloured, infusible powder. It is inso luble in water and a non-conductor of electricity. Boracic acid he sup poses to consist of about one third boron and two-thirds oxygen.

[e] This acid, when it is well crystallized, is in the form of small shinin

acid[f], and unalterable in the air. It forms, when combined with the alkalies, some earths[g], and some of the metallic oxides, the variety of salts called *borates*. One of the peculiar properties of this acid is, that it imparts a green colour to burning bodies[h].

What is ARSENIC *acid?*

Arsenic acid is a compound of arsenic and oxygen. It is a heavy, thick, incrystallizable mass; very soluble in hot water[i]; of an acid taste, and extremely poisonous. With different bases it forms the salts called *arseniates*.

What is TUNGSTIC *acid?*

The tungstic acid is a tasteless yellow powder, composed of oxygen and tungsten[k]. It is insoluble in water, but forms the salts called *tungstates*, by its union with alkalies, earths[l], or metals.

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flaky crystals. If exposed to a strong heat it becomes fused, and forms a solid white glass, which is sometimes employed in the composition of artificial precious stones.

[f] The taste of boracic acid is bitterish, with a slight degree of acidity. It is very soluble in hot water, and but sparingly so in cold. It is very useful in the analysis of minerals, as it brings almost all stones into solution.

[g] There is a native combination of boracic acid and magnesia called *boracite*, which contains 83 per cent. of that acid. It occurs also, though in a smaller proportion, in the *datolite* and *botryolite* minerals from Norway.

[h] When burnt with alcohol it communicates a green colour to the flame, which becomes more and more green as the alcohol burns away.

[i] Arsenic acid is not affected by exposure to the air. It is composed of 67 parts of arsenic and 33 oxygen. It is made by giving an extra dose of oxygen to the common white oxide of arsenic, known to chemists by the name of the *arsenous* acid.

[k] Tungstic acid is found native in wolfram and other minerals. It may be obtained from wolfram by boiling three parts of muriatic acid on one part of the mineral. The acid is to be decanted off in about half an hour, and allowed to settle: the powder which precipitates is to be dissolved in ammonia; the solution evaporated to dryness, and the dry mass kept for some time in a red heat. It is then yellow oxide, or the tungstic acid in a state of purity. This acid, which becomes blue by exposure to the light, is composed of about 20 per cent. of oxygen and 80 of tungsten.

[l] Tungstic acid unites with the alkalies to saturation. It dissolves se-

What is MOLYBDIC *acid?*

Molybdic acid is a pale yellow powder, composed of molybdenum and oxygen[a]. It requires a large quantity of water to dissolve it[b]. When combined with salifiable bases, the compounds are called *molybdates*.

What is CHROMIC *acid?*

Chromic acid is an orange-coloured powder composed of chromium and oxygen. It has an acrid metallic taste, is soluble in water, and crystallizable. When mixed with different saline solutions it assumes

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veral metals, and assumes a *blue* colour in proportion as it abandons to them a part of its oxygen.

[a] Molybdic acid was discovered by Scheele in 1778. It is procured from the sulphuret of molybdenum by distilling nitric acid off it repeatedly, till the sulphur and metal are both acidified; which is known by the conversion of the whole into a white mass. Hot water carries off the sulphuric acid, and ignition separates the water, and gives the molybdic acid in a state of purity. It requires 960 parts of boiling water to dissolve it. The solution is of a pale yellow.

[b] There is another combination of molybdenum and oxygen called the *molybdous* acid, which is in the state of a fine blue powder. For the process of making it, see Sir Humphry Davy's *Elements of Chemical Philosophy*, part i. page 460.

[c] The chromic acid was discovered by Vauquelin. It is procured from the red lead-ore of Siberia. He obtained it by boiling 100 parts of this mineral with 300 of carbonate of potash and 4000 of water, and separating the lead and the alkali by weak nitric acid. The native chromate of lead is a compound of 64 parts oxide of lead and 36 of chromic acid. There is also a native chromate of iron: but this is a combination of the oxide of chrome with the oxide of iron, intermixed with a little alumina and silica.

[d] In making vinegar, the casks should be only half filled; that a large surface of the liquor may be exposed to the atmosphere, from whence the oxygen is to be derived to acidify it.

[e] All kinds of wine, and all sorts of malt or saccharine fermented liquors, are capable of yielding this acid. The smaller the quantity of the wine the sooner will it be converted to vinegar, provided there be a free access of atmospheric air. Ample directions for making vinegar will be found in Fourcroy's *System of Chemistry*, vol. viii. page 250: but I believe the best treatise on this subject is by Citizen Parmentier, published in one of the volumes of the *Annales de Chimie*.

It is found that wine which contains most mucilage soonest becomes a variety of beautiful colours; it also forms with the earths and alkalies various salts, called *chromates*[c].

What is the ACETIC *acid?*

Acetic acid is principally obtained[d] from saccharine liquors[e] which have undergone the vinous fermentation[f].

What are the properties of acetic acid?

Acetic acid, as it is usually prepared, is a pleasant yellow liquor, well known. When distilled it is as colourless as water, and of an agreeable odour. In both states it is known in commerce by the name of vinegar[g].

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acid. On this account isinglass ought not to be added to wines, to fine them, till the moment of bottling them.

[f] It was formerly imagined that acetous acid could be prepared only from vinous liquors; but it is not an indispensable condition that it shall have been preceded by the vinous fermentation. This acid may be drawn from wood by the destructive distillation; but it is extremely impure, and offensive in its smell, being always intimately combined with a very nauseous empyreumatic vegetable oil: it is called the pyroligneous acid. Methods, however, have of late been discovered of purifying this acid so as to become a substitute for vinegar, and fit for every purpose of domestic economy. For information respecting the products which may be obtained by the distillation of wood, the reader may consult a Memoir by Dr. MacCulloch in the *Trans. of the Geol. Soc.* vol. ii. page 1.

Some time ago Vauquelin announced, as a *new* discovery, that pyroligneous acid is identically the same as the acetous;—but this was known to Glauber nearly 200 years ago. In the folio edition of his works, page 188, may be seen directions for its distillation, with a copper-plate of the apparatus that he employed. He there calls it the *vinegar* of wood.

According to recent experiments, detailed in a late volume of the *Annales de Chimie*, it appears that acetous acid exudes with the perspirable matter from the pores of the human body.

[g] There is so little difference between the volatility of vinegar and water, that it cannot be concentrated by boiling; but if it be mixed with charcoal dust, the charcoal will enable it to resist a strong heat, by which means the water may be thrown off by a boiling heat; and then the pure concentrated acetous acid may be drawn over in a proper apparatus by a stronger heat. We are indebted to Mr. Lowitz for this discovery. It is a curious circumstance, but this is the only vegetable acid except the Prussic that rises in distillation in combination with water.

How is the concentrated acetic acid, or radical vinegar as it is sometimes called, prepared?

Concentrated *acetic*[a] acid is obtained from acetate of copper, acetate of soda, or acetate of potash, by decomposing either of them by means of sulphuric acid, and then distilling the product.

What are the properties of acetic acid in this state of concentration?

Acetic acid thus prepared is very pungent, acrid and volatile[b], and corrodes animal substances. With various bases it forms the salts called *acetates*[c].

What is OXALIC *acid?*

The oxalic is a peculiar acid found in the juice of sorrel, in combination with potash[d]. Several substances also, and particularly sugar, contain the bases of this acid in a convenient form for conversion into oxalic

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[a] Darracq has shown that acetous and acetic acid both produced the same combinations, and gave the same products in their decompositions. He brought acetous to the state of acetic acid by distilling it several times over muriate of lime, and then could form as good ether with it as with acetic acid obtained from acetate of copper. *Annales de Chimie*, tome xxvii

[b] This acid evaporates entirely when exposed to the air; and when heated with free access of atmospheric air, it takes fire so readily that one is tempted to suspect the presence of *ether* in it. It dissolves camphor, and, with the addition of essential oils, forms the *aromatic vinegar*

[c] Acetic acid may be advantageously employed to separate manganese from iron. When both metals are dissolved in this acid, and the solution evaporated to dryness, the acid adheres to the manganese, but abandons the iron. Water will then dissolve the acetate of manganese from the oxide of iron. Two or three evaporations and solutions are sufficient to deprive acetate of manganese of the whole of its iron.

[d] Sal-acetosellæ, or the salt of sorrel of commerce, has usually been imported from Switzerland and the neighbouring countries, where it is prepared in large quantities from the juice of sorrel. According to Savary, one hundred pounds of the plant afford five ounces of the crystallized salt.

Deyeux has found a considerable quantity of this acid in chick-peas It was discovered by its action on the shoes of some persons who frequently walked over a field of this pea. There is reason to believe that by a chemical examination of other plants from which acid liquids sponacid by combining it with oxygen; and hence it has also been called the acid of sugar. It crystallizes in four-sided prisms, has a very acid taste, and is soluble in water. It is composed of oxygen, hydrogen, and carbon[e].

What are the uses of oxalic acid?

Oxalic acid is of service in detecting the presence of lime in solution[f]. It is also become an article of great consumption with the calico-printers, both in the state of crystallized oxalic acid, and in that of superoxalate of potash[g]. In combination with earths, alkalies, and metallic oxides, it forms the salts called *oxalates*[h].

What is TARTARIC *acid?*

Tartaric acid is a peculiar acid found in the tartar of commerce[i]. It is capable of crystallization, and

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aneously flow, this acid will be found to exist in greater abundance than has been suspected.

[e] Gay-Lussac and Thenard have determined that oxalic acid is composed of oxygen 70.689, carbon 26.566, and hydrogen 2.745. According to Dr. Thomson (*Phil. Trans.* for 1808), the perfect crystals consist of real acid 77 parts, and water 23, in every 100 parts of the acid.

[f] The oxalic has a greater affinity for lime than any other acid; and as it forms with it an insoluble substance, it is the most proper test for discovering this earth. Thus, if a few drops of the solution of oxalic acid be dropped into a neutral solution of muriate of lime, an abundant precipitate of insoluble oxalate of lime will immediately appear. If there be any excess of muriatic acid or oxalic acid in the solution, the lime will be redissolved.—Hence the superiority of oxalate of ammonia, to simple oxalic acid, as a test.

[g] The calico-printers have attempted to use the acidulous oxalate of potash instead of the citric acid; but it is so insoluble that they find a difficulty in making their solutions of a sufficient strength, and if pure oxalic acid be employed it is apt to leave a stain upon the calico.

[h] The superoxalate of potash attacks iron, zinc, tin, antimony, and lead. It dissolves also the oxides of all the other metals, and forms with them triple salts. It is employed to take out ink-spots from linen, &c., which it does in consequence of its powerful attraction for iron.

[i] Tartar is procured from vessels in which wine has been kept. The tartaric acid appears to be a necessary substance in all wine; for it seems from some late experiments that *must* will not ferment if all the

easily soluble in water. It is used by calico-printer to discharge false prints. The salts formed with it ar called *tartrates*.

What is CITRIC *acid?*

Citric acid is found in the juice of lemons and several other fruits[a]. It crystallizes in beautiful rhomboidal prisms, is extremely acid to the taste, and ver soluble in water. It is used in various ways for domestic purposes, for medicine[b], and in the arts[c]. Th salts formed with it are called *citrates*.

What is MALIC *acid?*

Malic acid is obtained from the juice of apples, i which it exists ready formed[d]. It is a very acid, red

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tartaric acid be taken from it. See Dr. MacCulloch's Essay on the ar of making wine, in the *Memoirs of the Caledonian Horticultural Societ* vol. ii. page 134.

Scheele was the first chemist who obtained this acid in a separate state Tartaric acid consists of 24.050 of carbon, 69.321 of oxygen, and 6.62 of hydrogen. In crystals it contains 11¼ per cent. of water.

All the vegetable acids seem to be formed from the same radicals, vi carbon and hydrogen, and perhaps in some there is also nitrogen: th different proportions of these, as well as of the oxygen, constitute th whole varieties.

[a] Scheele was the first person who obtained citric acid from the juic of lemons in a state of purity. When crystallized it suffers no alteratio from exposure to the air, though it is said to change after some time whe dissolved in water. This acid may be kept ready mixed with either of th dry carbonates of potash or soda; and as no effervescence ensues till th mixed powder is put into water, we have a ready mode of making a pleasant saline draught.

[b] Within these few years an important use has been made of this aci in medicine. It is said that the largest dose of opium may be checked i its narcotic effects, if a proper quantity of citric acid be taken with it and that with this adjunct it induces cheerfulness instead of stupefactio succeeded by gentle and refreshing sleep. Dr. Willich's *Lectures on Di and Regimen*, page 339.

[c] This elegant acid is very useful to our manufacturers on account c its solubility. One ounce of cold water will dissolve 1¼ oz. of it, and boiling water will dissolve double its weight. For the method of procurin it in crystals I beg leave to refer to my treatise on Citric Acid, in th *Chemical Essays*, vol. iii. Essay viii. page 11—48. According to Berzeliu citric acid consists of carbon 41.37, oxygen 54.83, and hydrogen 3.80 The perfect crystals contain 79 per cent. of real acid and 21 of water.

lish-coloured liquid, composed, like the other vegeta- le acids[e], of oxygen, hydrogen, and carbon. It is in- apable of crystallization, and has not yet been brought to any use except as a chemical test[f]. Its salts are alled *malates*.

What is LACTIC *acid?*

Lactic acid is prepared by a peculiar process from ilk after the curd has been separated. It is an acid f a yellow colour, incapable of crystallization, and has ot hitherto come into use. The salts formed with are called *lactates*[g]. The earthy and alkaline lac- tes are all deliquescent salts.

What is GALLIC[h] *acid?*

Gallic acid is found in the galls of commerce, and

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[d] The malic acid is found not only in apples, but in strawberries and her summer fruits. It was discovered by Scheele in the year 1785, who s given the following directions for preparing it. The juice of apples to be saturated with potash, and a solution of acetate of lead added til no further precipitation is perceived. The precipitate is then to be shed repeatedly in water, and diluted sulphuric acid poured upon it til the liquor acquires an acid taste without any of that sweetness which at first perceptible from the mixture of the solution of lead. If the lphate of lead which has precipitated be then separated by filtration, e remaining liquor will be pure malic acid, which may be concentrated the evaporation of the superfluous water until a thick liquor be ob- ined of a deep red colour.

[e] Malic acid by the addition of nitric acid may be converted into oxalic id.

[f] Malic acid is of use in the analysis of earths for separating alumina om magnesia, as it forms with the former an insoluble salt, which pre- pitates, leaving malate of magnesia in solution. It has also the pro- erty of decomposing muriate of gold, and will precipitate silver, mer- ry, and some other metals from their solutions in nitric acid.

[g] Fourcroy and Vauquelin have asserted, that the acid which is deve- ped in milk is nothing but acetic acid modified by some animal sub- ances and some salts which it holds in solution.—*Phil. Mag.* vol. xxii. ge 176. But Berzelius has since shown that the lactic is really a pe- liar acid, and that it may be detected in all the animal fluids. See homson's *Annals*, vol. ii. page 201, and the *Philosophical Magazine*, l. xli. page 241.

[h] Gallic acid is soluble in 10 parts of cold water, and in 3 of boiling ater. It is not altered by exposure to the air, but is decomposable by eat.

in most astringent vegetable substances[a]. It is ol tained in thin transparent plates, and in minut needle-shaped crystals, of an acid austere taste[b]. has the property of precipitating iron, from its sol tion in acids, of a black colour[c]. Its salts are calle *gallates*.

What is MUCOUS *acid?*

Mucous, or saccholactic, acid, as it has been calle is obtained by nitric acid from gum arabic and oth mucilaginous substances. It is in the form of a whi

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[a] Gallic acid exists in galls, in oak bark, and other vegetables, ind pendent of the astringent principle. It has been found that the proper of giving a black colour to the solutions of iron is owing to this acid, a not to the astringent principle as was formerly supposed. A short pr cess for procuring gallic acid in a separate state may be seen in Crel *Chemical Annals* for the year 1787. It was Seguin who proved that t gallic acid and the astringent principle are different substances.

A German apothecary, named Tromer, says that the excrescences the roots of young oaks may be used with advantage as a substitute f galls. I believe oak saw-dust has sometimes been used in this countr instead of galls, to produce a black dye.

[b] To procure gallic acid, prepare a strong aqueous infusion of nutgall and lay it aside where it can remain a considerable time undisturbed a exposed to the air in an open vessel. At length the fluid will becom covered with mould, and when this happens the mouldy part is to removed, when small yellow crystals will be found attached to the sid of the vessel. These are the gallic acid, and the crystals are to be pu fied by dissolving them in alcohol and evaporating the clear alcoholic s lution to dryness.

For the method of analysing astringent vegetable substances, consu Sir H. Davy's paper in the *Phil. Trans.* for 1803.

Every substance, an infusion of which precipitates gelatine from solution, possesses a tanning property. Its presence may be detect thus: Add a few drops of the solution of common glue to a wine-gla full of an infusion of the substance to be examined. If tannin be prese the liquor will become turbid, and a whitish substance will precipitat which is a true powder of leather. A table of the quantity of tan co tained in twenty different kinds of bark, showing the comparative val of each to the tanner, may be found in the *Philosophical Transactions* f 1799, drawn up by Mr. Biggin from actual experiments.

Tan has *lately* been employed with success in purifying the comm fish and vegetable oils. If any of these oils be boiled with tan, the t will combine with the substance that occasions their colour and smel and this latter being thus rendered *insoluble*, will precipitate.

The gallic acid may be entirely freed from the tanning principle ritty powder, with a slightly acid taste. Its salts are alled *mucites*[d].

What is BENZOIC *acid?*

Benzoic acid is prepared from a vegetable resin alled benzoin[e]. It is a light whitish powder, with a eculiar and aromatic odour. Its taste is acrid and itter. It is unalterable in the air, insoluble in cold ut soluble in boiling water[f]. It is used in medicine nder the name of flowers of benjamin[g]. Its salts are alled *benzoates*.

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eans of muriate of tin. The tan will unite with the muriate of tin, nd form with it an insoluble precipitate. There is reason to believe that n is the source of the astringent principle in all astringent vegetables.

[c] Gallic acid will not immediately give a black colour to green sul- hate of iron in dyeing black, or in making ink. Exposure for some me to atmospheric air is necessary, in order that the iron may thereby quire a further dose of oxygen. A few drops of oxygenized muriatic cid will instantly produce the effect.

[d] Mucous acid was discovered by Scheele in the year 1780: it is formed pouring two parts of nitric acid on one part of gum arabic, in a glass tort; and when the nitrous acid gas and the carbonic acid have been iven off by heat, suffering the remaining mixture to cool. A white ugh powder will at length gradually subside, which is to be separated om the fluid by filtration, and repeatedly washed in cold water. This the saccholactic or mucous acid.

[e] Benzoin is a resin procured from a tree which grows in the island of matra. The acid procured from this resin has been known for 200 ars. It is obtained from benzoin, in the form of flowers, by subli- ation.

This acid is found also in balsam of Tolu, Peruvian balsam, liquid orax, and other similar substances. It has been likewise discovered in e urine of children, and of graminivorous animals; in blood, and in me of the species of fungi.

Vauquelin advises the collection of the urines of cattle, as proper for rnishing economically the benzoic acid. He recommends the decomposition of it by the muriatic acid.

[f] Benzoic acid may be procured by boiling the resin with carbonate soda, and adding to the filtered decoction diluted sulphuric acid so ng as it produces any precipitation. The precipitate which forms, the benzoic acid. It is composed of carbon 74.41, oxygen 20.43, ydrogen 5.16.

[g] The best flowers of benzoin are of a brilliant white, entirely soluble alcohol, and likewise, though more sparingly, in boiling water, and ave no ashes when evaporated by heat.

What is SUCCINIC *acid?*

Succinic acid is prepared from amber[a]. It takes the form of shining white crystals, of a slight acid taste. It sublimes in a great heat[b]. It is soluble in hot, but dissolves in small quantities in cold water. It is useful as a re-agent[c], but of no use in the arts. Its salts are called *succinates*.

What is CAMPHORIC *acid?*

Camphoric acid is prepared from camphor by means of nitric acid[d]. It is in very white crystals, which have a slightly acid, bitter taste, and a smell like saffron. It is very slightly soluble, requiring 100 times its weight of cold water to dissolve it. In boiling water it is much more readily soluble, and will dissolve in any quantity in boiling alcohol. With salifiable bases it forms *camphorates*.

What is SUBERIC *acid?*

Suberic acid is not a native production, but is formed

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[a] Amber is a transparent combustible substance, dug out of the earth, or found upon the sea coast. It manifests electricity by friction, and was much admired by the ancients as an ornament of dress. The amber-pits of Prussia are said to afford the king a revenue of 26,000 dollars annually.

[b] Succinic acid may be obtained thus: Fill a retort half way with equal parts of powdered amber and dry sand; lute on a receiver, and distil in a sand-bath with a gentle heat. The succinic acid will attach itself to the neck of the retort. It is generally coloured by a portion of oil which comes over in distillation; but it may be purified by pouring nitrous acid upon it, and then expelling the nitrous acid by a heat not sufficient to drive off the succinic acid.

[c] When combined with ammonia this acid becomes a valuable re-agent, by the property of separating iron from its solutions, and not operating upon other metals. Thus, if a little of this succinate of ammonia be added to a solution of sulphate of iron, a succinate of the metal will be precipitated. It may be calculated that every 100 grains of the precipitate contain 68 grains of iron.

[d] Camphor is a white crystalline substance of a very strong taste and smell, obtained in the East from a species of laurel. La Grange's dif-

om cork, by means of nitric acid[e]. Its taste is acid; is generally seen in the state of powder, and is not ystallizable. Boiling water dissolves half its weight, it it is very insoluble in cold water. Its salts are lled *suberates*.

What is LACCIC *acid?*

Laccic acid is procured from a substance called *hite lac*[f]. It is a reddish fluid which has a bitter ltish taste, but not at all sour[g]. It crystallizes in edle-like crystals, and when dissolved in lime-water sumes a green colour.

What is PRUSSIC *acid?*

The prussic is a peculiar acid, composed of hydrogen, trogen, and carbon. It is a colourless liquid like ater, has a sweet taste, and does not alter the colour vegetable blues. It is of great use to chemists for tecting metals in solution[h]. It is prepared from ood and other animal substances[i]; and when united

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ent processes for preparing this acid were translated by the late Mr. cholson, and published in vol. ii. of his 4to *Journal*, pages 101 and 157.

[e] This acid was discovered by Brugnatelli in the year 1787. He gave he name of suberic acid from *suber*, the Latin name of the cork-tree. is chemist has lately noticed that suberic acid in considerable quanti- may be obtained from paper, by treating it with nitric acid. Neither acid nor any of its compounds have ever been of any use in the arts.

[f] White lac is a peculiar substance distinct from the shell lac and stick of commerce, and is brought from the East Indies. This substance, ich has a resemblance to bees'-wax, is secreted by an opaque and igh insect, of a gray colour.

[g] Laccic acid was discovered by Dr. Pearson. It is generally in a fluid te. Its specific gravity at 60° is 1.025, and when heated it has the ell of newly baked bread. For a more detailed account of the proper- of this acid I must refer the reader to Dr. Pearson's Memoir in the *ilosophical Transactions* for 1794, part ii.

[h] The colour of the precipitate indicates what metal, and its quantity bles us to ascertain the proportion of such metal contained in the so- ion to be examined. For this purpose the acid must previously be com- ed with an alkali or an earth. Prussiate of potash is generally used.

[i] A method of obtaining prussic acid in a state of absolute purity has

with iron, forms that beautiful colouring substanc called prussian blue[a].

What is SEBACIC *acid?*

Sebacic acid is procured from animal fat or tallow It is in the form of a liquid, has an acid, sharp, bitterish taste[b]; and when mixed with nitric acid wil dissolve gold. It combines with alkalies, earths, an metallic oxides, and forms the salts called *sebates*.

What is URIC *acid?*

The uric or lithic acid is found in human urine Some of the human calculi[d] are composed entirely o this acid. When pure it has neither taste nor smell but it reddens vegetable blues, and combines wit alkalies and earths. It is a composition of carbon nitrogen, hydrogen, and oxygen.

What is the AMNIOTIC *acid?*

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lately been announced: it is merely by distilling a mixture of two par of prussian blue, one of sulphuric acid, and one of water.

There is great reason for believing that prussic acid does not contai oxygen. The grounds on which this supposition is founded may be see in Berthollet's *Chemical Statics*, vol. ii. page 222.

[a] Prussian blue was discovered by accident in the year 1709; but was not till the year 1775 that Bergman ascertained that this colourin matter was a peculiar acid. Scheele, however, was the first who e plained its nature and composition, in the year 1782, announcing th he had formed it without animal matters, and that it is a compound ammonia and charcoal. Later experiments of Berthollet show that th acid does not contain ammonia ready formed, but that it is a compou of carbon, hydrogen, and nitrogen.

The process to prepare prussian blue may be seen in Neumann's *Ch mistry*, vol. i. page 106; in Shaw's *Lectures on the Arts*, 8vo. page 18 or in Bouillon La Grange's *Manual of Chemistry*, vol. ii. page 354. Th *Journal de Physique* for the year 1778 describes the process as it is co ducted in the manufactories of Germany.

[b] Sebacic acid crystallizes in needles, and when heated liquefies li tallow. For further information consult Nicholson's *Journal*, vol. 8vo. page 34; and Thenard's memoir in *Annales de Chimie*, tome xxxi page 193.

[c] If urine voided in the morning after sleep be preserved, the liqu will in a few hours present a light cloud, which occupies the upper pa of the vessel; this cloud, gradually augmenting in quantity, subside

Amniotic acid is obtained from the liquor of the mnios of the cow. It is slightly acid; it reddens the ncture of turnsole; and may be obtained in brilliant hite crystals[e]. It is scarcely soluble in cold water, ough very readily in hot water. It is incapable of ecomposing the alkaline carbonates, but unites with e pure alkalies, and with them forms neutral salts.

How many different distinct acids are there?

The number of the acids that are well known nounts to about thirty; besides which, a variety of bstances have been announced as new acids by some the foreign chemists, that require to be further amined before they be finally admitted into this ass of bodies.

What are the USES *of these various acids?*

The uses[f] of the acids are so many and important,

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becomes a sediment of small red crystals, with brilliant facets; this *ric acid.*

itric acid is a test for discovering uric acid. If a little uric acid be ed in a watch-glass over a lamp, the smallest quantity of nitric acid can possibly be conveyed upon it will instantly convert it to a very iant crimson. Uric acid dissolved in nitric acid stains the skin of a colour.

Those troublesome concretions called chalk-stones, which form upon joints of gouty persons, are for the most part composed of uric acid soda.

The amniotic acid was discovered by Vauquelin and his coadjutor iva. It dissolves readily in hot water, and but slowly and sparingly old. In order to obtain it, nothing more is necessary than to evapo- the liquor of the amnios of the cow to one fourth, and leave the re- nder to cool, which will be found to contain the acid in crystals.

ne MELLITIC and the COLUMBIC acids I have omitted to describe, use the minerals from which they are procured are so rare, that few nists will ever be likely to obtain even a specimen of them.

he acids are such powerful agents in a variety of chemical changes h take place in nature and in the arts, that it is of the utmost im- nce to acquire a knowledge of the modes in which they operate. t be recollected then, that there are two ways in which the acids uce changes in the substances with which they are brought into act. In some cases they effect an union with these substances, and me a part of the new compound, without having themselves under-that it is impossible to enumerate them. They are indispensable to various arts[a] and manufactures[b]; they are employed for culinary purposes[c], and for medicine[d]: they act an important part in the great elaboratory of nature,—they produce that numerous class of bodies called salts, and form a great proportion of many of the rocky and mountainous districts of th globe we inhabit.

Do you recollect any instances of acids entering into the composition of rocks and mountains?

The vast masses of limestone, chalk, and marble which are found in every part of the world, are combinations of lime and carbonic acid[e]: the mountain

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gone any decomposition. In others they become partially decomposed by affording a part of their oxygen to the bodies on which they operate The formation of salt-petre or nitre by the addition of nitric acid to potash is an instance of the first of these cases, and the action of the sam acid on iron will exemplify the latter.

[a] Sulphuric acid, in a diluted state, is used by the tanner in the operation called scouring; also by the dyer, in a concentrated state, for dissolving indigo. It is likewise employed by hatters. Silk-dyers use for whitening silks, and for giving them a beautiful lustre. The chemis employs it in the preparation of nitrous and muriatic acid, and as a agent in a variety of processes and decompositions. An account of great variety of other purposes to which sulphuric acid is applied in th arts may be seen in my *Chemical Essays*, vol. ii. page 468.

Nitric acid is used by dyers to make their solutions of tin. Silve refiners employ it in the operation of *parting*. It is also used by gilder brass-founders, calico-printers, colour-makers, &c.

Muriatic acid is employed in dyeing, calico-printing, and colour making The oxymuriatic acid, in bleaching, and sometimes in medicine.

[b] The acetic, oxalic, tartaric, citric, gallic, and prussic acids are all them employed in the different manufactures of the country.

[c] The acetic, the tartaric, and the citric acids are used for culinar purposes. According to some experiments of Dr. Macbride, it appea that all the mineral acids in a diluted state might be employed with gre advantage in preserving meat. Muriatic acid drawn in glass, would, believe, in a state of great dilution, be a pleasant and wholesome cond ment for our food. It was formerly used in this way. The celebrate Rudolph Glauber, who was the first to turn the residuum which is le after the distillation of this acid to a good account, describes the sever ways in which it was used in the kitchen in his time, page 12 of h *Treatise on Philosophical Furnaces*. That this acid possesses valuab

›f gypsum in the vicinity of Paris and elsewhere are ombinations of lime and the sulphuric acid[f]. The luor spar of Derbyshire is composed of lime and the luoric acid[g]; and there are masses of common salt, oth in the eastern and western hemisphere, which ontain such immense quantities of muriatic acid[h] as vould render every attempt to calculate the amount bortive.

Are you sure that the acids which Nature has mployed in the formation of mountains are of the ame kind as those which come under our common otice and observation?

Yes: any of these native mineral substances may

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ntiseptic qualities there can be no doubt. Sir William Fordyce gives account of a dry-salter who acquired a large fortune, from possessing secret, that had enabled him to send out to the Indies provisions in a tter state of preservation, than any others of the trade. His whole se-et was that of putting a small quantity of muriatic acid into each cask.

[d] Parliament voted a reward of 5000*l.* to Dr. Carmichael Smyth, for s discovery that nitrous acid, applied in the state of vapour, effectually stroys contagion, especially typhus, jail, yellow, and such like fevers. e Dr. Smyth on *The Effect of Nitrous Vapour*, 8vo. 1799.

[e] Limestone, chalk, and marble, are composed of about 44 parts car-ic acid, and 56 parts lime. Some observations by the Rev. W. ckland upon those beds of chalk which contain flints, tending to illus-te the history of their formation, will be found in the *Trans. Geol.* c. vol. iv. page 413.

Gypsum is composed of 41½ parts of lime, and 58½ of dry sulphu- acid. For Crystallized Gypsum, see page 116.

Dr. Thomson analysed a specimen of fluor spar from Northumber-d, and found it to consist of lime 67.34, and fluoric acid 32.66. eele analysed another variety of this fossil, and pronounced it to be nposed of 57 parts lime, 16 fluoric acid, and 27 water.

Common salt when in a state of purity is composed of 53½ parts soda 46½ of dry muriatic acid; but the salt of commerce is always impure. ery interesting and valuable paper by Dr. Henry, entitled 'An Analy-of several Varieties of British and Foreign Salt,' was read before the al Society in the year 1810. This memoir contains a succinct account, uced from actual experiments, of the real proportions of the earthy riates and earthy sulphates which usually occur in the different va-ies of common salt; and from this examination it appears that the shire salt is of much greater purity than any of the several kinds ch are imported from France and elsewhere. See the *Philosophical nsactions* for 1810, p. 1.

be decomposed, and their acids exhibited in a separate state for experiment or use[a].

Do you know of any other natural productions which contain considerable quantities of any of th acids you have described?

The large masses of celestine[b] and of ponderou spar[c] in different parts of the earth contain an incalculable quantity of the sulphuric acid; the cryolite[d] of Greenland is a compound of alumina, soda, an the fluoric acid; and several of the valuable minerals[e] together with some of the precious stones, are combinations of the different earths with the chromic o the phosphoric acids[f]; not to mention the annua

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[a] If the pupil be directed to pour a little diluted sulphuric acid upo some pieces of marble, the carbonic acid will be disengaged, and becom evident to the senses. In like manner he may disengage the fluoric aci from the fluor spar, the muriatic acid from rock-salt, and other acids fro those minerals in which they are found native. A few experiments of th kind will serve to show him how abundantly the mineral acids occur i nature.

[b] Celestine, which occurs in such large quantities in the neighbou hood of Bristol, is composed of about 57 per cent. of strontites and 4 per cent. of sulphuric acid.

[c] Ponderous spar, which is found plentifully in Staffordshire, Derb shire, &c. and there called *cawk*, is a compound of 67 per cent. of baryt and 33 of sulphuric acid. The granular kind consists of 90 per cent. sulphate of barytes and 10 of silica.

[d] The *cryolite*, which is a very rare mineral, found only in a drea and remote region of West Greenland, is, according to Vauquelin, co posed of 21 per cent. of alumina, 32 of soda, and 47 of fluoric acid.

[e] Some account of the minerals which are formed with the phospho and the chromic acids will be found in notes upon those acids in pag 161 and 166.

[f] Vauquelin thinks that the emerald owes its colour to the *oxide* chrome, and the ruby to the *acid* of that metal. According to this c mist, the ruby is a combination of the chromic acid, alumina, and ma nesia. *Annales de Chimie*, tome xxv.

[g] "Mr. Baumé, by a series of ingenious experiments, discovered t clays may be produced by the action of the sulphuric acid on vitrif substances. Mr. Ferber applied this fact to the grand operations of N ture on the matters ejected by volcanos: he discovered a fine white arg laceous matter in the hollow part of vitrified lava, evidently produc by the action of the sulphuric acid. Hence it appears that those s

changes which the vegetable kingdom undergoes by the formation and subsequent decomposition of the vegetable acids.

You speak of the formation of acids:—Are bodies of this class formed and decomposed by the common operations of nature?

Many of these bodies are the result of, and formed by the action of vegetable life, such as the malic and citric acids; some are formed principally by chemical changes effected on dead vegetable matter, as for instance the acetic; and others, as the sulphuric, occur in the mineral kingdom[g], and are also formed rtificially, in great abundance.

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tances which have by the action of fire been rendered otherwise intract-ble, again become, by the action of the sulphuric acid, subservient to egetable life."—Parkinson. See also Ferber's *Travels through Italy.*

Some very curious and important observations on the causes of the de-omposition of certain rocks, and on the recent formation of others, will be ound in an ingenious paper by Dr. Paris, published in the 1st vol. of the *rans. of the Royal Geol. Soc. of Cornwall*, page 1—20. There is so much teresting matter in this short memoir, that I have great pleasure in re-ommending it to the perusal of my geological readers.

CHAPTER VIII.

OF SALTS.

What is a salt?

When an acid is combined with an alkali, an earth, or a metallic oxide, it forms what is called *a salt*. Such compounds were formerly called *neutral* salts; but that term is now applied only to those salts in which there is no excess either of acid or of base[a].

How many salts are there?

As the acids are capable of forming various combinations with the different earthy, alkaline, and metallic bases[b], the precise number of the salts is not known[c]. Probably they amount to nearly two thousand[d].

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[a] To give the pupil a clear idea of this class of bodies, it may be advisable to set him to form some of the salts from their component parts. He might, for example, be directed to pour a little sulphuric acid into a solution of soda in water, to evaporate the superfluous water, and then to notice the crystallization of the newly-formed salt; for, if the liquor be allowed to stand for a few hours undisturbed in a cool place, the salt will be seen to shoot into beautiful crystals of sulphate of soda.

[b] It should be recollected that, besides the various salts which are formed artificially in the laboratory of the chemist, there are many mineral bodies belonging to each of these classes which are found native. These will be noticed in their proper places as we proceed.

[c] Fourcroy reckons that there are 134 *species* of salts; but how many distinct salts there are he has not calculated. Having, says he, 32 acids, and 57 bases, it would appear at first sight that there must be 1824 salts: but there are several of the metallic oxides which cannot combine with many of the acids; which is also the case with silica, one of the earths. However, to compensate for this deficiency, there are several acids capable of combining with two bases at once. These are called *triple salts*. Besides these there are super-salts, and sub-salts.

[d] Should a young person express his surprise that the number of one class of bodies should be so great, he may be told that Nature seems to aim at variety in all her productions. Saint Pierre informs us that there

What method has been taken to distinguish the ifferent salts?

Modern chemists have adopted a new nomenclature or this purpose, which is as simple and ingenious as t is useful[e].

How are the salts distinguished by this means?

In this nomenclature every salt has a double name, ne part of which indicates its acid, and the other its ase; so that, in a collection of many hundred differ- nt salts, the composition of each is immediately known y its appellation[f].

Can you explain the manner in which this is ef- ected?

All substances which are compounds of metallic xides, earths, or alkalies with the sulphuric acid, are alled *sulphates;* with the muriatic acid, *muriates;* ith the nitric acid, *nitrates;* with the carbonic acid, *arbonates*, &c. &c.[g]

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e 6000 species of flies, and 760 different butterflies. Ray computed e number of *species* of insects at ten thousand. There are above 1000 fferent species of beetles known to exist in Great Britain only, inde- endent of what are found in various other parts of the world.

[e] This nomenclature was drawn up by a society of French chemists, on after the new theory of chemistry was announced by Lavoisier; the undation of which was already laid by the previous discoveries of Dr. lack, Dr. Priestley, and Mr. Cavendish. See an ingenious volume en- led "*Remarks on Chemical Nomenclature, &c.*" by Richard Chenevix, sq. F.R.S. &c.

[f] Fourcroy has well remarked, that, if this arrangement had not been ade, it would have been absolutely impossible to know the characters the numerous salts which have been discovered, and the science of emistry would then have been confined to the very few men who were pable of extraordinary efforts of memory.

[g] These are the terms generally made use of in chemical language; t sometimes, in order to prevent monotony, we give an adjective ter- ination to the word which expresses the base of the acid. Thus we y calcareous salts, instead of salt of lime; ammoniacal salts, instead salts of ammonia; aluminous salt, instead of salt of alumina; and with e same design, the terms barytic, magnesian, and the like are used.

Do the advantages which we derive from this nomenclature compensate for the inconvenience of changing the names of so many substances?

The new nomenclature, by its scientific classification of bodies, gives such a facility to the acquisition of chemical knowledge, that this alone would have been sufficient to have justified chemists in adopting it; but its contrivance for pointing out the *nature* of the substances bearing the new names, gives it advantages far surpassing every inconvenience attending the alteration[a].

Describe the nature of some of these advantages.

In conformity with this plan the saline compound, formerly called *Glauber's* salt, is now called sulphate of soda, because it is a combination of sulphuric acid and soda[b]; what was called *gypsum*, or plaster of Paris, a compound of lime and sulphuric acid, is now called sulphate of lime; in like manner, what was called *green copperas* is now sulphate of iron, that substance being a compound, not of copper, as the old name seemed to import, but of *iron* and sulphuric acid[c].

Have the framers of this nomenclature been equally

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[a] As the boundaries of chemical science have been extended, the number of known salts has been surprisingly increased; so much so, that it would have been impossible to recollect the nature of each, without the assistance of a nomenclature of this kind. Thirty years ago not more than 20 or 30 species were known: since then more than 100 new species, comprising upwards of a thousand distinct salts, have been added to the list.

[b] It is necessary to remark, that when an acid is combined with *two* bases, the names of both are subjoined to that of the acid. Thus we say sulphate of alumina and potash, and tartrate of potash and soda.

[c] It would be easy to make out a long list of substances with names equally improper with those noted above, and which have characteristic and appropriate names now assigned them in the new nomenclature.

[d] I would advise those who may be desirous of learning this nomen-

happy in the choice of names for the salts which are composed with the other acids?

Yes: the principle upon which the nomenclature is formed is such, that the composition of every salt is designated by an appropriate name with the utmost perspicuity[d].

According to the new nomenclature, what is the common culinary salt called?

Common salt is called *muriate of soda*[e]; that is, a composition formed of soda and muriatic acid.

What do you call salt-petre?

Salt-petre is called *nitrate of potash;* it being composed of potash and nitric acid.

What is chalk now called?

Chalk, being a compound of lime and carbonic acid, s called *carbonate of lime*[f].

You have said that these bodies were formerly called neutral salts,—why is not that term now applied as before?

Because no salt can strictly be called *neutral*, except such in which the acid is completely neutralized y the base, and the base by the acid, so as to be mutually saturated by each other[g].

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ature to form some of the salts from their component parts, as directed the first note of this chapter; to register the proportions of the mate- als employed; and to lay them up, with labels of their proper chemical ames affixed to them. This will infallibly imprint the connexion between e nature of these salts and their modern names, upon the mind; and e practice should be continued till the pupil has a clear idea of the inciple on which the whole nomenclature is founded.

[e] Formerly the word SALT was confined to muriate of soda. No other bstance was then known as a salt. Afterwards, the acids and alkalies ere called salts also. There are innumerable proofs of this in the old emical writings.

[f] The calcareous crystals, the marbles, and the common lime-stones, e also all called carbonates of lime.

[g] The propriety of restricting the use of the term *neutral* will appear,

Is not that the case with all saline compounds?

No: some have an excess of acid, as cream of tartar and most of the metallic salts; others have an excess of base, as common borax.

How are such salts distinguished?

When a salt is found to contain an excess of acid, the preposition SUPER is generally prefixed to its name[a]; but when it does not contain a sufficiency of acid to saturate the base, the preposition SUB is added: thus we say super-tartrate of potash, and sub-borate of soda[b].

Some salts are formed with acids not fully oxygenized, as the sulphurous and phosphorous acids: how are such salts distinguished?

All salts that are composed with acids ending in *ous*,

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if we consider that we have some bases that combine with more than one dose of acid, and thereby form salts which differ in their appearance and properties. Thus we have *sulphate* of potash, and *super*-sulphate of potash. The one is a neutral salt, the other a salt with excess of acid. These salts are however now called sulphate of potash, and bi-sulphate of potash. These are more appropriate terms, because 100 parts of potash combine with 82 parts of sulphuric acid to form the sulphate; and with twice that quantity or 164 of acid to compose the bi-sulphate. In like manner we now speak of carbonates and bi-carbonates, and of oxalates and binoxalates.

[a] Many of these super-salts may be discovered by carbonate of magnesia: for, if an acid be present in the solution, an effervescence will take place on the addition of the magnesian carbonate.

[b] We are indebted to Dr. Pearson for this mode of distinguishing these salts. Before his method was adopted, the former of these salts was called tartrate of potash with excess of acid, or acidulous tartrate of potash; and the latter, borate of soda with excess of base.

[c] When sulphur is fully saturated with oxygen, it forms what is called sulphuric acid, and the salts composed with this acid are called sulphates. But when sulphur is partially oxygenized, an acid is produced called sulphurous acid, and the salts formed with it are called sulphites.

The new nomenclature enables us to distinguish between acids which are partially oxygenized, and those which contain a maximum of oxygen. This is of great importance, because the properties of the salts formed with these acids vary as much as the acids themselves. The salts formed with acids ending in *ic* are generally permanent; whereas salts formed with the same bases combined with acids ending in *ous* are seldom per-ake an ending in *ite*, instead of *ate*; as *sulphite* of me, or *phosphite* of potash[c].

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Having shown the nature of the present chemical omenclature as far as respects the salts, it will now necessary to enter on the consideration of each enus separately:—Therefore, What are the generic aracters of the SULPHATES*?*

The sulphates[d] have generally a bitter taste; are alays decomposed by the agency of a solution of barytes; d most of them afford sulphurets when heated red ot with charcoal[e].

Can you enumerate a few of the principal sulphuric lts?

Among the first of them are: sulphate of barytes[f],

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nent, but by exposure to the air attract oxygen, and are changed into ts of the former kind.

[d] The quantity of sulphuric acid contained in any of the sulphuric salts y be known by means of barytes. For, if any of the solutions of this rth be added to a solution containing sulphuric acid, sulphate of barytes ll instantly be formed and precipitated, and every 100 grains of the cipitate, if weighed after it has been intensely ignited, will indicate grains of dry sulphuric acid, or 42 of oil of vitriol.

[e] When a sulphate has been converted to a sulphuret by being burnt h charcoal, the sulphuret may be decomposed, and the sulphur preitated by the addition of pyroligneous acid. For some remarks on the erent methods of decomposing the *alkaline* sulphates in a large way sult *Encyclopædia Britannica*, Chemical Index, article 'Vitriolated rtar,' or my *Chemical Essays*, vol. i. page 373, and vol. ii. page 245. To analyse the *earthy* sulphates, proceed thus. First heat them to iteness, in a crucible, in order to find the quantity of water which they ntain; then boil them in a solution of carbonate of potash, which will casion their decomposition. A common Florence oil flask is sufficient this purpose. It may be ascertained when the solution has been fficiently boiled, by taking a little of the earth from the bottom of the sk, and trying it with muriatic acid. If the muriatic acid dissolves entirely, the decomposition is complete; but if this should not be the e, boil the undissolved portion with an additional quantity of carbonate potash, which will decompose the remainder.

[f] Sulphate of barytes, or *ponderous spar* as it has been called, is abunnt in different parts of the earth. Sulphate of strontites is found near istol and elsewhere in abundance. Sulphate of potash, sulphate of

sulphate of strontites, sulphate of potash, sulphate of soda[a], sulphate of lime[b], sulphate of magnesia[c], sulphate of ammonia, and sulphate of alumina and potash, commonly called alum[d]. Besides these, sulphates of the earths, glucina, zirconia, and yttria have been formed, and their properties ascertained, but neither of them has been found useful.

What are the generic characteristics of the SULPHITES?

The sulphites have always a disagreeable sulphurous taste and smell; they are decomposed or changed by the nitric, muriatic, and some other acids which do not affect *sulphates*; if exposed to fire they yield sulphur, and become sulphates: and even by mere exposure to the action of the atmosphere[e], if moistened with water,

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soda, and sulphate of ammonia are prepared by chemical manufacturers in many of their processes. Sulphate of lime, sulphate of magnesia, and sulphate of alumina are native productions. Sulphate of ammonia has also been found native in the neighbourhood of volcanoes, and sometimes occurs among the lavas of Ætna and Vesuvius. This native production is known to mineralogists by the name of *mascagnine.*

[a] Crystallized sulphate of soda is composed of about 19¼ per cent. of soda, 24¾ sulphuric acid, and 56 water. The fused salt is a compound of 44 soda and 56 sulphuric acid.

[b] Sulphate of lime is procured in Staffordshire, Derbyshire, and other counties of England. The hills around Paris contain large quantities of this earthy salt. Hence its name *Plaster of Paris.* When burnt and ground it is miscible with water, for which it has so great an affinity that it becomes solid almost immediately. This property renders it an excellent substance for forming busts, cornices, &c., which are very durable, if protected from the weather, and not exposed in damp situations. In America this substance has been long used as a manure; it is coming into use in this way also in some districts in England. The Count de Bournon has published a memoir on the properties of this valuable natural production in the *Trans. of the Geol. Soc.* vol. i. page 355.

[c] Sulphate of magnesia is a compound of 33 magnesia and 67 sulphuric acid. It occurs native in the quicksilver mines of Idria, and on the surface of the soil in some districts of Spain. A native combination of sulphate of magnesia and sulphate of soda is found in a crystallized state at Sedlitz. It is placed in cabinets under the name of *reussite.*

[d] Alum is prepared near Glasgow, by Messrs. Mackintosh and Co., at a much less expense than it can be made at Whitby, as it is there found

they absorb oxygen, and are converted into sulphates. These salts when pure are not decomposable by a solution of barytes, as is the case with the sulphates.

Can you enumerate some of the sulphurous salts?

The principal are: the sulphites of barytes, of lime, of potash[f], of soda, of ammonia, of magnesia, and of alumina.

What are the generic characteristics of the MURIATES?

The muriates, when acted upon by concentrated sulphuric acid, yield muriatic acid in the visible form of vapour. They are among the most volatile, and yet are the least decomposable by fire, of all the salts; not being perceptibly altered by combustibles, even when assisted by an intense heat[g]. They are soluble in water,

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ready formed in a state of silky efflorescence, and only requires to be dissolved and crystallized for sale; potash, or a salt of that alkali, having been previously added to the solution. It seems that a large quantity of aluminous schist was laid bare by the working of a coal-pit, at least 200 years ago; and that the action of the atmosphere during this period has completely acidified it. Whenever this is consumed, the work must be discontinued, on account of its inland situation; for, as every 100 tons of alum slate afford more than 90 tons of refuse, any work in the interior of the country would soon be blocked up by it. At Whtiby this refuse is thrown into the sea, as it occurs.

Vauquelin distinguishes seven different kinds of sulphate of alumina. It was he who first proved that soda is of no use in the formation of alum. He afterwards showed, that if a few drops of solution of potash, or of sulphate of potash, be added to an uncrystallizable solution of sulphate of alumina, the crystallization will immediately commence. See *Annales de Chimie*, tome xxii.

[e] See a memoir on these salts by Fourcroy and Vauquelin, in tome xxiii. *Annales de Chimie*.

[f] The *sulphites* were first pointed out by Stahl. Sulphite of potash was the first of these salts that he examined. From this circumstance it acquired the name of sulphureous salt of Stahl. These salts are mostly formed artificially, by saturating the alkaline and earthy bases with sulphurous acid.

[g] This is an evident and at the same time a most remarkable character of this species of salt. Muriate of soda may be volatilized by heat, but if the vapour be collected it will be found still to be muriate of soda. Some years ago I exposed several hundred weights of this salt to a most

and are often dissolved in it for the purpose of raising the boiling point of that fluid[a]. They evolve chlorine gas when treated with nitric acid.

Can you enumerate the chief of the muriatic salts?

The principal salts in the muriatic class are: the muriates of barytes, of potash, of soda[b], of strontites, of lime, of magnesia[c], of ammonia, and the muriate of alumina.

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intense heat in a reverberatory furnace for 48 hours, with a view to decompose it; but when it was removed from the furnace there was no change; it remained muriate of soda. Another portion was kept in a state of fusion for 36 hours with a considerable quantity of carbonaceous matter, but no decomposition was effected.

[a] According to my experiments, if water be saturated with muriate of soda its boiling point will be thereby raised 12°, that is, such a solution will not boil until it acquires the temperature of 224° of Fahrenheit.

[b] The most important salt in this class is muriate of soda, which consists of 46.5 of dry muriatic acid and 53.5 of soda. According to the new theory, however, this salt must be considered to be a true muriate of soda only while it remains in an aqueous solution; for when it is reduced to dryness the muriatic acid and the soda become both decomposed, and the hydrogen of the muriatic acid uniting with the oxygen of the soda, they both pass off in the form of water, while the chlorine of the muriatic acid unites with the metallic base of the soda to form chloride of sodium, which is the true character of our common salt when in a dry state.

Muriate of soda is of great use to the animal creation; horses are very fond of it; and cows give more milk when supplied with it. Dr. Mitchill relates, that in the back settlements of America, wherever this salt abounds, thither the wild beasts of the forests assemble to regale themselves; and that some of these places are so much frequented, that the ground is trodden to mud by them. The natives call these spots *licks*, or licking-places. In some parts of Africa, large herds of cattle travel from great distances at stated seasons, to enjoy the marine plants which grow on the coast and are saturated with sea-salt. The fattening property of our own salt-marshes is well known to graziers and farmers.

Whenever the finances of this country are in a state to allow the duty to be withdrawn, the greatest improvements in agriculture may be expected from the use of sea-salt. Mr. le Goux, in his history of the cocoa-nut-tree, tells us that the inhabitants of those parts of Hindostan and China which border on the sea-coast sprinkle their rice-fields with sea-water, and use no other manure; and that in the interior of these countries they sprinkle the lands with salt before they are tilled; and

What are the generic characteristics of the HYPEROXYMURIATES[d]?

The hyperoxymuriates yield very pure oxygen gas by the action of fire, and are thus converted into common muriates: and the stronger acids expel the hyperoxymuriatic acid from these salts, without the assistance of heat[e]. When mixed with combustibles, they detonate with great violence, by mere friction or percussion, and sometimes spontaneously[f]. They

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that this practice has been followed for ages with the greatest advantage.

In a conversation with the late Mr. Hollinshead, a gentleman who spent many years of a valuable life in making experiments on the employment of salt in agriculture, and in endeavouring to procure an act of parliament to sanction its use, I was informed that from one bushel to six bushels to an acre of pasture land always makes such land more productive; but that a larger quantity would for two or three years afterwards render it actually steril. A considerable collection of facts respecting the use of salt in agriculture and for feeding cattle, will be found in my work, entitled *Thoughts on the Laws relating to Salt.*

[c] Muriate of potash has been found native in the bogs of Picardy. Muriate of ammonia is the common sal-ammoniac of commerce. Muriate of barytes and strontites are both factitious salts. Muriate of lime is found native in various states; it is used for the production of artificial cold. When dissolved in alcohol it burns with a flame of a beautiful red colour, especially if the solution be agitated during the inflammation. Muriate of magnesia is found in mineral and in sea waters. This latter salt is soluble in alcohol. Hence the use of alcohol in analysing sea water.

[d] The hyperoxymuriates were first formed by Berthollet in 1786; but the gas from these salts was discovered by Sir Humphry Davy in *pure state* in January 1811. See his *Elements of Chemical Philosophy,* vol. i. page 238. He calls it *euchlorine.*

[e] Those salts which have been called oxymuriates, Mr. Chenevix very properly named hyperoxymuriates. He was desirous of exhibiting the acid in a separate state: but when he attempted to obtain it from only 00 grains of hyperoxymuriate of potash, the retort burst with a loud report, and was reduced almost to a powder, so that scarcely any fragment of it could be found in the laboratory. Dr. Vandier, who was present, was near losing his sight by the explosion.—*Philosophical Transactions,* vol. xcii. page 126.

The component parts of hyperoxymuriate of potash are, omitting fractions, chlorine 28, oxygen 38, and potassium 34.

[f] Of this salt Fourcroy remarks, that "it seems to include the elements of thunder in its particles. A chemist can produce effects almost

are all soluble in water, and some of them dissolve readily in alcohol.

Can you enumerate the hyperoxymuriates?

The chief are: the hyperoxymuriates of potash[a], of soda, of lime, of magnesia, of barytes, and of strontites.

What are the generic characteristics of the NITRATES?

The nitrates yield oxygen gas mingled with nitro-

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miraculous by its means, and Nature seems to have concentrated all her power of detonation, fulmination, and inflammation in this terrible compound." By *gently* triturating three grains of this salt and one of sulphur in a mortar with a metallic pestle, a series of detonations takes place resembling the cracks of a whip. If struck on an anvil, the report is as loud as a gun. But too great caution cannot be exercised in the use of this salt. Three parts of it with half a part of sulphur and half a part of charcoal produce most dreadful and violent explosions. But the shocking death of two individuals in October 1788, and the burns which others have suffered by it, render it feared by chemists in general. If the aforesaid mixture of this salt be thrown into concentrated sulphuric acid, a flame is developed so strong and brilliant that the eye can with difficulty support it. Fourcroy's *Elements of Chemistry*, vol. iii. page 313. It should be remembered that the mixture must always be made moist, and never kept *ready* mixed, as it is liable to explode spontaneously.

That such a mixture will explode spontaneously, was experienced by a friend of mine, above twenty years ago. He had a phial, containing not more than two drachms of the powder, placed on a shelf with other bottles; and after remaining quiet for many months, it exploded, attended with a tremendous report, and the destruction of most of the bottles near it.—The temperature of the place was uniformly about 65° of Fahrenheit.

[a] Hyperoxymuriate of potash is used not only for experiment, but also in medicine. From its explosive effects, Berthollet was induced to propose it as a substitute for nitre in the manufacture of gunpowder. The attempt was made; but no sooner did the workmen begin to triturate the mixture than it exploded with violence, and proved fatal to two individuals who were near it. *Philosophical Transactions*, vol. xcii. page 128. I have, however, reason to believe that gunpowder made with this salt was afterwards actually used by the French in one of their campaigns. See Additional Notes, No 56.

The other hyperoxymuriates are also prepared by art, and are of little use, except the HYPEROXYMURIATE OF LIME, which is employed in bleaching. This article is generally considered the best that has ever yet been introduced for that purpose; but Sir Humphry Davy recomgen gas by the action of fire; they give out a white vapour of nitric acid when acted on by concentrated sulphuric acid; and, when mixed with combustible substances, produce, at a red heat, inflammation and detonation[b]. They are soluble in water, and capable of crystallization; and when heated with muriatic acid, chlorine is exhaled from that acid in the form of gas.

Can you enumerate some of the nitric salts?

The more noted are: the nitrates of potash[c], of

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nends the hyperoxymuriate of magnesia in preference to it.—See his *Elements of Chemical Philosophy*, page 243.

[b] This may be shown by heating a little nitre in a crucible, and throwng powdered charcoal upon it. Detonation will ensue, and then the harcoal will combine with the oxygen of the nitrous acid, and pass off n the state of carbonic acid gas.

[c] Nitrate of potash (salt-petre) is generated by nature in abundance, particularly in the East: in some districts it appears in an efflorescence n the surface of the soil, from whence, at a certain season of the year, is regularly swept off two or three times a week, and as repeatedly renewed: it appears that nothing is necessary for its production but the presence of lime, animal and vegetable matters, heat, and dry atmosphec air. The atmosphere furnishes the acid; but how the potash occurs it, is not known with certainty. If it should be imagined that *nitrite* f potash would be preferable to salt-petre for any purpose of philosohical or economical chemistry, it may be prepared by submitting comon nitre to a strong heat in a retort, by which means so much oxygen ill be set at liberty as constitutes the difference between *nitric* and *trous* acids, and what remains in the apparatus will be a true *nitrite* of otash. See note [c] at page 158.

Notwithstanding the prodigious quantity of salt-petre collected in the ast Indies, it has been calculated that two thirds of the whole are nnually sent into China and other parts of Asia to make artificial fireorks. The fire-works of the Chinese exceed those of all other nations variety and beauty.

At Apulia near Naples, there is a natural nitre-bed, in which the rth contains 40 per cent. of nitre. Pelletier has published a memoir the analysis of this valuable treasure, in the *Annales de Chimie*, me xxiii.

In Switzerland, the farmers extract an abundant quantity of very fine lt-petre from the earth under the stalls of their cattle. The urine of adrupeds contains much potash, and this acquires nitric acid from the mosphere. See Additional Notes, No. 22.

In the reign of Charles the First, great attention was paid to the aking of salt-petre in England. Certain patentees were authorized royal proclamation to dig up the floors of all dove-houses, stables, barytes, of soda[a], of strontites, of lime[b], of magnesia, and of ammonia.

What are the generic characteristics of the CARBONATES?

All the alkaline carbonates are soluble in water, while those of the earths and metals are nearly insoluble, unless the acid be in excess; and they all effervesce, and give out the carbonic acid, when treated with the sulphuric and some other acids[c]. Some of the earthy carbonates are also decomposed by mere heat without the intervention of any other substance, as is exemplified in burning lime; in which process

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&c. the proprietors at the same time being prohibited from laying such floors with any thing but mellow earth.

Nitre is used in large quantities in the manufacture of *gunpowder*, every 100 parts of which are usually composed of about 76 parts nitre, 15 charcoal, and 9 sulphur. The best account we have of this manufacture was published by Mr. Coleman, a superintendant of one of the royal powder-mills, in the *Philosophical Magazine*, vol. ix. page 355. The gunpowder which is expended in the mines of Cornwall alone, costs more than thirty thousand pounds a year. See the *Trans. Roy. Geol. Soc. of Cornwall*, vol. i. page 92.

[a] Nitrate of soda, according to Mr. Bowles, has also been found native in Spain.

[b] Nitrate of lime is generally found native with salt-petre, and in the greatest proportion. This salt, if properly heated, becomes luminous in the dark, and forms what is called Baldwin's phosphorus. In India, where this salt occurs in abundance, the salt-petre makers lixiviate wood ashes, which contain carbonate of potash, and mix the lixivium with the soil of the salt-petre grounds. In this process the alkali combines with the acid of the nitrate of lime, and precipitates the lime in the state of carbonate of lime. The nitrate of potash remaining in solution is afterwards crystallized for exportation. A large quantity of salt-petre is thus annually made in France, where the plaster of old walls is washed to separate the nitrate of lime, which is a soluble salt; and this, by means of potash or muriate of potash, is afterwards converted into nitre.

[c] There are eleven species of carbonic salts at present known; only four, however, of the native earths are found combined with this acid, viz. lime, barytes, strontites, and magnesia.

[d] Carbonate of barytes was discovered by Dr. Withering in 1783. It is not so scarce and dear as it was formerly; and from the superior affinity of barytes for sulphuric acld, this mineral substance may become

the carbonic acid is expelled, and the base remains pure.

Endeavour to enumerate the principal carbonates, or bases combined with this acid.

The carbonates of barytes[d], of strontites, of lime[e], of magnesia, of potash[f], of soda[g], and of ammonia[h], are the principal salts of this class; and that of lime is probably the most abundant in nature.

What are the generic characteristics of the PHOSPHATES[i]*?*

The phosphates are fusible either into opaque or transparent glass; are phosphorescent at a high tem-

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a most useful article in the arts. It is a compound of 78 barytes and 22 carbonic acid. The carbonate of strontites was found at Strontian by Dr. Hope. It consists of strontites 69.5, water 0.5, carbonic acid 30. Carbonate of lime exists in great abundance in all countries and under an extensive variety of forms. The other carbonates are in general formed artificially.

[e] Carbonate of lime is not soluble in water, unless the water itself be charged with carbonic acid: it is by this means that Nature effects a solution of calcareous masses, to form stalactites, and other beautiful incrustations. Native carbonate of lime is a compound of lime 56, carbonic acid 44. See notes, page 110.

[f] There are two carbonates of potash, the one consisting of 68 potash and 32 carbonic acid, possessing alkaline properties; and the *bi-carbonate*, which is formed with a double portion of carbonic acid, and is incapable of changing the colour of turmeric paper.

[g] Crystallized carbonate of soda consists of soda 21½, carbonic acid 15½, and water 63. The dry carbonate of soda consists of 58½ of soda, and 41½ of carbonic acid. Whereas the bi-carbonate is a compound of 37 per cent. of soda, 52¼ of carbonic acid, and 10¾ water.

[h] Carbonate of ammonia, or the common smelling salt, is now much used by the bakers as a substitute for yeast. It consists of one volume of carbonic acid gas and two of ammoniacal gas. The bi-carbonate is composed of one volume of each gas, and consequently is less pungent than the former. The first is composed of 56 parts of carbonic acid and 44 parts of ammonia; the latter, of 72 of carbonic acid and 28 of ammonia.

[i] The phosphoric salts which are found native are the apatite, or phosphate of lime, which occurs in abundance in many parts of the world, and a phosphated lead ore, besides some other minerals to be mentioned

perature; are soluble in nitric acid without effervescence; and are precipitable from their solutions in that acid by lime water. They are partially decomposed by sulphuric acid, but neither the earthy nor alkaline phosphates are decomposable by being heated with combustible matter.

Which are the chief phosphoric salts?

The chief of them are: phosphates of lime[a], of soda[b], and of ammonia[c], and the phosphate of soda and ammonia, formerly called microcosmic salt[d].

What are the generic characteristics of the PHOSPHITES*?*

The phosphites yield a phosphorescent flame when heated[e]; and in a strong fire give out a portion of phosphorus, by which they become converted into phosphates. By a very strong heat they are fusible into glass; but if heated with nitre they detonate, and

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hereafter. For an account of the latter consult Kirwan's *Mineralogy*, vol. ii. page 207, and *Annales de Chimie*, tome ii. page 209.

[a] Phosphate of lime is found in bones, milk, and some other animal matters. It is white, tasteless, and insoluble in water. Entire mountains in Spain are formed of this salt. It is composed according to Dr. Wollaston of 48.5 lime and 51.5 of phosphoric acid. It is prescribed by the French physicians as a specific in the rachitis.—Fourcroy's *System of Chemistry*, vol. iii. page 346. See also Bonhomme's paper on this subject, in *Annales de Chimie*, tome xvii. The conchoidal apatite, or *asparagus-stone*, was analysed by Klaproth, and found to consist of lime 53.75 and phosphoric acid 46.25. The common *phosphorite* is composed of 59 per cent. of lime, 34 phosphoric acid, 2 silica, 2.5 of fluoric acid, and a trace of oxide of iron, carbonic acid, and muriatic acid.

Phosphate of lime exists also in the farina of wheat. La Grange remarks, that a person who eats a pound of farina a day will swallow 3 pounds 6 ounces 4 drams and 44 grains of phosphate of lime in the year. It is a curious fact, that the grain of wheat should contain *phosphate* of lime, while the straw, which was *not* intended for our food, should contain *carbonate* of lime only.

It is remarkable, that though phosphate of lime is always found in the urine of adults, this salt is not evacuated by infants. The rapid formation of the bones, in the first periods of life, requires that there should become converted into phosphates. A similar change is also effected in them, if they are treated with chlorine or nitric acid.

Endeavour to enumerate the principal phosphites.

The chief of them are: the phosphites of lime, of barytes, of potash, of soda, and of ammonia[f].

What are the generic characteristics of the FLUATES?

The fluates are decomposed by sulphuric acid, yielding a vapour which corrodes glass, and which, when condensed in water, forms liquid fluoric acid. They are not decomposable by mere heat, nor altered by combustibles. Some of them are insoluble in water, and others very sparingly soluble in that fluid. Some of them possess phosphorescent properties, and all of them combine with silica when intensely heated in connexion with that earth.

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be no waste of any of the phosphoric salts; and Nature, ever provident, has provided accordingly.

[b] Phosphate of soda is formed artificially. It was first made and recommended by Dr. Pearson. This salt is used in medicine as a cathartic, and is much pleasanter than either Glauber's or Rochelle salts. It forms very distinct crystals; and is used by some manufacturers as a flux, instead of borax.

[c] Phosphate of ammonia is found in urine, and is also prepared by art to be used as an ingredient in making pastes, to imitate precious stones. It is one of the best fluxes for experiments with the blowpipe.

[d] Phosphate of soda and ammonia is also found in human urine, from whence it may be procured by evaporation in the state of a triple salt.

[e] None of the phosphites have been found in nature; they are all formed artificially, by saturating the different bases with phosphorous acid, either directly or by means of double decomposition. None of them have yet been brought into use. Fourcroy distinguishes eleven species of the earthy and alkaline phosphites.

[f] Phosphite of ammonia exhibits several curious appearances when treated with caloric. For all the particulars, consult Fourcroy's *System of Chemistry*, vol. iii. page 405. If heated on charcoal by means of a blow-pipe, it boils, and loses its water of crystallization; it then becomes surrounded with a phosphorescent light, and bubbles of phosphuretted hydrogen gas are emitted, which burn in the air with a lively flame, and form a fine coronet of phosphoric acid vapour.

Which are the chief fluoric salts?

Fluate of lime[a], fluate of soda, fluate of ammonia[b], fluate of alumina, and fluate of silica.

What are the generic characteristics of the BORATES?

The borates are all fusible into glass, and, with several of the metallic oxides, form glass of different colours[c]. Concentrated solutions of some of the borates, especially that of soda, afford, when decomposed by the stronger acids, scaly crystals of boracic acid. None of the combustible substances have the power of decomposing the boracic salts.

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[a] Many varieties, both in form and colour, of fluate of lime have been found. If any of these coloured fluates be pulverized, and then heated on a shovel, they will emit a very curious violet-coloured phosphoric light, the cause of which is not known. We have no means of dissolving fluate of lime in water; but Nature dissolves it by some unknown process; for it is found in crystals, combined with its water of crystallization. This crystalline substance is known by the names of Derbyshire spar and blue John. It is of various colours, and bears an excellent polish: hence it is used in making ornamental vases, &c. Where there are flaws or cracks in the mineral, I am told the workmen have an ingenious method of filling them up with lead ore, which they execute so well, that it cannot be discovered but by very close examination. Such specimens of the mineral as are not fit for ornamental work, will answer very well for the production of fluoric acid. The refuse of these mines is, I understand, collected in Derbyshire, and used as a flux in the reduction of certain metallic ores. See note [e], page 116.

According to some modern experiments, it appears that fluoric acid forms a part of the human teeth. It may be conjectured that this was a contrivance of Nature, to give more durability to these important organs than they would have had by phosphate of lime only.

Fluate of lime is very abundant in nature. It is often found in beautiful octohedral or cubical crystals. The other fluates are factitious salts, except fluate of alumina and soda, which has lately been found in Greenland, in a scarce mineral called the *cryolite of Greenland*. The topaz also contains a small portion, say 5 per cent. of fluoric acid.

[b] Fluate of ammonia is a very delicate test of lime. This earthy salt was first recommended by Scheele for this purpose. It is indeed to this illustrious chemist that we are indebted for the knowledge of this species of salt. The first account of the native fluates was published by him in the year 1771.

Can you enumerate the boracic salts?

The principal are: the borates of lime[d], of magnesia[e], and of potash; and the sub-borate of soda[f], which is known in commerce by the name of borax.

What is the distinguishing characteristic of the ARSENIATES?

When heated with charcoal they are decomposed, and arsenic sublimes. This is known by its alliaceous or garlic-like smell.

Which are the chief salts formed with arsenic acid?

The arseniates of lime, of barytes, of magnesia, of

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[c] It is from the property which the borates possess of fusing mineral substances and metallic oxides, that they are used by braziers, tin-men, &c. We employ sub-borate of soda to fuse such stones as cannot be brought into fusion by the alkalies. In analysing stones and minerals, the great art is to bring them into solution. When this is effected, their component parts may be readily separated by the different chemical reagents. Mr. Chenevix was unable to dissolve corundum by any means, till he made use of borate of soda.

[d] What is called *boracite*, or cubic quartz, is a borate of lime and magnesia, consisting of lime 11, magnesia 13.5, and boracic acid 68, with a little silica, alumina, and oxide of iron.

[e] Borate of magnesia has also been found near Lunenburgh. The other borates are factitious salts.

[f] This salt, which is the common borax of commerce, is called sub-borate, because it contains an excess of soda. According to Bergman, it requires half its weight of boracic acid to bring it to the state of a neutral salt. Borax is generally brought from the East Indies in a state of impurity. The article is then called *tincal*. It has also been found near Lunenburgh, in the duchy of Brunswick, in a mountain of gypsum. From Klaproth's analysis it appears to consist of

Boracic acid . .	37.0
Soda	14.5
Water	47.0
	98.5

Borax is likewise found at the bottom of pools of stagnant water, in the kingdom of Thibet. A particular account of the management of the natives in procuring it may be seen in Dr. Anderson's periodical work entitled *The Bee*, vol. xvii. page 22.

Boracic acid is found dissolved in several lakes of Tuscany. In the waters of the lake Cherchiago, near Monterotondo, in the province of potash[a], of soda, and of ammonia[b]; also the super-arseniate of potash, long known under the name of 'the arsenical neutral salt of Macquer.'

In what respects do the ARSENITES differ from the salts last mentioned?

The arsenites are combinations of the alkalies or earths, with the white oxide of arsenic, sometimes called arsenous acid; while the arseniates are formed by the union of certain bases with the *arsenic* acid. The alkaline arsenites are soluble in water, but the earthy arsenites are insoluble.

Which are the principal salts formed with the arsenous acid?

The only salt of this kind with which I am acquainted is the arsenite of potash, which I have formerly made in very large quantities for the preparation of a beautiful pigment, known by the name of 'Scheele's green.' The salt is formed by boiling white arsenic in a solution of caustic potash; and then by mixing this with a solution of the sulphate of copper, the pigment in question precipitates in the state of an impalpable powder.

Sienna, this acid exists in sufficient abundance to be advantageously converted into borax, by soda. A notice respecting native concrete boracic acid, by Smithson Tennant, Esq. will be found in the *Trans. of the Geol. Soc.* vol. i. page 389. The substance found near Sasso in the territory of Florence, called *sassoline*, consists of boracic acid 86 per cent, sulphate of manganese and iron 11, and sulphate of lime 3. Some account of the other minerals of this family has already been given under the article Boracic Acid, page 164.

[a] Arseniate of potash may be formed by detonating in a crucible a mixture of nitrate of potash and arsenous acid. This salt when heated melts into a white glass.

Scheele discovered that whenever tin is dissolved in arsenic acid, hydrogen gas is evolved, holding a portion of arsenic in solution. If ignited

What are the characters of the TUNGSTATES?

The salts called tungstates are combinations of the ellow acid of tungsten with the alkalies and earths. Iost of them have a metallic and caustic taste[c].

Which are the principal salts formed with the ungstic acid?

The tungstates of lime[d], of magnesia, of potash, of oda, and of ammonia.

What are the generic characteristics of the ACE-ATES?

The acetates are all very soluble in water; are de-omposed by the action of heat, and afford acetic acid hen distilled with sulphuric acid. These salts, if xposed to the air when in a state of solution, are soon estroyed, owing to the gradual decomposition which e acid undergoes; an inconvenience which is expe-enced by the printers of calicoes whenever their red ordant (the acetate of alumina) has been long kept, ithout being properly preserved from the action of e atmosphere.

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the end of a metallic tube, this gas burns with a peculiar kind of lam-nt white flame.

[b] Most of the arseniates are formed artificially; and few of them are ed in the arts. The combinations of arsenic and sulphur, known by e names of *realgar* and *orpiment*, are both native productions. The st consists of 75 of arsenic and 25 of sulphur: the latter of 57 of arse-c and 43 of sulphur.

[c] We owe to Scheele the discovery of the salts of tungsten. They ve lately been described with great accuracy by Vauquelin, in *Journal s Mines*, No. 19.

[d] Tungstate of lime, and tungstate of iron, which are found native, are th well known to mineralogists: the other tungstates are formed by t. The mineral which is improperly called tungstate of lime is a com-und of 78 parts of the oxide of tungsten, 18 of lime, 3 of silica, and of the oxides of manganese and iron. The other mineral of this family, own by the name of *wolfram*, or tungstate of iron, is composed of 64 rts tungstic acid, 22 oxide of manganese, 13.5 oxide of iron, and 5 silica.

Which are the chief acetic salts?

We have the acetates of barytes[a], of potash[b], o soda, of lime[c], of ammonia[d], and of magnesia, beside the acetate of alumina of the calico-printer, just mentioned.

What are the generic characteristics of the OXALATES?

The oxalates are decomposable by a red heat; an those which are soluble in water are decompose also by lime- or barytes-water; and the precipitate oxalate is soluble in an excess of oxalic or of mos other acids[e].

Can you enumerate the principal oxalic salts?

Oxalate of lime[f], of barytes, of strontites, of alumina, of magnesia, of potash[g], of soda, and o ammonia.

What are the generic characteristics of the TARTRATES?

When the tartrates are exposed to a red heat, th acid is decomposed, and the base remains. Th

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[a] Acetate of barytes has been employed as a chemical test. It is th most delicate test that can possibly be for sulphuric acid, and is ofte used for the discovery of this acid in vinegar that has been sophisticate with it. This salt is, however, decomposable by the alkaline carbonate

[b] The acetates of potash, and of ammonia, have long been known an prepared for medicinal use; the other earthy and alkaline acetates hav not yet come into much use, except the acetate of alumina, which i employed by calico-printers as a mordant. Acetate of potash was know and described by Raymond Lully.

[c] According to Pliny, acetate of lime was used by the ancients in su gery. Lib. xxxvi. cap. 24.

[d] A solution of acetate of ammonia has been used from a very ear date in pharmacy, under the name of *Mindererus's spirit*. It is not crystallizable; for, if evaporated with that intention, it volatilizes entirely.

[e] This genus of salts was first described by Bergman in his disserta ion on oxalic acid. See his *Physical and Chemical Essays*, vol. i. page 305.

[f] Oxalate of lime is one of the compounds frequently found in huma calculi. Vauquelin, *Annales de Chimie*.

[g] Oxalate of potash and oxalate of ammonia are both very useful test

rthy tartrates are less soluble than the alkaline, but
l are capable of combining with another base, and
rming triple salts. The tartrates are also capable
combining with an excess of acid, and thus form-
g what are called super salts, of which common
rtar or super-tartrate of potash is a well-known in-
ance.

Can you enumerate the principal tartaric salts?

The principal are the tartrates of lime[h], of stron-
tes, and of potash; and the tartrates of potash and
nmonia, and of potash and soda, commonly called
ochelle salt.

What are the generic characteristics of the
TRATES?

The citrates are decomposed by the strong mineral
ids; they yield traces of acetic acid when distilled;
d the oxalic and tartaric acids decompose them, pro-
ucing an insoluble precipitate in their solutions.
he aqueous solutions of these salts are not permanent,
t are liable to be decomposed by age.

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lime. These never fail to discover the presence of this earth, except
e supersaturated with some acid—in which case it is necessary to
e up the excess of acid by the addition of caustic ammonia before
ng the test.

Superoxalate of potash is sometimes prepared in England, but it is
nd ready formed in the juice of *wood-sorrel.* The other oxalates are
t yet in use.

[h] Tartrate of lime is found in the tartar of commerce; and it is also
med by art, by adding lime or its carbonate to a boiling solution of
am of tartar. This latter salt is merely the common tartar, or argol,
rified, which adheres to the inside of wine casks, and is brought in
ge quantities from the wine countries. There is a considerable de-
nd for it by the dyers and other manufacturers; and both in the crude
d refined state there is an excess of acid, therefore they are properly
led *super*-tartrates of potash. It is composed of 77 per cent. of tar-
ic acid and 23 of potash. Tartrate of potash and soda, usually called
chelle salt, or sel de Seignette, is formed artificially by adding soda
crystals to a solution of cream of tartar, till the excess of acid is satu-
ed. This elegant medicinal salt is composed of 54 tartrate of potash

Which are the principal citrates?

The citrates of lime[a], of barytes[b], of potash[c], soda, and of ammonia[d].

What are the generic characteristics of the CA *PHORATES?*

The camphorates have generally a bitterish tas they are decomposable by heat, and burn with a b flame. The camphorate of potash and some ot of these salts crystallize very readily.

Which are the principal camphorates?

The camphorates of lime[e], of potash, of soda, barytes, of ammonia, of alumina, and of magnesia[f]

What are the general characters of the SU *RATES?*

The several suberates differ so much in their prop ties, that it would be difficult to characterize the ge otherwise than by saying that they generally posses bitter taste, and are decomposable by heat. T mineral acids also decompose them, and precipit from their solutions the suberic acid in distinct acicu crystals.

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and 46 tartrate of soda. A neutral tartrate of potash is also forme our laboratories, called soluble tartar. The other tartrates are m without any view to their use in the arts.

[a] Citrate of lime is now formed in this country in large quantities a preliminary process in preparing the citric acid in a crystallized st According to Vauquelin, it is composed of 63 acid and 37 lime. Fr actual experiment I have found that 100 gallons of good lemon ju will generally produce 90 pounds of dry citrate of lime well saturat A minute description of the process may be seen in the 3d volum my *Chemical Essays*.

[b] Citrate of barytes, according to Vauquelin, is composed of 50 cent. of crystallized citric acid and 50 of barytes.

[c] The citrates are all formed artificially. Citrate of potash is u much in medicine, and is usually called the *saline draught*. It is co posed of 56 acid and 44 potash. The other citrates are not yet found be of any use.

[d] The affinities of the citric acid are in the following order: lime, rytes, magnesia, potash, soda, ammonia, and alumina.

Which are the principal suberates?

Suberate of barytes, of potash, of lime, of magnesia, d of ammonia[g].

What are the generic characters of the PRUS-*ATES?*

The alkaline and earthy prussiates are easily formed boiling the alkalies or earths with prussian blue; which process the prussian blue is decomposed, prussic acid uniting with the alkali or earth in ference to the oxide of iron. The salts which are s formed retain however some iron, and are called ple prussiates. Those of potash and soda crystallize dily, and the former is much used as a test to detect presence of iron and some other metals.

Which are the principal prussiates?

The prussiates, or triple prussiates of potash, soda, ne, or ammonia, with iron: that of potash was for-rly called prussian alkali[h].

How are these different salts known from each er?

They are known by the peculiar figure of their cry-

This salt is composed of 50 per cent. acid, 43 lime, and 7 of water.

Camphoric acid saturated with potash forms crystals in regular hex-ns; with soda, irregular crystals; with ammonia it forms needle-ned crystals; and with magnesia, a white pulverulent salt.

hese salts, which have not been applied to any useful purpose, are all formed artificially. For an account of their properties, consult rcroy's *System of Chemistry*, vol. viii. page 14.

The suberates, which are all factitious, are more or less soluble: e readily crystallize, others with difficulty; there are some which ain pulverulent, whilst others are deliquescent. Although none of e salts are yet come into any use, a good account of their properties be found in a memoir by Chevreul, in the 23d volume of Nicholson's *nal of Natural Philosophy and Chemistry*.

The prussiates are all made by art, but the class is very interest-stals[a], by their taste, by their fusibility, and other d stinctive or *specific* characters.

What is meant by the figure of their crystals?

There is a great variety in the form of crystallize salts: and each salt preserves its own peculiar form[b]; thus common culinary salt generally crystallizes i small cubes, and sulphate of soda in six-sided prism

How is the crystallization of salts effected[c]*?*

When a certain portion of the water of solution i

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ing. There are two prussiates of iron, the white and the blue prussiat Prussiate of lime and iron, or the prussiate of potash and iron, is us as a test to ascertain the presence of metals held in solution. The latte known by the name of *prussian alkali*, is the best combination of t prussic acid for detecting the existence of iron. It is of the utmost i portance to us as a re-agent, from its property of forming insoluble co pounds with metallic oxides. By this property it occasions precipitat in metallic solutions, which vary in colour according to the kind of met precipitated.

[a] The chief works on crystallography are those of the Abbé Haüy, a M. Romé de Lisle, to which I refer the student. See Additional Note No 15.

[b] When, either by the diminution of the quantity of the liquid, or t reduction of the temperature, the force of cohesion causes a separati of a portion of the dissolved substance, in almost all cases the par which are separated form a regular arrangement, owing to the relati between their figure and reciprocal affinity. Hence those crystals whi Nature offers in such variety, and which are produced in so great a nu ber of chemical combinations.

The portions which continue to be added (either because the cryst acts on the dissolved substance, or because the cause of the separati continues to exist in the liquid) are composed of moleculæ similar to t first, and continue to augment the bulk of the crystal, preserving its fi form: nevertheless, this increase may be determined to one face in p ference to another, according to the position of the crystal, and the c cumstances in which the solution is found. See this subject more fu explained in Berthollet's *Chemical Statics*.

[c] Solution is effected by means of water or caloric, one of which necessary to keep the parts of the substance in a state of minute di sion. In order that regular crystallization may take place, it is necessa that the cause of fluidity, whether water or caloric, or both, should subtracted *gradually*, and without movement. This gives an opport nity for the parts of the substance to unite regularly, according to the several attractions, and to produce crystals as perfect as those exhibit by Nature; whereas, a sudden subtraction of the fluid causes the par cles often to unite in a shapeless mass.

When common salt brine is boiled with rapidity, fine-grained salt aporated, and the remainder left in a proper tempe- ture at rest, the salts will shoot into crystals[d], and ll be found dispersed through the mother water at e bottom and at the sides of the vessel[e], and some- nes also on the surface of the solution.

What is meant by mother water?

Mother water is the solution which remains after e separation of a part of the salt which it originally

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duced; but if the same brine be slowly evaporated by the rays of the , large crystals of bay salt are obtained. On the contrary, sirups ch are boiled quickly give large-grained sugar; but if large and re- ar crystals of sugar-candy be desired, it is necessary to keep the con- trated sirup for several days and nights *undisturbed* in a very high perature; for, if perfect rest and a temperature of from 120° to 190° not afforded, regular crystals of candy will not be obtained.

Sir Isaac Newton seems to have had a very clear idea of the cause of stallization. "When," says he, "a liquor saturated with a salt is porated to a pellicle, and sufficiently cooled, the salt falls in regular stals. Before being collected, the saline particles floated in the liquor, ally distant from each other; they acted therefore mutually on each er, with a force which was equal at equal distances, and unequal at qual distances: so, in virtue of this force, they must arrange them- es in an uniform manner."—Newton's *Optics*, book iii.

The free access of air has considerable influence on this process. s, if a saturated solution of Glauber's salt be put into a vessel boil- hot, and then excluded from the air, it will cool without crystalli- ; but if the pressure of the atmosphere be afterwards admitted, it crystallize immediately. See Experiments, No. 17. In consequence n unfavourable state of the atmosphere, this experiment will some- es fail; but if a bit of Glauber's salt of the size of a pea be dropped the fluid, the whole will instantly shoot into crystals.

n crystallizing salts in the large way, the manufacturers have remarked the largest crop of crystals is always found on that side of the cooler ch is exposed to the most light, and that in crystallizing some salts, e vessel be partially shaded, the line of interception will be evident, the part excluded from the light distinctly marked by the limit of crystallization.

In large laboratories the salts of commerce are prepared by evapo- on and cooling, but it is necessary to vary the process for almost y different kind of salt. So much nicety is necessary, that many ma- cturers are much perplexed by this part of their business, till they e established each process on the basis of experiment.

ome valuable directions for crystallizing salts may be found in Dr. npbell's paper, in Nicholson's *Journal of Natural Philosophy and mistry,* 8vo. vol. ii. page 117. See also Le Blanc's directions in the e work, vol. i. page 191; also the *Encyclopædia Britannica,* vol. iv. e 443. It may be remarked, that when saline bodies pass from a contained. By repeating the evaporation, and cooling[a], mother waters generally afford fresh portions of salt.

What is the original cause of the crystallization of salts?

The crystallization of salts is owing to the abstraction of the heat or water by which they were dissolved[b]; and, in those crystals which contain water, their peculiar form and crystalline appearance are in a great measure owing to that portion of water having parted with its caloric of fluidity and taken a solid form.

What is the water called which combines with salts during their crystallization?

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fluid to a solid form, as salts do in crystallizing, heat is given out and the liquor becomes warm. On the contrary, when salts are dissolved in water, heat is absorbed and the fluid becomes colder.

[a] For boiling down saline liquors, in the large way, leaden boilers, or boilers made with plates of sheet iron riveted together, are the most proper. The plates should not, according to my experience, be more than nine or ten inches wide, made of the best tough *hammered* iron, three-eighths of an inch thick in the middle, and one fourth of an inch thick at their edges. If made with plates wider or thinner, the bottom will warp, and soon become useless. Common rolled iron will be sufficient for the sides. These pans are manufactured best in Lancashire and Cheshire, where there is a great demand for them for the salt wiches. Boilers of *cast* iron would crack by the adhesion of the salt.

[b] It must not be imagined that all crystallization is owing to solution in water. Melted sulphur always crystallizes on cooling, which is the case with many substances that have endured a strong heat. Many of the metals crystallize in this way, particularly grain tin. Nothing can exemplify this kind of crystallization better than muriate of lead, commonly called patent yellow. It affords beautiful and regular crystals on cooling. See Additional Notes, No. 23. If glass be kept in a red heat for a long time and cooled gradually—instead of being the transparent body we generally see it—it will crystallize like the metals. Starch is another instance of what may be called *dry* crystallization; and probably, in every instance, the phænomenon may be attributed to the loss of caloric, and consequent shrinking of the whole substance. Dr. Garnet accounts for the origin of basaltes in this way. See his *Tour to the Western Isles.* The Giant's Causeway, in the county of Antrim in Ireland, is a most stupendous natural curiosity of this kind. It is formed of perpendicular pillars of basaltes, which stand in contact with each other. The pillars are irregular prisms of various forms, from three to nine sides; but they are principally hexagons. The appearance of the whole is as neat as it is magnificent. The columns at Fairhead are 250

It is called the water of crystallization[c], for it is generally this that gives them the crystalline appearance.

What quantity of water do salts combine with during their crystallization?

The quantity of this water varies very much in different salts[d]; for though some salts take up very little or no water, others combine with more than their own weight; which is the case with alum, subcarbonate of soda[e], and some others.

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feet high, arranged in the utmost regularity and order; and from the base to the level of the sea there is a precipitous declivity of at least 300 feet, making together a perpendicular height of 550 feet. For a further account of this most astonishing natural curiosity, I refer the reader to The honourable Mrs. Murray's *Companion to the Western Highlands of Scotland*, and to Dr. Richardson's "Observations," in Nicholson's *Journal*, vol. v. 4to. page 321. See also Additional Notes, No. 14. Basalt is now used in the manufacture of glass bottles. When calcined and pulverized it imparts to mortar the property of hardening under water.

[c] This water *solidifies* as the salt crystallizes, and becomes itself a part of the salt. When abstracted from salts, it is found to be as pure as distilled water.

[d] It is probable that salts generally combine with *two* definite proportions of water, viz. that with which they unite in *crystallizing*, and which is well known to exist only in fixed proportions; and secondly, that quantity which they combine with in *dissolving*: the first is called water of crystallization; the second, water of solution.

[e] Take a portion of crystallized sulphate of soda (Glauber's salt) and dry it over a common fire, which will reduce it to less than half its weight. Dissolve this dried salt in three times its weight of boiling water, set the liquor aside, and, when cold, beautiful crystals resembling the original crystals will be found in the liquor. By an attentive examination of the liquor, the crystals may be seen to form as the liquor cools. This is a cheap and easy experiment, and may be exhibited to the pupil as an example of crystallization in general.

The property of crystallization seems to be a peculiar mark by which the salts may be distinguished from other bodies. Thus, it was formerly disputed whether carbonate of magnesia should be called a salt; but when this combination was exhibited in a crystallized state, its saline character was readily admitted. In many cases, however, this test is more of a negative than of a positive nature; it being often much easier to say what a body *is not*, than what it actually *is*, by an examination of its crystalline form.

Are salts as unalterable in their appearances as they are in their chemical properties ?

No : *crystallized* salts are liable to changes in their appearance by exposure to atmospheric air[a]. Thus some salts deliquesce, and others effloresce, so as to lose their crystalline form entirely by such exposure.

What is meant by the DELIQUESCENCE *of a salt?*

Some salts have so great an affinity for water, that they absorb it with avidity from the atmosphere. Such salts thereby become moist or liquid, and are said to deliquesce, by exposure to atmospheric air[b].

What is meant by the EFFLORESCENCE *of a salt?*

Some salts, having less affinity for water than atmo-

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[a] A Table of the Action of Atmospheric Air on some of the most Common Salts.

Pure potash	Deliquesces
—— soda	Deliquesces
Carbonate of potash	Deliquesces
Bi-carbonate of potash	Remains unchanged
Carbonate of soda	Effloresces
—— ammonia	Do.
—— lime	Unchanged
—— magnesia	Do.
Sulphate of potash	Do.
—— soda	Effloresces
—— lime	Unchanged
—— ammonia	Sub-deliquesces
—— magnesia	Unchanged
Nitrate of potash	Unchanged
—— soda	Sub-deliquesces
—— ammonia	Deliquesces
—— barytes	Slightly efflorescent
—— lime	Deliquesces
—— magnesia	Deliquesces
Muriate of potash	Unchanged
—— soda	Do.
—— lime	Deliquesces
—— ammonia	Sub-deliquesces
—— barytes	Unchanged
—— magnesia	Deliquesces

[b] Some deliquescent salts have so little force of cohesion, that the action of water, however small the quantity, is sufficient to prevent their crystallization ; but even such salts may be crystallized by the addition of alcohol, for which the water has generally a greater affinity than it has for the salts. Therefore, whenever alcohol is added to such saline solutions, part of the water combines with the alcohol, and crystallization takes place. This shows that those salts do possess in themselves an active cohesion of parts.

[c] Muriate of barytes, *pure* muriate of soda, and some other salts, seem to have exactly the same affinity for water that atmospheric air

pheric air[c] has, lose their water of crystallization by xposure, and readily fall into powder: such salts re said to effloresce. The crystals of sub-carbonate f soda and of sulphate of soda are good examples of his property.

Are salts capable of any other changes besides ef-lorescence and deliquescence?

Yes: salts have the properties of solubility[d] and usibility.

What is meant by the SOLUBILITY *of a salt?*

It is its capacity to unite with and remain dissolved n water; but the different salts possess different degrees of solubility[e], requiring more or less of this luid for their solution.

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as. Such salts neither effloresce nor deliquesce by any exposure to e atmosphere.

[d] Table of the Comparative Solubility of some of the Common Salts.

SALTS.	Solubility in 100 parts of water.		SALTS.	Solubility in 100 parts of water.	
	at 60°	at 212°		at 60°	at 212°
ulphate of potash	6.25	20.	Muriate of potash	33.	
——— soda	37.	125.	——— soda	35.42	36.16
——— lime	0.22	0.2.	——— lime	200.	
——— ammonia	50.	100.	——— ammonia	33.	
——— magnesia	100.	133.	Carbonate of potash	25.	83.33
itrate of potash	14.25	100.	——— soda	50.	100.
——— soda	33.	100.	——— ammonia	50.	100.

[e] We generally denominate all salts as insoluble, which require for lution more than 1000 times their weight of water. An opinion may in me measure be formed of the *solubility* of a salt by its taste. Those lts which have the most taste are generally the most soluble in water. us Epsom salt dissolves in its own weight of water at the common mperature of the atmosphere, and the solution continues perfectly id and transparent; while sulphate of lime requires 500 times it own eight of water to hold it in solution.

The difference which there is in the solubility of salts is of great use

What is meant by the FUSIBILITY *of a salt?*

Salts have not only the property of dissolving in water, but will melt by exposure to great heat. The different salts require different degrees of heat to put them in a state of fusion[n].

Have the different salts any action upon each other?

Yes: we have many instances of salts mutually decomposing each other.

What takes place in these decompositions?

When such salts are mixed in solution, the acid of the *first* and the base of the *second* having more affinity for each other than for the base and acid with which they are respectively combined, double decomposition, as it is termed, ensues. The acid of the first unites with the base of the second, and consequently the base of the first combines with the acid of the second; so that two new salts are produced, differing in appearance, and possessing properties different from those of the original salts.

What is the cause of this effect?

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in separating them from each other. The refiners of salt-petre operat entirely on this principle. The rough petre, as it is called, is alway contaminated with a portion of muriate of soda and other salts. In orde therefore to separate them they dissolve the whole in water, and the by boiling the solution to evaporate a part of the water, the muriate soda, &c. falls down, while the salt-petre is held in solution. When t greatest part of these salts is thus separated, the remaining liquor suffered to cool, and the nitrate of potash is obtained in crystals. S Additional Notes, No. 22.

Most salts dissolve more copiously in hot than in cold water. Muria of soda is almost the only exception to this general law. Was this d viation of Nature contrived in reference to the waters of the ocean?

[n] Tables of the fusibility of different salts have not yet been forme but with the aid of Wedgwood's pyrometer it would be no very diffic task to ascertain the degree of fusibility of each. The relative fusibili of several of them is already known: for instance, it has been asc

It is occasioned by mutual chemical attraction, and the operation itself is called double decomposition, or the effect of compound affinities[b].

Can you give an example of this double decomposition?

Yes: If you add a transparent solution of sulphate of soda, or Glauber's salt, to one of muriate of lime, the solution is immediately rendered turbid, and two new salts are formed.—The sulphuric acid of the sulphate of soda combines with the lime of the muriate of lime and forms sulphate of lime or gypsum, and the soda which was combined with the sulphuric acid seizes the muriatic acid previously united to the lime and forms muriate of soda, or common salt, which continues in the solution, but may be obtained in a dry form by evaporation and crystallization. The white powder which precipitates, is the newly formed sulphate of lime.

What other use is made of these decompositions?

By these means many valuable salts are procured for the use of the chemist and the manufacturer, which can be formed in no other way[c].

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ined that sulphate of potash requires a much more intense heat to put in a state of fusion than sulphate of soda; whereas nitrate and muriate of soda melt as soon as they become red. Some salts acquire fusibility by the loss of a part of their acid. Thus caustic alkalies are incomparably more fusible than carbonate of potash or soda. In decomposing the sulphuric salts in my own manufactory, I have often hastened the process by the addition of a few shovels-full of quick-lime; but whenever this is had recourse to, the utmost caution is necessary in the management of the fire; as the alkali becomes, by this means, more liable to vaporization.

[b] Those who wish to investigate this subject may consult Bergman's treatise on *Elective Attractions*, or Fourcroy's *System of Chemical Knowledge*. See Nicholson's *Translation* of the latter work, vol. iv. page 173.

[c] The following are some of those useful salts which are not found native, but are formed entirely by art:—nitrate of ammonia, nitrate and muriate of barytes, oxymuriate of potash, phosphate of soda, phosphate of ammonia, &c.

What knowledge have we attained respecting the native salts?

Many of the salts are found native; and since the science of mineralogy has been so much cultivated, great attention has been paid to these natural productions.

What salts are furnished by nature in the greatest abundance?

The carbonates, the sulphates, and the muriates, are most abundant; but some of the nitrates, borates, &c., are also found native.

Which of the carbonates have been found native?

Of carbonate of lime[a] there are immense mountains in most parts of the world: carbonate of barytes has been found in Lancashire and elsewhere; carbonate of strontites, at Strontian in Scotland; carbonate of

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[a] Chalk, limestone, and marble are all included in the term, carbonate of lime. The late experiments of Sir James Hall have thrown great light on the formation of these natural productions. See *Edinburgh Philosophical Transactions*, vol. vi.

Carbonate of lime is found also in a crystallized state, in a mineral called *calcareous spar*. It has never yet been crystallized by art. This process of Nature may require many ages to effect, for aught we know.

[b] According to the analysis of M. Lavoisier, the proportion of sulphate of soda in sea-water is very small. Mr. Hume analysed the famous mineral-water at Godstone in Surrey, and found it to contain 160 grains of sulphate of soda per gallon. According to the analysis of the water of the several spars at Cheltenham by Mr. Brande and myself, they contain from 10 to 23.5 grains of sulphate of soda in each wine pint. See our paper on this subject in the *Journal of the Royal Institution of Grea Britain*, vol. iii. page 54—72.

[c] Sulphate of magnesia and sulphate of lime are both very common in our spring waters; the last salt and supercarbonate of lime are the chief causes of what we call *hard* waters, which are very unwholesome, and unfit for washing. When soap is used with these waters a double decomposition takes place; the sulphuric acid of the selenite unites with the alkali of the soap and forms sulphate of potash or sulphate of soda which remains in solution; while the magnesia or lime unites with the tallow, and forms an insoluble compound which swims upon the surface of the water like curds. In this way hard waters require much more soap for any given purpose than rain water, or waters which do not contai

soda, in the natron beds of Egypt, and in the East Indies; and carbonate of potash, as well as the carbonate of soda, has been discovered in some spring waters.

What sulphuric salts are found native?

Sulphate of soda is found in some salt springs[b]; sulphate of magnesia, in spring water[c]; the sulphate of alumina is abundant at Whitby and Glasgow; sulphate of barytes, in Derbyshire and other parts of the world; the sulphate of strontites abounds in some parts of Gloucestershire[d]; and few salts are more copiously disseminated than the sulphate of lime, particularly in the vicinity of Paris, and hence its name *Plaster of Paris.*

What native MURIATIC *salts are there?*

Muriate of lime occurs with rock-salt, and muriate

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these earthy salts. Such waters are also unfit for boiling any esculent vegetable; but they may be rendered soft by adding to them a very little carbonate of soda, or carbonate of potash, 24 hours previous to their use. By this addition a decomposition will be effected, and the carbonate of lime, a very insoluble salt, precipitated.

The property which sulphate of lime has of setting into a compact mass when mixed with water was well known to the ancients. Herodotus informs us of a curious method by which the inhabitants of Ethiopia preserved the remembrance of their deceased relatives.—They had the custom, he says, of drying the body in the sun, then covering it with a paste of gypsum, and afterwards painting the portrait of the deceased upon the plaster covering that encrusted the real body.

[d] Sulphate of lime is procured in great abundance at Chelaston near Derby, and Beacon Hill near Newark. At the former place 800 tons are annually raised; it is sold at 5*s.* per ton on the spot. The price at Gainsboro' is 8*s.* per ton. This mineral is much used in Derbyshire for making the floors of cheese-chambers, store-rooms, granaries, &c. They burn the gypsum, grind it to powder, and then mix it with water. In this state it is laid upon the floors about 2¼ inches thick, and when dry is a smooth and durable flooring. The whole expense is generally less than 1*s.* 6*d.* per square yard. Gypsum is also found in most of the cliffs of the Severn, especially at the Old Passage near Bristol. For the London market, perhaps, it might be gotten cheapest from the Isle of Sheppy, where it may be had in abundance.

of magnesia is found in abundance in sea-water[a]; muriate of ammonia appears in the neighbourhood of volcanos; and muriate of soda not only exists in immense quantities in the ocean[b], but vast mountains in different parts of the world are entirely formed of this salt[c].

Which of the NITRIC *salts are found native?*

Nitrate of potash is collected in various parts of the globe; nitrate of magnesia sometimes occurs in com-

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[a] The magnesia of commerce is generally procured from this source. It is prepared in great quantities in the island of Guernsey, and elsewhere.

[b] In the south of France large trenches are cut near the sea, which fill with sea-water at high tide: the water being confined there by floodgates, the sun evaporates it and leaves the salt in the trenches, from whence it is laid up to dry for use. Nicholas has published a long memoir on this manufacture of salt, in *Annales de Chimie*, tome xx. page 78—188.

Dr. Shaw gives an account of salt-works on the coast of Syria, where the rocks on the sea-shore have been hollowed into salt-pans two or three yards long. By continually throwing in sea-water, as the aqueous part evaporates a large quantity of salt gradually forms at the bottom. *Travels in Barbary*, last edition, page 344.

The ocean contains from $\frac{1}{25}$th to about $\frac{1}{35}$th of its weight of muriate of soda. On account of the cheapness of fuel at Newcastle, salt is procured there by the evaporaton of sea-water. They evaporate 30 or 40 tons of water to procure one ton of salt. An interesting account of the brine springs at Droitwich has been published by Leonard Horner, Esq. in the *Trans. of the Geol. Soc.* vol. ii. page 94: and further particulars may be learned by consulting my late work entitled *Thoughts on the Laws relating to Salt*, page 120.

At some places in Cheshire, they draw the brine from the salt-pits and saturate it with rock-salt previous to its being boiled. See a sketch of the natural history of the Cheshire rock-salt district, by Henry Holland, Esq. in the *Trans. of the Geol. Soc.* vol. i. page 38. The port of Liverpool is supplied from these works, where it is sold, free of duty, for 1*s.* per cwt. for exportation. According to Lord Dundonald, 100 tons of a saturated solution of rock salt in sea-water contain 23 tons of salt.

In Sweden they freeze the sea-water, throw away the ice, and boil down the remainder to salt.

In the landgravate of Thuringia in Saxony a new method has been adopted in the manufacture of salt. A number of vessels of wood are placed firm upon posts six feet from the ground, which may be covered or uncovered in an instant by a moveable roof, accordingly as the weather nation with that salt; and nitrate of lime[d] is found so in the same combination, and likewise in mineral rings:—these are the only nitric salts that have been een native in any large quantities.

Are any other of the salts found native?

Yes: vast rocks in Derbyshire and elsewhere are rmed of fluate of lime[e]; borate of soda is found in crystallized state in the kingdom of Thibet; borate magnesia at Luneburgh in the kingdom of Hanver[f]; and phosphate of lime, which is the basis of all

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dry or rainy. In this manner salt is obtained by the mere heat of the n, and such salt is much purer than that which is procured by evapotion in boilers. Nicholson's *Journal of Natural Philosophy*, &c. 4to. l. ii. page 72.

[c] The salt-mines near Cracow in Poland, which have been worked ever nce the middle of the thirteenth century, contain an immense store of uriate of soda. The excavations have been made with so much regurity and beauty, that these mines are visited by travellers as one of the eatest curiosities in the world. Eight hundred workmen are employed them, who raise 168,000 quintals of salt annually. Through the enorous mass of salt, which presents to the eye no interruption in its saline xture, and at the depth of 450 feet, flows a stream of pure, fresh, and ansparent water, which is received in large wooden vessels, where the orkmen and horses of these subterranean regions quench their thirst. it was impossible that this spring could filter through the salt, Nature, ho buries her masterpieces in the bowels of the deepest mountains, has aced in this monstrous mass a stratum of clay sufficiently thick to alw the stream of water, destined to refresh the workmen, to pass through in such a manner as to be protected from the action of the salt, of which very small quantity would injure its salubrity. See an interesting acunt of these mines in vol. x. of the *Philosophical Magazine*; and a meoir by Mr. Vivian in *Trans. Roy. Geol. Soc. of Cornwall*, vol. i. page 154.

[d] Some of the salt-petre grounds are now much more productive than rmerly, owing to a knowledge of the circumstance that carbonate of otash will decompose nitrate of lime. The salt-petre makers, in lixiviing the earths, now add a portion of *wood-ashes*, and hence their proice of nitre is rendered more abundant.

[e] This crystallized substance is used for vases and other ornamental ork, some of it being extremely beautiful. It obtained the name of *fluor ar*, on account of its property of increasing the fusibility of other miral substances. It has also been called *vitreous* spar, because when sed it has the appearance of glass. It is generally found in very regular bical crystals, and of various colours. See pages 116 and 198.

[f] This curious mineral is known to mineralogists by the name of

animal bones, exists native in Hungary, and composes several entire mountains in Spain.

How do you imagine that these immense masses of salts have been formed by nature?

The huge mountains of salts we have been speaking of, and which occur in various parts of the earth, were probably formed in very remote ages, and by processes of which we can form no idea. It may indeed be supposed that these changes have been slow and gradual, for several of the native salts exhibit marks

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boracite. It generally occurs in small cubic crystals. It formerly bore the name of *cubic quartz*, and also that of *sedative spar*. See Note [g], page 165.

[a] In order to account for these productions of Nature, various *theories* of the world have been formed by philosophers in different periods. Some of these have had many supporters. Thus we have had the theories of Burnet, Woodward, Whiston, Buffon, Whitehurst, Laplace, and other noted geologists who have written on the subject since their time.

The theories which divide the opinions of the philosophers of the present day, are those of Hutton and Werner. The former supposes the agency of heat, and is called the Plutonian system; the latter, which attributes all the present appearances of the globe to the effect of water, is called the Neptunian system. The reader may become acquainted with the arguments which have been adduced in support of both these theories, by means of the following works, which cannot fail to prove extremely interesting to those who are fond of such inquiries, viz. Playfair's *Illustrations of the Huttonian Theory of the Earth*, and *A Comparative View of the Huttonian and Neptunian Systems of Geology*, by Dr. Murray of Edinburgh, 8vo. 1802.

[b] We have abundant reason to believe that nothing is fortuitous, but that every thing upon this fair world of ours is the effect of design; for every thing around us bears evident marks of the skill and beneficence of its Omnipotent Author. Is it not then reasonable to infer, that the formation of the whole of the globe entered into the divine plan; and that the constitution of the interior of its mountains resulted from the determination of infinite wisdom, and must have important uses in some future period of the world?—

> "For, lives the man whose universal eye
> Hath swept at once the unbounded scheme of things;
> Mark'd their dependence so, and firm accord,
> As with unfaltering accent to conclude
> That this availeth nought?"

It is probable indeed, that the profusion of earthy and alkaline salts which occur in the more elevated parts of the earth may, among other purposes, have been intended as magazines for the future renovation of f regularity and beauty in their crystallization, which annot be imitated by art[a].

Have geologists attempted to account for the pro-uction of the immense quantities and varieties of alts found in different states in various parts of the arth?

The cause of this order of things can only be re-erred to the will of the Creator[b], who has seen fit, in e composition of many of the mountainous parts of e globe, to prefer these compound substances to the ore simple and inert earths.

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e soils in their vicinities. They are in general of a nature to be washed own by the rains; and, by means of rivers, &c. are sometimes trans-orted to considerable distances from their native beds. It is remark-ble that these salts are generally found only in the *secondary* moun-ains, the materials of the *primitive* rocks being entirely different. These tter contain no remains of organic bodies whatever, and are composed, or the most part, only of five ingredients, viz. silica, alumina, lime, agnesia, and iron; of which *silica* is by far the most abundant and niversal. Though a comparative softness has been given to the se-ondary mountains, which thus appear to have been designed for the uccessive production of alluvial depositions, for the renovation of soils, c.—the rocks of granite, the foundations of the globe, are so extremely ard, that it is imagined they would resist the constant washing of the cean for ages without any apparent diminution. Where they were ori-inally fixed by the hand of Nature—

"they still remain,
Amid the flux of many thousand years,
That oft has swept the toiling race of men
And all their labour'd monuments away." Thomson.

In this arrangement we perceive nothing like a fortuitous concourse f atoms, but, on the contrary, the same satisfactory marks of contri-ance, which force themselves upon our notice whenever we contem-late the various phænomena of the world, or study any of the great perations of nature.

CHAPTER IX.

OF SIMPLE COMBUSTIBLES.

WHAT is a SIMPLE substance?

Those bodies[a] which have never yet been decomposed, nor formed by art, are called simple substances.

How many simple substances are there?

Very lately the simple substances were said to amount to more than 50 in number[b]; but since the truly interesting and very important discoveries of Sir Humphry Davy, it is scarcely possible to say what substances are not compound bodies.

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[a] The most minute particles into which any compound substance can be divided *similar* to each other, and to the substance of which they are parts, are termed the *integrant* particles: thus the smallest atom of powdered marble is still marble; but if by chemical means the calcium, the carbon, and the oxygen of this marble be separated, we shall then have the *elementary* or constituent particles.

Suppose a little common salt were reduced to powder, even though it be ground as fine as could be effected by art, still every single particle, however minute, would consist of a particle of sodium and a particle of chlorine; common salt being a *compound* body incapable of decomposition by mechanical means. But if we take a piece of sulphur, and pulverize that in the same way, every particle will be a homogeneous body, sulphur being one of the *simple* substances.

[b] If these substances were all capable of combining, the compounds formed by them would amount to many thousands; but several of them cannot be united by any means we know of.

[c] Of these simple substances it may be remarked that four are imponderable; four others exist in a gaseous state; six are bases of acids; and thirty-eight are metallic bodies.

[d] Iodine is a peculiar substance procured from kelp: it possesses the singular property of being convertible into a violet vapour by heat.

[e] If we omit the earths and alkalies (and there is abundant evidence that these are compound bodies), most of the simple substances are

Can you enumerate what are now deemed simple substances?

All the simple substances that we are acquainted with are fifty-two[c]; viz. electricity, magnetism, light, caloric, chlorine, oxygen, nitrogen, iodine[d], the metals, (reckoning as such the bases of potash, soda, and some of the earths,) and the simple combustibles, carbon, phosphorus, sulphur, hydrogen[e], boron, and fluorine[f].

Is it well ascertained that these are all simple substances?

It is extremely probable that some of these bodies may be compound; but as no mode has yet been discovered of decompounding any of them, it will be more conducive to science, to consider them, for the present, as simple undecomposable bodies[g].

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combustible, or bear some relation to combustion. Light and caloric are evolved during combustion; oxygen is the principal agent of combustion; and hydrogen, sulphur, phosphorus, carbon, and the metals, are the subjects, or the true instruments of this process.

[f] For some account of boron and fluorine, see the notes to boracic and fluoric acid, pages 162 and 164. Boron is a dark olive-coloured powder, which burns with a red light when considerably heated in atmospheric air. Fluorine, which is of a chocolate colour, will burn when heated in oxygen gas.

[g] It is curious that most of those substances which were thought by the old chemists to be the elements of all other bodies, are found by our improved methods of experiment to be more or less compounded; while, of those which were formerly ranked among the class of compounds, there are a great number that are really not decomposable, and can only be placed among the simple bodies. *Air*, *fire*, *water*, and *earth* were by the ancients called the elements of the globe: modern chemistry has demonstrated, that the three first of these are really compound bodies; and there is reason to believe that the earths are also compound. On the other hand, *sulphur*, *phosphorus*, *carbon*, and the *metals*, which we call simple substances, were supposed formerly to be compounds.

Oxymuriatic acid, or chlorine, the basis of boracic and fluoric acids, and a substance of recent discovery, called *iodine*, have lately been added to the list of simple substances.

Having already examined the nature of all these substances, except the combustibles, we shall now enter upon the consideration of that class of bodies.—Endeavour, therefore, to enumerate the simple COMBUSTIBLES.

Besides the metals[a] there are six simple combustibles, viz. hydrogen, sulphur, phosphorus, carbon, boron, and fluorine.

Why are these substances called SIMPLE *combustibles?*

They are called *simple* because we have no proof that they are compounded: whereas oil, spirit of

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[a] The metals ought to have been included in this chapter, with the other simple combustibles; but as several of their properties are so very different from the four substances now described, it was thought advisable to treat of them separately.

[b] For the nature of the compound combustibles, consult the chapter on Combustion.

[c] Mr. Cavendish was the first person who examined hydrogen gas and pointed out its nature. This was in the year 1766. Dr. Black then suggested the propriety of applying it to the inflation of air-balloons; and Mr. Cavallo was the first who put it in practice. This gas is about thirteen times lighter than atmospheric air.

[d] I say the basis, because hydrogen is not combustible unless it be mixed with atmospheric air, or with some other of the supporters of combustion; for without such previous admixture it is absolutely destructive of flame, as may be proved by immersing a lighted taper in a phial of hydrogen gas (from which *the utmost care has been taken* to exclude the presence of atmospheric air), which will be extinguished the moment it comes in contact with the pure hydrogen gas.

[e] Like all other combustibles, hydrogen will not burn unless in contact with atmospheric air, or some substance that contains oxygen. If a portion of atmospheric air be mixed with this gas, and fire be applied, it will explode with violence. It is related of Pilatre de Rosier, that, having mixed one part of common air with nine parts of hydrogen gas, and drawn the mixture into his lungs, it caught fire by accident as he respired it, and the whole of the gas exploded in his mouth and nearly deprived him of life. The shock was so violent, that at first he thought the whole of his teeth had been driven out, but fortunately he received no lasting injury. Being myself engaged some years ago in a process in which a large quantity of hydrogen gas was evolved, and having incautiously brought a lighted candle too near the apparatus, the whole exploded with a tremendous crash; and several 12-gallon glass receivers were shattered into ten thousand pieces, and driven in all di-

vine, wax, tallow, and other combustible bodies, re well known to consist of two ingredients at the east[b].

It will be necessary to examine each of these sub-tances separately:—therefore, what is the nature of *IYDROGEN*[c]*?*

Hydrogen is the basis[d] of what has been generally alled inflammable air[e], and is one of the component arts of water[f]; but it cannot be exhibited in a se-arate state. We therefore know it only in combi-ation with other substances[g], or in the gaseous form, hat is, with caloric[h].

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ections throughout the laboratory. Such accidents should be noticed 1 every elementary chemical work, in order to inspire the young pupil ith caution when operating on such substances.

[f] Hydrogen is the most inflammable substance we are acquainted with; hat is, it combines with more oxygen than any other body, and occasions nore heat by its combustion. It may be remarked that OXYGEN is *mild* hen in the proportion of 21 per cent. in atmospheric air, and highly *orrosive* in the proportion of 74 per cent. in nitric acid or even in that f 49 per cent. in sulphuric acid:—How is it then, that it is found in the atio of 88 per cent. in water, and that this compound, compared with he others, should be perfectly mild and innocent? Instances of a similar ccommodation of the elementary substances have been adduced; and hough we cannot comprehend the nature of their operation, we can erceive that the ultimate end of the Creator is our convenience and appiness. See pages 48 and 160. Most oxidized substances, when aken internally, act perceptibly on the system; yet water, the most oxi-ized of all others, has comparatively little influence, because its oxygen so forcibly retained and so completely neutralized by the hydrogen. ad it been otherwise, what is now the most salubrious beverage would ave operated as a corrosive poison.

Berthollet has shown that at all temperatures there is a greater dis-osition in hydrogen than in carbon to combine with oxygen. See his *hemical Statics*, vol. i. page 244.

Oil, tallow, wax, &c., used for producing light, do all acquire their ower of burning *with flame*, from the hydrogen, which is a component art of all these substances.

[g] Although hydrogen when in an aërial form is the lightest of all nown substances, yet when imbibed by living vegetables it becomes a olid, so as to form wax, resin, &c.; and in combination with oxygen it onstitutes water, which has the property of becoming either solid, fluid, r aëriform.

[h] A mixture of oxygen and hydrogen gases produces the most powerful

In what other compounds is hydrogen an ingredient?

Hydrogen gas may be combined with water, sulphur, phosphorus, or with carbon.

What is the nature of the compound of hydrogen and water?

Water may be made, by pressure, to absorb a considerable portion of hydrogen gas. It is called hydrogenated water, and is said to be useful in medicine.

What is the nature of the compound of hydrogen and sulphur?

Sulphur dissolved in this gas forms sulphuretted hydrogen gas[a], which is a very fetid elastic fluid, somewhat heavier than atmospheric air and soluble in water.

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heat yet known. This may be shown by preparing a bladder full of each of these airs, and forcing some out of each into a common tube connected with both, and throwing a stream of the mixed gases on burning charcoal, or on any other substance in the act of combustion. These bladders should each be furnished with a small metallic pipe and stop-cock, and the tube connecting with both should have a very small orifice, in order that a regular stream of the commixed gas may be thrown upon the burning substance. *In performing this experiment all solid vessels should be discarded, for fear of an accident by explosion. When bladders are used no damage can arise, even if such an accident should happen.* See Dr. Clarke's very interesting 'Account of some experiments made with Newman's blow-pipe,' published in the *Journal of the Royal Institution of Great Britain*, vol. ii. page 104.

[a] To obtain sulphuretted hydrogen gas, melt together in a crucible three parts by weight of iron-filings and one of sulphur; reduce the mass to powder, and put it with a little water into a glass vessel with two mouths: lute one end of a crooked glass tube into one of these mouths, and let the extremity of the tube pass under a glass jar in a pneumatic trough, the jar being inverted and full of water. Then pour diluted muriatic acid through the other mouth of the vessel, which must immediately be closed up. Sulphuretted hydrogen gas will now be disengaged in abundance and flow into the glass jar, displacing the water. It may also be procured by heating together sulphuret of antimony and muriatic acid, and collecting the gas which is evolved by their mutual action on each other.

This gas is composed of 15 parts of sulphur and 1 of hydrogen.—Its specific gravity, compared with hydrogen, is 16 to 1. 100 cubical inches of it weigh 36 grains.

What are the properties of sulphuretted hydrogen gas?

SULPHURETTED HYDROGEN gas [b] is transparent and colourless; it has the property of inflammability, is nauseous to the taste as well as fetid to the smell; it possesses all the characters of an acid [c]: it combines with earths [d], alkalies, and with several of the metallic oxides; and forms with them those substances called *hydrosulphurets*.

What are the properties of the hydrosulphurets?

The HYDROSULPHURETS are generally soluble in water, and their solutions precipitate the metallic oxides, from metallic solutions. Exposure to the air, however, decomposes these hydrosulphurets when dissolved in

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Water impregnated with sulphuretted hydrogen gas is of use to separate ome metallic oxides when in solution. Thus, if it be added to a solution acetate of lead, the lead will be precipitated of a deep brown colour.

[b] This gas was long known by the name of *hepatic* gas, because the bstances from which it was first obtained were called *hepars* or livers sulphur.

When this gas is set on fire in contact with oxygen gas, it burns with pale blue flame, without exploding. It will of itself extinguish burning dies, and destroy animals which are made to inhale it.

Sulphuretted hydrogen gas is decomposed by atmospheric air. The ygen of the atmosphere combines with the hydrogen and forms water, ile the sulphur is precipitated. The sulphur which is found in the ighbourhood of mineral springs originates from this cause.

The fetid smell which arises from house-drains is owing in a great easure to a mixture of this gas with other putrid effluvia. As the difsion of this noxious matter within our dwellings tends to produce disease d mortality, it cannot be too generally known that a cheap and simple paratus has been contrived for carrying off the waste water, &c., of ks, and which at the same time prevents the possibility of any air ever urning back into the house from thence, or from any drain which may connected with it. It is known by the name of a *stink trap*, and may had of some of the ironmongers in London.

As sulphuretted hydrogen gas is formed without oxygen, and yet ssesses strong acid properties, it seems to overthrow the doctrine of voisier, who asserted that oxygen was the only principle of acidity. riatic acid also has been proved to contain no oxygen.

We have a mineral called *swinestone*, (or fetid carbonate of lime,) ich is so fully impregnated with this compound, that, if it be merely water[a], and partially converts them into hydroguretted sulphurets.

How many compounds are there of sulphur and hydrogen with the alkaline and earthy bases?

There are three distinct combinations of sulphur and hydrogen with the earths and alkalies, which differ in their properties in consequence of the difference there is in the proportions in which their constituent parts are combined.

Can you explain what difference there is in the composition of these three distinct classes of substances?

The first, which are called *sulphurets*, are merely compounds of sulphur united to some earthy or alkaline base; the second, called *hydrosulphurets*, are formed by the union of some base with sulphuretted

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rubbed, the disagreeable odour of sulphuretted hydrogen will be very perceptible.

[a] The waters of Harrowgate, Aix la Chapelle, and others of a similar nature, owe their medicinal properties to sulphuretted hydrogen gas and muriate of soda. The *salt of bitumen* of the Hindoos, which is almost the only article of Hindoo physic, and is sold in every village, is chiefly composed of muriate of soda and sulphuretted hydrogen. It is taken by these people for every complaint. The farriers give it to the horses, and seem to understand the principle on which it acts; for when they have given a dose to the animal they always give him water to extricate the gas.—Henderson on *Hindoo Physic.*

Secret correspondence has often been carried on by means of Harrowgate water. A letter written with a solution of acetate of lead is illegible; but if it be dipped in this water, the writing will appear, and shortly become almost black. Hydrogen has the property of reviving metallic oxides; hence ladies who have used metallic cosmetics, have become dark tawnies by bathing in these waters. See a note on bismuth, chapter x.

[b] The hydroguretted sulphurets may be formed by the following process. Let an hydrosulphuret be mixed with flour of sulphur and digested in a gentle heat; by this means an additional portion of sulphur will be dissolved, part of the sulphuretted hydrogen will escape, and the remaining compound will have become an hydroguretted sulphuret. There are other modes also of forming similar compounds.

The hydroguretted sulphurets have the following properties and ap-hydrogen; and the third, called *hydroguretted sulphurets*[b], consists of a base united with supersulphuretted hydrogen.

What is the nature of supersulphuretted hydrogen?

Supersulphuretted hydrogen is merely sulphuretted hydrogen combined with an additional proportion of sulphur; that is to say, one part of hydrogen combines with 15 parts of sulphur to form sulphuretted hydrogen, and with 30 parts of sulphur to constitute supersulphuretted hydrogen.

What is the nature of the combination of hydrogen and phosphorus?

Hydrogen gas when combined with phosphorus forms *phosphuretted hydrogen gas*[c]. This gas has a

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pearances. Their colour is deep yellow tinctured with green, they smell offensively, and have a taste extremely bitter and pungent. On the addition of the stronger acids they become decomposed, and sulphur precipitates from them: a similar precipitation also occurs when kept or any length of time even in close vessels. They have the property of bsorbing oxygen with great rapidity from the atmosphere, and on this ccount are very proper for purposes of eudiometry. See Additional Notes, No. 63.

[c] Phosphuretted hydrogen gas may be formed by boiling a little phoshorus in a solution of pure potash. The water is decomposed thereby, nd furnishes the hydrogen. The retort should be nearly filled with the olution, otherwise the gas will inflame.

This gas may be formed by introducing phosphorus into a glass jar ull of hydrogen gas standing over mercury, and melting the phosphous by means of a burning-glass. This compound gas burns with great apidity in common air, but in oxygen gas the combustion is extremely rilliant. If bubbles of it be made to pass up through water, they exlode in succession as they reach the surface of the liquid, and a beauful coronet of white smoke is formed, which rises slowly to the ceiling f the room. This gas is one of the most combustible substances we now of.

Sir Humphry Davy forms phosphuretted hydrogen gas by decomposing ater with zinc and sulphuric acid, and adding to the mixture small ieces of phosphorus. But as some management is necessary in order conduct the process successfully, I refer the reader to his paper in icholson's *Journal of Philosophy and Chemistry*, for April 1802.

fetid putrid smell, and takes fire whenever it comes in contact with atmospheric air[a].

What is the nature of the combination of hydrogen with carbon?

This elastic substance, which is called *carburetted hydrogen gas*[b], is carbon dissolved in hydrogen; it has likewise been called heavy inflammable air[c]. It is this gaseous compound which has occasioned so many dreadful accidents in coal-pits. The miners call it the *fire damp*[d].

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[a] If bits of phosphorus be kept for some hours in hydrogen gas, *phosphorized hydrogen* gas is produced, having somewhat of the smell of garlic. If bubbles of it are thrown up into oxygen gas, a brilliant blueish flame will immediately pervade the whole vessel. This slow combustion is owing to the gas containing *less* phosphorus than the *phosphuretted hydrogen* gas. Perhaps it is this gas which is sometimes seen hovering on the surface of burial-grounds, known by the name of *will-o-the-wisp*.

[b] In hot weather this gas is formed at the bottom of stagnant waters, and may readily be collected at their surface, by suspending a bottle of water over the pool, similar to the decanting of gases over a pneumatic trough, and stirring up the mud to disengage the carburetted hydrogen.

This gas generally contains a portion of carbonic acid mixed with it. Both these aëriform fluids are produced by the decomposition of water by putrid animal and vegetable matter. Such decompositions take place chiefly when the sun shines upon these waters, caloric being necessary to all gaseous compounds.

Carburetted hydrogen may be formed artificially by exposing charcoal in glass vessels filled with hydrogen gas to the rays of the sun. It is invisible, elastic, and inflammable. The proportions of carbon and hydrogen vary according to the processes by which the gas is obtained. Its specific gravity, in its purest form, is to that of hydrogen gas as rather less than 9 to 1. One hundred cubical inches weigh about 20 grains.

[c] This gas is procured from pit-coal by dry distillation for the purpose of forming the thermo-lamp, and is now employed for lighting the public streets, light-houses on the sea-coasts, mines, manufactories, &c. See page 10. One pound of coal yields about 24 gallons of this inflammable gas, and the remainder serves for fuel; it being excellent coke. Its combustible property, and that it serves for the purposes of light and heat, were discovered about 70 years ago by the Rev. Dr. John Clayton. See Mr. Hume's letter in Nicholson's *Journal*, vol. xvi. page 170. For an account of its employment in the support of a popular superstition, see page 140. See also Additional Notes, No. 66.

All oils, resins, gums, wax, sugar, and numberless other inflammable

What is meant by SUPER-CARBURETTED HYDROGEN*?*

This is a gaseous compound of carbon and hydrogen, containing exactly twice as much carbon as the carburetted hydrogen gas. It is extremely inflammable, and emits more light during combustion than is given out by the inflammation of that gas. It has been called *olefiant gas*[e].

What is the origin of SULPHUR*?*

Sulphur is found in most parts of the world[f] com-

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substances, are composed of hydrogen and carbon in various proportions, and, in many cases, with the addition of oxygen. Hydrogen is also one of the bases of all animal and vegetable acids; and with nitrogen it constitutes ammonia.

[d] What renders this gas so extremely dangerous in mines is the circumstance that whenever the atmosphere of a mine becomes charged with more than one-thirteenth of its volume of carburetted hydrogen gas, the whole becomes explosive. It is, however, now expected that the safety-lamp of Sir Humphry Davy, which is a most important discovery, will be a means of lessening the number of these accidents.

[e] When a mixture of four parts of oil of vitriol and one of alcohol is heated in a retort, a gas is generated which is found to be a compound of carbon and hydrogen, called *super-carburetted hydrogen* and also *olefiant gas*. When kindled it burns with a beautiful white flame of intense splendour. According to Sir Humphry Davy the specific gravity of this gas is to that of hydrogen nearly as 13 to 1. One hundred cubical inches of it weigh between 29 and 30 grains. When olefiant gas is mixed with an equal volume of chlorine, the two gases condense each other, and a peculiar fluid is formed, which has been supposed to be an oil, and has occasioned the supercarburetted hydrogen to be called *olefiant gas*.

[f] Sulphur is so plentifully diffused, that probably it was known very early: according to Pliny, it was used in his time in medicine, and for bleaching wool. Apuleius, who lived in the time of the Antonines, re-ates in the romance of *The Golden Ass*, a singular anecdote which proves the early employment of sulphur for bleaching wool. See that work, book ix. page 136, edit. Scrivenii, Amst. 1624, or my Treatise on Bleach-ng in *Chemical Essays*, vol. iv. page 154.

Sulphur is procured in large quantities from martial pyrites and other metallic ores. It is also found in abundance in the state of native sulphur, s it is called, near several volcanos, in different parts of the world. According to Dr. Anderson, there are mines of it in the kingdom of Thibet. *The Bee*, vol. xvii. page 25. In the Isle of Anglesea it is sub-imed from the copper ore, and collected in large chambers which are connected with the kilns by means of long horizontal flues. See Hen-kel's *Pyritologia*, octavo, London 1757. Dr. Nugent has published an bined with metals, from which it is procured by roasting; it also flows from volcanos; it is sublimed from the sulphureous grounds in Italy, and is found in many mineral waters[a], combined with hydrogen.

What is the nature of sulphur?

Sulphur, or brimstone as it is sometimes called, is a solid, opaque, combustible[b] substance, of a pale yellow colour, insoluble in water, very brittle, and possessing a peculiar taste and smell. Its specific gravity is 1.990, or nearly twice as heavy as water, and it is a non-conductor of electricity. It has various uses in medicine and the arts.

What compounds[c] *are formed by means of sulphur?*

Sulphur is the base of several compounds; it unites with oxygen, hydrogen, carbon[d], phosphorus, the alkalies, the metals, and with some of the earths[e].

What are the compounds of sulphur and oxygen?

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account of the sulphur of the Island of Montserrat, in the *Trans. of the Geol. Soc.* vol. i. p. 185.

[a] Sulphur has been discovered in cresses, horseradish, and several other vegetables. It is also evolved from animal substances, during their putrefaction, in combination with hydrogen. The change which silver undergoes when immersed in an egg, shows the presence of sulphuretted hydrogen.

[b] Sulphur during its combustion combines with oxygen, and becomes an incombustible substance. Like phosphorus, it is eminently combustible, owing to its great affinity for oxygen. See pages 146, 147.

If sulphur be kept melted in an open vessel, it at length becomes thick, as has often been observed; but I believe it has not been noticed by any writer on chemistry, that it has the peculiar property of becoming *thinner* as it cools, till it is nearly as thin as water. This is an exception to the general law, by which caloric causes the particles of bodies to recede from each other.

[c] "Nature employs sulphur in a great number of her operations: she presents it under many forms among fossils; charges with it the waters denominated sulphureous; mineralizes with it the metals; causes it to pass into the vegetable and animal fibres; and exhibits it to chemists in an infinite number of combinations."

[d] Sulphuret of carbon, which is prepared by a peculiar process from a

If sulphur be kept in fusion in atmospheric air, it absorbs a small quantity of oxygen, and forms oxide of sulphur[f]; if it be heated sufficiently to take fire, it burns with a pale blue flame, and becomes converted to *sulphurous* acid; but if sulphur be burned in pure oxygen, it absorbs the full dose of this gas, and *sulphuric* acid is the product[g].

What are the compounds of sulphur and the alkalies?

Sulphur will combine with potash, with soda, and with ammonia; which compounds possess several curious and interesting properties.

What are the general characteristics of the alkaline and earthy sulphurets?

They are hard substances of a brown colour, resembling the liver of animals; they absorb water from the atmosphere, and then emit a fetid odour, similar to that of putrid eggs[h]. They have the property of

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heated mixture of charcoal and sulphur, is a colourless liquid of the specific gravity of 1.272, highly inflammable, and capable of forming compounds with the earths and alkalies. It is composed of sulphur 84.83, and carbon 15.17, and is called *alcohol of sulphur*. Dr. Marcet has discovered that its property of producing cold exceeds that of every other known substance. See *Philosophical Transactions* for 1813. For an account of the compounds of hydrogen and phosphorus with sulphur, see pages 224, 225, and 235, 236.

[e] Sulphur is used in large quantities for making gunpowder. When exhibited as a medicine, it penetrates to the extremities of the most minute vessels, and impregnates all the secretions; as may be perceived by those who have taken it for any length of time. Sulphur has many uses in the arts, and has been employed with advantage in stopping the progress of fermentation in wines and other fermented liquors.

[f] See the chapter on Oxides; also Fourcroy's *System of Chemical Knowledge*, vol. i. page 276.

[g] For an account of the changes which take place in sulphur when it becomes oxygenized, see page 146, 147.

[h] Sulphuret of potash is formed by the explosion of gunpowder, and it is this compound which occasions that peculiar smell which a gun usually has after firing.

decomposing water, and by that process become partially converted to alkaline or earthy sulphates[a].

What knowledge have we acquired of the combinations of sulphur with the earths and metals[b]*?*

Sulphur may be combined artificially with most of the metals[c], and with some earths: but many of the metallic sulphurets are found native in great abundance.

What is the origin of PHOSPHORUS*?*

Phosphorus is a peculiar substance, both of animal[d]

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[a] The sulphurets can only exist in a state of desiccation, or at least can contain but a very small portion of water without the water being decomposed, which occasions the sulphurets to be changed into hydroguretted sulphurets. The alkaline sulphurets have also the property of decomposing the metallic oxides. See Additional Notes, No. 63.

[b] There have been instances, where people have taken frequent doses of mercurial medicine, of the human skin becoming suddenly quite black a few hours after the outward application of sulphur-ointment; to the great terror and amazement of the patient. This was occasioned by the mercury exuding through the pores of the skin to unite with the sulphur, in consequence of its affinity to that substance; and a true æthiops-mineral was formed over the whole body.

[c] Some of the metallic sulphurets have much colour, and are employed as pigments. *Realgar* and *orpiment*, which are sulphurets of arsenic, are of this class. Some account of these native minerals will be found in Chapter X. in the Notes on Arsenic.

Sulphuret of lime is recommended by Mr. Higgins as a cheap substistute for potash in bleaching. For the method of preparing it, consult his work on *the Theory and Practice of Bleaching*, published in Ireland and also in London in 1799.

[d] The real origin of phosphorus is very obscure: some have supposed it to be a product of the process of animalization, and several curious facts might be adduced to strengthen this opinion.

[e] Phosphorus was accidentally discovered at Hamburg, in 1669, by an alchemist of the name of Brandt, in his search after gold; and two years afterwards one Kraft brought a small piece of this substance to London, on purpose to show it to the king and queen of England. Mr. Boyle afterwards discovered the process, which he described in the *Philosophical Transactions* for 1680, and in a little book which he published in the same year, entitled *The Aërial Noctiluca*. Mr. Boyle instructed Mr. Godfrey Hankwitz of London how to procure it from urine, so that he was the first who made it for sale in England; and he continued to supply all Europe with it for many years. I have in my possession a scarce portrait, by Vertue, of this chemist in the midst of his laboratory surrounded by his chemical apparatus; the form of which shows that even at that

and mineral origin. It was formerly obtained by a very tedious and disgusting process; but is now generally procured by the decomposition of the phosphoric acid which is found in animal bones[e].

What is the nature[f] of phosphorus?

Phosphorus is a solid inflammable[g] substance, which burns at a very low temperature, when in contact with oxygen gas or atmospheric air, and, when thus saturated with oxygen, it forms a peculiar acid[h]. It

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ime they had the means of accurate analysis, if they had had a rational heory to direct them. From a Latin inscription it appears that he had his print engraved to present to his customers on his taking leave of hem, when about to enter upon his travels abroad to sell phosphorus.

The discovery of phosphorus proves that valuable discoveries may be nade even by men who have no means of appreciating their nature. Stahl maintained that it was the *marine salt* contained in urine which ielded phosphorus.

[f] Phosphorus when taken internally is poisonous. It is related in the *Annales de Chimie* that a great number of domestic fowls and turkeys vere poisoned, merely by drinking the water in which some newly made hosphorus had been washed. Though poisonous, it has been given in *mall* quantities by some French physicians, in malignant fevers, to stop he progress of gangrene, in which it succeeded beyond all hope. Niholson's *Journal of Philosophy and Chemistry*, vol. iii. page 85.

[g] If a piece of phosphorus be placed on the surface of water a little elow the heat of boiling, it will immediately inflame. This is one chaacteristic of phosphorus, and distinguishes it from all other substances. t melts at the temperature of 90°, and takes fire at about 148°.

[h] Phosphorus is used in forming phosphoric acid, in various chemical xperiments, and in making phosphoric match-bottles. These bottles ay be prepared by mixing one part of flour of sulphur with eight of hosphorus. When used to procure light, a very minute quantity is taen out of the bottle on the point of a match, and rubbed upon cork or ood, which produces an immediate flame.

Phosphorus is employed in making phosphoric ether, phosphoric oil, hosphoric tapers, phosphuret of lime, and various phosphoric fireworks. he methods of forming these combinations may be seen in Dr. Thomson's in Dr. Murray's *System of Chemistry*.

Phosphorus, surrounded by cotton rubbed in powdered rosin, and placed nder the receiver of an air-pump, takes fire after exhaustion, and dislays very beautiful phænomena on the gradual admission of the air.—an Marum.—Parkinson.

These experiments require caution; for phosphorus should always be andled with great care, lest any part of it get under the finger nails, a mall portion of which might occasion great inconvenience.

may be easily cut by the knife, and melts at 90° of Fahrenheit. Its specific gravity is nearly twice that of water.

What compounds are formed by means of phosphorus?

Phosphorus may be combined with oxygen, hydrogen, chlorine[a], sulphur, or with most of the metals[b], and also with some earths[c].

What is the nature of these compounds?

Phosphorus forms with oxygen, according to the proportion of the latter, either oxide of phosphorus[d], or phosphorous acid, except it be saturated with oxygen, and then phosphoric acid[e]; with hydrogen, phosphuretted hydrogen[f]; with sulphur, phosphuret of sul-

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[a] Sir Humphry Davy has formed two compounds with phosphorus and chlorine; the one is a white powder, composed of about 1 of phosphorus, and 6.8 of chlorine by weight; and which he calls *phosphorana*; the other is a fluid as clear as water, and its specific gravity is 1.450; he calls it *phosphorane*. See note[g], page 155.

[b] Phosphorus will combine with all the metals except gold and zinc. It unites with iron, and forms that kind of iron called *cold-short*. Iron of such property acquired this name on account of its being very brittle when cold, though malleable when heated. Such iron may however be made good and fit for most purposes, by heating it with carbonate of lime. *Annales de Chimie*, tome xlii. page 832.

[c] Several species of animals have the property of emitting light. The light of the glow-worm is well known, but the *pyrosoma atlanticum* has not been described by naturalists. M. Peron, on his voyage from Europe to the Isle of France, observed this animal between 3 and 4 degrees north latitude. Its phosphorescent quality (as it has been called), so truly prodigious, renders it one of the most beautiful of all known zoophites, and its organization ranks it amongst the most singular. The darkness was intense when it was first discovered; the wind blew with violence, and the progress of the vessel was rapid. All at once there appeared at some distance, as it were a vast sheet of phosphorus floating on the waves; and it occupied a great space before the vessel. The vessel having passed through this inflamed part of the sea, the crew discovered that this prodigious light was entirely occasioned by an immense number of small animals, which swam at different depths, and appeared to assume various forms. Those which were deepest looked like great red-hot cannon balls; whilst those on the surface resembled cylinders of red-hot iron. Some of them were soon caught, and were found to vary in size from three to

phur, and sulphuret of phosphorus; with the metals, metallic phosphurets[g]; and with some of the earths, earthy phosphurets[h].

What is the origin of CARBON?

Pure carbon is known only in the diamond: but it may be procured in the state of charcoal by burning a piece of wood closely covered with sand, or any other convenient material, in a crucible, so as to preserve it from the action of the atmosphere.

What compounds are formed by means of carbon?

Carbon is capable of forming various combinations: it unites with oxygen, hydrogen, nitrogen[i], sulphur, or phosphorus, and with iron.

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even inches. All the exterior surface of the animal was bristled with thick oblong tubercles, shining like so many diamonds; and these seemed to be the principal seat of its wonderful power of emitting light. In the inside also there appeared a multitude of little oblong narrow glands, which possessed the same virtue in a high degree. The colour of these animals, when in repose, is an opal yellow mixed with green; but on the slightest movement of those spontaneous contractions which it exercises, or those which the observer can at pleasure cause by the least irritation, the animal inflames, and becomes instantly like red-hot iron, and of a most brilliant brightness. As it loses its phosphorescence, (if this property be phosphorescent,) it passes through a number of tints successively, which are extremely agreeable, light, and varied; such as red, aurora, orange, green, and azure blue: this last shade is particularly lively and pure. A further account of this curious creature may be seen in one of the early volumes of the *Journal de Physique*.

[d] Oxide of phosphorus is a solid body of a red colour, which does not melt until it be heated to 212° or upwards: it has no acid properties, but its proportion of oxygen has not yet been ascertained.

[e] See an account of the nature of these acids in the chapter on Acids, page 160.

[f] For an account of phosphuretted hydrogen gas see page 272.

[g] See Note, page 234.

[h] For some account of the native phosphates see chapter 7, page 161, note [e].

[i] The compound formed by the union of carbon and nitrogen is known by the name of prussic gas. It was discovered by Gay Lussac, and by him called *cyanogen*. It is obtained from prussiate of mercury by distillation. It is a permanent gas, very inflammable, and nearly twice as heavy as atmospheric air. It affects the nostrils violently when inhaled by them.

What is the nature of these compounds?

Carbon with various doses of oxygen[a] forms carbonic oxide[b] or carbonic acid[c]; with hydrogen and caloric, carburetted hydrogen gas[d]; with nitrogen and caloric, carburetted nitrogen gas; with sulphur, sulphuret of carbon; with phosphorus, phosphuretted carbon; and with iron, plumbago, or carburet of iron[e].

Some of these compounds having been already examined, it will now be expedient to consider the other states and combinations of carbon;—therefore, what is charcoal?

Charcoal, which is the combination with which we

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[a] Messrs. Allen and Pepys have lately shown that charcoal ought not to be considered as an *oxide of carbon,* for that, when well prepared, it requires as much oxygen for its combustion as the diamond; and that diamond and all pure carbonaceous substances differ generally from each other only in the state of aggregation of their particles. See *Philosophical Transactions* for 1807, part ii. page 267.

[b] For some account of carbonic oxide see what is said of the oxides of carbon in chapter xi. of this work.

[c] See page 158.

[d] For some account of carburetted hydrogen gas see page 228.

[e] See some account of plumbago, in page 247.

[f] Charcoal for common purposes is made by a less expensive process. The wood is disposed in heaps regularly arranged, and covered with earth, so as to prevent the access of any more air than is absolutely necessary to support the fire, which is kept up until all the water and oil are driven off; after which the fire is extinguished by shutting up all the air-holes. A more economical method is first to collect the pyroligneous acid from the wood, by dry distillation in large iron cylinders; and then the residuum in the cylinders will be charcoal of the best quality. By this process His Majesty's gunpowder works have for some time past been supplied with charcoal.

[g] Charcoal is so porous that it may be seen through with a microscope; and, however large the piece, it may be readily blown through.

[h] "All sorts of glass vessels and other utensils may be purified from long retained smells of every kind, in the easiest and most perfect manner, by well rinsing them out with charcoal powder, after the grosser impurities have been scoured off with sand and potash. Putrid water is immediately deprived of its offensive smell by charcoal."—See Crell's *Journal*, vol. ii. page 170.

Meat, which is only a little tainted with putridity, may at once be made sweet by charcoal: and if common raw spirits be agitated with charcoal are the most familiar, is the coaly residuum of any vegetable substance that has been burnt in close vessels[f].

What are the characters and appearances of charcoal?

Charcoal is generally black, sonorous, and brittle; very light, and destitute of smell[g].

What are the properties of charcoal?

Charcoal is a powerful antiseptic[h]; when ignited it has great affinity for oxygen[i]; is unalterable and indestructible by age[k]; is a non-conductor of electricity, and a bad conductor of heat; and if air and moisture be excluded, is not affected by the most intense fire.

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they will be deprived of their bad flavour. A gentleman in the spirit trade however informs me, that spirits treated in this way are very apt to resume the old flavour, if kept in the cask only a few months.

[i] Charcoal, from its affinity with oxygen, will decompose the sulphuric and nitric acids. It decomposes the latter with great rapidity. If the charcoal be dry and finely powdered, and the acid strong, and allowed to run down the inner side of the vessel to mix with the charcoal, it will burn rapidly, giving out a beautiful flame, and throwing up the powder so as to resemble a brilliant fire-work.

[k] "The beams of the theatre at Herculaneum were converted into charcoal by the lava which overflowed that city; and during the lapse of seventeen hundred years the charcoal has remained as entire as if it had been formed but yesterday; and it will probably continue so to the end of the world. The incorruptibility of charcoal was known in the most ancient times; the famous temple at Ephesus was built upon wooden piles, which had been charred on the outside to preserve them." See Watson's *Chemical Essays*, vol. iii. page 48.

"It is said that there still exists charcoal made of corn in the days of Cæsar, which is in so complete a state, that the wheat may be distinguished from the rye."—Willich.

"About forty years ago a quantity of oak stakes were found in the bed of the Thames, in the very spot where Tacitus says that the Britons fixed a vast number of such stakes, to prevent the passage of Julius Cæsar and his army. They were *charred* to a considerable depth, retained their form completely, and were firm at the heart."—Dr. Robison's *Introduction to Black's Lectures*. The ancients wrote with levigated charcoal, the most indestructible substance we know of; and accordingly, the writings found in Herculaneum are still a perfect black. Ib. vol. ii. page 480.

[l] Casks charred in the inside are now used to preserve water in sea voyages; and such casks are found to preserve the water uncorrupted. Dr. Black's *Chemical Lectures*, vol. ii. page 285.

To what uses is charcoal applied?

In the preparation of gunpowder charcoal is a most important ingredient; it is also employed in purifying rancid oils, and abstracting the colour from sirups and many other valuable preparations; for decomposing the sulphuric salts, which it effects by absorbing the oxygen of their sulphuric acid and liberating the sulphur; and for so many other purposes, by the chemist and the manufacturer [a], that it would be impossible to enumerate them.

Is charcoal a simple or a compound substance?

Common charcoal is a compound substance: it is an *oxide* of carbon, or the woody fibre partially oxidized; it also contains hydrogen [b], and a portion of fixed

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[a] Charcoal is used by mathematical instrument-makers and engravers to polish their brass and copper plates. Plates of horn and lantern leaves are polished with it. It is also much used by artists in tracing the outlines of drawings. See Additional Notes, No. 2.

[b] To the attention of those manufacturers who reside near coal-works where the small coal is fit for making coke, I take this opportunity of recommending the coke ovens of the Duke of Norfolk, drawings of which I have lately had engraved for *The Chemical Essays*. See also Additional Notes, No. 50. The small of some coal will not coke.

[c] Messrs. Allen and Pepys have lately determined by experiment that charcoal properly prepared contains no sensible quantity of hydrogen, but that it absorbs moisture if exposed to the air only a few hours, which renders the result of analysis uncertain.

[d] The diamond is chiefly found near Golconda in Asia, and in Brazil. It always occurs crystallized; indeed, if not, it would be carbon and not diamond. See a note respecting the diamond under the article Steel, in the chapter on Metals; where you have an additional proof that diamond is simple carbon. It is wonderful that Newton, who had no chemical means of examining the diamond, should have conceived the idea of its inflammable nature. See Additional Notes, No. 35.

Mr. Tennant has satisfactorily shown that the diamond is pure carbon, carbon crystallized. See *Philosophical Transactions* for 1797. The diamond is the hardest substance in nature, and one of its rarest productions. From its hardness it is employed for sawing and boring the hardest stones. It is a conductor of electricity, though charcoal is a non-conductor of that subtile fluid. "Diamonds are usually found in an ochreous yellow earth, under rocks of grit-stone; they are likewise found detached in torrents, which have carried them from their beds. The sovereigns alkaline salt and some earth, but these are rather adventitious than essential ingredients[c].

What is the substance which you call carbon?

The base of common charcoal, divested of all impurities, is known to chemists by the name of CARBON.

What is the most striking property of pure carbon?

Carbon is capable of crystallization, though not by art; and in that state it is called *diamond*[d].

What are the other properties of carbon?

Carbon has the property of de-oxidizing the oxides of metals and other combustible substances[e], and with this view it is often used in the arts. These purposes are effected by means of fire, the carbon uniting to the oxygen to form carbonic oxide, or carbonic acid[f]; and

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of India reserve the largest, in order that the price of this article may not fall. Diamonds have no brilliancy when dug out of the earth, but are covered with an earthy crust. Diamonds are also found in considerable numbers in the island of Borneo. Whenever the mines are searched for them, an overseer attends, and watches the workmen with great care, that the largest may be secured for the sovereign prince. Notwithstanding, they are frequently conveyed away clandestinely by the workmen, who will swallow them." Von Wurmb's *History of Borneo*.

A minute account of the diamond mines of Brazil may be seen in *Annales de Chimie*, tome xv. page 82; in Nicholson's *Journal*, 4to, vol. i. page 24; and more particularly in Mr. Mawe's *Travels into the Interior of Brazil*, 4to, 1815, page 219—238.

The usual method of calculating the value of diamonds, is by squaring the number of carats, and then multiplying the amount by the price of a single carat: thus, supposing one carat to be worth 2*l*., a diamond of 8 carats is worth 128*l*., being 8 × 8 × 2. A carat is four grains. *Polished* diamonds, without blemish, are worth about 6*l*. per carat.

In the year 1772, the empress of Russia purchased a diamond that weighed 779 carats, nearly 6½ ounces troy. She paid the immense sum of twelve tons of gold for it, and granted a pension of 4000 roubles per annum to the vender.

[e] Charcoal has such a powerful affinity with oxygen, that in a proper degree of heat it will abstract it from all other substances.

[f] The merit of the discovery of carbonic acid is due to the illustrious Dr. Black of Edinburgh. Those who have not been in the habit of reading the early chemical writers can have no idea of the service which this great man has rendered the science by his very accurate investigation of this compound gaseous substance.

the metal thus deprived of oxygen, is left in its pure state.

Does carbon enter into any other combinations?

Carbon is found in large proportions in bitumen, petroleum, and pit-coal[a]; it seems to be ready formed also in all vegetables, and in most animal substances; and combined with oxygen, enters into the composition of a great variety of the products of the mineral kingdom[b].

What is the proportion of carbon in pit-coal?

Pit-coals vary in quality, according to the different

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[a] There are good reasons for supposing that bitumens and pit-coal have been formed in the bed of the sea by the decomposition and deposition of animal matters. The quantity of volatile alkali which these substances yield on distillation favours this opinion. An interesting paper by the late Dr. Kirwan, on the proportions of carbon in the different kinds of coal, will be found in Nicholson's *Journal of Philosophy and Chemistry*, 4to, vol. i. page 487.

See an ingenious paper by Mr. Hatchett, on the origin of bitumen, &c., in the *Philosophical Transactions* for 1804. See Additional Notes, No. 39.

An interesting account of the springs of fossil tar near Shrewsbury, and at Colebrook Dale, may be seen in Archdeacon Plymley's *View of the Agriculture of Shropshire*.

[b] The principal mineral substances to which I have alluded are, the native carbonates of barytes, lime, copper, lead, magnesia, silver, strontites, and zinc. For a description of these several minerals, I must however refer to Professor Jameson's *System of Mineralogy*, or some other work of that nature.

[c] The immense quantity of pit-coal which is deposited beneath the surface of the earth is truly astonishing, and affords abundant matter for reflection. This kind of fuel is consuming day after day in incalculable quantities; and so great is the store, that there is no probability of its being exhausted for ages yet to come. Supposing the formation of pitcoal to be owing to the deposition of vegetable and marine animal matter; the same process must be still going on, and the inmost recesses of the present seas may be receiving the materials of fuel for the inhabitants of new continents in the most remote periods of the world. The wise economy of the great Author of Nature, in this constant circulation of the elements of matter, is equalled by nothing but his own infinite beneficence:

"Who, not content
By one exertion of creative power
His goodness to reveal; through every age,
Through every moment up the tract of time
Adjusts, accommodates, and blesses all."

proportions of carbon and bitumen which they contain [c]; but carbon is the *chief* ingredient in all. What are called *slaty* coals hold also from 10 to 40 per cent. of earth [d]; and some coals likewise contain a considerable quantity of the sulphuret of iron, known by the name of *martial pyrites*.

What is the use of carbon in the vegetable kingdom?

Carbon is not only a component part, but it forms early the whole of the solid basis of all vegetables, rom the most delicate flower in the garden to the uge oak of the forest [e].

On the formation of coal, consult Mr. Williams's *History of the Mi-*
eral Kingdom, and Parkinson's *Organic Remains of a Former World.*

[d] There are four species of coal, very distinct from each other: the
raphite of Werner, or plumbago; the *anthracolite*; the *jet*, or pitch coal;
nd the common coal.

One hundred parts of plumbago contain, according to Berthollet, about
0 per cent. of charcoal and 10 of iron. That of the best quality, and
hich is found at Keswick in Cumberland, is used in making pencils.
lumbago has also been found lately in considerable quantities in an es-
te about 7 or 8 miles north of the town of Ayr in Scotland, and in some
rts of that neighbourhood it even occurs at the surface of the ground.

Anthracolite, or anthracite, is distinguished from other coal by burn-
g without flame. It is composed of 64 charcoal, 33 silica, and 3 parts
iron.

Jet occurs in Scotland, at Whitby in Yorkshire, in Bavaria, &c. and
France near the Pyrenees. At the latter place more than a thousand
en, it is said, are constantly employed in fabricating it into ornaments
dress, drinking-vessels, rosaries, &c. It is composed of bitumen and
arcoal: 76 parts charcoal, 22 parts bitumen, and 2 parts earth.

Common coal is composed of bitumen and charcoal in different pro-
rtions, according to its quality, and the places whence it is procured.
Newcastle-upon-Tyne, martial pyrites are often found mixed with the
al, in such abundance as would render the coal unsaleable; but persons
employed to pick out these pyrites and remove them to a proper si-
ation, where in process of time they become acidified, and fit for the
oduction of green vitriol. See an account of this process in Chapter X,
der the article Salts of Iron. This species of coal, when in contact
h water, is apt to be decomposed, and to burn spontaneously. Ships at
have sometimes been suspected to have been lost by this means. His
jesty's ship Ajax, of 74 guns, took fire a few years ago in the middle
the night on a station in the Mediterranean, and no cause for that
adful catastrophe has yet been assigned.

It has been discovered that air which has been spoiled by the breath-
of animals is peculiarly fitted for the vegetation of plants; and no

If carbon forms so large a part of all vegetables, what occasions that infinite variety which we observe in the vegetable creation?

We are in a great measure strangers to the economy of vegetables; but much of this variety may be attributed to the different modifications of carbon [a], as well as of the other principles which enter into their constitution [b].

What products of vegetation are there which are indebted to carbon for their formation?

Carbon not only constitutes the base of the woody

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doubt this is owing to its containing a larger portion of carbonic acid. By the analysis of soils it has been proved, that of all the substances found in the mixture of earths which constitute a soil, calcareous earth contributes most certainly to its fertilization. An interesting account of some experiments on manures, by Mr. Arthur Young, may be seen in the *Retrospect of Philosophical and Chemical Discoveries*, vol. i. page 118. There is an ingenious memoir by Dr. Paris on the application of mineral manure to land, and on the connexion which subsists between the geological structure of any particular district and its agricultural economy, in the 1st volume of the *Trans. of the Roy. Geol. Society of Cornwall*, pages 168—200.

[a] Vegetables have the power to absorb oxygen from the atmosphere, and to transmit it to the absorbent vessels of the roots. It cannot be questioned but that this oxygen becomes useful in vegetation, by converting the carbon of manures into carbonic acid. See Additional Notes, No. 48.

The operation of paring and burning turf, which is always found by farmers extremely serviceable to their lands, is doubtless rendered universally advantageous from the carbonaceous matter which is produced by the burning.

[b] When we consider the small number of simple substances which enter into the composition of plants, how astonishing is the variety that has been given us by the profuse hand of Nature! The species of vegetables already known are more than 40,000, and large additions are daily making to this number by new discoveries. Is it possible that so bountiful a provision can have been made by Nature ultimately for the use of man?—Yes: "for him she has covered the earth with plants and though their species be infinite in number, there is not one but may be converted to his use. She has selected some out of every class to minister to his pleasures, or his support, wherever he shall please to fix his habitation. Others serve for his bed, for his roof, for his clothing for the cure of his diseases, and for the fire of his hearth."—St. Pierre's *Studies of Nature*.

Fourcroy has remarked that "vegetables may be considered as beings fibre, but is a component part of sugar, and of all kinds of wax, oils, gums, and resins; and of these again how indefinite is the variety!

How are these substances formed by the vegetating organs of plants?

All living vegetables have the power of decomposing water[c], and of combining in different proportions the hydrogen of the water with the carbon of the soil, as well as with that of the carbonic[d] acid of the atmosphere[e], to form the numberless productions of vegetable nature[f].

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intended by nature to *begin* the organization of crude matter, and to dispose the primitive materials of the earth and atmosphere in order to become the source of life, and consequently to establish a communication between minerals and animals ; from whence it follows, that plants are truly chemical apparatus employed by nature to produce combinations which would not take place without them.—Fourcroy's *System of Chemistry*.—Nature is as admirable in the simplicity of her means, as in the constancy and regularity of her operations.

[c] When we decompose water, we can do it only by abstracting its oxygen and liberating the hydrogen, which is easily effected by some combustible bodies. But vegetables perform this process in a different way: they preserve the hydrogen and set the oxygen free. This process of Nature, in the latter instance, has been noticed in a former chapter. See p. 53.

Berthollet has remarked that the decomposition of water must always take place to give rise to substances of a resinous character, when the vegetation is performed without the concurrence of foreign bodies. See his *Essay on Chemical Statics*, vol. ii. page 393.

[d] Van Helmont planted a willow, weighing fifty pounds, in a certain quantity of earth, covered carefully with sheet lead: he kept it in this state for five years, watering it with distilled water; and at the end of that time the tree weighed 169 pounds three ounces: the earth in which it had vegetated being weighed at the same time, was found to have lost only three ounces. This was repeated by Mr. Boyle with a similar result. See Additional Notes, No. 57.

[e] Organized beings cannot live upon the matter in which they vegetate: Nature, therefore, by making the air their food, has afforded them nourishment without offering violence to their tender organs.

[f] Sennebier found that plants watered by water impregnated with fixed air grew more luxuriantly than plants watered as usual; and that when insulated from every substance which could afford it to them immediately, they acquired carbon by the decomposition of carbonic acid gas in the atmosphere. This they take in by the under surface of their leaves, as well as by their roots.

It appears from hence, that it is not requisite to the growth of vege-

If carbon and hydrogen enter into the composition of all these substances, how is it that one vegetable affords gum, another resin, another oil, &c.[a] *?*

The infinite variety which there must be in the internal organization of vegetables, to enable different orders to prepare such different substances from the same elements, renders this subject too intricate and minute for our investigation. We feel the insufficiency of our faculties—" The will of God is the ultimatum of all human knowledge."

Is it known what other substances are employed by nature for the formation and growth of vegetables?

All orders of vegetables are produced from four or five natural substances, viz. caloric, light, water, air, and carbon[b]. Nature has required only these in

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tables that matter should be presented to them in the solid form, but that they owe their increase chiefly to the decomposition of water and carbonic acid. See page 54.

[a] Carbon and hydrogen are not the only principles which enter into the composition of all these substances. Most of them contain a proportion of oxygen also, as may be seen by the following statement:

Olive oil is a compound of	
Carbon	79
Hydrogen	21
	100

Sugar of	
Carbon	28
Hydrogen	8
Oxygen	64
	100

Resin of Carbon and Hydrogen proportions unknown. Saturated with Oxygen

Gum of	
Carbon	23
Hydrogen	11
Oxygen	65
Nitrogen & Lime	1
	100

Wax of		
Carbon	82	Saturated with Oxygen
Hydrogen	18	
	100	

The formation of resin and wax has lately been explained thus:—That when a volatile or a fixed oil is expelled out of plants, and has its surface exposed to the air, the first becomes a resin by losing hydrogen, the second a wax by absorbing oxygen.

order to form even the most exquisite of her productions—

> "With hues on hues expression cannot paint,
> The breath of Nature and her endless bloom."

How is it that such an inexhaustible variety of forms, colours, tints, odours, tastes, qualities, &c. so conspicuous in this kingdom of Nature, can be produced from such a scanty number of natural substances?

The means by which all this is effected are unknown to us: but this we know, that "these wonderful harmonies are not by necessity in the nature of the elements, but in the will of Him who has ordained them, in subordination to the wants and the enjoyments of his numerous creatures[c]."

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[b] It has been shown that water and atmospheric air are the natural food of plants. Caloric is necessary to enable vegetables to decompose water and air; and light is equally requisite to give a part of the oxygen of these substances a gaseous form, and to put it in a proper state to be thrown off by the leaves. The other portion of oxygen goes to the formation of sugar and the vegetable acids. The analysis of vegetables confirms this theory; for, however they may be examined, the result is always the production of oxygen, hydrogen, and carbon. Some plants yield also a portion of silica, and others lime; but these no doubt are taken up by the roots from the soil. See Sir Humphry Davy's paper on the silica found in the epidermis of reeds, &c. in Nicholson's *Journal of Philosophy*, &c. for May 1799.

When we consider that the many thousand tribes of vegetables are not only all formed from a few simple substances, but that they all enjoy the same sun, vegetate in the same medium, and are supplied with the same nutriment, we cannot but be struck with the rich economy of Nature, and are almost induced to doubt the evidence of those senses with which the God of Nature has furnished us. That it should be possible so to modify and intermingle a few simple substances, and thence produce all the variety of form, colour, odour, &c. which is observable in the different families of vegetables, is a phenomenon too astonishing for our comprehension. Nothing short of Omnipotence could have provided such a paradise for man.

> "Soft roll your incense, herbs, and fruits, and flowers,
> In mingled clouds to Him, whose sun exalts,
> Whose breath perfumes you, and whose pencil paints."

[c] The various orders of vegetables provided in every part of the globe,

What is the office of carbon in the animal *kingdom?*

As carbon is a necessary part of sugar, of oils, &c., it consequently enters into the composition of animal milk, and of animal oils and fat; it is also found in albumen, gelatine, fibrina, and in many of the animal secretions.

Does carbon enter into any mineral combinations?

It is imagined that most of the metals may be combined with carbon: but at present we know only of its combinations with iron.

What does carbon form when combined with iron?

In one proportion it forms cast iron[a]; in another,

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for the countless forms of animated existence, are eminently illustrative of the provident care of the Creator, and show us how great and how good is the Father of the families of the whole earth. The following passage from St. Pierre's *Studies of Nature* is so well calculated to impress this truth, that it is unnecessary to apologize for its introduction:—"The sluggish cow pastures in the cavity of the valley; the bounding sheep on the declivity of the hill; the scrambling goat browses among the shrubs of the rock; the duck feeds on the water-plants of the river; the hen, with attentive eye, picks up every grain that is scattered and lost in the field; the pigeon, of rapid wing, collects a similar tribute from the refuse of the grove; and the frugal bee turns to account even the small dust on the flower. There is no corner of the earth where the whole vegetable crop may not be reaped. Those plants which are rejected by one are a delicacy to another, and even among the finny tribes contribute to their fatness. The hog devours the horse-tail and henbane; the goat, the thistle and the hemlock. All return in the evening to the habitation of man, with murmurs, with bleatings, with cries of joy, bringing back to him the delicious tributes of innumerable plants, transformed, by a process the most inconceivable, into honey, milk, butter, eggs, and cream."

[a] Cast iron acquires carbon from the charcoal used in the smelting furnaces for its fusion. See the article Iron, chap. x.

[b] The name which plumbago has so long borne shows how necessary it was to give a new nomenclature to the science. It is now known that its metallic appearance is owing to *iron*; and that there is no lead in its composition. Many other instances might be adduced in which the names of substances have given false ideas of their nature and properties:—thus, white and green copperas contains no *copper*, but are formed the one with zinc, the other with iron.

[c] Cast iron does not owe its brittle qualities to the carbon which is combined with it; for that iron which contains most carbon is found to be the best metal. Cast iron generally contains some phosphuret of

steel; and in a third proportion, plumbago, generally, though improperly, called black lead[b].

What is the proportion of carbon in cast iron?

Upon an average cast iron contains, according to the analysis of Bergman, about one forty-fifth of its weight of carbon[c].

What quantity of carbon enters into the composition of steel?

Steel is iron, combined with about one part of carbon in two hundred of iron[d].

How is carbon combined with iron to form plumbago?

Carburet of iron, or plumbago[e], has been found to consist of nearly nine parts carbon to one of iron.

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iron, and frequently a portion of oxygen; these substances give it its hard brittle quality. To convert cast iron into wrought iron the metal is submitted to a long intense heat, by which means the carbon burns, and, uniting with the oxygen, both go off in the state of carbonic acid gas. The iron is then carried to the forge hammer, which beats out the phosphuret of iron and brings the particles closer together. When the iron is required to be pure and good, it undergoes repeated hammering till it is brought to the desired quality.

[d] To procure steel, nothing more is necessary than to heat good pure iron for several hours in a proper furnace, with charcoal, or any substances proper for furnishing a sufficient quantity of carbon, which is absorbed by the iron in the process. Iron has so great an affinity for carbon that it is even capable of decomposing carbonic acid in a high temperatare. See *Philosophical Magazine*, vol. ii. where there is an account of a late mode of making steel by fusing soft iron in crucibles with carbonate of lime. The diamond, which is pure carbon, will also convert iron into steel. This was proved by the ingenious Mr. Children, who inclosed a diamond within a slit which he had made in one end of a large iron wire, and having submitted it to the action of galvanism, the diamond disappeared and the iron was found to be changed into steel.

[e] Plumbago is found in great plenty at a place called Borrowdale in Cumberland. Besides making pencils, it is likewise useful to rub over wooden machinery to prevent friction. See Note[d], page 241.

According to Fabroni plumbago is formed in the humid way, at the bottom of certain wells in the kingdom of Naples, from whence it is regularly collected every six months.

Carburet of iron is found also in various parts of the continent. It

You said that carbon formed an acid by its union with oxygen:—how is that effected[a]*?*

Carbon has so great an affinity to oxygen, that when assisted by heat it will take it from most substances with which it may be combined; in certain proportions they then form carbonic acid gas[b].

What quantity of oxygen is necessary to convert carbon into carbonic acid?

Twenty-eight parts by weight of carbon require about 72 parts of oxygen to saturate them; so that 100 parts

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often occurs in mountains, in the midst of beds of quartz, or calcareous earth. It has sometimes been found crystallized in octohedrons.

Plumbago, like charcoal, is indestructible by heat, unless with the presence of atmospheric air. It is therefore much used for making crucibles and portable furnaces. It protects iron from rust, and on that account is rubbed on various ornamental cast-iron works, such as the fronts of grates, &c.

[a] Take one of those glass receivers generally used for deflagrating the gases; fill it with oxygen gas, and invert it in a shallow pan of water. Then having a piece of ignited cortical part of charcoal ready, suspend it by a wire to the stopper of the receiver, and immerse it quickly in the gas. The charcoal will be seen to burn for a considerable time with the greatest splendour, throwing out the most beautiful coruscations. When the inflammation is over, the oxygen gas will be consumed, and the water will be found to be impregnated with carbonic acid; and if some transparent lime-water be poured in, the whole will become opaque from the carbonate of lime now formed.

[b]. There can be no doubt that carbonic acid is formed by the union of carbon with oxygen; for steel may be made as effectually by the decomposition of carbonic acid, as it can by the direct union of iron with carbonaceous matter.

Carbon takes a gaseous form also by combining with hydrogen and caloric, and forms what is called carburetted hydrogen gas; likewise in the gas discovered by Dr. Priestley, and which Mr. Cruickshank named the *gaseous oxide of carbon.*

[c] Oxygen has a greater affinity for carbon than for most other substances. Lavoisier burned small quantities of charcoal in pure oxygen gas in close vessels, and found that a part of this gas was converted into fixed air, or carbonic acid. He separated this from the rest of the oxygen by means of caustic alkali, and weighed the alkali after it had attracted the fixed air. He also expelled the air again by an acid, and examined its bulk. Thus he learned the weight of the air, and what measure of it had been produced. Then, comparing this weight with that lost by the charcoal which had been consumed, he found it to exceed greatly the weight of the charcoal; and that it was exactly equal to the weight of the

of carbonic acid are composed of nearly twenty-eight parts of carbon and 72 of oxygen[c].

What is the specific gravity of carbonic acid?

Carbonic acid can only be exhibited in the form of gas; each cubical inch weighs about half a grain, 100 cubical inches having been found to weigh exactly 47.26 grains[d].

What are the properties of carbonic acid gas?

Carbonic acid gas is invisible and elastic; is much heavier than atmospheric air[e]; will mix with vital air; may be combined with water, to which it gives a brisk and acidulous taste[f]; is destructive of flame, and

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charcoal added to that portion of the oxygen gas which had been changed into fixed air. Dr. Black's *Lectures on Chemistry*, vol. ii. page 100.

The composition of carbonic acid has been further proved by analysis, as it has actually been decomposed, and the charcoal exhibited entire. See Mr. Tennant's experiments on fixed air, in *Philosophical Transactions*, vol. lxxxi. page 181. When a diamond is burnt, the proportions are similar to the above, for diamond is the purest carbon we are acquainted with.

Much attention has been paid to the appearances in the combustion of the diamond, by Sir George Mackenzie, by Mr. Tennant, by Messrs. Allen and Pepys, and by Sir Humphry Davy. See Nicholson's *Journal*, 4to, vol. iv. page 103; the *Philosophical Transactions* for 1807, and some of the subsequent volumes.

Carbonic acid gas may be readily procured for experiment by pouring a little diluted sulphuric acid into a phial, or a retort, upon a little pulverized chalk. An action will immediately commence; and if one end of a bent tube be made fast in the neck of the phial, and the other brought under the mouth of a jar filled with water, and inverted in a vessel of water, the gas will pass from the mixture into the inverted jar.

[d] When charcoal is burnt in oxygen gas, every 100 cubical inches of the gas, which originally weighs 33.75 grains, will then weigh 47.26 grains; and as the gas acquires no alteration in volume, this shows that 100 cubical inches of oxygen will combine with 13.51 of charcoal.

[e] This gas, on account of its density, may be poured from one vessel to another like water, or may be drawn from a cask by a cock like other uids. In consequence of its great specific gravity it is frequently found t the bottom of mines, wells, &c. See pages 250—254.

[f] In order to saturate water with this gas, it is necessary to subject it to a considerable degree of pressure. The persons who are engaged in making the acidulous soda water have peculiar conveniences for this purpose. Cider, perry, bottled beer, and other fermented liquors, owe their briskness and sparkling to the presence of this gas.

will occasion the death of animals that are obliged to breathe it[a].

In what states does carbonic acid exist in Nature?

Carbonic acid is found in three different states; viz. in gas, in mixture, and in chemical combination: it is perhaps the most abundant of all the native acids[b].

What instances are there of its natural existence in the state of gas?

It is found in the proportion of about one part by

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[a] Carbonic acid has also the property of rendering lime soluble i water. As the carbonic acid escapes by exposure to the air, the calcareous matter is precipitated from the water which held it in solution whence arise the various earthy incrustations found in different parts o the world. Fourcroy has very aptly remarked, "that when natura history was less enlightened by chemistry, springs of this kind were calle *petrifying* waters, and were by the vulgar reckoned among the numbe of miracles.

Some very interesting remarks on the utility of this property of certain waters to dissolve calcareous earth may be seen in Parkinson' *Organic Remains of a Former World*, vol. i. page 379.

At Guancavelica in Peru, artists obtain statues and even stones fo building, by filling moulds frequently with a mineral water of tha district.

[b] Plants of all kinds give out carbonic acid gas while growing in th shade: but when assisted by the rays of the sun, there is reason to thin that the plants have the power of decomposing this acid; for then th leaves give out only oxygen gas. *Annales de Chimie*, tome xiii. page 31

Mons. Saussure has shown that when vegetables decompose carboni acid gas, they throw off only half of the oxygen; and that the other hal with the whole of the carbon, enters into the composition of the plan He also says that the leaves absorb oxygen gas in darkness, and em an equal quantity when exposed to the light. If this account of veget tion be correct, growing vegetables deteriorate the atmosphere in th night, and purify it in the day. The roots, wood, and petals perform r inspiration. See *Philosophical Magazine*, vol. xx. page 307.

[c] The floor of the Grotto del Cane, in Italy, is lower than the doo and this hollow is always filled with fixed air, which can rise no high than the threshold, but there flows out like water. It has been a commo practice to drive dogs into this cavern, where they suffer a tempora death, for the entertainment of the passengers; but a man enters wi safety, because his mouth is far above the surface of this deleterious ai From the loss of so many dogs in this cavern it acquired the name the Grotto del Cane. The lake of Averno, which Virgil supposed to be th

measure, in every thousand parts of atmospheric air; also in caverns and mines, where it is called the choke-damp[c].

What instances are there of carbonic acid being found mixed with fluids?

It is abundant in Spa-water, and in some other acidulous waters[d].

In what substances is carbonic acid found chemically combined?

Carbonic acid is found in all parts of the world in

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entrance to the infernal regions, evolves so large a quantity of this gas, that birds flying over it drop with suffocation. Fatal accidents have happened to persons who have incautiously descended into brewers' vats, and wells, before they have been purified from this gas.

Carbonic acid gas so often occupies the bottoms of wells, that workmen ought never to venture into such places without previously letting down a lighted candle. If the candle burns, they may enter it with safety; if not, a quantity of *quick-lime* should be let down in buckets, and gradually sprinkled with water. As the lime slacks, it will absorb the carbonic acid gas, and the workmen may afterwards descend in safety.

Fatal accidents often happen from burning charcoal in chambers; because wherever charcoal is burned this gas is always formed.—Workmen have also lost their lives by sleeping too near lime-kilns, where this gas is extricated in abundance. Whenever persons are discovered in such situations, or are suffering from the effects of carbonic acid gas, the same means should be made use of as are directed by the Humane Society in cases of apparent death from drowning: or when it can be done without loss of time, atmospheric air, or even pure oxygen gas, should be forced into the lungs. I have known galvanism sometimes employed in such cases with the best effects.

Dr. Henry has suggested to naturalists, that butterflies and other insects, the colours of which it is desirable to preserve for the purpose of cabinet specimens, may be suffocated in carbonic acid gas, better than by the common mode of killing them with the fumes of sulphur.

[d] These waters have a pleasant light acidity and briskness, and sparkle in the glass like fermented liquors; which is well known to be the case with water when artificially impregnated with fixed air. Dr. Percival esteems it highly medicinal in pulmonic consumptions, and in malignant fevers.

By great pressure water may be combined with more than twice and a half of its own bulk of carbonic acid gas. Such waters are considerably more acidulated than those afforded by nature, and have much greater medicinal effects.

A description of a proper apparatus for impregnating water with this gas will be found in Bouillon la Grange's *Chemistry*, vol. i. page 93.

great plenty, in combination with the alkalies, with some metallic oxides, in earths, and in stones; particularly in chalk, limestone, and marble[a].

What is the effect *of the combination of carbonic acid?*

Carbonic acid renders mild and salutary some of the most acrid and destructive of all known substances[b].

How is the carbonic acid separated from alkalies and earths?

Carbonic acid may be disengaged by most of the other acids; but it is usually separated from alkalies by the addition of quick-lime, which absorbs this acid, and thus is converted into carbonate of lime[c].

How is carbonic acid usually procured for chemical purposes?

Carbonic acid gas may be collected in abundance

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[a] Carbonic acid is found combined with alkalies and with several metallic oxides. These combinations are called carbonates.

A cubic inch of marble contains as much carbonic acid in combination as would fill a six-gallon vessel when in the state of gas.

Marble contains of carbonic acid	437 parts in 1000
Crystals of carbonate of soda	155 parts in ditto.
Carbonate of ammonia	500 parts in ditto.
Carbonate of barytes	220 parts in ditto.
Carbonate of magnesia	580 parts in ditto.
Carbonate of lead	165 parts in ditto.

[b] We all know the causticity of pure quick-lime, and the corrosive qualities of the fixed alkalies; but whenever these substances are *fully* saturated with carbonic acid, the first forms mild calcareous earth (or chalk), and the others mild neutral salts, applicable to many purposes of medicine and domestic economy.

[c] Though the alkalies readily part with their carbonic acid to caustic calcareous earth, yet they have a great affinity to this acid, as may be shown by the following interesting experiment:—Fill a jar with carbonic acid gas, then pour into it a small quantity of a solution of *caustic* potash, or soda; and having tied the mouth over with a wetted bladder, move the vessel so as to spread the alkali over its inner surface, when a vacuum will be quickly formed by the absorption of the gas, which will appear by the bladder being pressed inwards by the weight of the atmosphere. If this experiment be made in a glass vessel, its surface will be

rom the surface of fermenting liquors; but it is more ommonly obtained by pouring sulphuric acid upon a mixture of chalk, or marble and water[d].

How do you account for the production of carbonic cid gas in the process of fermentation?

In all vinous fermentations a decomposition of the accharine matter takes place; and a part of the dis-ngaged oxygen, uniting with a part of the carbon of he sugar, forms carbonic acid[e]. A decomposition lso of part of the water of solution perhaps promotes he process.

What is the cause of vinous fermentation?

The cause of vinous fermentation is not well un-erstood; though it is a process which nature employs nd which art can imitate, for the decomposition of ertain vegetable substances[f], (when in favourable

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een covered with crystals of the alkali, as the carbonic acid always promotes the crystallization of the fixed alkalies.

[d] This process beautifully demonstrates the indestructibility of matter: n it we remark that the gas which has bound together the massy rock r a thousand years, is still carbonic acid, and is as capable of forming variety of combinations as any carbonic acid would be if recently pro- uced. How economical is Nature in all her proceedings! See Addi- onal Notes, No. 25.

[e] It has been matter of surprise that no advantage has been taken of e vast quantities of carbonic acid gas, which are perpetually escaping om the vats of the large breweries in this metropolis. It might surely collected, and applied to many useful purposes, if the commissioners excise would admit of it. The benefit which is derived from *yeast* in trid diseases is due to its carbonic acid. An interesting paper on the e of this remedy may be seen in the sixth volume of the *Philosophical agazine*, page 56.

[f] It is now pretty generally known, that no substances are capable of rmentation but such as have been elaborated by the principle of ani- al or vegetable life. See a memoir on this subject by Fourcroy, part , chap. 22.

Fourcroy admits five distinct species of vegetable fermentations, viz. e saccharine (or that which forms sugar), the vinous, the acetous, the olouring (or that which is developed by the maceration of the indigo- lant), and the putrid. See Fourcroy's *System of Chemical Knowledge*, l. viii. page 148. Some writers have spoken of another kind of vegecircumstances of temperature and solution,) and also for their recomposition to form new products.

What circumstances are necessary to produce vinous fermentation?

The presence of vegetable matters, of water, of sugar[a], a certain degree of heat, and free escape for the carbonic acid as it is generated[b].

Can you at all account for the change which is effected in saccharine liquors by fermentation?

By the process of fermentation the sugar, which is a vegetable oxide[c], parts with a portion of its oxygen to form carbonic acid, and becomes converted into alcohol[d] by being thus partially deoxidized.

Does sugar then become spirit of wine, or alcohol, merely by losing a part of its oxygen?

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table fermentation, viz. the panary, or that which manifests itself in making bread; but surely this is a species of the acetous, for its tendency to acidity is very evident.

[a] It appears from several late experiments carefully made, that sugar is composed entirely of hydrogen, oxygen, and carbon. Mr. Cruickshank made many experiments on fermentation, and invariably found, that whenever he added a fourth substance to the three which compose saccharine matter, no fermentation took place. He tried lime, and at another time a small quantity of potash; and the addition of either prevented fermentation. See Mr. John Thomson's *Notes to Fourcroy*, vol. iii. page 128; also Dr. Rollo on *Diabetes*; and the Additional Notes to this volume, No. 49.

[b] To produce vinous fermentation, it is necessary that the matters subjected to that process should be placed in a temperature not lower than about 55 degrees of Fahrenheit. No kind of fermentation is ever known below the freezing point.

[c] Lavoisier, having analysed sugar, found that it was composed of hydrogen, oxygen, and carbon, in the following proportions. Hydrogen 8lbs., oxygen 64lbs., carbon 28lbs., in every 100 pounds weight of sugar. Lavoisier's *Elements of Chemistry*, page 188. Having subjected 100lbs. of sugar to fermentation, he found the products (alcohol, carbonic acid, and acetous acid,) when analysed, contained the precise quantities of hydrogen, oxygen, and carbon, which were contained in the original sugar. The particular detail which he has given of these experiments is extremely interesting. Ibid. page 185 to 197. In consequence of the results which were obtained, he remarks, " The effect of the vinous fermentation upon sugar is thus reduced to the mere separation of its ele-

No: it parts with a portion of its carbon at the same time, in the form of carbonic acid gas, and a new arrangement of the principles, both of the sugar, and of the water in which it is dissolved, taking place, furnishes an increased proportion of hydrogen, in order to form vinous liquor[e].

Endeavour to recollect the different properties of charcoal, which you have enumerated in this chapter.

Charcoal appears to be indestructible by age; it is not in the least altered by the most intense heat, if heated in *closed* vessels; when burnt in atmospheric air it becomes converted into carbonic acid gas; it is a valuable antiseptic; it is the basis of all vegetables; it is one of the component parts of wax, oils, gums, and resins; and from its affinity to oxygen it has the

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ments into two portions: one part is oxygenized at the expense of the other, so as to form carbonic acid; while the other part, being deoxygenized in favour of the former, is converted into the combustible substance called alcohol."—Ibid. page 196. The strongest alcohol of commerce is seldom of a less specific gravity than that of 0.825. Proof spirit, or the spirit of wine employed in pharmacy, has a specific gravity of 0.930.

[d] Alcohol, according to the analysis of Lavoisier, is composed of

Carbon about	30 parts.
Hydrogen	7.5 ditto.
Water	62.5 ditto.
	100.0

But as this analysis was made by burning alcohol in oxygen gas, it is probable that the greater part of the water was formed during combustion. Hence the real component parts of alcohol are not accurately known.

[e] The spirituous or intoxicating quality of all fermented liquors is owing to the alcohol they contain, whether it be malt-liquor, wine, or spirits. Alcohol expands by slight degrees of heat more than any other fluid;—hence the propriety of employing it in forming thermometers. The same degree of heat which expands glass *one* degree will expand alcohol 180 degrees.

Alcohol has various uses in pharmacy and chemistry. It dissolves the resins and volatile oils,—hence its employment in the preparation of spirit varnishes. It is employed also in chemistry, in separating those salts from each other which cannot easily be separated by any other property of decomposing many substances in which oxygen constitutes a material part.

How did chemists become acquainted with all these properties of charcoal?

Formerly, nothing was known of charcoal but its indestructibility and its antiseptic qualities. The other peculiar and surprising properties of charcoal were reserved for the discoveries of the present age; for these we are most especially indebted to the labours and genius of Black[a], Priestley[b], Cavendish, Lavoisier, Guyton, Tennant, and Berthollet, and to the gradual development of the present improved system of chemistry.

What reflections naturally present themselves on

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means. It dissolves the oxalic, tartaric, and some other acids. The salts which are dissolved in the greatest quantity by alcohol are the muriates of magnesia and of lime, and the several nitrates of magnesia, lime, alumina, ammonia, and soda.

Saussure jun. has demonstrated that alcohol of the specific gravity of .792 consists of

Carbon	51.98
Oxygen	34.32
Hydrogen	13.70
	100

Sulphuric ether, of

Carbon	67.98
Oxygen	17.62
Hydrogen	14.40
	100

Dr. Henry pronounces it to be composed of two atoms of charcoal, three of hydrogen, and one of oxygen.

By the action of alcohol upon sulphuric or nitric acid, *ether* is formed, which is a peculiar fluid, of less specific gravity and more highly inflammable than alcohol. Good sulphuric ether has a specific gravity not higher than .750.

[a] In the year 1755 Dr. Black discovered the acid gas which is thrown off from fermented liquors and from mild calcareous earth. He called it fixed air.

[b] Dr. Priestley explained the effect of charcoal in decomposing nitrous

the consideration of the various properties of charcoal and the other simple combustibles?

This subject, when considered in all its connexions, is calculated to produce the most profound admiration; and serves to convince us of the unbounded comprehension of the Divine mind, which, in the act of creation, could foresee and appoint such important effects to result from the combinations and changes of the most inodorous and insipid substances. We also learn, that all the works of the Creator are perfect; and perceive with astonishment, that they are composed of elements which are in themselves incapable of destruction[c].

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acid, examined the gas that is thrown off in this decomposition, and pointed out the necessity of distinguishing the different gases from common air; for which the Royal Society awarded him an honorary prize.

In the years 1766 and 1767 Mr. Cavendish published papers in the *hilosophical Transactions*, on the nature of elastic fluids, in which he announced that he had produced fixed air by the burning of charcoal. This assurance called the attention of all chemists to that surprising bstance, and was the forerunner of the many discoveries which have nce been made respecting its properties, &c.

Lavoisier pointed out the nature of the action of charcoal in reducing etallic oxides; investigated the nature of the combustion of the dia-ond; announced the exact quantity of carbon in carbonic acid, and the oduction of carbonic acid by the decomposition of water with ignited arcoal.

[c] See Additional Notes, No. 25 and 37.

CHAPTER X.

OF THE METALS.

What are the distinguishing characteristics of the metals?

The general characters of the metals are, hardness, tenacity, lustre, opacity, fusibility, malleability, and ductility[a]: but a metal may notwithstanding want one or more of these characters.

How are the metals procured?

They are generally taken from the bowels of the

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[a] In the former editions of this work "*great specific gravity*" was mentioned as one of the characteristics of the metals; but as the ingenious and indefatigable researches of Sir Humphry Davy have discovered metallic substances which have less specific gravities even than water, this character could no longer be given to that class of bodies.

[b] Metals are generally found in mountainous countries, in such as form a continued chain; but the metallic part of a mountain usually bears but a small proportion to its whole contents. Granite rocks seldom contain any metallic ores.

It is deserving of notice, that if minerals had been placed on the *surface* of the globe, they would have occupied the greatest part of the earth, and would have prevented its cultivation. Their being deposited *below* is a proof of management and design worthy of that Being who could furnish so great a variety of this class of bodies.

[c] When metals are found combined with other metals, they are called native alloys. The following are some instances of this kind of combination:—There is a native amalgam of silver found in Hungary, Sweden, and other places in Europe; a specimen of which was analysed by Klaproth, and found to consist of mercury 64, silver 36; a mineral called *electrum* occurs in Siberia, consisting of 64 per cent. of gold and 36 of silver. A different alloy of these noble metals is found in Norway, and known to mineralogists under the name of *auriferous native silver*, which consists of silver 72 and gold 28. Native nickel has been found at Johanngeorgenstadt in Saxony, alloyed with cobalt. And not to enumerate more instances, the native iron from Johannes mine near Kamsdorf in the same country, may be mentioned, which is an alloy of that metal by lead and copper, in the proportion of iron 92.5; lead 6; and copper 1.5.

earth[b], in a state of combination either with other metals[c], with sulphur, oxygen, or with acids[d]; though a few of them have occasionally been found in a state of purity[e].

By what methods are the metals purified from these substances?

The metals are purified from their ores by various means,—such as washing, roasting, fusion[f], &c.; but the method must always be regulated by the nature of the ore to be purified[g].

How many metals are there?

There are forty-two distinct metals, which possess properties very different and distinct from each other[h].

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[d] The sulphuric, muriatic, phosphoric, and carbonic acids are some of hose which are more generally found in combination with metals.

[e] Among those metals which most frequently occur in the *metallic* tate may be ranked quicksilver. In Bishop Watson's *Chemical Essays* ention is made of such a mine in this country, viz. at Berwick in orthumberland, in the midst of that town; and Mr. Hume, a native of hat place, assures me that he was an eye-witness to this fact.

[f] The analysis of metallic ores in the great, is always performed by re, and this is called the *dry* way; but the more accurate analysis is ffected by means of various chemical re-agents which modern chemistry as applied to that purpose, and is termed the *moist* way. Before the me of Bergman every kind of analysis of minerals was conducted by re; he was the first chemist who resorted to the method of solution in cids, which is easy, simple, and generally effectual.

[g] Those who wish to investigate this subject may find ample information in Schlutter's work on *Mineralogy*; in Henkel's *Pyritologia*; in ramer on *Metals*; in Kirwan's *Mineralogy*; and in Klaproth's *Essays*.

[h] For a knowledge of most of the metals, we are indebted to the ore perfect modes of analysing minerals which modern chemistry has forded. The ancients were acquainted with only seven of these metals. he properties of these were tolerably well known to the early chemists, ho acquired their knowledge from the alchemists. These infatuated eople tortured silver, mercury, copper, iron, tin, and lead, in every ay they could devise, in order to convert them into gold. Alchemy was obably introduced into Europe by the crusaders, whose minds were epared for the reception of any delusion. In all likelihood they picked the idea of the transmutation of metals on their return from Palestine; d as error generally operates more powerfully than truth with such natics, they deluged their native country with these absurdities. The in and conceited Paracelsus, a Swiss physician, was one of the last of

Has there not been great difference of opinion as to the best mode of classing the metals?

There has: but as all the metals combine with oxygen, though in different proportions and under different circumstances, the mode in which this combination takes place, and the properties of the compound, furnish the best data for any division of the metals; and it is upon these principles that the whole have now been divided into the seven following classes[a].

1st. The metals which combine with oxygen and form alkalies. These are, potassium, sodium, and lithium.

2d. Those metals which by combining with oxygen form the alkaline earths; viz. calcium, magnesium, barium, and strontium.

3d. Those metals which by combining with oxygen, constitute the remainder of the earths. These are silicum, alumium, zirconium, glucinum, ittrium, and thorinum.

4th. The metals which absorb oxygen and decompose water at a high temperature. These are iron, tin, zinc, cadmium, and manganese.

5th. Those metals which absorb oxygen at different temperatures, but do not decompose water at any temperature This class is composed of twelve distinct metals.

6th. Those metals which do not decompose water, bu

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the alchemists. He announced to the world that he had discovered medicine which would render man immortal: but worn out by hi debaucheries and excesses he gave the lie to this assertion; for h himself died, in the year 1534, at the age of 41.

In the reign of Henry IV. an act was passed to make it felony t transmute metals. This act was repealed in consequence of the suggestions of Mr. Boyle, who was aware of its absurdity.

[a] In consequence of the discovery of several new metals, and th great mass of information which has lately been obtained respectin this important class of bodies, I was desirous of forming a different a rangement of the whole from that which I had formerly chosen; an the new order which I have now adopted, is that which has been fo lowed by my friend Mr. Richard Phillips, in his Chemical Lectures a

absorb oxygen and are thereby converted into acids. This class includes arsenic, molybdenum, tungsten, chromium, columbium, and selenium.

7th. The metals which do not decompose water, nor absorb oxygen from the atmosphere at any temperature. These are platina, gold, silver, palladium, rhodium, and iridium.

To begin with the first class;—Let me ask you what are the names of the metals which form alkalies by their union with oxygen?

Two of these metals were discovered by Sir H. Davy, and by him named potassium and sodium; the other, which is of later discovery, is called lithium.

It will be expedient to consider these and each of the forty-two metallic bodies separately; therefore what is the nature of potassium?

Pure POTASSIUM is solid at the usual temperature of the atmosphere, but quickly becomes soft and malleable by the warmth of the hand; it is perfectly white and has the lustre of polished silver[b]; its specific gravity is only .865 when compared with that of water at 1.000; it fuses at 150° of Fahrenheit, and becomes volatile at a temperature below that of a red heat; it has a stronger affinity for oxygen than all

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the London Hospital, and which is a modification of that proposed by Thenard in his *Treatise on Chemistry*. In order, however, fully to avail myself of this classification, I have found it necessary to rewrite the greatest part of the chapter, and to enlarge it throughout very considerably.

[b] Although potassium, when fresh cut, possesses a brilliant metallic lustre, it soon tarnishes in the air by the absorption of oxygen, and therefore it is usual to keep it immersed in recently distilled naphtha, which is a very attenuated mineral oil, brought to us in its native state from Italy and elsewhere. Owing to the low specific gravity of this fluid, and to the circumstance of its containing no oxygen when newly rectified, it is peculiarly adapted to the preservation of these metalloids in their original purity.

other known substances[a], and is a conductor of electricity.

What is the origin of potassium?

Potassium occurs in the animal, vegetable, and mineral kingdoms[b], but on account of its great affinity for oxygen it is impossible ever to find it in an uncombined state. All that has hitherto been obtained has been procured by chemical means from the potash of commerce, or what has usually been called the vegetable alkali[c].

What is the effect of oxygen upon potassium?

The affinity of potassium for oxygen is, as it has been before stated, stronger than that of any other known substance. It is susceptible of three distinct degrees of oxidizement[d], forming the gray, the white, and the orange-coloured oxides of potassium.

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[a] The strong affinity of potassium for oxygen is very strikingly exemplified in its action upon water. If a morsel of it be laid upon the surface of water, it immediately becomes ignited, and burns, as it swims upon the water, with a beautiful flame; or if laid upon a sheet of moistened turmeric paper, it runs along it in search of water, leaving a deep-coloured alkaline mark behind it, similar to that which would be given by caustic potash; and when placed upon ice it instantly inflames, and the hole which it forms in the ice is found to hold a solution of potash. See the chapter of Experiments, No. 135 to 137. In these cases the potassium decomposes the water and absorbs the oxygen, while the hydrogen of the water escapes and takes fire by the heat which the rapidity of the action produces.

[b] Potassium is found in the animal kingdom in the state of alkaline salts; from vegetables it is produced in the state of common potash, in which state it is also found in several minerals, especially in felspar, a stone which enters into the composition of granite, and consequently forms a large proportion of the highest mountains of the globe. According to Vauquelin and Klaproth, *adularia* and the *glassy felspar* contain 14 per cent. of potash, which would give more than 11½ per cent. of potassium.

[c] Potassium was discovered by Sir H. Davy in the year 1807, by the agency of voltaic electricity upon pure potash. By this means he was enabled to detach the oxygen, when the alkaline base made its appearance in the form of small bubbles, having the lustre and outward characters of quicksilver. Potassium has since been procured in large

What salts of potassium are there with which you are acquainted?

When potassium has become converted into potash by means of oxygen, it is then capable of uniting with most of the acids and forming salts, such as the sulphate, the muriate, the nitrate or the acetate of potash, as has been already explained in the chapters on the alkalies and the salts[e].

What are the uses of potassium?

In the state of an oxide, or that of the potash of commerce, it has innumerable and very important uses in the arts, and in medicine[f]; but in a state of purity it has hitherto only been employed for purposes of philosophical chemistry[g].

What is the nature of the second alkaline metal called sodium?

SODIUM has properties very similar to those of potas-

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quantities merely by means of keeping potash in fusion with intensely hot iron.

[d] The gray oxide of potassium is composed of about 100 parts of potassium and 10 of oxygen; the white oxide, or common potash, is composed of 100 of potassium and 20 of oxygen, and the orange-coloured oxide of 100 of potassium and about 40 of oxygen. The gray or protoxide is procured by exposing small pieces of potassium to the air. It has alkaline properties, is highly caustic, and capable of fusion. If heated in oxygen gas it inflames and passes to the state of the peroxide. The deutoxide is common potash similar to that which is found in wood ashes; and the peroxide is the result of potassium gently heated in oxygen gas. If this oxide be melted, it will crystallize on cooling in the form of thin plates.

[e] Some account of the salts of potassium has already been given at page 124, and pages 188—205.

[f] For an account of the uses of potash, or the oxide of potassium, see the chapter on the alkalies, pages 122—132.

[g] Potassium is a most important agent in the hands of the philosophical chemist, as it is capable of detecting and separating oxygen wherever it may exist and however intimate and energetic may be the nature of its combinations. By its means water may be detached from the most highly rectified alcohol and ether; and by its decomposition hydrogen gas will be evolved. Potassium also combines with phosphorus, sulphur, and hydrogen; it forms metallic alloys with gold, silver, mer-

sium[a]. It has the whiteness and lustre of silver, is exceedingly malleable[b], and is a conductor of electricity. It has greater specific gravity than potassium, and yet is lighter than water[c]. It does not melt until it be heated to 180° of Fahrenheit, and requires a strong red heat[d] to convert it into vapour. It slowly absorbs oxygen if exposed to the air, and thus becomes converted to oxide of sodium, or common soda. Unlike potassium it does not inflame when laid upon water, although in decomposing the water in order to absorb its oxygen the action is evidently very energetic[e]. If it be much heated and then plunged into oxygen or chlorine gas[f], it will burn with great splendour.

What is the history and origin of sodium?

Sodium is the metallic base of soda, or the mine-

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cury, and some other metals; at a red heat it will decompose glass, and is even capable of reducing all the metallic oxides.

[a] Sodium differs from potassium in a few particulars, viz. its affinity with or attraction for oxygen is not so strong,—it is also less fusible, nor will it dissolve in hydrogen gas like potassium.

[b] Sodium is not only malleable, but two or more globules of it by the sole action of pressure may be forced to unite into one homogeneous body, similar to the union which is effected between two pieces of iron by means of a strong heat and continued hammering, a process well known to workmen by the name of welding.

[c] The specific gravity of sodium is about 0.935, water being 1.

[d] When sodium has been heated with plate glass until the latter melted, the sodium, though in a state of perfect fluidity, showed no tendency to vaporization, a circumstance which would alone be sufficient to distinguish it from potassium.

[e] When sodium is laid upon water, the appearance of effervescence and the loud hissing noise which accompanies it, bespeak strong chemical action, and show that the affinity of the metallic substance for the oxygen of the water is great and energetic, though it does not inflame like potassium.

[f] Sodium has a much stronger attraction for chlorine than for oxygen; for if soda be decomposed by chlorine, the oxygen will be expelled from the sodium; and if the hydrate of soda be employed, oxygen and water will be expelled by the same means.

ral alkali, and was discovered by Sir H. Davy about the time when he discovered potassium: it is obtained by means of voltaic electricity, from purified soda[g], in the same manner as potassium is obtained from potash.

What is the effect of oxygen upon sodium?

Sodium like potassium is susceptible of three degrees of oxidizement, forming the gray[h], the white[i], and the orange-coloured oxide of sodium[k].

What salts of sodium are there?

All the sodaic salts which have already been described in the chapters on the alkalies and salts, as formed by means of the various acids and soda, may be said to be salts of sodium[l]; soda, the base of these several salts, being merely sodium in a state of oxidizement.

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[g] The mineral alkali or soda is obtained from the ashes of sea weeds by solution in water, which being evaporated and set to crystallize, yields crystals of carbonate of soda. These being again dissolved in water and treated with quick-lime to absorb the carbonic acid, the solution is boiled to dryness, and the dry alkaline mass dissolved in alcohol to separate the impurities. Then by distilling off the ardent spirit, a pure hydrate of soda is obtained, and it is from this that sodium is collected by means of voltaic electricity; or by heating it with iron, as was described when treating of potassium.

[h] The first oxide of sodium may be procured by heating together, to the point of fusion, some sodium with some pure dry soda. At first a dark *brown* fluid is obtained, but on cooling this becomes a solid of a dark *gray* colour.

[i] The white, or deutoxide of sodium, is the basis of many saline compositions; and in fact it is soda, or the mineral alkali. It may be prepared by burning sodium in such a portion of atmospheric air as does not contain oxygen enough to convert it to the peroxide. It is however usually procured from kelp or barilla by a process already described. It consists of 77.5 of sodium and 22.5 of oxygen.

[k] The orange, or peroxide of sodium, is obtained by burning sodium in an excess of oxygen. It possesses a deep orange colour, and unlike the deutoxide it melts very readily. It is a non-conductor of electricity.

[l] For an account of the salts of sodium, the reader is referred to pages 126—131, and pages 187—205.

What are the uses of sodium[a]*?*

Pure sodium has hitherto been employed only for the purpose of philosophical experiments. In the state of an oxide it is however eminently useful in the arts, independently of that important class of salts which is formed by its means.

What is the origin and history of lithium?

LITHIUM is a metal of a white colour resembling sodium. It was lately discovered, by M. Arfvredson a young Swedish chemist, in a mineral called petalite[b]. As its oxide is strongly alkaline, it was at first supposed to be soda: it is however distinguished both from potash and soda, by its power of neutralizing a much larger quantity of any acid. The alkali, which is called *lithia*, was shown by Sir H. Davy to be a metallic oxide, like potash and soda. This new alkali has since been found in two other mineral substances, viz. in *spodumene*, and in crystallized *lepidolite*.

What is the effect of oxygen upon lithium?

Sir H. Davy having decomposed carbonate of lithium by a powerful voltaic battery, the metallic base of this

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[a] For an account of the uses of soda, or the oxide of sodium, see the chapter on the Alkalies, pages 126—131. Pure soda consists of 100 parts of sodium and 34½ parts of oxygen; and 134½ of soda combine with 39 parts of water to form the hydrate of soda. That which is sold for philosophical experiments, and called pure soda, is always in the state of a hydrate, as I have shown in the chapter on the Alkalies; but if sodium or potassium be burnt in oxygen gas or atmospheric air that is perfectly dry, an alkali will be obtained that is entirely free from water.

[b] The petalite is a mineral which is brought from the mine of Utoen in Sweden. The method of separating the new alkali from it, may be seen in the *Journal of the Royal Institution*, vol. v. page 337.

[c] According to Vauquelin, lithia attracts carbonic acid very rapidly from the atmosphere, and in neutralizing the acids is more powerful even than magnesia.

[d] To procure calcium, a portion of lime or chalk is to be made into a paste with water, and placed on a piece of platina; a small hole is to be made in the paste sufficiently large to receive a globule of mercury, and then the whole should be connected with a very powerful galvanic ap-

alkali was obtained; but when this was exposed to the action of the atmosphere, it burned rapidly and was re-converted to *lithia*, or the oxide of lithium.

What salts may be formed by means of lithia?

Several salts have already been formed by the artificial combination of this alkali with the acids. The sulphate of lithia crystallizes in small prisms of a shining white colour. It is more fusible and soluble than sulphate of potash, and its taste is not bitter, but saline. The muriate and nitrate of lithia are both deliquescent salts; while the carbonate[c] is efflorescent, and sparingly soluble in water. Like other alkalies, lithia has the property of turning vegetable yellows brown.

Having thus dismissed the first class of metals, endeavour to recollect what are the names of those metalline bodies which form the second class, and when combined with oxygen constitute the alkaline earths?

They are called *calcium*[d], the base of lime; *magnesium*[e], the base of magnesia; *barium*[f], the base of

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paratus. In doing this, it must be recollected that the mercury is to be *negatively*, and the platina *positively*, electrified. The oxygen will thus be separated from the lime and an amalgam of mercury and calcium obtained. It is a bright metal, white as silver, which burns when heated a little, and lime is re-formed. Sir H. Davy calculates that 20 parts of calcium combine with about 7.5 of oxygen. Berzelius states the proportion at about 18 and 7.

[e] Magnesium is procured by the same means as calcium, yet with more difficulty. Sir H. Davy also procured it by passing the vapour of potassium over some magnesia intensely ignited. This metal burns with a red light when strongly heated, and becomes magnesia.

[f] Barium, which is procured also by voltaic electricity, is unlike the two former metals, being of a dark colour and possessing but little splendour, even less than that of fresh cast iron. It is so heavy as to sink rapidly in sulphuric acid. When exposed to the air it quickly tarnishes and falls into a white powder, which is barytes. The oxide is supposed to consist of about 90 of barytes and 10 oxygen.

barytes; and *strontium*[a], the base of the earth called strontia, or strontites.

What is the history and nature of these metalline bodies?

We are indebted for whatever knowledge we possess of the nature of these bodies to the discoveries of Sir H. Davy, who, encouraged by his success with the alkalies, soon afterwards undertook a much more laborious series of experiments with the earths; which required to be operated upon in various ways[b], in consequence of the attraction of their bases for oxygen being much stronger than that of the metalloids composing soda and potash. The results of these experi-

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[a] Strontium has a resemblance to barium in some of its qualities—it is procured by the same means; it has but little lustre; is difficultly fusible, and not volatile. Sir H. Davy conjectures that the earth strontia is composed of 86 parts strontium and 14 oxygen. It was first obtained in the year 1808.

[b] In these experiments the simple exposure of the earths to the galvanic action was found to be insufficient; they were therefore first placed in contact with some metallic oxides, such as the red oxide of mercury, with the design of forming amalgams with the new metals, and this process was successful. The earths were afterwards electrified negatively with metallic mercury, and amalgams were obtained by this method also, which had the power of decomposing water; and in these cases the respective earths were always regenerated.

[c] Owing to the minute quantities which have been procured, it is impossible to ascertain whether these metals are susceptible of more than one degree of oxidizement; though Gay Lussac and Thenard conceive that barium is capable of combining with more than one dose of oxygen; for when they heated pure barytes in dry oxygen gas, the gas was rapidly absorbed, and the earth changed colour and acquired a glazed surface.

[d] Several years ago, Baron Born and some other well-known chemists were of opinion that the earths, including silica, are all metallic oxides; but these ideas were, I believe, unsupported by any experiments. In the year 1806 Mr. Hume published a very singular and novel opinion respecting silica, viz. that it is oxygen in a solid form. See the 1st edition of the *Chemical Catechism,* page 151. The various facts which induced Mr. Hume to suppose that the greater part of silica is oxygen, have been detailed in a very perspicuous manner by Dr. Rees in the 32d volume of the New Cyclopædia, under the article *Siliciate*; to that paper I must therefore refer the reader. From the experiments which

ments were however sufficiently conclusive to demonstrate the metallic nature of the bases of most of the earths; but the quantities which have been separated are too small to allow of the proportion of oxygen and metal [c] in any case being exactly ascertained.

What are the names of those substances which form the third class of metals, and which by combining with oxygen constitute the five earths not possessing alkaline properties, and which are therefore called the simple earths?

These metals, or presumed metals, are *silicum* [d], which by oxidizement is converted into silica, or flint-earth; *alumium* [e], the base of alumina, or common

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Sir Humphry Davy made upon silica, he was induced to pronounce it to be a compound of 31 base and 30 oxygen; but Berzelius, who afterwards succeeded in decomposing this earth by heating it with charcoal and iron to the point of fusion in a blast furnace, makes it to consist of silicum 45.92, and oxygen 54.08. Some years ago Mr. Smithson announced that silica possessed the properties of an acid, and since then Berzelius and some other eminent chemists have so far favoured the idea, as to admit an entirely new class of substances under the name of *silicates*; but the matter deserves further investigation. I am however of opinion that silica performs a more important part in the composition of a great variety of substances, and in the general economy of the universe, than had formerly been imagined; but I have not room for enlargement.

If iron be negatively electrified and fused in contact with silica, a metalline globule is procured containing a substance that yields silica when it is acted upon by acids. Again, if potassium be placed in contact with silica and both be ignited to whiteness, a compound is formed consisting of silicum and potash. In the mass certain black particles are diffused, which will burn when strongly heated, and thus become converted into true silica. The proportion of oxygen which is required to convert silicum into silica has not however been accurately ascertained. Silicum is not supposed to be in itself metallic, but a substance somewhat resembling *boron*.

[e] In his attempts to decompose alumina, Sir H. Davy submitted the earth to the same kind of experiments as those which had been made upon silica, but he did not succeed in exhibiting the base of this earth in a separate state. There can however be no doubt of the constitution of alumina being similar to that of the alkaline earths, as it has the power, when fused with potassium, of converting that metal into potash; and

clay; and four others, viz. *zirconium*[a], *glucinum*[b], *ittrium*[c], and *thorinum*[d].

What is the peculiar nature of these metals?

Little is known of these substances, as the earths from which they are obtained have hitherto resisted the means which were employed with success upon the alkaline earths. Methods were however afterwards devised by which they were partially decomposed, and though the quantity of the base was in every instance very small, the phenomena which accompanied the experiments were such as to leave no doubt that silica, alumina, zirconia, and glucina, are real metallic oxides. The earth called yttria may very probably have also a similar base.

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when fused with iron a globule of metal was obtained which was whiter than pure iron, which effervesced in water, became covered with a white powder, and which by a different examination yielded real alumina and oxide of iron.

[a] The evidence which we have for believing that zircon is a metallic oxide, rests upon a similar foundation to that afforded by the action of potassium upon the earths last enumerated. When zirconia is ignited to whiteness and a morsel of potassium brought in contact with it, a great part of the zirconia is converted into dark coloured particles, which when examined by a magnifying-glass, evidently appear in some parts to be metallic. The potassium is at the same time converted into potash.

[b] When glucina is treated in the way just described for zirconia, the potassium is in this instance also converted into potash by the oxygen afforded by the earth: hence the natural conclusion is, that the base of glucina is likewise metallic. Its name will be *glucinum*.

[c] Considerable doubt exists as to the nature of the base of yttria. All that is known in favour of its being a metallic oxide is, that when ignited with potassium it imparts its oxygen and converts the alkaline metal into potash; and when it has been intensely heated and then dissolved in muriatic acid, it gives out oxygenized muriatic acid.

[d] Thorina is a rare earthy substance lately discovered by Berzelius in a species of gadolinite. Its properties are little known, but it is presumed to be a metallic oxide, and the metal will of course be denominated *Thorinum*.

[e] There is a great variety of iron ores (chiefly composed of the oxides of iron and clay), which have different names given them by the workmen, and are of very different qualities;—for particulars consult Bergman, Kirwan, and others.

Native metallic iron has been found in Siberia and in Peru, in a state

What are the names of those substances which constitute the FOURTH *class of metals; and what are their distinguishing characteristics?*

They are those metals which absorb oxygen, and decompose water at a high temperature. Of these there are only four, viz. iron, tin, zinc, and manganese.

What is the origin *of iron?*

Iron is plentifully and universally diffused throughout nature, pervading almost every thing, and is the chief cause of colour in earths and stones. It may be detected in plants and in animal fluids. It is found in great masses, and in various states, in the bowels of the earth in most parts of the world[c].

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of malleability, and yet in such enormous masses as to preclude any supposition of their being the productions of art. Besides, they are found entirely insulated, and at great distances from any mountain, volcano, or bed of ore, from whence they might have been supposed to be derived. They are so similar in their composition to the meteoric stones, that it is probable they have the same origin. Laplace and Dr. Hutton suppose that these meteoric stones have been projected from a volcano in the moon. The one which fell in the year 1751, near Agram in Croatia, consists of 96½ per cent. of iron and 3½ of nickel. Fragments from the mass which lies in the Great Desert of Sahra were analysed by Mr. Howard, and found to consist of 96 per cent. iron and 4 nickel; but there is an immense mass which was discovered many years ago in South America, and supposed to weigh 30 tons, which was found by Mr. Howard to be composed of 90 iron and 10 nickel.

In the museum of the Academy of Sciences at Petersburg is a mass of *native iron* twelve hundred pounds weight. In the 78th vol. of the *Philosophical Transactions*, page 183, there is an account of an immense mass of native iron 15 tons weight;—both these also contain nickel.

Iron is found in greater abundance than any other metal. In the northern parts of the world whole mountains are formed of iron ore, and many of these ores are magnetic. Of the English ores, the common Lancashire hematite produces the best iron. See Additional Notes, No. 34.

In the great iron works, the ore, broken into small pieces and mixed with lime or some other substance to promote its fusion, is thrown into the furnace; and baskets of charcoal or coaks, in due proportion, are thrown in along with it. See Note[e], page 113. A part of the bottom of the furnace is filled with fuel only. This being kindled, the blast of the great bellows is directed on it, and soon raises the whole to a most intense heat: this melts the ore immediately above it, and the reduced metal

What is the nature *of iron?*

Pure iron is of a blueish-gray colour; it is one of the hardest metals, though extremely ductile[a]; when dissolved in an acid it has a nauseous styptic taste, and emits a peculiar smell when rubbed strongly; it is attracted by the magnet, and has the property of becoming itself magnetic[b]. It is fused[c] with great difficulty, but gives fire by collision with flint, and is

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drops down through the fuel and collects at the bottom. The rest sinks down, to fill up the void left by the consumed fuel and metal: this, in its turn, comes next in the way of the bellows, and is also reduced. More ore and fuel are supplied above, and the operation goes on till the melted metal at the bottom, increasing in quantity, rises almost to the aperture of the blast: it is let out by piercing a hole in the side of the furnace, snd then forms what are called *pigs* of cast iron.

The rationale of making iron from the ore is well explained by Dr. Thomson, in his *System of Chemistry*, vol. i. page 156. See also an excellent paper by Mr. Collier in the *Manchester Memoirs*, vol. v.

[a] An iron wire only one-tenth of an inch in diameter, will carry 450 pounds without breaking. A wire of tempered steel of the same size will carry nearly 900 pounds. Dr. Black.

Iron becomes softer by heat, and has the capability of being welded to another piece of iron, so as to form one entire mass; and this may be done without melting either of the pieces. No other metal possesses this singular property, except platina. Notwitstanding this, pure iron is nearly infusible. In order to effect the fusion of this metal, it is necessary to surround it with the fuel, and to urge the fire to the utmost possible pitch. Crude or pig iron is fused readily: hence, it may be cast into any form, and is employed in the fabrication of a vast variety of machinery and utensils.

[b] If a bar of iron be suspended for some time in a perpendicular position, it become magnetic. If friction be employed in a peculiar way, it quickly acquires strong magnetic powers. For particulars consult Cavallo's *Elements of Natural Philosophy*. The late Dr. Godwin Knight possessed a surprising skill in magnetism; being able not only to communicate an extraordinary degree of attractive and repulsive virtue to his artificial magnets, but even to alter or reverse their poles at pleasure. This singular man refused every offer that was made to him for the discovery of his method, and, to the last, declared that the largest sum that could possibly be tendered, should not induce him to divulge it. Of course these curious and valuable secrets died with him. It may be remarked that cobalt and nickel are the only two metals besides iron, which are obedient to the magnet. There are however many natural and artificial compound bodies, which contain a large portion of iron, and yet are not magnetic.

The advantages which we derive from the magnetic property of iron the most elastic of all the metals. Its specific gravity is about 7.7.

Is iron always used in the state in which it is procured from the ore?

No: iron is employed in three states; viz. that of *cast* iron[d], *wrought* iron[e], and *steel;* each of which is of a different quality, and used for different purposes.

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are incalculable. To this astonishing property we are indebted for an instrument—the mariner's compass—by which man is enabled to traverse the ocean, to open a friendly or commercial intercourse with every quarter of the world, and to steer his course towards any particular country with the utmost accuracy and certainty.

> "Tall navies *hence* their doubtful way explore,
> And ev'ry product waft from ev'ry shore;
> Hence meagre want expell'd, and sanguine strife,
> For the mild charms of cultivated life." BLACKLOCK.

[c] Mr. Wedgwood fused some soft iron nails in a crucible at the heat of 154° of his scale. Sir George Mackenzie did not produce the same effect till his furnace acquired the temperature of 158°: cast iron melts at 130° of Wedgwood.

Prussiate of potash is the usual test for iron. When added to a liquid which contains iron, it will cause a blue precipitate, if the iron has its full complement of oxygen; but if the iron is partially oxidized, the precipitate will be gray. Succinate of ammonia will precipitate oxide of iron from its solutions.

[d] To convert *cast* iron into *wrought* iron, the former is kept in a state of fusion for a considerable time, and, by repeated stirring in the furnace, the oxygen and carbon which it contains form an union, and rise from the mass in the state of carbonic acid gas. As the carbon and oxygen thus go off, the iron becomes more infusible; it gets thick or stiff in the furnace, and the workmen know by this appearance that this is the time to remove it from the fire, and to submit it to the action of the hammer, or the regular pressure of large steel rollers, by which the remaining impurities are forced out, and the metal is rendered malleable, ductile, and nearly infusible. In this state it is known in commerce by the name of bar iron. A considerable loss in weight, however, is sustained by this process; not only from the impurities, but from the surface of the iron oxidizing and falling off in scales while hammering.

[e] In purchasing wrought iron, the workmen distinguish two kinds which are both of very inferior value. They are called *hot-short* and *cold-short* iron. The former is a fusible metal, which possesses ductility when *cold*, but is so brittle when *heated* that it will not bear the stroke of the hammer. The cause of this variety is not known. The latter kind is very malleable and ductile while hot, but the utensils made with it are as brittle as cast iron when cold. Such iron contains a portion of *phosphuret of iron*, which Bergman believed to be a new metal, and called *siderite.*

What constitutes the difference in these three kinds of iron?

Cast iron is the metal in its first state, rendered fusible by the combination of carbon and oxygen [a]. *Wrought* iron differs from the former, in being deprived of this carbon and oxygen, by continued heat and repeated hammering, which render the metal malleable [b]. *Steel* is made of wrought iron, by various processes, whereby the metal resumes a small portion

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[a] Cast iron which breaks of a *white* colour should be refused, as it contains a portion of phosphuret of iron. From some experiments by Berzelius and Stromeyer it has been concluded that iron will form a combination with silicum and carbon, and Mr. Daniell has shown that the metallic base of silica enters largely into the composition of *cast iron*. See an interesting paper by this gentleman in the *Journals of the Royal Institution*, vol. ii. page 278—293.

[b] Though iron is deprived of part of its carbon and rendered malleable by hammering, a long continued hammering will entirely deprive it of its malleability. Dr. Black was of opinion that this arises from the loss of a portion of its latent caloric, and that metals are malleable in proportion to the matter of heat which they contain in a latent state. *Chemical Lectures*, vol. i. page 139.

[c] Steel, like cast iron, contains carbon; but it is divested of oxygen, which is always combined with the latter.

If a slender rod of wrought iron be plunged into cast iron in fusion, it will absorb part of the carbon, and become steel. What is called *case-hardening* is a conversion of the *surface* of iron into steel.

Mr. Morveau exposed a diamond to intense heat, shut up in a small cavity in a piece of tough iron. When he opened the cavity he found the diamond entirely gone, and the iron around it converted into steel. *Annales de Chimie,* tome xxxi. page 328. This is one proof that the diamond is carbon, and shows that it is *pure* carbon which combines with iron to form steel, and not charcoal, which is generally an oxide of carbon. The peculiar hardness of steel is to be ascribed to its union with a portion of pure carbon or *diamond.*

It is no uncommon thing for jewellers to expose such diamonds as are foul, to a strong heat imbedded in charcoal to render them clear; but in this process great care is taken to have a sufficient quantity of charcoal to exclude the atmospheric air, otherwise the intense heat would produce combustion.

Steel, by repeatedly heating and hammering it, may be converted into wrought iron.

A steel instrument may be known from one of iron thus: If a drop of nitric acid be let fall upon it, it will occasion a black spot if it be steel, but will not have this effect if it be wrought iron. The blackness is probably owing to the iron being dissolved and the carbon thereby exposed to of carbon, and acquires a capacity of receiving different degrees of hardness [c].

What is the effect of oxygen *upon iron?*

Iron has such an affinity for oxygen, that it will become oxidized merely by exposure to the air. The oxides of iron are found in great plenty ready formed in the bowels of the earth. This metal is susceptible of two degrees[d] of oxidizement; the one pro-

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view. For a method of ascertaining the quality of bar iron or steel, chemically, consult Nicholson's *Philosophical Journal*, 4to, vol. i. page 470.

Cast steel is manufactured in some parts of this kingdom with great secrecy; but it is now known that it may be made merely by fusing iron in an intense heat with carbonate of lime. Cast steel contains more carbon, and is more fusible than common steel.

As different tempers are given to all kinds of edge-tools, by the different degrees of heat to which they are submitted, what is now a very precarious operation, might be reduced to a certainty by means of a metallic bath of fusible metals, containing a thermometer, to show the degrees of temperature. A mixture of bismuth, lead, and tin will afford a compound that will continue fusible with the heat of boiling water. Mr. Stodart has long availed himself of this method in making surgical instruments. It was first suggested, I believe, by David Hartley, Esq. formerly M. P. for Hull, who in the year 1789 procured a patent for its exclusive use. In the year 1815, desirous of improving upon Mr. Hartley's proposal, I undertook a long series of experiments on the different melting points of various metallic alloys, from whence I constructed three Tables for the use of working cutlers, and printed them in the 5th volume of my *Chemical Essays*, page 262—272.

Another interesting illustration of the use of metallic alloys has been lately presented to us in the construction of an instrument called the *safety bar*, and which is incapable of eliciting sparks by collision. This important instrument has been much used in Cornwall, and thereby the tremendous accidents which so frequently occurred heretofore during the process of blasting rocks with gunpowder, have been prevented. Dr. Paris, the ingenious inventor, has published a paper upon this subject in the 1st volume of the *Transactions of the Royal Geological Society of Cornwall*, page 78—96, to which I beg to refer the reader.

[d] The chief distinction between *black* and *red* oxide of iron is, that the latter contains one half as much more oxygen in a given portion as the former; 69 parts of the metal combining with 20 of oxygen to form the black oxide, and with 30 parts of oxygen to produce the red oxide. The scales which are detached from forged iron by a high degree of heat, and which Dr. Priestley employed in several of his last experiments in America under the name of *finery cinder*, are in the state of black oxide, and rust of iron is the red oxide. The iron contained in martial pyrites is in a *metallic* state and combined with sulphur. The super-sulphuret

ducing the black[a] and the other the red oxide of iron[b].

What salts *of iron are there?*

The most useful salts of iron are those composed with the sulphuric, the nitric, the muriatic, and acetic acids; and these with some others are very essential

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of iron in this mineral is converted into *sulphate* of iron at the great copperas works, by exposing the pyrites to the air and rain for several months, in large beds prepared for the purpose. The sulphur decomposes the water which falls upon the beds, and is itself converted thereby into sulphuric acid, which combining with the iron forms the salt in question, and this is afterwards extracted from the mass by lixiviation and crystallization. The process is carried on upon a large scale at Deptford, near London, where the united acidifying powers of air and water are well exemplified. A notice respecting the decomposition of this salt by animal matter, by W. H. Pepys, Esq. will be found in the *Trans. of the Geol. Soc.* vol. i. page 399.

Mr. Chenevix has stated that there are four oxides of iron, the first or least degree of oxidizement being white, and progressively to green, black, and red; and he founds his opinion upon the different colours which minerals possess that contain iron: but it is now generally believed that there are but two oxides of iron, and that this variety of colour results from the various combinations into which the two oxides enter, difference of colour being a very uncertain mark of difference in the degree of metallic oxidizement.

[a] The Swedish iron ore which produçes such excellent iron, is in this state of oxidizement. The loadstone is also constituted of this oxide of iron.

[b] There is some difference of opinion respecting the composition of the red oxide of iron. Bucholz states it to be formed of 100 parts of iron and 42 of oxygen; Dr. Wollaston, 100 iron and 43.5 oxygen; and Berzelius, 100 of metal and 44.25 of oxygen. Both the oxides of iron are capable of combining with water and forming what may be called hydro-oxides of iron. See *Annales de Chimie,* tome lxxx. page 163.

[c] *Green vitriol,* which is of so much use in dyeing, in colouring hats, and in other manufactures, is a sulphate of iron formed by the decomposition of martial pyrites. The iron in the pyrites is in a metallic state, and in the salt it is in the state of the black oxide. The nitrates, muriates, and acetates of iron are prepared by art for the use of the calico-printers, who consume great quantities of these salts in a state of solution.

[d] The compound of iron and sulphur often occurs in cubic crystals of a brilliant yellow colour, known to mineralogists by the name of iron pyrites. This natural production generally consists of about 52 parts sulphur and 48 iron. Some of the specimens are so fine as to be often mistaken for gold.

[e] The native arsenite of iron is found in Cornwall; native sulphate of iron occurs frequently with pyrites; phosphate of iron ready formed is

to our manufactures[c]. The arsenite, sulphate, phosphate, chromate, and tungstate of iron, as well as the sulphuret[d] of this metal, are all found native[e].

What are the uses *of iron?*

The uses of iron are innumerable; every thing we possess is manufactured by its means; it is assuredly the most useful substance in the world[f]. When con-

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een frequently in bogs,—it is called native prussian blue ; chromate of ron has been found in France and in Siberia ; and tungstate of iron xists native in a mineral found in Britain and elsewhere, called wolfram. The sparry iron ore is a carbonate of iron.

Carbonate of iron is also commonly found in solution in chalybeate aters : such waters may be known by the dark orange-coloured film hich generally appears upon their surface : the oxide of iron is rendered oluble by an excess of carbonic acid. This may be shown by adding a ew grains of quick-lime to a small quantity of such water; the lime will ombine with the carbonic acid, and the oxide of iron will be precipitated.

Besides the above, *carburet* of iron (usually called *black lead*) is found n several parts of the world. A combination of alumina, iron, and silica so occurs native, and forms what is called *emery*; a substance very seful in the arts, and of which large quantities are found in the island Jersey. It is employed by lapidaries and by glass-cutters to cut glass nd to stopper bottles for chemical and other purposes. It is a compound of 86 alumina, 4 iron, and 3 silica. The diamond spar or *corundum* China is a compound of 84 alumina, 7.5 of iron, and 6.5 of silica. An ccount of the Swedish corundum from Gallivara in Lapland, has lately en published by Swedenstierna in the *Trans. Geol. Soc.* vol. iii. page 415.

Some of the ores of iron are used in their native state; such as the ematite, which is made into burnishers, &c. This mineral is composed 94 oxide of iron, 2 of silica, 2 of water, and 1 of lime.

Iron was in use in the time of Moses. *Deuteronomy* iv. 20., viii. 9., and iii. 5. The Greeks understood the method of tempering it. Homer deribes the firebrand driven into the eye of Polyphemus, as hissing like hot on immersed in water:

> "And as, when arm'rers temper in the ford
> The keen-edged pole-ax, or the shining sword,
> The red-hot metal hisses in the lake,
> So in his eye-ball hiss'd the plunging stake."
>
> Pope's *Odyssey*, book ix. page 465.

[f] The property of *welding*, which, except sodium and platina, no other tal possesses, renders iron the most suitable of all others for every mmon purpose. It becomes softer by heat, and thus may be moulded the hammer into any form, and united in as many parts as the workn pleases, without rivets or without solder.

Were it not for this peculiar quality of iron, many works of the utmost portance could never have been executed. The most stupendous verted into steel it is employed in various ways[a], especially for edge-tools; all which are formed in part with this metal, from the ponderous pit-saw to the finest lancet[b]. Its oxides are used in painting, enamelling, dyeing, and in medicine.

Where is tin *procured*[c]*?*

Tin is found in Germany, in Saxony, in South America[d], and in the East Indies; but in England it is chiefly procured from Cornwall[e] and Devonshire.

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fabric that I recollect to have ever read of, that was achieved by means of *welded* iron, is the Chinese *bridge of chains*, hung over a dreadful precipice in the neighbourhood of Kingtung, to connect two high mountains. The chains are twenty-one in number, stretched over the valley, and bound together by other cross chains, so as to form a perfect road from the summit of one immense mountain to that of the other.

Fourcroy says, iron is the only metal which is not noxious, and whose effects are not to be feared: Indeed its effects on the animal economy are evidently beneficial. For a detailed account of its various and important uses in medicine, consult Fourcroy's *Elements of Chemistry*, Thomson's edition, vol. ii. page 466.

The ancients had an idea that iron was poisonous, and that wounds made with iron instruments healed with difficulty. Hence, after the expulsion of the Tarquins, Porsenna stipulated with the Romans that they should not use iron except in agriculture.

[a] Good steel is much more ductile than iron, and hence the most minute instruments are generally made with it. A finer wire may be drawn from it than from any other metal. See page 247.

[b] The excellence of edge-tools depends upon the temper given to them by heat. This requires great skill and peculiar management. A valuable report on the art of making fine cutlery may be seen in Nicholson's *Journal of Natural Philosophy*, 4to. vol. iv. page 127. A more circumstantial account of these processes may be seen in my *Chemical Essays*, in a distinct "Essay on edge-tools," vol. iv. page 399—524.

Sulphate of iron is not only used by the hatters and dyers, but also in making ink, in the manufacture of prussian blue, in preparing leather, and in forming *colcothar* for painters. Colcothar is nothing more than sulphate of iron calcined to redness. It not only makes an useful pigment, but is employed in polishing several kinds of metals. The oxide of iron imparts its colour to a great variety of natural substances. It is the cause of the redness of common bricks; it gives colour to the carnelian, the garnet, and other precious stones. With different proportions of oxygen it imparts other and different colours. Thus it gives the blue to the lapis lazuli, the yellow to the topaz, &c. The common garnet consists of 40 silica, 20 alumina, 8 lime, and 20 iron. The precious garnet, 36 silica, 27 alumina, a trace of manganese, and 36 oxide of iron.

What is the nature *of tin?*

Tin is a white metal, of little elasticity, and small specific gravity [f]. It is not very ductile, but is so exceedingly malleable that it may be beaten out into leaves thinner than paper. It emits an uncommon smell when rubbed; and if suddenly bent, affords a crackling noise, which is peculiar to this metal.

What is the effect of oxygen *upon tin?*

Tin absorbs different proportions of oxygen; but

The lapis lazuli is composed of 66 alumina, 10 silica, 18 magnesia, 2 lime, and 2½ oxide of iron. The Brazilian topaz, 47.5 alumina, 44.5 silica, 7 fluoric acid, and 0.5 of oxide of iron.

[c] Tin must have been known very early, as it is mentioned by Homer, and also in the books of Moses. The edge-tools of the ancients, and their coins, were made with mixtures of copper and this metal.

Tin is found only in the primitive mountains. Its ores occur most frequently in granite, but never in limestone. About 3000 tons weight of tin are furnished annually in Cornwall, two-fifths of which are usually exported to India by the East India Company; and in order to induce them to take so large a quantity out of this market, they are allowed to have it at 70*s.* per cwt. See Additional Notes, No. 30. An interesting account of a tin mine which was sunk in the midst of the sea near Penzance, will be found in the 1st volume of the *Trans. of the Roy. Geol. Soc. of Cornwall*, page 127.

[d] A very large quantity of tin is raised in South America, called Spanish tin. It is very pure, but not so neatly manufactured as the Cornish tin. A duty of 30*l.* per cent. prevents its being used in this country.

[e] According to Aristotle, the tin mines of Cornwall were known and worked in his time. Diodorus Siculus, who wrote about forty years before Christ, gives an account of the method of working these mines: he says that their produce was conveyed to Gaul, and from thence to different parts of Italy. The miners of Cornwall were so celebrated for their knowledge of working metals, that about the middle of the seventeenth century the renowned Becher, a physician of Spire, and tutor of Stahl, came over to this country on purpose to visit them; and it is reported of him that when he had seen them he exclaimed, that, "he who was a *teacher* at home, was a *learner* when he came there."

[f] The specific gravity of tin is 7.291. The purity of this metal may be known by its specific gravity, its purity being in exact ratio with its levity; while gold, on the contrary, provided it be not alloyed with platina, is fine in proportion to its density. Some important information on the refining of tin may be obtained from a paper by Mr. John Hawkins in the *Trans. of the Roy. Geol. Soc. of Cornwall*, vol. i page 201.

Tin is much more combustible than many of the metals. It will burn in oxygen gas, before it acquires a heat sufficient to fuse it.

Tin is soluble in all the mineral acids. It may be precipitated from its only two well defined oxides of this metal are known. viz. the yellow[a] and the white; the first being composed of 100 parts of tin and 13.5 of oxygen, the latter of 100 of tin and 27 of oxygen.

What salts *of tin are there?*

The muriate, the nitro-muriate, and the sulphate of tin are most known, though many others may be formed with this metal which might possibly become useful to the arts. There are also two distinct combinations of tin with chlorine[b], and two with sulphur[c].

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solutions by potash, but an excess of potash will re-dissolve the metal. Nitro-muriate of gold is a test for the presence of tin in solution, with which it forms a fine purple precipitate.

[a] A *yellow* oxide of tin may be procured by dissolving granulated tin in very dilute nitric acid, and precipitating it from the solution by an alkali: by pouring very strong nitric acid on granulated tin, a *white* oxide may be prepared, which precipitates in a pulverulent form, and is to be washed and dried for use.

The yellow oxide of tin found in commerce is called putty; but what is sold generally contains also oxide of lead. It is employed in polishing fine steel goods, and the best kinds of ornamental glass.

A *white* oxide of tin is used to form the opake kind of glass called enamel. This composition is made by calcining 100 parts of lead and 30 parts of tin in a furnace, and then fluxing these oxides with 100 parts of sand and 20 of potash. But I am of opinion that soda would answer the purpose better than potash. To this enamel every kind of colour may be given by metallic oxides.

Tin by means of the muriatic acid decomposes water, and then, having been thus oxidized, dissolves readily in the acid to form muriate of tin. A recent solution of this metallic salt has a great affinity for oxygen. It deoxidizes a solution of indigo in an instant, and changes it from blue to green. On native muriate of tin consult the *Transactions of the Royal Geological Society of Cornwall,* vol. i. page 51.

[b] When tin is burnt in chlorine, a volatile clear liquor is formed, which when mixed with a little water becomes a crystalline solid. The liquor, which was formerly known by the name of liquor of Libavius, may also be formed by distilling a mixture of one part of tin filings and three of corrosive sublimate. The product consists of 55 tin and 67 chlorine.

The other compound of tin and chlorine, which is a gray semitransparent mass, is procured by heating together an amalgam of tin and calomel. It consists of 55 tin and 13.5 of chlorine.

[c] Sulphuret of tin, which is a blueish substance with a lamellated texture, is formed by fusing tin and sulphur together at a high temperature. It is composed of 100 parts of tin and 27½ of sulphur. The supersulphuret of tin, formerly known by the name of *aurum musivum,* is of a bright golden colour, and in light soft flakes. It is prepared by heating

None of the salts of tin have been discovered native, notwithstanding the ores of this metal are found in great abundance[d].

What are the uses *of tin?*

Tin is consumed in large quantities by the dyers[e]; t is used also for covering sheet iron to prevent its rusting[f], and in forming plumbers' solder, speculum metal, pewter, and some other alloys. Its oxides are used in polishing glass, in glazing some kinds of earthen-ware, and for various other purposes.

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gether the white oxide of tin and sulphur in a retort; the usual pro-
ortions are equal parts of each. During the process the whole of the
xygen and a part of the sulphur is dissipated, and the product is a com-
ound of 100 parts of metallic tin and 55 of sulphur. This article,
hich is sometimes called *mosaic* gold, is used by artists to give a beautiful
lour to bronze. I suspect that the change produced in tin by this
rocess gave rise to the idea of the transmutation of metals. If the
chemists were acquainted with this compound substance, no wonder
at they should indulge the hope of being able to form gold. An expe-
mentalist without theory is the dupe of every illusion. Tin also com-
nes with phosphorus in the proportion of 55 of tin and 10 of phospho-
s. The compound has a metallic appearance, but it has hitherto been
plied to no use.

[d] We are acquainted with three distinct tin ores, known by the names
tin-pyrites, tinstone, and wood-tin. Tin-pyrites having a specific gra-
y of 4.350 was analysed by Klaproth, and found to consist of 34 tin,
copper, 3 iron, 25 sulphur, and 2 earthy matter. Tinstone has a spe-
ic gravity of from 6.30 to 6.97, and contains from 68 to 78 per cent.
tin, and from about 16 to 24 per cent. of oxygen, with a trace of iron
d silica. Wood-tin, which abounds in Mexico, but is a scarce mineral
Cornwall, is a compound of the oxides of tin and iron. The Cornish
said to consist of 91 oxide of tin and 9 oxide of iron; the Mexican of
oxide of tin and 5 of oxide of iron. A paper on the native oxide of
, by William Phillips, Esq. will be found in the *Trans. of the Geol. Soc.*
l. ii. page 336.

[e] Tin is used to form boilers for dyers, worms for rectifiers' stills, and
ny other utensils employed in the arts.

[f] The consumption of tin for covering thin rolled iron, and forming
at are improperly called sheets of tin, is very considerable: besides
s, tin is used for coating the inside of iron and copper utensils, brass
d iron pins, &c. For the method of doing this consult Additional Notes,
. 30.
The use of tin was known to the Greeks. Homer mentions it in the
ad. Pliny says, the Romans learnt the method of tinning their culi-
ry vessels from the Gauls. They used tin also to alloy copper for

What is the use of tin to the dyers?

Tin is employed by the dyers to give a brightness to cochineal, archil, and other articles used in forming reds and scarlets; and to precipitate the colouring matter of other dyes[a]. For these purposes it is previously dissolved in a peculiar kind of aqua-fortis, called *dyer's spirit.*

What is the nature of zinc?

ZINC is a very combustible[b] metal possessing but a small degree of malleability[c] and ductility, except under certain circumstances[d]. When broken it ap-

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making those elastic plates which they employed in shooting darts from their warlike machines.

Tin is employed to form bell-metal, bronze, brass for cannon, and a variety of other compounds. The addition of tin renders copper more fluid, and disposes it to assume all the impressions of the mould. It was probably with this view that it was used by the ancient Romans in their coinage. Many of the imperial *large brass*, as they are called, are found to consist of copper and tin alone. Coins also frequently occur, which are undoubtedly antique, that contain a very large proportion of tin, made by the forgers, in the different reigns, in imitation of the silver currency. There are coins of Nero of a most debased and brittle brass.

[a] Several of the colouring substances which produced to the ancients only faint and fleeting colours, give us such as are brilliant and durable by the use of this metallic solution. A considerable degree of nicety and judgement is, however, requisite for its preparation. The difficulty is in a great measure owing to the nature of the acid that is used; as those makers of aquafortis, who know but little of chemical affinities, or of the nature and operation of this invaluable mordant, often furnish the dyers with an article which is unfit for their use. Few arts have received such improvements from chemistry as the art of dyeing; for even cochineal gave but a dull kind of *crimson* till a chemist of the name of Kuster, who settled at Bow near London about the middle of the sixteenth century, discovered the use of solution of tin, and the means of preparing with it and cochineal a durable and beautiful *scarlet.*

[b] Zinc, if beaten out into thin leaves, will take fire from the flame of a common taper. It is the most combustible metal we have. Next to manganese, it has the strongest affinity for oxygen of all the metals. When intensely ignited it burns freely, and is thereby converted into an oxide. By the usual processes of sublimation this oxide is frequently formed and collected for medicinal purposes, and sold under the name of flowers of zinc, or that of *zinci-oxydum.* It is extremely light, and has the appearance of fine wool.

[c] The nature of zinc is such, that it seems to form the link between brittle and malleable metals. It is difficult to procure it in small parti-

pears of a shining blueish white; and when exposed to the air, it becomes covered with a pellicle, which, in consequence of its affinity for oxygen and carbonic acid, reflects various colours. It is readily acted upon by acids[e] and alkalies, either in its metallic state or when oxidized. It melts at 680° of Fahrenheit, and its specific gravity is 6.861.

How is zinc *procured?*

Zinc, generally called by our artists *spelter*, is not found native[f], but, in England and elsewhere, is ex-

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cles, as the hammer flattens it instead of reducing it to powder. Macquer says, that if it be heated very hot, it becomes brittle, and may then be pulverized.

[d] Messrs. Hobson and Sylvester, of Sheffield, have shown, that at a temperature between 210° and 300° of Fahrenheit, zinc is really a malleable metal; that it yields to the hammer, and, while kept at this temperature, may even be wire-drawn. They moreover say, that after having been thus annealed and wrought, it continues soft, flexible, and extensible, and does not return to its partial brittleness, but may be bent and applied to many uses for which zinc has hitherto been thought unfit. This is an important discovery; and in future there will be no impediment to its being formed into vessels of capacity, into utensils for var ous manufactories, sheathings for the bottoms of ships, and for other obvious applications.

Since the above was written, I have been informed that Mr. Phipson, an ingenious manufacturer of Birmingham, was acquainted with this property of zinc long before Messrs. Hobson and Sylvester took out their patent, and that he sent plates of this metal, which he had himself rendered malleable, several years ago to Dr. Priestley in America.

[e] Muriatic acid, when diluted with water, acts with great energy upon zinc, first oxidizing it and then dissolving it. In this process the water becomes decomposed, and hydrogen is evolved. This is indeed one of the methods of procuring hydrogen gas of the greatest purity. Diluted sulphuric acid and nitric acid also act upon this metal with great rapidity. All the solutions of zinc are colourless.

[f] Zinc is one of the most abundant metals in nature, excepting iron. Calamine, which is one of its ores, is found both in masses and in a crystallized state. The sparry calamine of Derbyshire consists of oxide of zinc 65 and carbonic acid 35, whereas the earthy calamine consists of about 71½ per cent. of oxide of zinc, 13½ of carbonic acid, and 15 water. The electric calamine contains from 25 to 50 per cent. of silica. Zinc occurs also in an ore called *blende,* which is an impure sulphuret, containing from 16 to 30 per cent. of sulphur. By the miners this mineral is called black-jack, and until lately was employed in Wales for mending the roads.

In China there is a great abundance of zinc: it is used in that country tracted from calamine and blende, two of its ores, by distillation[a].

What is the effect of oxygen *upon zinc?*

When zinc is heated[b] it readily attracts oxygen; and at a white heat the absorption of oxygen, even in the common atmosphere, is so rapid and violent that the oxide actually sublimes : hence its oxide acquired the name of *flowers* of zinc. It may also be oxidized by acids. We are acquainted with only one oxide of this metal, which is white, and consists of zinc 80.39 and oxygen 19.61.

What salts *of zinc are there?*

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for current coin, and for that purpose is employed in the utmost purity. These coins have frequently Tartar characters on one side, and Chinese characters on the other. They have generally a square hole in the centre, that they may be carried on strings, and more readily counted.

[a] Metallic zinc is procured from calamine by distillation *per descensum.* The calamine is pounded, and with powdered charcoal put into large pots, which are placed in a furnace like a common oven. These pots have tubes fixed in the bottom, which pass through the bottom of the furnace into a vessel of water. After the tops of the pots are covered, and rammed close with clay, a strong fire is made around them, so that the metallic zinc, being separated from the ore, and being of a volatile nature, is forced to rise to the upper entrance of the tubes, and thence passes downwards into the water.

In order to analyse the ores of zinc, it is necessary to operate upon them in retorts, and to collect the distilled metal in close receivers; for, if reduced in a common furnace, the greater part of the produce would be dissipated. The same attention is necessary when operating upon arsenic.

Zinc may be known by dissolving it in a mineral acid, and then adding ammonia, which precipitates it of a white colour, and redissolves it instantly. Sulphuretted hydrogen, added to a solution of this metal, produces a white and lasting precipitate.

[b] Water at the usual temperature of the atmosphere acts very slowly upon zinc; but if the vapour of boiling water be allowed to pass over a plate of metallic zinc, the metal becomes oxidized by the decomposition of the water, and hydrogen is evolved.

[c] Zinc has so great an affinity for oxygen, and its salts are so permanent, that none of the metals except manganese will precipitate it from its solutions in a metallic form.

[d] Sulphate of zinc, formerly called *white vitriol,* is usually formed in Germany from the ore called *blende,* which is a sulphuret of zinc. By

A great number of salts[c] have been formed with this metal; but the carbonate, the sulphate, and lately the acetate of zinc[d] are most known; the two first are found in a native state[e]; a compound may also be formed of chlorine and zinc[f], and another with zinc and phosphorus[g].

What are the uses *of zinc?*

Zinc is frequently combined with copper or tin, in various proportions, and these mixtures constitute some of the most useful compound metals or alloys[h]; it is also largely employed in its metallic state unmixed

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the agency of fire and the access of atmospheric air, the sulphur is converted into sulphuric acid, and by means of proper evaporation and cooling, the salt is obtained in a crystallized state. The white vitriol of commerce ought however never to be administered in medicine without previous purification; for all I have examined contains copper as well as iron. Sulphate of zinc occurs in some mineral waters. When perfectly crystallized, this salt consists of 27.3 per cent. of acid, 28.4 oxide of zinc, and 44.3 of water.

Acetate of zinc has been recommended by Dr. Henry to be applied in cases of inflammation. This salt is easily formed by dissolving oxide of zinc in acetic acid.

[e] Carbonate of zinc occurs in great abundance in Derbyshire, Somersetshire and elsewhere: but the native sulphate of zinc is a rare production. It has been found in Switzerland, in Hungary, and at Holywell in Flintshire.

[f] This compound may be formed by burning zinc in chlorine gas. The product is of a whitish gray colour, and semitransparent. In this formation of chloroid of zinc, 100 parts of the metal combine with about 108 parts of chlorine.

[g] This compound is nearly of the colour of lead, has some metallic lustre, and is malleable. It has not been applied to any use.

[h] Three parts of copper and one of calamine, or native carbonate of zinc, constitute *brass*; five or six of copper and one of zinc, form *pinchbeck*. *Tombac* has still more copper, and is of a deeper red than pinchbeck. *Prince's metal* is a similar compound, excepting that it contains more zinc than either of the former. A mixture of tin and copper with zinc forms *bronze*. Vessels of bronze, covered with silver, were dug out of Herculaneum. In order to make *brass*, the calamine is previously roasted; it is then mixed with charcoal and grain copper, and put into large crucibles, which are kept for a considerable time in a heat that will not melt the copper; after a time the heat is raised so as to fuse it, and the compound metal is then run into ingots. Brass is a valuable alloy on many accounts, especially the superior brightness of its colour,

with any other metal[a]; it is used in medicine; it the base of white vitriol; and its carbonate or oxi may be advantageously substituted for white lead house-painting[b].

What is the history and origin of cadmium?

Cadmium was discovered in 1817, in an ore of zi by Mr. Stromeyer. It resembles tin in its colo lustre, softness and ductility; and also in the sou which it gives when doubled. Its specific gravity 8.635. It melts and volatilizes at a few degrees heat below that which is required by tin. It do not tarnish by exposure to the air.

What is the effect of oxygen *upon cadmium?*

When cadmium is heated in atmospheric air, combines with oxygen, and is converted into an oran coloured oxide, which is not volatile, and is read reducible to the metalline state.

What is the nature of the salts of cadmium?

Cadmium readily dissolves in acids, and forms wi

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in its not being so liable to tarnish by exposure to the air as copper, in its being more readily melted, and more malleable when cold. Sie of extreme fineness are wove with brass wire, after the manner of ca brick weaving, which could not possibly be made with copper wire.

[a] In addition to what has been said in note [d], page 283, I am desir of stating that plates of zinc of various thickness are now used with vantage for making water pipes, for covering the roofs of houses, and other important purposes, to which lead, iron, or copper were form applied.

[b] See *Annales de Chimie*, No. 103. This pigment is not of so per a white as may be obtained from pure lead, but I have found by exp ence that it preserves a good colour much longer than white lead. once had some rooms painted with it, and its durability gave me g satisfaction.

Zinc, in fine filings, is used to mix with gunpowder, to produce th brilliant stars and spangles which are seen in the best artificial fire-wo It is also one of the metals employed to form galvanic batteries.

An amalgam of zinc is used to rub upon the cushions of electrical chines. It is very conveniently amalgamated by melting it in a bow a tobacco-pipe, and pouring it while hot into the mercury. I have an them soluble salts, which give a white precipitate with the alkalies, and yellow with sulphuretted hydrogen, resembling arsenic; and on this account it was at first supposed to be arsenic.

What is the nature of manganese?

Manganese is a brilliant metal[c], of a darkish white colour inclining to gray, very brittle, of considerable hardness, and of difficult fusibility. Its specific gravity[d] is somewhat greater than that of the two last-described metals tin or zinc; it is not attracted by the magnet except when a portion of iron is combined with it; and if exposed to the air, it absorbs oxygen with rapidity and falls into powder. On account of its great affinity for oxygen, it is not likely ever to be found in a metallic state[e].

Where is manganese found?

The manganese which we use in this country is obtained in the state of black oxide from Somersetshire and Devon[f]. It also abounds in America, and in

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amatized bismuth and other metals, but never found one of them to answer for electrical purposes equal to zinc, or an amalgam made with a mixture of tin and this metal.

[c] Manganese was first procured in its pure metallic form by Kaim and ahn between 1770 and 1775. An account of the process which they adopted, may be seen in Sir Humphry Davy's *Elements of Chemical Philosophy*, part i. page 366.

[d] The specific gravity of manganese has been estimated at 6.850 by Bergman, at 7.00 by Hielm, and at 8.013 by Dr. John in his paper published in Dr. Thomson's *Annals of Philosophy*.

[e] The oxide of manganese is abundant and easily procured; but the *pure* metal can only be obtained by art, and requires to be carefully defended from oxygen, which it readily absorbs. In order to preserve specimens in a metallic state it is necessary to varnish them, or to keep them immersed in oil, or ardent spirits.

[f] Manganese is found either in the state of an oxide or a salt. But the discovery of English mines of it is comparatively a new acquisition to this country, owing to the spirit of research which chemistry has given birth to.

Dr. William Dyce, of Aberdeen, has communicated to the Society for various parts of the Continent. It is usually found i large amorphous masses, but it occurs sometimes i well defined prismatic crystals of the colour of steel.

What is the effect of oxygen *upon manganese?*

This metal, as I have already observed, become oxidized by mere exposure to the air ; and is susceptible of at least two different degrees of oxidizement forming the olive and the dark brown, or as it is mor commonly called the black oxide of manganese, th first being a compound of 100 of manganese and 26 of oxygen, and the latter of 100 of manganese and 39 oxygen [a].

What salts *are there of manganese?*

A variety of salts have been made with the oxide

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the Promotion of Arts, &c., the discovery of a mine of manganese in hi vicinity, of great extent, and of very fine quality. The gold medal of th Society was awarded to him for this discovery. Professor Beattie o Aberdeen has also discovered manganese in his neighbourhood, upon th river Don, of good quality.

Scheele discovered manganese in the ashes of some burnt vegetables

If one part of the black oxide of manganese and three parts of nitrat of potash, both reduced to powder, be mixed together and thrown int a red hot crucible and continued there until no more oxygen gas is disengaged, a greenish friable powder is obtained, called *mineral cameleon* from its property of changing colour during its solution in water. If a small quantity of this powder be put into a glass of water, the solution is first *blue* ; oxide of iron then separates, and by its *yellow* colour renders the fluid green ; this subsiding, the blue re-appears ; then, as the oxide of manganese absorbs oxygen from the atmosphere, it becomes reddish brownish, and at last black. It then subsides, and leaves the fluid colourless. Again, if *hot* water be poured upon this singular substance a beautiful green solution will be produced, whereas *cold* water will give one of a deep purple. These changes depend upon the various states of oxidizement which the metal acquires by change of temperature. In the first formation of this compound, care should be taken that no sulphur comes in contact with it ; as the addition of a very small portion of sulphuret of potash would counteract its effects.

[a] There is some uncertainty still existing as to the nature of the oxides of manganese ; and as I have not made any direct experiments myself on this metal, I can only give the results obtained by others on this subject. Sir Humphry Davy admits only two oxides, and the above are the proportions of oxygen which he assigns to them. Dr. John says there are three oxides, viz. the green, the brown, and the black : and Berzelius

of this metal; but this class of salts has not yet been rendered useful[b]. A carbonate of manganese is found native in Norway and Sweden. A sulphuret of this metal also occurs in Cornwall and in Transylvania; and at Limoges in France a phosphate of manganese has been found which contains 27 per cent. of phosphoric acid. An artificial compound of manganese and chlorine, and another of manganese and phosphorus, may also be obtained.

What are the uses *of manganese?*

The oxides of manganese are used in preparing the bleaching liquor[c]; in purifying glass[d]; and in glazing black earthen-ware. It is also employed in some cases to give colours to enamels in the manufacture of porce-

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enumerates no less than five oxides; the first of which he says is formed with 100 parts of the metal and (omitting fractions) with 7 of oxygen, the second with 14, the third with 28, the fourth with 42, and the fifth with 56 of oxygen.

[b] There is this peculiarity in the salts of manganese, that, when dissolved in water, the manganese cannot be precipitated from its solution, in a metallic state, by any of the other metals, because, compared with all others, this metal has a superior attraction for oxygen.

[c] Where manganese is employed in making oxymuriatic acid, the purest, such as that of Upton-Pyne, should be used. That from Bristol and the Mendip Hills generally contains lead.

[d] Its use in making white flint glass may be seen in Berthollet's *Treatise on Dyeing*, vol. i. page 8. According to Pliny, it was employed for this purpose more than two thousand years ago. The rationale of its operation has been admirably explained by Bergman. See my treatise on making glass, in the third volume of the *Chemical Essays*, page 421.

Dr. Dyce has suggested that manganese may be advantageously employed to separate the pure from the baser metals. An account of the process may be seen in one of the volumes of the *Transactions of the Society of Arts*, &c.

According to Monsieur Gazeran, manganese forms a component part of steel, and ought to be added to iron for its formation; the best German steel being, according to him, composed of

Iron	97
Manganese	2
Carbon	1
	100

lain[a]. The black oxide is much used by chemists for producing oxygen gas, which, by the application of a red heat[b], it yields in great abundance.

What are the names of those substances which constitute the FIFTH *class of metals, and what are their distinguishing characteristics?*

They are those metals which absorb oxygen at different temperatures, but have not the power of decomposing water at any temperature. Of these there are twelve in number; viz. osmium, cerium, tellurium, titanium, uranium, nickel, cobalt, copper, lead, antimony, bismuth, and mercury; but the five first have been found only in very small quantities, and have hitherto been considered as mere matters of curiosity, and applied to no use.

What is the origin and history of the first metal in this class, and which is called osmium?

OSMIUM was discovered in the year 1804 by Mr. Tennant, in the black powder which remains when crude platina has been digested in nitro-muriatic acid; and from the singular property which it possesses of forming an oxide having a strong smell, he was induced to name it *osmium*. Since then, Dr. Wollaston has discovered a distinct ore[c] of osmium

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[a] The *rubelite*, or red tourmaline, and the *amethyst* owe their colours to the oxide of manganese. A *violet* colour may be given to flint glass by melting it with a large portion of the *black* oxide of this metal.

[b] Black oxide of manganese contains about 36 per cent. of oxygen. It quickly gives out 11 or 12 per cent. of this oxygen merely by the application of a red heat; but the remaining portions cannot be separated by the most intense heat.

[c] Dr. Wollaston found the specific gravity of this ore to be 19.5, whereas that of crude platina is usually only 17.7. The grains are also considerably harder than those of platina, and possess a peculiar lustre.

[d] A portion of this metal was submitted to an intense white heat in a cavity made in a piece of charcoal; but it was not melted, nor did it un-

and iridium intermixed with the grains of crude platina.

What is the nature of osmium?

Osmium is a dark blue metal, which is insoluble in any of the acids. It is difficultly fusible, and even unchangeable in the most intense heat[d] unless in contact with air, when it combines with oxygen, and is converted into a volatile oxide possessing that kind of pungent smell which has not been recognised in any other body[e]. Its oxide, which is soluble in water, is a solid colourless semi-transparent substance, having a sweet taste, and giving when combined with potash an orange-coloured solution in water[f]. It imparts to the skin an indelible stain of a dark colour, and produces a purple with an infusion of galls[g]. On account of the small quantities of osmium which have been obtained, it has not been applied to any use, and its combinations are but little known.

What is the history and origin of cerium?

Cerium was discovered in the year 1804 by Messrs. Hissinger and Berzelius, in a peculiar mineral found at Ridderhytta in Westmannland in Sweden, which is of a reddish colour, and in appearance very like tungsten[h]. They called the new metal *cerium*, from the

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dergo any apparent alteration. When exposed in a similar way with copper and with gold, it melted, and with each of those metals formed an alloy which was quite malleable.

[e] If the oxide of osmium be dissolved in water and then agitated with luid mercury, the solution will lose its peculiar smell, and the metal combining with the mercury will form an amalgam.

[f] This oxide imparts a yellow colour to pure ammonia; with lime it ecomes a *bright yellow*; and with alcohol or ether, *black*.

[g] An infusion of galls is the best test of this very peculiar oxide. It rst produces a purple colour, and soon after this changes to a bright deep blue.

[h] This mineral, which has been denominated *cerite*, occurs in a bed of

circumstance of the planet Ceres having been discovered by Piazzi about the same time [a].

What is the nature of cerium?

The quantities of this metal which have hitherto been procured are so small that nothing respecting its nature or properties has been discovered [b], except that it is capable of being volatilized at a great heat [c]. Hissinger, one of the original discoverers of this metal, has lately announced that it is susceptible of two degrees of oxidizement, producing the white and the red oxide of cerium [d].

What is the history and origin of tellurium?

TELLURIUM was discovered by Klaproth in the year 1798, in an ore of gold found near Zalethna in

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copper pyrites, with other minerals. It has been analysed by Klaproth and Vauquelin, and according to the former of these mineralogists consists of 54.5 per cent. oxide of cerium, 34.5 of silica, 3.5 oxide of iron, 1.25 lime, and 5 per cent. of water. Cerium has also been found by Mr. Thomas Allan of Edinburgh, in a mineral which occurs in a granite rock in West Greenland, and which has been named *allanite,* in honour of Mr. Allan, who first pointed it out as an undescribed species. See Jameson's *System of Mineralogy,* 2d edit. vol. iii. p. 571.

[a] The ancient alchemists named the seven metals which were then known, from the planets, and allotted to each metal the name of that planet which they imagined to have occasioned its production and matured its growth. The discoverers of some of the new metals have therefore named them in the same way, and cerium is one instance of this fanciful adaptation.

[b] Cerium had not been seen in a metallic form till Sir Humphry Davy procured it from some of the oxide discovered by Hissinger and Berzelius in 1804. Its scarcity will prevent its being applied to any useful purpose. See Davy's *Elem. of Chem. Philos.* page 433.

[c] Monsieur Vauquelin, after many unsuccessful trials, at last succeeded in producing a few metallic grains of cerium. This he effected by exposing the oxide of cerium, mixed with lamp-black, oil, and borax, to a very intense heat; but the metallic particles which were obtained did not amount to one-fiftieth of the weight of the oxide which he employed; and from hence he concluded that cerium, like mercury, is a volatile metal.

[d] The white oxide is stated to consist of 100 parts of cerium and 17.41 of oxygen, and the red oxide of one half more, viz. 26.115 of oxygen. The white oxide may be converted to the red by mere calcination.

Transylvania[e]. It occurs in its metallic state, and 100 parts of the ore yield more than 90 parts of tellurium[f].

What is the nature of tellurium?

Tellurium is a metal of considerable lustre; its colour is nearly white, or rather similar to that of antimony. It easily fuses, and rises in vapour at an intense red heat. It is soluble in nitric and nitro-muriatic acids, but its solutions are decomposed by the addition of water. It is capable of combining with sulphur[g], with some of the other metals[h], with hydrogen[i], and with chlorine[k]. Its specific gravity is 6.115. It has not been employed in the arts.

What is the effect of oxygen upon tellurium?

If tellurium be heated in atmospheric air, it burns

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[e] Klaproth named this metal tellurium, from *Tellus* the Latin name of our own planet the Earth; but Kirwan had called it *sylvan* from the circumstance of its having been found in Transylvania.

[f] One hundred parts of this ore have been found to consist of tellurium 92.55, iron 7.20, gold 0.25. There are also three other distinct ores of this metal; viz. the *graphic tellurium*, which is composed of tellurium 60, gold 30, and silver 10: the *yellow* ore of tellurium, which contains nearly 20 per cent. of lead; and the *black* ore, containing 54 per cent. of lead and other impurities. A new ore of tellurium has also been lately found in Norway—for an account of which see the 4th volume of Dr. Clarke's *Travels*. A description of a new ore of tellurium, by Professor Esmark of Christiana, will be found in the *Trans. Geol. Soc.* vol. iii. page 413.

[g] Tellurium unites by fusion to nearly its own weight of sulphur, producing a striated mass of the colour of lead.

[h] This metal by fusion combines readily with potassium and sodium, emitting heat and light. These alloys are fused with difficulty, but when thrown into water they produce purple solutions consisting of the respective alkali united to telluretted hydrogen.

[i] Tellurium, as a metal, possesses the peculiar property of forming an acid with hydrogen gas. By union with hydrogen it forms two distinct compounds; one of which is gaseous, and called *telluretted hydrogen gas*; the other solid, and called *hydruret of tellurium*.

[k] If tellurium be burnt in chlorine, a substance is formed which rises in vapour at a strong heat and crystallizes. Its colour is white and semitransparent; water decomposes it, and the white hydrated oxide precipitates. This compound of tellurium and chlorine is composed of 100 of the metal united to 90.5 of chlorine.

with a pale blue flame edged with green, and becomes converted to an oxide. The oxide of tellurium is white, tinted with yellow; it is soluble in the various acids, and is composed of 83 tellurium and 17 oxygen[a]. No other oxide is known of this metal.

What is the history and origin of titanium?

TITANIUM is obtained from a mineral known by the several names of *rutile*, *red schorl*, and *titanite*. The oxide of this metal was first discovered in the year 1781 by Mr. Gregor of Cornwall, in an ore of iron[b] found in the valley of Menachan in that county, and hence called *menachanite*; but metallic titanium was not produced until 1796 by Vauquelin and Hecht. We are now acquainted with several minerals which contain the oxide of titanium[c]. This metal, or rather its oxide, was first named by its original discoverer *menachine*; but Mr. Klaproth afterwards gave this new metallic substance the name of titanium[d].

What is the nature of titanium?

Titanium resembles copper in its colour, and has much lustre, but it tarnishes by exposure to the air.

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[a] These proportions were assigned by Klaproth, and are equal to tellurium 100 and oxygen 20.5; but Berzelius has stated that 100 of tellurium combine with 27.83 of oxygen.

[b] This ore, which is attractable by the magnet, occurs in the form of a black sand, having a great resemblance to grains of gunpowder. They are flattish angular grains, which have a rough shining surface. Their specific gravity, as stated by Mr. Gregor, is 4.427. This ore has very lately been discovered on Colonel Sandys's estate lying in the parish of St. Keverne, Cornwall.

[c] There are six species of this order of minerals, all containing the oxide of titanium, viz. menachanite, iserine, nigrine, sphene, rutile or red schorl, and octahedrite. For an account of the particular composition of these several minerals see Jameson's *System of Mineralogy*, second edition, vol. iii. page 338—357.

[d] "Whenever no name can be found for a new body which indicates its peculiar properties, I think it best," says Mr. Klaproth, "to choose

It is a brittle metal, and requires a most intense heat even for its imperfect fusion[c]. Little else is known of its properties, as it has hitherto been produced but in very minute quantities, and in a very imperfect state of reduction.

What is the effect of oxygen upon titanium?

Titanium is thought to be susceptible of three degrees of oxidizement. The first oxide is blue[f], the second red, and the third white[g]. The proportion of oxygen in these different oxides has not been ascertained; but Vauquelin and Hecht have found that the white, or per-oxide, is composed of 89 parts of the red oxide and 11 parts of oxygen. This metal, in the state of an oxide, has been employed in the porcelain manufactory at Sevres near Paris, as it produces on china a brown of greater richness than can be obtained by any other means.

What is the origin of uranium?

Uranium was discovered by Klaproth in the year 1786, in a mineral which he procured from Joachimsthal in Bohemia[h], called *pechblende;* and as the new

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such a denomination as means nothing of itself, and thus can give no rise to any erroneous ideas. In consequence of this, as I did in the case of uranium, I shall borrow the name for this metallic substance from mythology, and in particular from the *Titans*, the first sons of the earth; I therefore call this new metal *titanium*." Klaproth's *Analytical Essays*, vol. i. page 210.

[c] To the above account of the properties of titanium may be added, that it forms an alloy with iron which is perfectly infusible; and that it seems incapable of combining with sulphur.

[f] If metallic titanium be heated in contact with atmospheric air, it combines with oxygen and takes a *blue* colour.

[g] The red oxide of titanium occurs native in the mineral kingdom; and what has been called the white oxide of this metal is prepared by fusing the red oxide with potash; but Sir H. Davy inclines to the opinion that this is merely a compound of the red oxide with water.

[h] This metal is found in our own country in the county of Cornwall,

planet discovered by Mr. Herschel was known in Germany by the name of *uranus*[a], Mr. Klaproth named this metal *uranite*, but he afterwards changed that name for *uranium*.

What is the nature of uranium?

Uranium is somewhat of the colour of iron, but of considerable lustre. It is hard and brittle, and internally of a reddish brown colour. It has hitherto been obtained only in small grains[b]. It fuses with great difficulty, and does not tarnish by exposure to the atmosphere at its usual temperature[c]. It dissolves in nitric acid, but is not soluble either in the sulphuric or muriatic acid. Its specific gravity is 8.1.

What is the effect of oxygen upon uranium?

Uranium is susceptible of two degrees of oxidation, from whence result the black and the yellow oxide[d]

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in the state of an oxide, which frequently occurs of a brilliant green. This is usually seen in the form of thin square tables, and is known to mineralogists by the name of *uran mica*, or *uranite*. It contains about 74 per cent. of the oxide of uranium, 8 per cent. of oxide of copper, and the remainder water. Mr. Wm. Phillips has fully described this mineral in the *Trans. Geol. Soc.* vol. iii. page 112.

[a] This planet was named Georgium sidus by Mr. Herschel, in honour of our king; but I believe it is not called by this name any where but in England.

[b] Metallic uranium may be procured by making the yellow oxide into a ball with wax, and giving it an intense heat with charcoal.

[c] Notwithstanding this metal is totally unchangeable in the usual temperature of the atmosphere, yet if it be heated strongly in contact with atmospheric air it will be converted into a black oxide.

[d] Bucholz, who has made many experiments on this metal, has stated that the yellow oxide consists of 80 metal and 20 oxygen. From some of these experiments Sir H. Davy concludes that the oxygen in the black oxide is to that in the yellow as 1 to 3. This metal has only been used in enamel-painting on porcelain. Its yellow oxide imparts to china a permanent deep orange yellow colour. Klaproth, by different proportions of this oxide, gave the following bright colours to glass: brown, apple-green and emerald green. By dissolving the yellow oxide in weak nitric acid he procured beautiful transparent oblong green crystals. When dissolved in acetic acid it gave him topaz-yellow crystals.

[e] M. Richter, who has been occupied in a series of experiments upon

of this metal. A sulphuret of uranium may also be obtained.

What is the nature of nickel?

Nickel is a fine white metal, ductile and malleable, but of difficult fusion[e]. It is attracted[f] by the magnet, and has itself the property of attracting iron. Like copper, it is soluble in ammonia when converted to the state of an oxide[g]. It bears a fine polish, but its colour changes to that of bronze when ignited. Its specific gravity is usually 8.38, but some specimens have acquired that of 8.932 after having been thoroughly hammered.

Where, and in what state, is nickel found?

Nickel was discovered by Cronstedt in the year 1751, and about twenty years afterwards its properties were examined by Bergman. Its ore[h] is very similar to

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ickel, has found that this metal in its pure state is *very* malleable, early as brilliant as silver, and more attractable by the loadstone than ron. It is generally combined with copper; but he has found a method f freeing it from that metal. He says that when pure it is not liable to e altered by the atmosphere; that it is perfectly ductile, and has great enacity. *Annales de Chimie*, tome liii. page 173.

[f] Many have imagined that nickel and cobalt are magnetic, only in onsequence of a portion of iron which they contain; but in a paper in icholson's *Journal*, 8vo. vol. iii. page 286, Mr. Chenevix has shown hat these metals are really magnetic; and that, when they appear to be estitute of this property, it is owing to arsenic which is combined with hem. Indeed, magnetic needles have been made with purified nickel, nd have been esteemed more than those of steel, as being less liable to e affected by a damp atmosphere.

"So turns the needle to the pole it loves,
With quick librations trembling as it moves."

[g] Nickel dissolves readily in several of the acids, and communicates to hem a green colour; but sulphuric acid acts very slowly upon it, even ith the assistance of heat. Nitric acid dissolves it more readily.

[h] The most abundant ore of this metal is a sulphuret of nickel, called *upfernickel*, which is generally a compound of nickel, arsenic, and sulhuret of iron. It has lately been raised from a mine in the parish of t. Ewe, Cornwall, where it occurs at the depth of about 25 fathoms.

It is a curious circumstance, that all the specimens that have been that of copper; it is procured from the mines of Saxony and from various parts of Germany; and is generally found with cobalt. Native nickel has been found in Saxony and Bohemia in small quantities. The nickel of commerce is always impure.

What is the effect of oxygen *upon nickel?*

If purified nickel be exposed to atmospheric air[a] in an intense heat, it is slowly converted to a dark brown oxide which is still magnetic. There are two oxides of this metal, but their composition is not perfectly known[b]. What has been called the *green* oxide, is found to be a hydrated oxide, which contains more than a fourth of its weight of water.

What salts *of nickel are there?*

Numerous salts have been formed with nickel, but none of them have hitherto been brought into any use. A native arseniate of this metal called nickel-ochre[c] has been found in Scotland and at several other

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examined of the stones which have been said to fall from the atmosphere contain iron alloyed with nickel. These stones, which have at different periods been seen to fall on every quarter of the earth, are supposed by many to be cast from a volcano in the moon. So lately as 1803 a shower of them fell in Normandy, which covered an extent of three quarters of a league long, and half a league broad. Several dissertations on this curious subject may be seen in the *Philosophical Magazine*; Nicholson's *Journal*; and other periodical and scientific works.

[a] An oxide of nickel is more easily obtained by exposure to heat with nitre: it is of an apple-green colour. According to Thenard, another oxide of this metal may be obtained of a black colour, by exposing the green oxide to a red heat, or by treating it with oxygenized muriatic acid. *Philosophical Magazine*, vol. xx. page 67.

According to M. Richter, the oxides of *purified* nickel are of a much more lively green colour than the ordinary oxides; and their solution in ammonia is of a pale blue colour.

[b] According to Tupputi, the first oxide is composed of 78.8 of nickel and 21.2 of oxygen; whereas M. de Rothoff states the first to be a compound of 100 of metal and one portion of oxygen 27.30, and that 100 of nickel combines with 1½ part or 40.95 of oxygen to form the per-oxide.

[c] For a description of this native salt, consult vol. ii. of Kirwan's

places in Europe. Nickel is also capable of combining with chlorine, sulphur, and phosphorus.

What are the uses *of nickel?*

Nickel is employed in China in making *white* copper, which is a beautiful metallic compound; but it has not been much used elsewhere, except in the potteries[d], and at Birmingham[e]. It might however be mixed with iron by fusion, to great advantage, as an alloy of these two metals is not liable to rust like common iron[f].

What is the nature *of cobalt?*

COBALT when in a pure metallic state is of a light gray colour, nearly resembling fine hardened steel. It is difficult of fusion and oxidizement; it is obedient to the magnet, and is harder than copper; but it is so brittle that it may easily be reduced to powder. It suffers little change when exposed to the air or to water at common temperatures, though when fused on charcoal by a stream of oxygen gas it burns brilliantly. Its specific gravity is 8.7[g].

Mineralogy, page 285; or Jameson's *System of Mineralogy*, vol. iii. page 522.

[d] The oxide of nickel is said to afford the French manufacturers of porcelain a very delicate grass green; and, like other metallic colours, bears the intense heat of their ovens without injury. A hyacinthine colour may be given to flint glass by melting it with this oxide.

[e] It is generally said that nickel has never been brought into use in England: but I have heard from Birmingham, that some of the manufacturers of that town combine it with iron, and thus use it with great benefit; and that others melt it with brass in such proportions as to form a very handsome compound metal, exceedingly useful for many purposes. The Chinese employ it also in conjunction with copper and zinc for making children's toys.

[f] The valuable qualities which M. Richter has discovered in nickel, show that it might be applied to many important uses, particularly for surgical instruments, compass-needles, and other such articles, as it is not liable to oxidize by the atmosphere. Should an easy method of working it ever be discovered, we may possibly find this to be better calculated for a variety of purposes than any other metal.

[g] According to Bergman the specific gravity of cobalt is only about .700; Tassaert makes it to be 8.538.

How is cobalt procured?

Formerly all our cobalt came from Saxony[a]; but i is now found abundantly in Sweden, in the Mendip-hills in Somersetshire, and in a mine near Penzanc in Cornwall[b]. Metallic cobalt was first obtained b Brandt in 1733[c].

What is the effect of oxygen *on this metal?*

Cobalt may be oxidized by an intense heat. Th oxygen prepares it for acquiring that beautiful blu colour which is seen on earthen-ware and porcelain[d]. There are at least two oxides of cobalt, viz

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[a] The cobalt ores of Hesse produce a nett profit of 14,000*l.* a year though formerly they were used for no other purpose than to repair th roads. Baron Born's *Travels through Transylvania, &c.* For an accoun of the methods of preparing cobalt in Bohemia, consult a memoir b J. H. Vivian, esq. in the 1st volume of the *Trans. Roy. Geol. Soc. o Cornwall*, page 60.

[b] Zaffre is now made from the cobalt ores found in these hills. Ha it not been for the rapid promulgation of chemical science in these kingdoms, this important metal might have lain in the bowels of the earth undiscovered, for ages yet to come.

Cobalt ores generally contain arsenic; they are so contaminated wit it, that the workmen who are employed seldom live many years. It i to be hoped that some mode will be devised to protect these wretche from the baneful effects of this mineral.

The ores of cobalt may be analysed thus: Take 100 grains of the ore, dissolve them in nitrous acid, precipitate the iron by the addition o ammonia, and separate it from the solution by a filter. The nickel, whic is mostly found in these ores, may afterwards be precipitated by the addition of a solution of potash, and separated in the same manner as th iron. The remaining solution may be evaporated to dryness, and th oxide reduced by the usual fluxes.

[c] Cobalt may easily be obtained in a metallic state, by fusing *strewing-smalt* with 6 or 8 times its weight of soda. The soda forms an unio with the sand, and leaves the cobalt free. It may also be obtained fro zaffre by fusing it in a crucible with three or four times its weight o black flux.

[d] The oxide of cobalt forms the most permanent blue colour that we are acquainted with. La Grange says that the old painters used thi oxide mixed with oil in their paintings, which is the reason why the sk and drapery in some old pictures are of so durable a blue.—*Manual of Chemistry*, vol. i. page 408.

Zaffre, which we have long imported from Saxony, is an oxide of cobalt, mixed with three times its weight of ground silica. The oxide of cobal he blue which is the protoxide, and the black which s considered to be the per-oxide of this metal[e].

What salts *are there of cobalt?*

A great variety of salts have been formed with the xides of this metal; but the muriate of cobalt is hat which has, perhaps, been longest known[f]. An rseniate[g] and a sulphate[h] of cobalt have been found ative. This metal is also capable of combination ith phosphorus and sulphur; and a chloride of obalt may be formed by burning the metal in chlorine gas.

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r the potter's use, has generally been prepared from this article of reign production.

[e] There is still considerable uncertainty respecting the real composi- on of these two oxides. Proust makes the protoxide to consist of obalt 100, oxygen 19.8, and the per-oxide of 100 metal and 33.25 of ygen. Sir H. Davy gives to the first 166 of cobalt and 30 of oxygen; d to the latter 166 of cobalt and 45 of oxygen. Later experiments by othoff assign to the first 100 parts of cobalt and 27.3 of oxygen, and to e per-oxide 100 of the metal and 40.95 of oxygen.

[f] Muriate of cobalt much diluted, has been long used in forming Hellot's mpathetic ink. Whatever is written on paper with this ink remains visible, while it is cold; but if the paper be gently warmed, the letters ill appear of a beautiful green colour:—Thus by warming or cooling e paper, the writing may be made to appear and dissappear at pleasure. is, however, from some iron generally found in cobalt that the muriate rms a *green*; for, if it be perfectly pure, it is always of a most beautiful ue; so that by proper management one may be provided with both. y means of these two inks, a picture of winter may be drawn, which, holding it near the fire, will be transformed to a summer landscape; is again will appear gradually to lose its verdure, and resume its winter ess, on being removed to a cold situation. The *acetate* of cobalt is al- ays of a *red* colour in the cold solution, but as a sympathetic ink, when e writing is warmed, it is a fine *blue*.

[g] The arseniate of cobalt occurs in Scotland, in Cornwall, and in various her parts of the world. It is known by the names of *red cobalt* and *balt bloom*. Its constituent parts are cobalt 39, arsenic acid 38, and ater 23. What is called the *silver white* cobalt ore, is a compound of 44 rts cobalt, 55.5 of arsenic, and 0·5 of sulphur.

[h] The native sulphate of cobalt is an extremely rare mineral, having een discovered only at Hessingrund in Hungary. It is in the form of alactites and of a pink colour, similar to the mineral called milk *quartz*. hese stalactites are generally found to contain some drops of water.

What is the use *of cobalt?*

Cobalt has hitherto been chiefly used for making the different kinds of smalts for painting and enamelling[a]. It is extremely valuable to the manufacturers of porcelain; for it not only produces a beautiful colour, but endures the extreme heat of their furnaces without any deterioration[b]. This colour is so intense that a single grain of the pure oxide will give a deep tint of blue to 240 grains of glass.

How is copper *procured?*

The mineral called *cobalt pyrites* is a combination of cobalt 43.20, sulphur 38.50, copper 14.40, and iron 3.53.

[a] The *strewing-smalt*, an article which was formerly much used by sign-painters, is made by melting the oxide of cobalt with flint-glass, and grinding the whole to a coarse powder. The same composition reduced to an impalpable powder forms the smalt sold under the name of powder blue, and which is now not only used by laundresses, but is made the basis of several pigments. It has also been much employed by paper-manufacturers to give a blue tinge to writing and printing papers.

In the fifteenth century cobalt was employed to colour glass, and yet till lately but small quantities of it have been used. Formerly the miners threw it aside as useless. They considered it so troublesome when they found it among other ores, that a prayer was used in the German church that God would preserve miners from *cobalt* and from evil *spirits*. Beckmann's *History of Inventions and Discoveries*, vol. ii. page 363. Other ancient uses of this metal as a colour may be seen in the same work.

[b] The greatest consumption of cobalt is by the potters and porcelain-manufacturers, some of whom make their own colour from foreign zaffre. But in Staffordshire there are several people who make an entire trade of preparing this colour for the earthen-ware manufacturers, and who conduct the process with great secrecy. The usual price of the prepared colour is two guineas the pound.

[c] Copper mines have not been worked in England above 160 years. Before that period, whenever the workmen met with copper ore in the tin mines of Cornwall, they threw it aside as useless, no English miner at that time knowing how to reduce it to a metallic state. To chemical science, therefore, we are entirely indebted for such an ample supply of this valuable metal. The Romans, however, were acquainted with copper, for copper was the only money used by that people till the 485th year of their city, when silver began to be coined. In Sweden, houses are covered with this metal.

When miners wish to know whether an ore contains copper, they drop a little nitric acid upon it; after a little time they dip a feather into the acid, and wipe it over the polished blade of a knife; and if there be the smallest quantity of copper in it, the copper will be precipitated on the

Copper is found in several parts of England and Wales, particularly in Cornwall, and in the Isles of Man and Anglesea[c]. It is an abundant metal, and has been raised in various other parts of the world [d].

Of what nature *is copper?*

Copper is a brilliant metal of a red colour; extremely nauseous to the taste; very hard, sonorous[e], and elastic[f]; and the most ductile of all the metals, except gold. Its malleability is also so great that it is hammered into leaves, and sold in thin paper books in

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nife. A better mode of ascertaining the fact, perhaps, could not be devised.

[d] Copper mines have been worked in China, Japan, Sumatra, and in the north of Africa. Native copper is found in Siberia crystallized in ubes. The copper pyrites found in Cornwall are *sulphuret* of copper. Anglesea formerly yielded more than twenty thousand tons of copper annually. The vein of metal was originally more than 70 feet thick. See Additional Notes, No. 32.

In the museum of the Academy of Sciences at Petersburg is a piece of native malleable copper of extraordinary magnitude, found on the copper-island lying to the east of Kamtschatka. Storch's *Picture of Petersburg*, page 319.

Native oxides of copper are found in Cornwall and in South America. Carbonate of copper occurs as a natural production in two varieties called *malachite* and *mountain green*.

I am informed that a large copper mine has been worked for some time in the state of New Jersey in America, and that the ore raised there is brought to this country to be smelted.

Sulphate of copper is also found of a very rich quality in the state of Connecticut. The stream destroys vegetation in its course; and where settles in places near the spring, large lumps of metallic salt are collected. The practice of precipitating the metal by means of iron is also adopted in the United States.

[e] It is on account of this property that copper is chosen for making trumpets and other musical instruments.

[f] Copper, on account of its elasticity, is used by rope-dancers, &c. A wire $\frac{1}{10}$th of an inch diameter will support nearly 300lbs.

Copper will not burn so easily as iron; which is evident from its not striking fire by collision like iron. On this and other accounts this metal has been substituted for iron in the machinery which is employed in gunpowder-mills.

Copper does not enter into combustion till it has acquired a heat more than sufficient to melt it. But if kept in a stream of oxygen gas, it will burn with a vivid blue flame.

Oxide of copper is soluble in ammonia, and precipitable from its solution by sulphuretted hydrogen.

imitation of leaf gold[a]. The specific gravity of English copper is from 8.607 to that of 8.735[b]. It melts at 27° of Wedgwood's pyrometer.

What is the effect of oxygen *upon copper?*

Copper will in some measure become oxidized by long exposure to atmospheric air[c], in which case its surface will be covered with a green or blue crust[d] similar in appearance to verdigris. It is susceptible of two degrees of oxidizement, forming the red[e] and

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[a] This article is known in commerce under the name of Dutch metal, and is employed for covering children's toys, and for a variety of inferior purposes in the arts.

[b] Copper frequently varies in its specific gravity. Lewis, in the *Commercium Technicum*, makes it to be 8.830, whereas Mr. Hatchet found fine Swedish copper to be 8.895, and the copper of Japan, according to Cronstedt, has a specific gravity of 9.

[c] If copper be heated considerably with free access of atmospheric air, this oxide forms with great rapidity. See the following note on the preparation of sulphate of copper.

[d] In domestic economy, the necessity of keeping copper vessels always clean is generally acknowledged; but it may not perhaps be so generally known, that fat and oily substances, and vegetable acids, do not attack copper while *hot*; and, therefore, that if no liquor be ever suffered to grow *cold* in copper vessels, these utensils may be used for every culinary purpose with perfect safety.

Dr. Johnstone relates the shocking case of three men who died, after excruciating sufferings, in consequence of eating some victuals prepared in an unclean copper, on board the Cyclops frigate. Thirty-three other men became ill and were put upon the sick-list, at the same time and from the same cause. *Essay on Poisons*, page 102.

Dr. Percival gives an account of a young lady who amused herself while her hair was dressing, with eating samphire pickle impregnated with copper. She soon complained of pain in the stomach, and in five days vomiting commenced, which was incessant for two days. After this her stomach became prodigiously distended: and in nine days after eating the pickle, death relieved her from her sufferings. *Medical Transactions*, vol. iii. page 80.

[e] To prepare the red oxide of copper, dissolve the metal by means of heat in muriatic acid, and when the solution is formed let it be closely secured from the atmosphere with some fresh copper inclosed in the liquor. By degrees the solution will lose its green colour and deposit small crystals. When this has taken place, the liquor and the crystals are to be put into a solution of caustic potash, which will occasion an abundant precipitate of the protoxide of copper of an orange colour.

[f] To form the black oxide of copper, all that is necessary is to take scales of copper procured in the usual way, and having made them red

the black oxide[f]; the red or protoxide being a compound of 100 of copper and $12\frac{1}{2}$ of oxygen, while the black or per-oxide consists of 100 of the metal and 25 of oxygen[g].

What salts *of copper are there?*

There are many salts of copper[h]; but those most used are the sulphate of copper[i], acetate of copper[k]; nitrate, muriate, and arsenite of copper; and the tartrate of potash and copper. Besides these, which are

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hot, to keep them some time in that state with free access of air until they become black. They are then a true per-oxide of this metal.

[g] There are only three native oxides of copper, viz. *copper-black* or black oxide of copper; red copper ore; and a mineral of a hyacinth red colour, called *tile ore.*

[h] Roman vitriol, much used by dyers and in many of the arts, is sulphate of copper. Fowling-pieces and tea-urns are browned by washing them with a solution of this salt. *Verdigris* is an acetate of copper. *Blue verditer,* much used in staining paper for hanging rooms, is a nitrate of copper combined with hydrate of lime. It is composed of copper 50, carbonic acid 30, oxygen $9\frac{1}{2}$, and hydrate of lime $10\frac{1}{2}$, in the 100. The beautiful grass green colour of the shops, called *mineral* green, is precipitated in a peculiar way from sulphate of copper, by means of caustic potash and oxide of arsenic. The colour known by the name of *Scheele's* green is an arsenite of copper. The colour called *Brunswick* green is a triple salt, formed with potash, copper, and the tartaric acid.

[i] Sulphate of copper is frequently found in the streams of water in copper mines: these waters were suffered to run to waste, till an attention to chemical affinities taught the proprietors of the mines how to turn them to a good account. The quantity of salt which they contain is not sufficient to reimburse the expense of boiling it down to blue vitriol; but by throwing waste iron into these waters the salt becomes decomposed, and the copper is precipitated in a metallic form. This is owing to the sulphuric acid having a greater affinity for iron than it has for copper. In the isle of Anglesea this principle is turned to a very advantageous account.

Bishop Watson relates, that the waters which issue from the copper mines in the county of Wicklow in Ireland are so impregnated with sulphate of copper, that one of the workmen having accidentally left an iron shovel in this water, he found it some weeks after so incrusted with copper that he imagined it was changed into copper. The proprietors of the mines, in pursuance of this hint, made proper receptacles for the water, and now find these streams of as much consequence to them as the mines.

[k] The acetate of copper is known in commerce by the name of verdigris. An account of the process of making verdigris at Montpelier may be seen in Monsieur Pomet's *History of Drugs*, page 338, or in *Annales*

generally formed by art, the carbonate, the arseniate, the muriate, the phosphate, and the sulphate of copper are found in a native[a] state. Two distinct combinations of copper and chlorine have also been formed[b]; besides which this metal is capable of being united with sulphur[c], phosphorus[d], and iodine[e].

What are the uses *of copper?*

The uses of this metal are too various to be enumerated. Besides its employment to make boilers and

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de Chimie, tome xxv. page 305. The whole of the manufacture of the *rough* verdigris is a regular part of household business in the wine-farms in that neighbourhood, and is generally done by the women. It requires little attendance or capital.

Mr. Hume, of Long Acre, sells a very useful chocolate-coloured pigment which he forms by the combination of copper with the prussic acid. See *Philosophical Magazine*, vol. xx. page 142.

[a] The ores of copper, called *malachite*, and mountain green, are native carbonates of copper, as was before mentioned. The *blue* carbonate is of more rare occurrence, but it is found occasionally in most mines of copper. The green sand brought from Peru is a native submuriate of copper. A phosphate of copper, containing 30 per cent. of phosphoric acid, has been found near Cologne. The arseniate of copper occurs plentifully in the Huel Garland mine in Cornwall; and sulphate of copper has been found in some mineral waters.

[b] The two combinations of copper with chlorine are produced at the same time by the combustion of that metal in chlorine gas; one is a fixed, easily fusible, substance, like rosin in its exterior characters; the other is a *sublimate* of a yellow colour. The first consists of 36 chlorine and 64 copper; the second of 53 chlorine and 47 copper. Sir H. Davy's *Elements of Chemical Philosophy*, page 417.

[c] Sulphuret of copper is prepared by fusing the metal with sulphur. When completely formed it will be a compound of 78 copper and 22 of sulphur.

[d] To form phosphuret of copper, pieces of phosphorus are to be dropped gradually upon red-hot copper. This compound has been found to consist of 20 parts of phosphorus and 80 of copper.

[e] The properties of this compound are as yet but little known. It is said to be of a deep brown colour, and insoluble in water.

[f] The most important of these alloys is brass, which is formed by the union of copper and zinc; though brass is never made with pure zinc, but generally with calamine, which is a native oxide, or, rather, carbonate of zinc. Bishop Watson was of opinion that the *orichalcum* of the ancients was the same as our brass. Pliny says that the best mirrors were anciently made with a mixture of copper and tin; but that in his time those of silver were so common, that they were used even by the maid-servants. These metallic mirrors were very much in request among the

other vessels of capacity, and to sheathe the bottoms of ships, it enters as a component part into several of the most valuable metallic alloys[f]; it is also combined with sulphuric acid to form Roman vitriol[g]; and its oxides are employed in enamel-painting, and in the manufacture of several colours[h].

What is the nature of lead?

Lead is a metal of a blueish white colour, very brilliant when first cut with a knife, but it soon tarnishes

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ancient nations. The Egyptian women, whenever they went to their temples, carried one of these mirrors in their left hand. A process for separating zinc from brass will be found in *Annales de Chimie*, tome xxxviii.

Copper is sometimes alloyed with arsenic, to which a little tin is afterwards added for the formation of what is called *tomback* or *white copper*.

Pinchbeck is made by alloying copper or brass with a certain portion of metallic zinc. This alloy, which approaches nearest to the colour of gold, is also called *prince's metal*, and sometimes *Prince Rupert's metal*.

Bronze and gun-metal are formed by the union of copper and tin in the proportions of 100 parts of the former to 10 or 12 of the latter. This alloy has more tenacity than copper, and its surface is not so easily tarnished by the atmosphere.

Bell-metal is also an alloy of tin with copper, but this usually contains one fourth of its weight of tin. According to Klaproth, the metallic mirrors of antiquity already spoken of were formed with 2 of copper and of tin. Some of these are extremely hard and admit of a beautiful polish.

Copper is likewise capable of forming alloys with nickel, manganese, ron, and lead. With the latter metal it forms, according to Fourcroy, a very useful compound for making the larger kind of printers' types.

Mr. Sage has asserted that copper combined with phosphorus acquires he hardness of steel, is susceptible of the finest polish, and does not become altered in the air. See *Philosophical Magazine*, vol. xx. page 159: but since the publication of the former editions of this work, an ingenious manufacturer assures me, that this combination is so very brittle and refractory, as to be unfit for any use in working.

[g] In order to make Roman vitriol, plates of copper are heated red hot an oven, by which means they become quickly covered with a crust of xide, which separates as the plates cool; this oxide is then boiled in ulphuric acid, and when it is dissolved and the solution is become of a roper strength, the whole is poured into leaden vessels to cool and cryallize. The crystals are composed of the black oxide of copper 32, lphuric acid 32, and water 36.

[h] Oxide of copper is employed in making French green, mineral green, ue verditer, &c. and it is also used by the coloured-glass-makers. It rms a beautiful *green* glass.

by exposure to the air; it will mark writing-paper, though in a fainter manner than plumbago; and emits a peculiar smell[a] when rubbed violently. It is malleable and ductile, but possesses very little tenacity[b]. Water has no action upon this metal when preserved from the air; otherwise it soon becomes oxidized by the aid of the water, and then it absorbs carbonic acid from the atmosphere[c]. Lead is scarcely sonorous, is unelastic, and being the softest of all metals yields readily to the hammer. Its specific gravity is 11.35[d],

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[a] Lead, when dissolved in acids, has the property of imparting a saccharine taste to substances with which it may be mixed. The ancients knew that this metal rendered harsh wine milder, but they did not suppose that it was poisonous. According to Pliny the Greeks and Romans proved the quality of their wines by dipping a plate of lead in them. Beckmann's *History of Inventions*, vol. i. page 398. 400. I have a treatise on the management of wines, printed so lately as 1783, which directs the use of lead in order to preserve them from acidity. How much is the present age indebted to chemical science, which instructs us respecting the properties of different substances! Some of our wine-merchants, probably in consequence of this direction, may have contaminated their wines with lead, without suspecting that they were distributing a slow poison to their customers.—For the effects of lead on the animal system consult a late work by Dr. Lambe, *On the Nature of Spring Water*. See also Additional Notes, No. 31.

Lead will not only correct the acidity of wines, but it will also take off the rancidity of oils. With this intention I have been informed it is often used to make inferior olive oil pass for good.

Vats of lead have been used in some cider countries, and have produced incalculable mischief. What is called the Devonshire colick is occasioned by this practice, and is identified, by its effects on the system, with the colick of the plumbers, the painters, and the white-lead makers.

"Lead in its metallic state, like all the other metals, is probably inert: but it is so easily acted upon by the weakest acids and alkalies, that it cannot be taken even in this form without the most imminent danger." Dr. Johnstone's *Essay on Poisons*, page 113.

Sir George Baker has carefully investigated the effects of lead on the animal economy, and in the first volume of the *Medical Transactions* has fully described the *peculiar kind* of colick produced by it.

[b] A leaden wire of the size of $\frac{1}{13}$th of an inch is not capable of supporting much more than 18 pounds weight without breaking.

[c] A person may satisfy himself of the insalubrious nature of leaden cisterns to hold water for culinary purposes, by examining the internal surface of such vessels; for if the water has stood in them for several days undisturbed, a small coating of white oxide will be observed just at

and it melts at 612°. It generally contains a small portion of silver[c].

Where *is lead procured?*

Lead ore is very abundant in Scotland, in the western parts of Northumberland and Durham[f], in Derbyshire, and in many other parts of the world[g]. Most of the lead of commerce is however procured from a common mineral (which is a sulphuret of this metal) known by the name of lead glance, or galena.

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the upper edge of the water. On every fresh addition of water this oxide is washed off; and if there be the slightest degree of acidity in the vessel, this oxide of lead will be dissolved in the water, and thus an insidious poison will be conveyed into the stomach.

[d] Brisson, page 264. It is singular that the specific gravity of this metal becomes *less* by hammering.

[e] Lead may be mixed with gold and silver in a moderate heat, but when the heat is much increased the lead rises to the surface combined with all heterogeneous matters. The art of refining the precious metals is built upon this property of lead.

[f] The lead found in these countries occurs on the estates of Colonel Beaumont, and those of the late Lord Derwentwater. These last were forfeited to Government, and are now in possession of Greenwich Hospital.

[g] Lead ore is generally found in veins, both in siliceous and calcareous rocks. Galena, or sulphuret of lead, is very common both in masses and crystallized. That of the county of Durham has been analysed by Dr. Thomson, and found to consist of lead 83.18, sulphur 13.02, and iron 0.50. There is an ore found in Cornwall called *antimonial lead-ore*, which contains 24 per cent. of antimony, 13 of copper, 1 of iron, and 17 of sulphur.—Hatchett. Lead is also found combined with silver, antimony, and bismuth. Oxides of lead combined with various earths also occur in mining countries.

Lead was in common use among the ancients. The Romans sheathed the bottoms of their ships with this metal, fastened by nails made with bronze. During the first century, lead at Rome was twenty-four times as dear as it is now in Europe; whereas tin was only about eight times its present price.

Lead, in the state of ceruse, was in great request among the Roman ladies as a cosmetic. Plautus introduces a waiting-woman refusing to give her mistress either ceruse or rouge, because, forsooth, in the true spirit of a flattering Abigail, she thought her quite handsome enough without them. Bishop Watson's *Chemical Essays*.

The lead ores which are found in the primitive slate mountains contain much silver, generally 8 or 9 per cent.

What is the effect of oxygen *upon lead?*

Lead presents us with three distinct oxides[a]; and according to the dose of oxygen[b], we have the yellow, the red, or the brown oxide[c] of this metal. Lead is capable also of combining with chlorine, with iodine, with phosphorus, and with sulphur[d].

What salts *of lead are there?*

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[a] When lead is melted in an iron ladle, a scum will quickly appear upon its surface: if this be removed, another will immediately succeed; and in this manner the whole of the lead may be converted into a pellicle, which is the *yellow* oxide of lead. If this oxide be exposed to a low red heat in a reverberatory furnace, it will acquire a further dose of oxygen, and be converted into yellow massicot: and if the heat be continued, it will at length be changed to *red* oxide of lead.

[b] According to Berzelius, the yellow or protoxide of lead is composed of 100 of lead and 7.70 of oxygen; the red oxide known in commerce by the name of red-lead, of 100 of metal and 11.08 of oxygen; and the brown or puce-coloured oxide, of 100 parts of lead and 15.60 of oxygen. The yellow and the red oxides have been found native, but they are both of very rare occurrence.

[c] When nitric acid of the specific gravity 1.260 is poured upon the *red* oxide of lead, 185 parts of the oxide are dissolved; but 15 parts remain in the state of a deep brown, or brilliant flea-brown powder. This is the *brown* oxide of lead, containing 13½ per cent. of oxygen.

Lead may be converted into an oxide by heating it in a situation where it can have free access of atmospheric air. All the oxides of lead may, however, be reduced to metallic lead by heating them with a mixture of tallow and charcoal, or any substance that will absorb the oxygen. This may readily be shown by placing a few grains of red lead upon a piece of charcoal, and fusing it with a blow-pipe. Even the oxide of lead which is combined with flint glass may be revived by melting the glass with any carbonaceous substance.

Fourcroy says that the oxides of lead have the property of absorbing carbonic acid from the atmosphere; and that if an oxide of lead be required in a state of purity, it ought to be defended from the access of air.

[d] Chloride of lead is a compound of chlorine 25.78 and lead 74.22. Iodide of lead is composed of about 54½ parts iodine and 45½ lead; phosphuret of lead is a compound of about 12 of phosphorus and 88 of lead. The artificial sulphuret of lead is formed with 87 of lead and 13 sulphur; besides which there is a bi-sulphuret consisting of about 75 of lead and 25 of sulphur.

[e] Muriate of lead, when fused in earthen crucibles, produces that beautiful pigment known by the name of Turner's yellow, or patent yellow.

[f] According to Mr. Hume, nitrate of lead, as a chemical test, should always be preferred to acetate of lead, as the last is liable to give false

The salts of lead are very numerous, perhaps equal to the number of acids; but the muriate[e], nitrate[f], sulphate[g], carbonate[h], and acetate of lead[i], are those most known. An artificial chromate of lead has lately been sold in considerable quantities as a pigment, and it possesses great beauty. The carbonate[k], murio-carbonate[l], sulphate[m], phosphate[n], molybdate[o],

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results. *Philosophical Magazine,* vol. xx. page 160. The *yellow* is the only oxide of lead that is soluble in nitric acid.

[g] Lead forms an insoluble compound with sulphuric acid, and hence this acid is sometimes used to detect the presence of this deleterious metal; but the best test is a solution of sulphuretted hydrogen, or of some hydrosulphuret. To the suspected solution add a little of this test, and if lead be present it will give it a dark brown or blackish tinge. This test is however somewhat ambiguous, for it also blackens solutions of bismuth, silver, and some other metals. For a method of detecting the presence of lead in wine, See Additional Notes, No. 31.

[h] Carbonic acid is incapable of dissolving metallic lead, but it will combine with the yellow oxide readily. The white lead used in house-painting is a mere carbonate of lead.

[i] Most of the acetate of lead employed in the arts is now made by dissolving the oxides of this metal in pyroligneous acid. It is used in large quantities for decomposing alum, to form thereby acetate of alumina for the purposes of dyeing and calico-printing.

[k] Carbonate of lead or *white-lead ore* is found at Leadhills in Scotland. It is found also with galena in Cumberland, Durham, and Shropshire. It consists of oxide of lead 82, carbonic acid 16, water 2. Klaproth. What is called *black-lead ore* is a native carbonate of lead also.

[l] The murio-carbonate, known to mineralogists by the name of *corneous lead-ore,* occurs near Matlock in Derbyshire, and in Germany. Its colours are usually pale straw, or transparent white. It occurs in a state of crystallization, and is harder than the common white-lead ore. It consists of oxide of lead 85.5, muriatic acid 8.5, and carbonic acid 6.0.

[m] Sulphate of lead or *lead vitriol* occurs at Leadhills and elsewhere in Scotland, in the Isle of Anglesea, and at Penzance. Its usual colours are yellowish gray and grayish white, and it is generally found crystallized. Its constituent parts are oxide of lead 71, sulphuric acid 24.8, water 2, oxide of iron 1.

[n] The native phosphate of lead has two varieties, viz. the *brown* and the *green* lead ore. Their constituent parts are nearly alike, viz. oxide of lead about 78.5, phosphoric acid about 20, and muriatic acid 1.5. An arsenio-phosphate of lead is also found in several places in Europe, consisting of oxide of lead 76, phosphoric acid 13, arsenic acid 7, muriatic acid and water 3.5.

[o] This ore occurs at Bleiburg in Carinthia, both massive and crystallized. Its colour is wax yellow. It consists of oxide of lead 58.40, molybdic acid 38, oxide of iron 2.08, silica 0.28. Hatchett.

arseniate[a], and chromate of lead[b] are native productions.

What are the uses *of lead?*

Lead is employed to cover buildings, to form water-pipes, to make a great variety of vessels for economical and chemical purposes[c]; and its oxides in refining gold and silver[d]. Its oxides are also used for dyeing and calico-printing; in the manufactures of glass[e], earthenware, and porcelain[f]; and in the preparation of various pigments. Moreover, as lead is capable of forming alloys with several of the metals, such as cobalt, arsenic, bismuth, mercury, platina, iron, and zinc, its uses may hereafter be extended. The several alloys formed by means of lead, with copper, tin, and antimony, are now constantly employed in the arts[g].

What is the nature of antimony?

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[a] Arseniate of lead occurs in France and in Siberia. Beautiful specimens of this native salt have been found in Huel Unity Mine near Redruth in Cornwall, in six-sided prisms; colour wax yellow, splendent and translucent. According to Gregor, they are composed of oxide of lead 69.76, arsenic acid 26.40, muriatic acid 1.58, loss 2.26. *Philosophical Transactions*, 1809, page 205.

[b] This beautiful mineral, which has been found only in a gold-mine in Siberia, occurs in prismatic crystals of a hyacinth red colour, inclining to aurora. Its constituent parts are oxide of lead 64, chromic acid 36. In some of the specimens the crystals of chromate of lead are very pleasingly intermixed with the green phosphate of lead.

[c] Sheet lead is made by suffering the melted metal to run out of a box through a long horizontal slit upon a table prepared for the purpose, while the box is drawn by appropriate ropes and pulleys along the table, leaving the melted lead behind it in the desired form to congeal.

[d] Litharge of lead is often used in the analysis of the ores of what are called the *perfect* metals. It has the property of combining with all the other metallic oxides, and of preventing their evaporation during the cupellation; while it separates them from those metals which do not become oxidized by heat only.

[e] Lead is used in the finer kind of glass, in order to make it bear sudden changes of heat and cold better; also to give it a proper degree of weight, a susceptibility of its being cut without breaking, a greater power of refracting the rays of light, and a capacity to bear a higher polish.—Notwithstanding, lead is seldom used in plate or crown glass, as

ANTIMONY is a brilliant, brittle metal, of a silvery white colour[h], which has not much tenacity, and is entirely destitute of ductility. It has a laminated or striated texture, and when rubbed on the hand communicates to it a peculiar smell. Though seemingly hard, it may be easily cut with a knife; and yet it suffers but little change by exposure to the air, except in the loss of a portion of its lustre. Its specific gravity according to Mr. Hatchett is 6.712. It melts at 810° of Fahrenheit, and on cooling crystallizes in the form of pyramids. At a still greater heat it may be entirely volatilized. It is also susceptible of vitrification, and produces a hyacinth-coloured glass.

How is antimony *procured?*

Antimony is procured from an ore which is found hiefly in Sweden, Saxony, Hungary, and Norway[i];

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always renders glass softer, and consequently more liable to be defaced
hard substances. See my "Essay on Glass," in the 3d volume of the
hemical Essays, page 420: also Neri's *Art of Glass*, chap. 61, page 105.

[f] The oxides of lead and of tin were employed by the ancient Romans
the manufacture of earthenware, &c.

The oxides of lead, dissolved in various menstrua, are used as embro-
tions, and for several other preparations, by the practitioners of medicine
d surgery.

[g] An alloy of this metal with tin forms pewter, and in different pro-
rtions soft solder. With antimony it is employed in making printers'
pes. It enters likewise into the composition of other useful alloys,
pecially one that is employed in the manufacture of white metal but-
ns: for it has lately been discovered that a certain proportion of lead
ay be mixed with the metal formerly used, without injuring the ap-
arance of the button; thus affording a very considerable additional
ofit to the manufacturer. There is also a large consumption of lead
making shot. See Additional Notes, No. 27.

[h] What is called antimony in the shops, is not pure metallic antimony,
t a sulphuret of that metal. The pure metal, or regulus of antimony
it is called, is obtained by fusing the sulphuret in a peculiar way with
ude tartar and salt-petre.

Antimony may be known from bismuth thus:—Bismuth is very soluble
nitric acid, but antimony dissolves in it with some difficulty.

[i] There are several distinct ores of antimony, but the gray is the only
e which is found in sufficient quantity for the manufacturer; it is a

it is known in these countries by the simple name o ore of antimony.

What are the effects of oxygen *upon this metal?*

Antimony according to Thenard's theory may b susceptible of several degrees of oxidizement; but a present we are acquainted with only three well-define oxides of this metal; viz. the gray [a], the white [b], an the yellow [c]. Antimony is also capable of combinin with chlorine [d], iodine [e], phosphorus [f], and sulphur [g].

What salts *of antimony are there?*

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sulphuret of antimony. In mineralogical cabinets this ore is divided int four subspecies, viz. the compact, foliated, radiated, and the plumose Besides these there is what is called the nickeliferous ore of antimony the red antimony ore, the white ore of antimony, and antimony ochre See Jameson, vol. iii. 471—490. To prepare antimony, the gray ore i purified by exposure to a strong heat in a reverberatory furnace. B this process the pure sulphuret runs from the earthy matter; this i afterwards re-melted, and cast into cakes for sale. This sulphuret ma be divested of nearly all its sulphur, by long roasting, leaving the meta in a state of almost a pure oxide.

Native antimony, alloyed with a small portion of silver and iron, ha been found in Sweden. I have been informed by a native American that it is found also in the state of Connecticut nearly in the pure metalli form; that it frequently lies on the surface of the ground; that in som places large masses of it are to be seen; and that Elihu White, esq. o Hartford, brought specimens of it to England for analysis.

If oxide of antimony be precipitated by water from nitro-muriatic acid the precipitate will be white; but if it be precipitated by a clear solutio of galls, the precipitate takes a light yellow. Some solutions of th oxides of this metal are very powerful and even poisonous when take internally, except in very small quantities.

[a] The gray, or protoxide, is procured by diluting a solution of muriat of antimony with water, which will occasion this metallic oxide t precipitate in combination with a little muriatic acid, from which it i afterwards separated by boiling it with a solution of carbonate of potas According to Berzelius, this oxide consists of 100 antimony and 18.6 o oxygen. But Dr. Thomson supposes it to be composed of 100 meta and 17.775 of oxygen.

[b] The white, or deutoxide of antimony, which is obtained by variou methods, is also called *antimonious* acid, it having the property of unitin with salefiable bases and forming salts called *antimonites*. This oxid was formerly called *argentine flowers of antimony*. It is thought to b composed of antimony 100, oxygen 23.7.

[c] The yellow, or peroxide of antimony, is in the form of a straw coloured powder. It is procured by digesting antimony in nitric acid an

Many different salts have been formed with the oxides of this metal ; but those most known are the muriate of antimony[h], the phosphate of lime and antimony[i], and the tartrate of potash and antimony[k]. The first has been found native.

What are the uses *of antimony?*

Antimony is combined with some other metals in making printers' types, and specula for telescopes. Its oxides are employed in medicine[l], and in colouring glass. In times of remote antiquity its sulphuret

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hen drying the white powder which results, by a heat that is insufficient separate the oxygen. It is said to consist of antimony 100, oxygen 5.556. It may with propriety be called *antimonic* acid.

[d] If this metal be ground fine, and thrown into a dry glass jar filled ith oxymuriatic acid, it will inflame immediately, and continue to burn ith great rapidity and with a brilliant white flame. The combustion ffords a beautiful spectacle. Chloride of antimony may be thus formed, by distilling a mixture of one part antimony with two parts of cor-osive sublimate. It is what was formerly called *butter of antimony*, and a compound of antimony 54.88, chlorine 45.12.

[e] Iodide of antimony is a compound of a dark red colour. It is formed heating the two substances together, and is supposed to consist of odine 15.625 and antimony 5.625.

[f] Antimony combines with phosphorus by fusion ; but the compound, which is brittle and has the metallic lustre, has not been found useful. The best account of the properties of this phosphuret has been pub-shed by Pelletier in *Annales de Chimie*, tome xiii.

[g] Sulphur and antimony also combine by fusion and form a substance xactly similar to the native sulphuret of this metal. It has a metallic ppearance, but is much more fusible than antimony. Proust and Vau-uelin make it to consist of antimony 75, sulphur 25.

[h] Muriate of antimony is the common *butter of antimony* of the shops. he white oxide of antimony, called the *powder of algaroth*, is made by merely dropping this solution into pure water. Muriate of antimony has een found native in Bohemia.

[i] The well-known medicine called *James's powder* is a phosphate of me and antimony. It is a triple salt in the form of a white powder. For method of preparing it, consult *Philosophical Magazine*, vol. xi.

[k] *Emetic tartar* is a tartrate of potash and antimony, composed of about 5 parts tartrate of antimony, 36 tartrate of potash, and 8 of water. A ery elaborate examination of this medicinal preparation has been given Mr. Richard Phillips in his *Experimental Examination of the Pharma-pœia Londinensis*, London, 1811 : and some further observations by is author will be found in his *Remarks on the Editio Altera* of the same ork, London, 1816. I refer the reader to both these treatises.

[l] Perhaps we have no metal more valuable as a medicine than anti-

was used by females as a black pigment, for staining the eye-lashes.

What is the nature of bismuth?

Bismuth is of a reddish white colour, of a lamellated texture, and moderately hard, but neither ductile nor malleable. It loses its lustre when exposed to the action of atmospheric air, but when immersed in water remains unaltered. Its specific gravity according to Mr. Hatchett is 9.822, but this degree of density may be increased by weak and cautious hammering; and yet it is so brittle that it breaks readily under a smart stroke of the hammer, and may be reduced by that means even to powder. This metal has but little

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mony, or one that is applied in such various ways. For particulars, consult the *New Edinburgh Dispensatory*, by Dr. Duncan jun.

Kermes mineral, and what was called *golden sulphur* of antimony, are both made from the sulphuret of this metal, by means of potash. The first took its name from its resemblance in colour to the kermes insect, used in dyeing. The sulphuret, and some other preparations of antimony, are given to horses and cattle, more than any other medicines. They act as alteratives, and are generally to be depended upon for the certainty of their effects.

[a] Bismuth has the singular property of *expanding* as it cools. Hence, probably, its use in the metallic composition for printers' types; as from this expansive property are obtained the most perfect impressions of the moulds in which the letters are cast. In manufactories this metal is known to the workmen by the name of *tin glass*. The larger kind of printers' types are generally made with lead and antimony only; in the proportion of four parts of the former to one of the latter. It surely is not possible to contemplate the advantages which the world has derived from the invention of printing, without very peculiar emotions!

> "Sad Superstition wails her empire torn,
> Art plies his oar, and Commerce pours her horn."

Bismuth is one of the metals, that will inflame when suspended in oxymuriatic acid gas.

[b] A more detailed account of the properties of bismuth and of its various compounds may be seen in Neumann's *Chemistry*, vol. i. page 157—171.

[c] The ores of bismuth are found in veins in the primitive mountains on various parts of the continent of Europe. A sulphuret of this metal has been discovered in Cornwall.

[d] Native bismuth occurs in veins in gneiss, mica slate and clay slate-

taste or smell. It melts at 476°, and on cooling crystallizes in parallelopipeds[a]. At a great heat it volatilizes; and when ignited, burns with a beautiful kind of lambent blue flame[b].

How is bismuth procured?

Bismuth is generally found with cobalt in the cobaltic ores of Saxony and England[c]. Native bismuth and sulphuret of bismuth are also found at several places upon the continent[d], but this is not an abundant metal.

What is the effect of oxygen *upon bismuth?*

Bismuth is gradually oxidized by fusion in atmospheric air; and may be thus converted into an oxide[e]

It is found at St. Columb and Botallack in Cornwall, but more frequently in Saxony and Bohemia. Jameson, vol. iii. page 449. It occurs also in the state of Connecticut in America. Bruce's *American Mineralogical Journal*, page 267. *Bismuth glance*, or the sulphuret of bismuth, has been found in Herland Mine in Cornwall, and in Bohemia, Saxony, and Sweden. It is a rare mineral. It consists of 60 parts bismuth, and 40 sulphur. It much resembles sulphuret of antimony, and is liable to be mistaken for it. Phillips, page 237. In Siberia a mineral occurs, known by the name of *needle-ore*, of a dark steel-gray colour, consisting of sulphuret of bismuth 50.76, sulphuret of lead 28.07, sulphuret of copper 5.13, nickel 1.58, tellurium 1.32, and gold 0.79. This mineral was formerly thought to be an ore of chrome. A very rare variety called *cupreous bismuth ore* occurs in granite near Wittichen in Furstenberg in the circle of Swabia, consisting of bismuth 47, copper 35, and sulphur 13.

[e] *Pearl-white* is an oxide, or rather a sub-salt, of this metal. Ladies have used it for painting the skin, to which it imparts a beautiful white; but it has the inconvenience of becoming black by the contact of sulphuretted hydrogen gas, or the fumes of fetid substances. The gas which arises from the burning of mineral coal will have the same effect. It is related of a lady of fashion, who had incautiously seated herself too near the fire at a quadrille-table, that her countenance changed on a sudden from a delicate white to a dark tawny, as though by magic. The surprise and confusion of the whole party had such an effect upon the disfigured fair one, that she was actually dying with apprehension, when the physician dispelled their fears, by informing his patient that nothing more was necessary than for her to abstain from the use of mineral cosmetics, and to trust in future to those charms which nature had bestowed upon her.

Some of the French chemists recommend the use of the oxides of consisting of about 90 of bismuth and 10 of oxygen. At present we are acquainted with only one oxide of this metal[a]. Bismuth is however capable of forming compounds with chlorine, iodine, and sulphur[b]. To phosphorus it seems to have no affinity.

What salts *are there of bismuth?*

Several salts of bismuth have been formed, but their properties have not been much examined by chemists. Their chief characteristics are, that sulphuretted hydrogen will occasion a dark brown, and gallic acid a pale yellow precipitate in their solutions; and that when the metal is held in solution by acids, a white oxide of bismuth is precipitated by the mere addition

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bismuth for dyeing, to fix some particular colours. It is said that pomatum prepared with the oxide of bismuth will turn the hair black.

[a] A native oxide of bismuth is known to mineralogists by the name of *bismuth ochre*, consisting of oxide of bismuth 86.3, oxide of iron 5.2, carbonic acid 4.1, water 3.4. It has been found at St. Agnes in Cornwall, and in Saxony and Bohemia, but it is a rare mineral. Jameson, *System of Mineralogy*, vol. iii. page 460.

[b] For an account of the combinations of bismuth with sulphur, chlorine, &c., see a memoir by Dr. John Davy in *Philosophical Transactions* for 1812, page 169.

[c] Nitrate of bismuth does not dissolve in water like other metallic salts, but becomes decomposed, forming one of the most delicate white precipitates; hence, this metal is readily distinguished from most others. This precipitate, washed and dried, is what has been called *magistery* of bismuth, or pearl-white. The solution of bismuth in nitric acid has been used as a sympathetic ink. When first written, the letters are invisible; but if the paper be plunged in water, the characters become white and perfectly legible. See Brugnatelli, *Annales de Crell*, 1788, or *Annales de Chimie*, tome iii. page 296.

[d] *Butter* of bismuth, as it was formerly called, is a muriate of this metal.

[e] The common mixture for *pewter* is 112 pounds of tin, 15 pounds of lead, and 6 pounds of brass; but many manufacturers use also bismuth and antimony to compose this metal. Bismuth is likewise generally mixed with tin for vessels of capacity, &c., as it gives to that metal a greater degree of brilliancy and hardness. From its property of rendering lead more fusible, it is too often employed with that metal to adulterate quicksilver.

[f] If 8 parts of bismuth, 5 of lead, and 3 of tin be melted together, the mixed metal will fuse at a heat no greater than 212° Tea-spoons made

water. The nitrate[c] and muriate of bismuth[d] re casionally prepared, but no salts of this metal have een found in a native state.

What are the uses *of bismuth?*

Bismuth is used with other metals not only to form inters' types, but also to make pewter[e], and for me other compounds. It remarkably contributes the fusibility[f] of some alloys; hence, it is employed make solder. Bismuth is likewise given in medine, though, now, very rarely.

How is mercury *procured?*

MERCURY, which is found in various states[g] in the wels of the earth, is for the most part brought to urope from the East Indies and from Peru[h]; but it

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h this alloy are sold in London, to surprise those who are unacquainted h their nature. They have the appearance of bright pewter tea-spoons, melt as soon as they are put into hot tea. A composition of lead, c, and bismuth, in equal parts, will melt with so small a portion of oric, that it may be kept in fusion upon *paper* over a lamp. A table ich I lately constructed from a long series of actual experiments on fusibility of different metallic alloys will be found in the fifth volume the *Chemical Essays*.

The ores of mercury are divided by mineralogists into five species; . native mercury, native amalgam, horn ore or corneous mercury, rcurial hepatic ore, and native cinnabar. The first of these occurs in small quantity; it is found in Peru and in various places in Europe. e second species, native amalgam, which occurs in Hungary and in Palatinate, consists of mercury 64, silver 36. The third species, or n ore, was discovered about thirty years ago in the mines of the Palaate, and found to consist of mercury 76, muriatic acid 16, sulphuric 18. The fourth, or hepatic ore, is found at Idria, at Almaden, and Siberia. It is a compound of 82 mercury, 14 of sulphur, 2 of carbon, a small portion of each of the following substances, viz. silica, alua, oxide of iron, copper, and water. Of the last species there are varieties, viz. the dark red and the bright red cinnabar. These ocin various places in Europe, Asia, and South America, and consist about 85 of mercury and 15 of sulphur. Jameson's *Mineralogy*, vol. iii. e 20.

The quicksilver mine of Guanca Velica, in Peru, is 170 fathoms in umference, and 480 deep. In this profound abyss are seen streets, ares, and a chapel where religious mysteries on all festivals are celeted. Thousands of flambeaux are continually burning to enlighten The mine generally affects with convulsions those who work in it.

is found in still greater abundance at Almaden[a] in Spain, where it is extracted from the ore by distillation[b].

What is the nature *of mercury?*

Mercury, in the temperature of our atmosphere, is a white fluid metal[c], having the appearance and brilliancy of melted silver: in this state it has neither taste nor smell, and is extremely divisible[d]. It is the

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Notwithstanding this, the unfortunate victims of an insatiable avarice are crowded all together, and plunged *naked* into these abysses. Tyranny has invented this refinement in cruelty, to render it impossible for any thing to escape its restless vigilance—

> " For in the dark Peruvian mine confined,
> Lost to the cheerful commerce of mankind,
> The groaning captive wastes his life away,
> For ever exiled from the realms of day;
> While, all forlorn and sad, he pines in vain
> For scenes he never shall possess again." FALCONER.

[a] Mercury is raised in such abundance in Spain, that in the year 1717 there remained above 1200 tons of it in the magazines at Almaden, after the necessary quantity had been exported to Peru for the use of the silver mines there.

The quicksilver mines of Idria, a town in the circle of Lower Austria, have been wrought constantly for 300 years, and are thought upon an average to yield above 100 tons of quicksilver annually. Bishop Watson's *Chemical Essays.*

[b] Mercury is found also in Hungary and China; it occurs most commonly in argillaceous schistus, limestones, and sandstones. It is likewise found in Sweden amalgamated with silver, and frequently combined with sulphur. Running mercury is seen in globules, in some earths and stones, in America, and is collected from the clefts of the rocks there. Cinnabar, or sulphuret of mercury, is generally found also in those countries which produce the fluid metal. To extract the metal from the cinnabar, this ore is mixed with quick-lime and then submitted to heat. The lime combines with the sulphur, and the mercury which sublimes from the mixed mass is collected in receivers. An account of the whole process may be seen in the *Memoirs of the French Academy* for 1776. See also Note, page 259.

[c] We see mercury always in a *fluid* state, because it is so very fusible that a small portion of caloric is able to keep it in a state of fluidity; but it is as perfectly opaque as other metals. All metals require different portions of heat to fuse them. Tin melts at 442° and lead at 612° of Fahrenheit; whereas gold requires the heat of 32° of Wedgwood, or 1300° of Fahrenheit, to melt it, and platina cannot be fused by the strongest heat of our best furnaces. Mercury, when submitted to a sufficient degree of cold, is similar in appearance to other metals, and may be

heaviest of all the metals except platina and gold[e], having the specific gravity of 13.568, and when frozen, that of 14.465. This fluid metal freezes at 39 degrees below the zero of Fahrenheit[f], and is then malleable and ductile. It boils at 656° and becomes gradually converted into an invisible and elastic vapour[g]. It readily combines with several of the other metals[h],

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beaten into plates. At the poles quicksilver would probably be always solid.

[d] Quicksilver is so extremely divisible that it may be strained by moderate pressure, through the pores of leather, and thus freed from dust, or other like impurities, as is well known to the practitioners of pharmacy. See Neumann, vol. i. page 133.

[e] According to Mr. Biddle, the specific gravity of mercury at 47 degrees above zero is 13.545; but when frozen into a solid at 40 *below* zero, 15.612.

[f] It had been imagined that the liquid state of mercury was essential to it. The contrary was discovered by accident in the year 1759, by professor Braun of Petersburg. Being engaged in experiments on the power of freezing mixtures, and having perceived that one of his thermometers was stationary even after he removed it from the mixture, he broke the bulb of the thermometer and found the mercury completely congealed. Dr. Murray, vol. iii. page 160.

In the winter of 1799, Mr. Pepys froze 56 pounds of mercury into a solid and malleable mass. A minute and entertaining account of the whole process may be seen in the *Philosophical Magazine*, vol. iii. page 76.

At Hudson's Bay, frozen mercury has lately been reduced to sheets as thin as paper by beating it upon an anvil that had previously been reduced to the same temperature. On plunging a mass of this frozen quicksilver into a glass of warm water, the former became fluid, and the latter was immediately frozen. By the rapidity of the action, the glass was shivered into a thousand pieces.

[g] Mercury is so volatile that it may be distilled like water. It is sometimes purified in this way from a mixture of other metals, it being often adulterated with lead and bismuth. There is no better way of ascertaining the purity of mercury than by mixing it with an equal weight of iron-filings, and submitting it to distillation. It is also so elastic when in a state of vapour, that it is capable of bursting the strongest vessels. Mr. Hellot, of the Academy of Sciences, was present when a person pretending to fix mercury had inclosed some of it in an iron box closely welded. When the mercury was heated, it burst the iron and was dissipated in invisible vapours. Macquer's *Dictionary*, article *Mercury*.

[h] Mr. Chenevix has pointed out a singular anomaly in the amalgamation of platina. The specific gravity of the amalgam he states at only .5, whereas the specific gravities of the metals from which it is formed are not less than 13.5 and 21. No one has hitherto given any satisfactory explanation of this curious circumstance.

and forms with them what are called amalgams[a]. It is also capable of combining with chlorine[b], with phosphorus, with iodine, and with sulphur[c].

What effect has oxygen *upon mercury?*

Mercury does not readily combine with oxygen in the ordinary temperature of the atmosphere, even when an extended surface is exposed[d]; but if heated to about 600° of Fahrenheit, it gradually becomes oxidized[e]. It is capable of two degrees of oxidizement, forming the black, or protoxide, and the red, or per-oxide of this metal[f].

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[a] An amalgam of bismuth is used for silvering the inside of glass globes, for ornamenting the houses of the poor; the amalgam of tin is employed in silvering the backs of glass mirrors; and the amalgam of zinc is the best preparation which has ever been discovered for promoting the excitement of electrical machines. See Note[b], page 286.

[b] When mercury is heated in chlorine gas it burns with a faint red flame, and the product is corrosive sublimate, which is a compound of mercury 74, chlorine 26.

[c] Phosphuret of mercury may be made by distilling phosphorus with the red oxide of mercury. An iodide of mercury may be formed by mere mixture; but according to Gay Lussac there are two iodides of this metal; the one formed with 100 of mercury and 62½ of iodine, the other with 100 of the metal and 125 of iodine. By combination with sulphur mercury gives two distinct compounds, viz. the *black* sulphuret, consisting of 100 of mercury and 8 of sulphur; the other a *red* sulphuret, which is composed of 100 of mercury and 16 of sulphur. By peculiar management the latter forms *vermilion.*

[d] This must be taken with some limitations; for, if it be agitated for a considerable time in contact with atmospheric air, it will at length combine with oxygen and be converted to the black oxide. Boerhaave put a small quantity of mercury in a bottle, and having closely corked it, he fastened it to the sails of a windmill, where by constant agitation it became oxidized. Boerhaave's *Lectures on Chemistry*, vol. i. 4to. page 380.

[e] Mercury may readily be oxidized by dissolving it in nitric acid, and then the oxide may be separated by precipitating it from its solution by the addition of a pure alkali, or by exposing the solution to a proper degree of heat to expel the remaining acid.

The beautiful scarlet pigment called *vermilion* is prepared from mercury. It is the red sulphuret of mercury. Europe has hitherto been furnished with it by the Dutch manufacturers, and of greater beauty than any which has been procured from other markets; though it is said that even this article is inferior in splendour to that which is manufactured in China. What is imported from thence comes in small papers, and is nearly of the colour of fine lake.

What salts *are there of mercury?*

There is a great variety of mercurial salts; but the cetate, the sulphate, the nitrate, and the muriate of ercury are best known[g]. The latter is found native n the Palatinate[h].

What are the uses *of mercury?*

Mercury is used in large quantities for separating old and silver from their several ores[i]; for silvering irrors, for water-gilding[k], for making barometers nd thermometers; by the philosophical chemist for

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[f] The protoxide, which may be formed by agitating mercury with atospheric air, as mentioned above, or by decomposing calomel by a sotion of potash, is a black powder composed of 100 of mercury and 4 oxygen; the per-oxide, which is obtained by means of heat, or by the ency of nitric acid in a peculiar process, is of a bright scarlet, consistg of 100 of mercury and 8 of oxygen.

[g] Several salts are formed by art with this metal for medicinal purposes; viz. *Keyser's pill,* which is an acetate of mercury; *Turbith mine-l,* a sub-sulphate of mercury; *Red precipitate,* or oxide by means of e nitric acid; *Calomel,* or mild muriate of mercury; and *Corrosive subli-te,* which is an oxymuriate. Besides these there is a preparation lled *Precipitate per se,* which is a true oxide of the metal; and *Ethiops neral,* and *Cinnabar,* which are both combinations of mercury with lphur.

One of the most valuable of the above salts is *calomel,* which is made triturating fluid mercury with corrosive sublimate, and then submitg the mixture to sublimation. As this medicine is much used in prie families, and as dreadful consequences might ensue if it were imperly prepared, it ought to be generally known, that if it be not pertly insipid to the taste, and indissoluble by long boiling in water, it tains a portion of oxymuriate of mercury, or corrosive sublimate, and consequently poisonous.

This native production is known by the name of *horn ore,* or corus mercury. For an account of its constituent parts, see note page 9).

In South America mercury is used to separate gold and silver from extraneous matter found with those metals. By triturating the mass h mercury, the gold and silver become amalgamated with it; and rwards this amalgam is submitted to heat, when the mercury subes, and the perfect metals are left in a state of purity.

everal of the uses of mercury were known to the ancients. Therastus, an ancient Greek philosopher, who wrote about 300 years re Christ, was acquainted with it, and knew how to work it so as to n vermilion.

For the process of water-gilding see Additional Notes, No. 29.

many purposes of the laboratory[a]; and in the manufacture of vermilion. It has also various and important uses in medicine, besides its employment in the preparation of the mercurial salts.

What are the names and distinguishing characteristics of those substances which constitute the SIXTH *class of metals?*

They are those metals which do not decompose water, but yet are capable of absorbing oxygen, and are thereby converted into acids. They are arsenic, molybdenum, tungsten, chromium, and columbium.

What is the origin and history of the first metal in this class, known by the name of arsenic?

ARSENIC or some of its native combinations was known to the ancients more than eighteen hundred years ago; but nothing was understood of its real na-

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[a] A fulminating powder has also been made with this metal, which might in some particular instances be employed for blasting rocks, as its immediate force is much greater than that of gunpowder, though it does not extend so far. This is said to have been discovered by Mr. Howard, and is usually called "Howard's fulminating powder:" but it appears from a pamphlet I have lately seen, entitled *Miscellanea vere utilia*, by Mr. Boyle Godfrey, published many years before this discovery, that this same powder had then actually been prepared; and that, as the author's attention was chiefly occupied with the nitrous ether, he luckily escaped the danger of operating upon the rejected fulminating mercury.

[b] The ores of arsenic are found only in veins in the primitive mountains; and generally these are accompanied by the ores of cobalt and some other metals.

[c] Some of the arsenic of commerce is prepared in Saxony in the operation of roasting the cobalt ores for the manufacture of zaffre. The reverberatory furnace in which the ores are roasted terminates in a long horizontal chimney; and in this chimney the arsenical vapours are condensed, forming a crust, which at stated times is cleared off by criminals, who are condemned to this work for crimes for which they would otherwise have suffered death. White arsenic is prepared by mixing the common oxide with potash, and submitting it to sublimation. By this process the white oxide of arsenic is separated, and sublimed, leaving its sulphur behind, united to the potash. See *Trans. Roy. Geol. Society of Cornwall,* vol. i. page 60.

ture until its properties were examined in a philosophical manner by Mr. Brandt in the year 1733. Arsenical pyrites, from which the white oxide of arsenic is procured, is found[b] in Bohemia, Norway, Sweden, Hungary, Saxony, and other places on the Continent[c]; at Alva in Stirlingshire; and abundantly in Cornwall and Devonshire[d]. Arsenic is also united with, and contaminates, many of the other metallic ores in England[e].

What is the nature[f] *of arsenic?*

Arsenic is generally found in certain parts of Germany in combination with acids, sulphur, or oxygen; but when reduced to its pure metallic state it is a brilliant metal, of a blueish white colour, easily tarnishing, that is, oxidizing by exposure to the air[g],

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[d] We are acquainted with only four other ores of arsenic, viz. red orpiment, or *realgar* and *yellow orpiment*, both which are described at page 358; *native arsenic*, which is found in Germany, and always contains some iron; and a very scarce mineral which occurs in the Hartz and is an oxide of arsenic. This mineral very much resembles *pharmacolite*, but, unlike that mineral, is soluble in water.

[e] Arsenic is frequently found in martial pyrites and in copper ores. See Gellert's *Metallurgic Chemistry*, and Henckel's *Pyritologia*. Arsenite of iron also occurs native, in a mineral called *mispickel* or arsenical pyrites.

Lead, when contaminated by arsenic, may be purified by melting it with a few iron filings. The iron combines with the arsenic, and these, being lighter than the lead, float on the surface, from which it may be readily skimmed off.

[f] Arsenic may be known by the smell of garlic, and by the white fumes which it exhales when thrown on a piece of red hot coal. If this experiment be made with *arsenious* acid (the white arsenic of commerce), it must be burnt in contact with charcoal or some other substance that has a powerful affinity for oxygen, as Dr. Paris has lately discovered that the oxide of arsenic in vapour is entirely inodorous, and that the alliaceous smell is wholly confined to *metallic* arsenic in a state of vapour. See the *Journal of the Royal Institution*, vol. vi. page 341.

[g] If arsenic in its pure metallic state be kept covered with alcohol, its metallic brilliancy will be preserved.

though so long as it is kept under water it will remain unaltered. It is extremely brittle, and at the same time the softest of all the metals. It has no smell while cold, but when heated it exhales a very strong odour, resembling that of garlic. This metal is volatile[a], and when sublimed it becomes the protoxide which crystallizes in tetrahedrons. According to Lavoisier the specific gravity of metallic arsenic is 5.7633[b]. In all its states it is extremely poisonous[c].

What is the effect of oxygen *upon arsenic?*

Arsenic has a great affinity for oxygen, and two combinations of it are known, viz. the white oxide of arsenic or *arsenious acid*, which is a hard and brittle substance with a glassy texture; and that with a fur-

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[a] If metallic arsenic be previously inflamed, it will burn in oxygen gas till the whole is consumed. The combustion is very brilliant, and forms a striking experiment.

[b] See the Appendix to Lavoisier's *Elements of Chemistry*, page 572.

[c] Dr. Pearson has said, that white arsenic, in the quantity of *one sixteenth* part of a grain, is as harmless as a glass of wine, and in that dose is a remedy for inveterate agues. See Dr. Pearson on Sulphate of Iron, &c. *Philosophical Magazine*, vol. xxi. page 56.

Whenever arsenic has been taken internally, by design or mistake, the best medicine is sulphuret of potash (liver of sulphur) dissolved in water. A few scruples should be dissolved in half a pint or a pint of water, and administered a little at a time as the patient can bear it.

[d] The first of these oxides, which may be formed by the combustion of metallic arsenic, is the common white arsenic of commerce, and is composed of about 75 arsenic and 25 oxygen. The arsenic acid is procured by digesting the protoxide in nitro-muriatic acid and distilling to dryness. It may also be formed by dissolving arsenic in nitric acid and evaporating the solution to a white solid mass. Arsenic acid is a compound of about 67 of metal and 33 of oxygen.

[e] The oxides of arsenic in solution are discovered by sulphuretted hydrogen, which produces a yellow-coloured precipitate. This precipitate is the same as that beautiful ore called orpiment, to be described hereafter.

[f] Arsenite of potash or of soda may be formed by boiling caustic potash or soda with the white oxide of arsenic, or what is usually known by the name of white arsenic. Other arsenites may be formed by double

ther proportion of oxygen which constitutes *arsenic acid*[d], and which, according to the mode of its preparation, is either in the form of a white solid, or of the consistence of jelly. Both are poisonous[e].

What salts *of arsenic are there?*

The salts which have been formed with this metal are few[f]; though muriate of arsenic, known by the name of *butter* of arsenic, was made by the old chemists. None of the salts of this metal, considered as a base, are found native[g].

Besides the oxides and salts, what other combinations are there of arsenic?

Arsenic is capable of combining with hydrogen[h],

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decomposition, such as arsenite of lead by the mere mixture of a solution of nitrate of lead with a solution of arsenite of potash; and arsenite of copper by adding a solution of sulphate of copper to one of arsenite of potash. The *arseniate* of potash may be prepared as directed in note, page 200.

[g] Though there are no native salts in which arsenic forms the base, yet we are acquainted with several in which it is combined as an acid; such are the arseniates of lime, copper, iron, &c. The mineral called *pharmacolite* or *arsenic-bloom*, is of this class. It occurs in Germany, and consists of 25 lime, 50.54 of arsenic acid, and 24.46 of water.—Klaproth.

[h] When arsenic is combined with hydrogen, a permanently elastic and invisible fluid is formed of less specific gravity than atmospheric air, known by the name of *arsenuretted hydrogen gas.* It has a fetid smell, would destroy animal life, and is incapable of supporting combustion. It is itself combustible and burns in a curious manner, as already described at page 200. A stream of this gas issuing from a small orifice and set on fire in a large receiver of oxygen gas, burns with a blue flame of surprising splendour. If the flame of a taper be brought in contact with a mixture of this and oxygen gas in the proportions of two measures of the former to three of the latter, a violent explosion will take place; and water, with arsenious acid, will be precipitated. If concentrated nitric acid be poured into a jar containing arsenuretted hydrogen gas, the red fumes of nitrous acid gas will be suddenly evolved, and an explosion accompanied with flame will ensue. Too much care, however, cannot be exercised in making experiments with this dangerous elastic fluid. An eminent foreign chemist of the name of Gehlen lost his life in consequence of his operations upon it. According to Gay Lussac, it is possible to form a *solid* compound of hydrogen and arsenic; it is a flocculent mass of a chesnut brown colour.

with clorine[a], with iodine[b], with phosphorus[c], and with sulphur[d].

What are the uses *of arsenic?*

Arsenic is used to whiten copper[e], and enters into most compositions for the specula of reflecting telescopes, and for other optical purposes[f]. Its oxides are employed in many processes of the dyer[g]; also in the manufacture of glass[h], and in several of the arts. The sulphurets of arsenic are also employed in the arts[i],

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[a] When arsenic is introduced into chlorine gas it burns with great splendour, and the result is chloride of arsenic, the same with the article already mentioned under the old name of *butter of arsenic*; and which has usually been prepared by distilling a mixture of arsenic and corrosive sublimate. It is a compound of two parts arsenic and three of chlorine.

[b] Iodide of arsenic is a solid, similar in colour to that of the vapour of iodine. It is soluble in water, and the solution will decompose nitrate of silver and produce a yellow precipitate of nitrite of silver.

[c] Arsenic and phosphorus readily combine and form together a brilliant black powder. The proportions in which they unite have not yet been ascertained.

[d] Sulphur and arsenic readily unite by fusion, and form a red, vitreous, semitransparent mass, which is a true sulphuret of arsenic: but this compound occurs as a native production in various parts of Europe, and is used as a pigment under the name of *realgar*. There is also a yellow sulphuret of arsenic called *orpiment*, which consists of 62 arsenic and 38 sulphur. Realgar is a compound of 69 arsenic and 31 sulphur.—Klaproth.

[e] Copper alloyed with arsenic forms a malleable and flexible metal that takes a fine polish. On account of these properties, this mixed metal is frequently employed for making sundry articles which are designed to be plated with silver.

[f] The use of arsenic, in making factitious metals for the specula of reflecting telescopes, may be seen in an able paper on that subject by the Rev. John Edwards of Ludlow, in the *Nautical Almanac* for 1787.

Arsenic is used in making small shot. The design of it is to render the lead more brittle, and better capable of granulating. See Additional Notes, No. 27.

[g] The white arsenic of commerce was formerly much employed in dyeing; but Lagrange and M. Berthollet inform us that the foreign dyers have now discontinued the use of it for some time, being persuaded of its utter inutility in any of their processes.

[h] Arsenic is useful in purifying flint glass when in fusion. See Loysel *Art de la Verrerie*, or vol. iii. of my *Chemical Essays*, page 422

[i] Sulphuret of arsenic is much used in calico-printing, on account of

and form likewise valuable pigments of different colours.

What is the nature and origin of that metal which is known by the name of molybdenum?

MOLYBDENUM is obtained from a mineral found in Sweden and elsewhere called *molybdena*, which is a sulphuret of molybdenum[k]. This metal, which has hitherto been obtained only in small grains, is very brittle, of the colour of silver, and has a specific gravity of 8.611[l]. When heated in open vessels, it com-

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its property of deoxidizing indigo, and thus rendering it soluble in an alkali.

Orpiment and realgar are both sulphurets of arsenic. Realgar is of the colour of scarlet or dark orange; orpiment, which is formed with more sulphur, is of a beautiful lemon-colour. Realgar always occurs in primitive mountains, whereas orpiment is generally found in secondary mountains. They are both much nsed in dyeing and calico-printing. The pigment called *king's* yellow is made from yellow orpiment. Besides the several uses which have been enumerated, I am told that beautiful shades of different colours may be given to valuable furs by arsenical solutions. So that the substance which is most injurious to the animal economy, appears to be endowed with properties for embellishing the works of creation, and is made to minister in various ways to our gratification, by imparting colour to other bodies. How diversified are the means which the Creator hath adopted for the promotion of these designs!

> "Who, not content
> With every food of life to nourish man,
> By kind illusions of the wondering sense
> Has made all nature beauty to his eye,
> Or music to his ear." AKENSIDE.

Arsenic is used in preparing the beautiful colour called *Scheele's green*. For the method of making this colour consult Scheele's *Chemical Essays* or Gren's *Principles of Chemistry*. See also page 200 of the foregoing sheets.

The Chinese and other Orientalists form *realgar* into medical cups, and use lemon juice that has stood some hours in them, by way of a cathartic.

[k] Molybdena is found at Glenelg in Inverness-shire, imbedded in chlorite-slate; also in granite at Shap in Westmoreland; at Coldbeck in Cumberland, and Huel Gorland in Cornwall. It occurs also in Norway and other parts of Europe; in Siberia and in Greenland. This mineral, in outward appearance, is very similar to plumbago. It is a compound of 60 of molybdenum and 40 of sulphur.

[l] Molybdenum was first procured in a metallic state by Hielm in the

bines with the oxygen of the atmosphere and is converted into the white or peroxide. It is susceptible of three states of oxidizement, giving a brown, a blue, and a white oxide[a]. The two latter having acid properties, are known also by the names of the *molybdous* and the *molybdic* acids[b]. Molybdenum is capable of forming alloys with many of the other metals, but I believe none of these have been brought into use.

What is the nature, history, and origin of tungsten?

Túngsten is a heavy metal, procured from a mineral which occurs in Sweden[c], and from an ore called wolfram[d] found in Cornwall, Germany, and elsewhere. The pure metal is extremely hard, very brittle, and of the colour of steel; it possesses much brilliancy, and has a specific gravity of 17.40, which is but little inferior to that of gold. It is not attracted by the magnet; it requires a temperature equal to 170° of Wedgwood to melt it; but when heated in atmospheric air, it absorbs oxygen and is thereby converted into an oxide.

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year 1782; it has been employed, I believe, in some processes of dyeing in Germany. As the ore may be had in great plenty, it will probably some time hence come into general use here. At present it is not employed in any of the arts. A method of procuring the metal from its ore is given by Sir H. Davy, *Elements of Chemical Philosophy*, part i. page 459. A very interesting and valuable memoir by Mr. Hatchett on the nature of this metal will be found in the *Philosophical Transactions* for 1795, to which I refer for further particulars.

[a] The protoxide appears to consist of 100 molybdenum and 17 oxygen; the molybdous acid, of 100 molybdenum and 34 oxygen; the molybdic acid of 100 molybdenum and 50 of oxygen.

[b] For the method of forming these acids see Notes [a] and [b], p. 166.

[c] This native substance, which is known to mineralogists by the names of *scheelium* or *tungsten*, is composed of tungstic acid 65, lime 31, and silica 4. It was called scheelium by Werner, in honour of Scheele who discovered the peculiar metal which it contains; and tungsten, which signifies a heavy stone, from the great weight of the metal which is obtained from it.

There are two oxides of the metal, viz. the *brown*, which consists of 100 of tungsten and 16.6 of oxygen; and the *yellow*, consisting of 100 of tungsten and 25 of oxygen. Tungsten will form alloys with several of the other metals, but none of these have yet been brought into use[e]. Sulphuret of tungsten may also be formed by art[f].

What is the history, origin, and nature of chromium?

Chromium was unknown until the year 1797, when Vauquelin analysed some of the *red lead ore* of Siberia[g], and found it to consist of the oxide of lead and a peculiar acid possessing a metallic base. By exposing this acid to an intense heat in conjunction with carbonaceous matter, he succeeded in reducing it to a metallic state. The metal, which he named *chromium*[h], is white and brittle, and has a specific gravity of not more than 5.90. It is magnetic, though less so than iron or nickel; it takes a good polish, which remains unchanged by exposure to atmospheric air; and yet when heated is slowly converted to an oxide. It

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[d] Wolfram, which was originally mistaken for antimony, is composed of tungstic acid 64, oxide of manganese 22, and oxide of iron 13.5.

[e] I have been told that tungsten has been employed in France to precipitate the colouring matter from certain woods for the purpose of forming lakes for the limner's use.

[f] Berzelius formed sulphuret of tungsten by the agency of sulphuret of mercury. It was a black powder, which he found to consist of tungsten 100 and sulphur 33.26.

[g] This beautiful and rare mineral has been analysed by Vauquelin, and found to consist of 64 oxide of lead and 36 chromic acid. The chromate of iron varies according to the place from whence it is obtained. The specimen which Vauquelin analysed gave oxide of chromium 43.0, oxide of iron 34.7, alumina 20.3, and silica 2.0.

[h] Vauquelin named this metal *chromium*, because of its property of imparting a lively colour to a variety of other bodies. The *emerald* owes its colour to the oxide of chromium, and the *spinelle ruby* to the chromic acid.

requires a most intense heat to melt it[a], and does not readily enter into combustion. It resists the action of all the mineral acids, except that of the nitro-muriatic acid; this, however, acts slowly upon it, and at length forms with it muriate of chromium. It is susceptible of three degrees of oxidizement, from whence arise the *green* or protoxide; the *brown* or deutoxide; and the chromic acid, or per-oxide, which is of a *deep scarlet*[b]. The effects which chlorine, iodine, phosphorus or sulphur have upon this metal are unknown.

What is the history and origin of the metal known by the name of columbium?

Columbium, or tantalum as it has also been called, was discovered by Mr. Hatchett in the year 1801, in a mineral belonging to the British Museum, supposed to be brought from Massachusetts in North America, and which he found to consist of a metallic acid combined with oxide of iron[c]. Although Mr. Hatchett had failed in his attempts to reduce the acid to a metallic state, he had no doubt of its base being metallic, and therefore was desirous of giving it a name; and as the ore from which he had obtained the acid was the produce of America, he called it *columbium*. Soon afterwards Mr. Ekeberg, a Swedish chemist, detected a

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[a] The temperature at which chromium melts, has not been accurately ascertained.

[b] The green oxide consists of chromium 100 and oxygen 43.86; whereas the metal combines with a double portion of oxygen to form the chromic acid, which is a compound of chromium 100 and oxygen 87.72. The proportion of oxygen in the brown oxide is not yet accurately known.

[c] The mineral from whence Mr. Hatchett obtained the first specimen of columbic acid has been described as being of a dark brownish gray colour, moderately hard and very brittle; its lustre vitreous inclining to metallic; its fracture imperfectly lamellated; its particles not attracted by the magnet; and its specific gravity 5·918. See *Philosophical Transactions* for 1802.

metallic substance in two minerals found in Sweden, different from any metal already known. This metal he named *tantalum*, and the minerals from which he obtained it, *tantalite*[d] and *yttrotantalite*[e]. In the year 1809, Dr. Wollaston submitted the two Swedish minerals to analysis; and having separated the metallic oxide, he compared it with the oxide of columbium which Mr. Hatchett had obtained from the specimen in the British Museum, and hence discovered that columbium and tantalum are one and the same species. In the year 1815, Berzelius succeeded in reducing the oxide of tantalum to its metallic state, by intensely heating it in a crucible of charcoal.

What is the nature of columbium?

Columbium, or tantalum, is of a dark gray colour, and so infusible that none of it has hitherto been reduced by heat to a fluid mass. Professor Berzelius found that the metallic substance only approximated towards fluidity, having the appearance of hard grains closely agglutinated together. Its specific gravity in this state was 5.61. It may be reduced to powder by trituration in a mortar, but even in this state it is not acted upon by any of the mineral acids. When converted to an oxide, it possesses acid properties; and

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[d] Tantalite occurs in masses, but principally crystallized in acute octahedrons, with a square base. Its colour is iron-black, sometimes with a shade of blue. Its lustre is metallic, inclining to resinous. It is found in coarse red granite, at Brokärns, Zinnsgute in the parish of Kemito in Finland.—Jameson. Its constituent parts are, oxide of tantalum 83, oxide of iron 12, oxide of manganese 8.

[e] Yttrotantalite occurs imbedded in angular pieces, sometimes as large as a hazel-nut, and also crystallized. Its colour is dark iron black. Its lustre is resinous, sometimes inclining to metallic. Its specific gravity is 5.130. It occurs along with gadolinite in a bed of flesh-red felspar in gneiss, at Ytterby near Roslagen in Sweden.—Jameson. It consists of oxide of tantalum 45, oxide of iron and ittria 55.—Vauquelin.

when the oxide is converted to an hydrate[a] it becomes soluble in oxalic, tartaric, and citric acids. If metallic columbium be heated to redness, it takes fire, and slowly consumes without flame. In several respects it differs from all the metallic bodies yet discovered[b].

What is the history and origin of selenium?

SELENIUM was discovered by Professor Berzelius. He found that the sulphur which is procured at Fahlun in Sweden, deposited a reddish mass in the chambers for manufacturing sulphuric acid. This substance is principally sulphur; but on burning it emitted an odour, which induced Berzelius to suppose that it contained tellurium: he found, however, upon minute examination, that its peculiar smell was owing, not to tellurium, but to the presence of a new substance, to which he gave the name of selenium. This substance he considered to be a metal, though in the opinion of some persons it might with more propriety be classed with sulphur and phosphorus.

What is the nature *of selenium?*

Selenium has a gray colour, its lustre is metallic and very brilliant, and it is slightly transparent. At 212° of Fahrenheit it softens, and at a few degrees higher it melts. When cooling it is ductile, may be kneaded between the fingers, and drawn into fine threads, the lustre of which is strongly metallic; when slowly cooled it has a granular fracture. It boils at

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[a] From the concurrent testimony of those who have examined the compounds formed by means of columbium, it appears that columbic acid consists of columbium 100, oxygen 5.5; and that the hydrate consists of oxide of columbium 100, water 12.5. An alloy of columbium and iron and another of columbium and tungsten have been formed by art. The former has the appearance of brittle cast iron; the latter is similar in appearance to pure tantalum, but it is harder and takes a fine polish.

bout 600° of Fahrenheit; and the portion which is olatilized, condenses on cooling into opaque metallic rops, or sometimes sublimes into a fine red-coloured owder. When heated before the blow-pipe it tinges e flame of a fine azure blue, and gives out a strong nell resembling that of horse-radish. This effect is so stinctly perceived, that a portion not exceeding $\frac{1}{50}$th a grain is sufficient to produce it throughout a large oom. It is a bad conductor of heat and a non-conuctor of electricity.

What is the effect of oxygen *upon selenium?*

When selenium is heated in nitric acid, it is dis-olved; and by decomposing a portion of the acid and ombining with its oxygen is converted into selenic id. This acid, after evaporation to dryness, may be olatilized by heat or sublimed into needle-formed ystals which are often a foot in length. These are luble in water, and have the taste and other proper-es of an acid.

What salts *are there of selenium?*

Selenic acid unites readily with the fixed alkalies, d with them forms salts of the colour of vermilion. hese alkaline seleniates crystallize with difficulty, d deliquesce when exposed to the atmosphere. If a ate of zinc be immersed in an aqueous solution of y of these salts, the selenium will be precipitated in metallic state.

Dr. Murray, who has published a very succinct historical account of discovery of columbium, has stated that it differs from any of the own metals, or metallic oxides or acids, in the precipitates it affords h prussiate of potash, and tincture of galls—in not combining with monia—and in being insoluble, and unalterable with regard to colour, nitric acid.

What are the names of those metals which constitute the SEVENTH *and last class; and what are their distinguishing characteristics?*

The principal characteristics of this class are, that the metals which constitute it do not decompose water, nor absorb oxygen from the atmosphere at any temperature. These are platina, gold, silver, palladium, rhodium, and iridium.

What is the origin and history of platina?

PLATINA is found in grains in a metallic state[a] in various parts of South America, more especially at Santa Fé near Carthagena, in the kingdom of New Granada; in the district of Choco in Peru[b], and in the mines of Taddo near the Rio-de-la-Plata in the same kingdom. It has also been discovered in the island of St. Domingo[c], and in a new mineral brought from the gold mines of Brazil. Of late years it has likewise been found in considerable quantities in a gray silver ore from the mines of Guadalcanal, in the

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[a] Platina generally occurs in small roundish flattened grains of the size of sand, but there are instances of its being found in granular pieces as large as a pea. Humboldt has lately presented the king of Prussia with a specimen of native platina larger than a pigeon's egg, which weighs 1088 grains, and is of the specific gravity of 18.947.

[b] The platina found in this vicinity occurs among alluvial ores of gold, in the parishes of Novita and Cataria, somewhat north of Choco. The Spanish government once prohibited it from being wrought, lest it might be employed to adulterate gold. Heron's *Elements of Chemistry,* 8vo, (1800,) page 353.

[c] In St. Domingo it is met with in the eastern part of that island, in the sands of a river called Jaki, at the foot of the mountains of Sibao. The grains are larger than those of Peru, and are accompanied by magnetic iron ore, gold, &c. Phillips's *Mineralogy,* page 275.

[d] Charles Wood was the first person who brought any of this metal to England. He brought it from Jamaica in the year 1741, and published an account of his experiments upon it in the *Philosophical Transactions* for 1749 and 1750.—Platina in the language of Peru means *little silver.*

The ore of platina contains no less than nine different substances, viz.

province of Estramadura in Spain. This important metal was however not known nor heard of in Europe until the year 1748[d], and was not described as a peculiar metal, at least in England, before 1754; when Dr. Lewis published several papers upon it in the Philosophical Transactions for that year.

What is the nature of platina?

Platina is the heaviest of all the metals[e]; is nearly as white but not so brilliant as silver, and is difficultly fusible, though by great labour it may be rendered malleable, so as to be wrought into utensils like other metals. It has considerable tenacity, and is so ductile that it may be drawn into wire less than one-eighteen-thousandth part of an inch in diameter. Hence it may by means of powerful rollers be reduced to sheets of almost any thinness that may be desired. It has neither taste nor smell[f], nor is it oxidizable by the action of air or water. It is nearly as hard as pure iron, and therefore is susceptible of a fine polish[g]. It is a con-

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llica, iron, lead, copper, platina, iridium, osmium, rhodium, and palla-ium. For the methods of analysing the ore of platina, consult Dr. Wol-ston's and Mr. Tennant's papers in the *Philosophical Transactions.*

[e] The specific gravity of hammered platina is nearly 22, which is uble that of lead. It may always be known from other metals by this perior specific gravity, it being the heaviest body in nature.

[f] Platina may be distinguished from all other metals by adding a solu-n of muriate of ammonia to a solution of the metal in nitro-muriatic id, when a red-coloured precipitate will instantly appear. This is the ly means yet known to discover when gold has been alloyed with this etal. Gold is generally known, if weighed hydrostatically, by its spe-ic gravity; but if it be alloyed with platina, some other test is neces-ry, as platina has a greater specific gravity than gold.

Some of the methods which have been employed to procure platina in tate of purity may be seen in the *Philosophical Transactions* and other dern publications.

[g] From its hardness, platina would be very suitable for the fabrication coins and medals, especially as it is not liable to be injured by acids, d would admit of the most delicate impressions that a die could pos-ly impart.

ductor of electricity, but conducts heat more slowly than any other metal. It will resist the strongest heat of our fires without melting[a], and, like iron, is capable of being welded when properly heated. A great variety of alloys have been formed with platina[b]. Its specific gravity is 21.47.[c]

What is the effect of oxygen *on platina?*

The oxygen in atmospheric air has no effect upon platina[d], unless when assisted by an intense heat; but the oxide may be procured by dissolving the metal in nitro-muriatic acid, and then precipitating it by an alkali[e]. From some late experiments it appears to be susceptible of two degrees of oxidizement, affording the black and the gray oxide[f]; and that it is the latter

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[a] The strongest of the pure mineral acids has no effect upon this metal, if employed separately; neither has the strongest fire, unless it be urged by a stream of oxygen gas. This metal may, however, be melted by a burning lens, or dissolved in oxymuriatic acid or nitro-muriatic acid. If mixed with arsenic, and then exposed to a great heat, it fuses readily. By putting a platina wire into the flame produced by the combustion of mixed hydrogen and oxygen gases, it burns with all the brilliancy of iron-wire, and emits sparks in abundance.

[b] For an account of the most valuable alloys of platina consult Mr. Hatchett's paper in the *Philosophical Transactions* for 1803.

[c] By repeated hammering, Dr. Wollaston was enabled to increase the density of platina to the specific gravity of 21.5313. The specific gravity of crude platina is generally 17.70.

[d] On account of this property, as well as its hardness, it has been recommended for the fabrication of national standard weights. On other accounts it has long been employed for the touch-holes of all the best fowling-pieces. The peculiar advantage which results from its use for this purpose is circumstantially explained in the *Chemical Essays*, vol. i. page 376.

[e] This metal may also be oxidized by the electric spark, or by heating it with nitre. The latter method was introduced by Mr. Tennant. See *Philosophical Transactions* for 1797. This oxide, which is of a gray colour, consists, according to Mr. Chenevix, of 87 parts metal and 13 of oxygen. Native oxide of platina is not known.

Proust says, that when platina is combined with other metals it oxidizes more easily than has hitherto been believed. *Annales de Chimie*, tome xxxviii.

oxide which enters into the composition of the salts of platina, and which according to Berzelius contains twice as much oxygen as the former. Platina is also capable of combining with chlorine[g], phosphorus[h], and sulphur[i].

What salts *are there of platina?*

A variety of salts may be formed with the oxide of this metal; but none of them have yet been brought into much use[k], except the muriate of platina, which is employed as a test to discriminate between potash and soda when these alkalies are in a state of solution[l]. No salt of platina has yet been found native.

What are the uses *of platina?*

Platina has hitherto been chiefly used for chemical

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[f] Much valuable information on the oxides and other combinations of this metal, will be found in a paper by Mr. Cooper in the *Journal of the Royal Institution of Great Britain*, vol. iii. page 119.

[g] Metallic platina does not burn when introduced into chlorine gas, as is the case with some other metals, but it gradually imbibes chlorine and becomes converted to a chloride.

[h] Phosphorus and platina combine with great energy when the phosphorus is made to act in vapour in exhausted tubes, on platina heated to dull redness: the combination is so violent, that the mass becomes vividly ignited. The phosphuret of platina is an infusible blueish gray powder with little lustre. It is a compound of platina 100 and phosphorus 21.21.—Davy. A super-phosphuret of this metal may also be obtained.

[i] According to the experiments of Mr. Edmund Davy platina combines with three portions of sulphur; the first sulphuret being a compound of 100 platina and 19.04 of sulphur; the second of 100 platina and 28.21 of sulphur; the third of 100 platina and 38.08 of sulphur.

[k] In order to form any salt of platina, the metal must be previously dissolved in nitro-muriatic acid or oxymuriatic acid, these being the only menstrua that will act upon it. And in making the nitro-muriatic acid, three parts of muriatic acid should be mixed with one part of nitric acid; Proust having determined that this mixture dissolves the largest proportion of the metal. A solution of any other salt is then to be added, and by double affinity the new salt required may be obtained. Thus a solution of phosphate of soda when mixed with muriate of platina would probably give a *phosphate* of platina.

[l] For the method of using this test see note, page 128.

utensils, such as crucibles[a], small tongs[b], rods, spoons, &c. also for retorts to concentrate sulphuric acid[c], and to make mirrors for reflecting telescopes. To Dr. Wollaston we are indebted for instruction how to render platina sufficiently malleable for these purposes. This metal has also been beaten into leaves, and applied to porcelain[d] in the manner of leaf gold. Its

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[a] The important uses to which this precious metal may be applied can be easily conceived, when it is considered that it unites the indestructibility of gold to a degree of hardness almost equal to that of iron; that it resists the action of the most violent fire, and also of the most concentrated acids. Vessels of capacity made with this metal must, however, always come extremely dear, as it is necessary to solder them with gold. There is also another disadvantage attending the use of this metal for chemical purposes, which is, that it is corroded by caustic alkalies. Indeed, crucibles of platina have been eroded by analysing minerals in them which have contained some of the neutral salts.

[b] Platina being so slow a conductor of heat is peculiarly fitted for making these small utensils, as they may be safely held in the hand, while the other extremity is immersed in a fluid metal, or thrust into an intense fire. And lately the genius of Sir H. Davy has enabled him to found on this property of platina and its small capacity for heat, an improvement of his safety lamp, which appears to me to be the most important instrument that science has presented to the arts since the discovery of the steam-engine. One inconvenience only was attached to it; viz. that the perfect safety which attended its use often induced the men to go into more deteriorated atmospheres than they otherwise would, which sometimes occasioned the lights to be extinguished. To obviate this inconvenience, Sir Humphry has now contrived to suspend a coil of platina wire over the flame of each lamp, the effect of which is, that the moment the light is extinguished by the superabundance of carburetted hydrogen gas in the atmosphere, the coil of platina wire becomes of an intense red heat; and this affords light enough to enable the men to find the road through the different passages to the entrance of the mine. This alone would have been an important improvement—but this is not all; for no sooner is the lamp brought into a part of the mine in which the atmosphere contains less than one-fourth of carburetted hydrogen gas, than the heated platina wire of itself re-lights the lamp, and the men are enabled to return to their work without further interruption and in perfect safety. A description of the lamp, with an appropriate drawing by Sir Humphry Davy, may be seen in the first volume of the *Journal of the Royal Institution of Great Britain.*

[c] Some years ago I had a vessel of platina constructed for the purpose of rectifying sulphuric acid. It holds 32 gallons, and cost a few hundred pounds; but the advantages which result from its employment are fully adequate to the expense.

[d] A very neat method to cover other metals with platina was lately

oxide is used for certain articles of pottery, and in enamel painting[e].

What is the nature of gold?

Gold is of a light yellow colour inclining to red; it is the heaviest of all the metals except platina[f]; it is not very elastic, nor very hard[g]; it has neither taste nor smell; it possesses less tenacity than iron, copper, platina, or silver[h]: very few, however, of the metals have more lustre, and it is so malleable and ductile[i]

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discovered by Mr. Stodart, who found that, like gold, it may be taken up from its solution by sulphuric ether. See Nicholson's *Journal* for the year 1805. Where the expense of ether would be an objection to its use, good oil of turpentine may be employed in its stead.

It is said that M. Strauss has, after many experiments, succeeded in applying platina to the coating of copper with as much ease as the common operation of tinning. The durability of this metal, and its resistance to acids and saline matters, will render this a most valuable discovery.

An alloy of copper with this metal is likely to prove very valuable; as it is malleable and ductile, is susceptible of a fine polish, and receives no tarnish of its lustre by exposure to the air.

Crude platina melted with copper and silver affords a compound that oxidizes but little by muriatic or nitric acid, and which when drawn into wire is highly elastic, and very useful for springs that are designed to be exposed to the action of the atmosphere. An alloy of this kind is employed in the manufacture of Mr. Stansbury's patent locks, and is likely to give them great durability.

By melting 15 parts of gold with one part of purified platina, Mr. Hatchett produced a yellowish white alloy, extremely ductile, and very elastic; so much so, that he is of opinion it might be used with great advantage in making watch-springs.

[e] Klaproth proposed the use of platina in enamel painting, instead of ilver, which is liable to tarnish. Platina has not this inconvenience; nd when intermixed with figures of gold has a beautiful appearance. esides, various coloured alloys may be formed by the union of the two etals so as to produce a great variety of shade of colour. Directions r using platina in this way may be seen in the 17th volume of the *Phisophical Magazine*. The method of using platina for what is called *silver stre*, may be seen in the *Chemical Essays*, vol. iii. page 333.

[f] Gold may be known from all other metals by its bright yellow colour, nd its weight. Its specific gravity is 19.3; when heavier it must be ombined with platina; when lighter, and of a deep yellow colour, it is loyed with copper; if of a pale colour, with silver.

[g] Gold possesses a hardness between that of silver and tin. For puroses where the metal would be liable to wear, it is rendered much rder by the addition of a small portion of copper.

[h] Such is the tenacity of gold, that a wire $\frac{1}{10}$th of an inch in diameter ll support a weight of 500 pounds without breaking.

[i] Although gold exceeds all other metals in ductility, this ductility

that it may be drawn into wire of extreme fineness, and beaten out into leaves thin enough to be carried away by the slightest wind [a]. It is not affected by long exposure either to atmospheric air or water; nor is it acted upon by sulphuric, nitric, or muriatic acid, whatever may be their states of dilution or concentration, its only solvent being nitro-muriatic or oxy-muriatic acid [b]. Its solution imparts a purple stain to the skin, and its oxide when united with ammonia possesses strong fulminating properties [c]. It melts at 1300° of Fahrenheit, and when melted takes a bright green colour inclining to blue; but it is so fixed that it may be kept in this state of fusion for any length of time without suffering any diminution either in its weight or its qualities [d]. When allowed to cool, it contracts in bulk

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may be entirely destroyed by the admixture of a very minute portion of lead or antimony. It has been found that $\frac{1}{1900}$dth in weight of either of these metals will produce this effect.

[a] Dr. Black has calculated, that it would take fourteen millions of films of gold, such as is on some fine gilt wire, to make up the thickness of one inch; whereas fourteen million leaves of common printing paper would occupy nearly $\frac{3}{4}$ths of a mile in thickness. Vol. ii. page 654. The ductility of gold is such, that one ounce of it is sufficient to gild a silver wire more than thirteen hundred miles long.

[b] This noble metal may be detected when in solution, by green sulphate of iron; this precipitates it of a brown colour, which soon changes to the colour of gold.

[c] Fulminating gold is made by diluting a saturated solution of gold with three times its measure of distilled water, and precipitating the oxide by solution of ammonia *gradually* added. The precipitate, when dried on a filter, forms this fulminating powder, which detonates by heat or friction. A shocking account is related by Macquer, of a person losing both eyes by the bursting of a phial containing fulminating gold, at the house of Baumé, and which exploded by the friction of the glass stopper against a minute quantity that adhered unobserved to the neck of the bottle. This accident ought to deter every one from making incautious experiments with this dreadful compound.

[d] Gasto Claveus, in an apology for the alchemists, (printed in the 2d volume of the *Theatrum Chymicum*,) relates, that he put an ounce of pure gold in an earthen vessel, into that part of a glass-house furnace where the glass is kept constantly melted, and continued it there in fusion for two months together: and Kunckel mentions a like experiment made in the glass-furnace of the Duke of Holsatia, in which the gold was

and crystallizes in short quadrilateral pyramids. It is however capable of combustion[e]; for although neither air, water, nor fire seem to have any effect upon it, it may be burnt by the action of a galvanic battery, or by exposing it in the state of wire to a stream of inflamed oxygen and hydrogen gases, whereby it becomes converted to an oxide[f]. Gold is capable of forming alloys[g] with other metals. Its specific gravity is upon an average 19.3.

Where is gold found?

Gold is found native in Peru, in Brazil[h], in Siberia, in North Carolina, in Hungary, and in several other parts of the world. It generally occurs in a metallic state, alloyed with a little silver[i] or copper[k], and com-

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exposed to the fire for almost thirty weeks. These vehement and continued degrees of heat it was found to support, without suffering any sensible alteration of its quality or diminution of its weight. Lewis's *Commercium Philosophico-Technicum*, page 70.

[e] Gold leaf, thrown into oxymuriatic acid gas at the temperature of 70° or 80°, takes fire and burns with great brilliancy.

[f] According to Berzelius there are two oxides of gold, the green and the brown; the first being a compound of 96.13 gold and 3.87 oxygen; the second 89.225 of gold and 10.775 of oxygen.

[g] Gold will form alloys with most of the metals. That with copper is the most useful, as it renders the gold harder, and when in small quantity does not impair its colour. For current coin the metal is alloyed with a mixture of gold and silver. Sterling gold is a compound of eleven parts pure gold and one part of some other metal. One pound of sterling gold is always coined into 44½ guineas. An alloy of silver and gold is employed in soldering the articles made with gold, as such an alloy is more fusible than pure gold.

[h] Mr. Mawe has given an interesting account of the gold mines of Jaragua and Santa Rita in Brazil, with a copper-plate engraving of the manner of washing the gold. See Mawe's *Travels into the Interior of Brazil*, 4to, 1815, pages 77—79 and 120—126.

[i] The native gold known to mineralogists by the name of *brass-yellow gold*, is found to consist of gold 96.9, silver 2.0, iron 1.1. It occurs principally in Hungary, Transylvania, and Bohemia. That which is called *argentiferous native gold* occurs in Siberia, along with massive heavy spar, or splintery hornstone. It was analysed by Klaproth, and pronounced to consist of 64 parts gold and 36 silver.

[k] To obtain gold in a state of purity, the gold is dissolved in nitro-

monly in the form of grains[a]. Most of the gold of commerce is at present brought to Europe from Africa and from the continent of America[b].

What is the effect of oxygen *upon gold?*

Gold has so little affinity for oxygen, that it cannot be easily oxidized like the other metals: this may however be effected by amalgamating it with mercury, and

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muriatic acid; the silver will remain an insoluble muriate, and must be separated; to the clear solution, a solution of green sulphate of iron must be added; the gold will be precipitated in the state of a fine powder, and after being well washed in diluted muriatic acid and then in distilled water, may be fused into a mass in a proper crucible. For the methods of purifying gold by cupelling and quartation, see Bouillon Lagrange's *Manual of Chemistry*, vol. ii. page 141.

[a] Gold frequently occurs in the ores of other metals, but it is chiefly found in the warmer regions of the earth. It abounds in the sands of many African rivers, in South America, and in India. Several of the rivers in France contain gold in their sands. It has also been discovered in Sweden, Norway, and Ireland. Near Pamplona, in South America, single labourers have collected upwards of 200*l.* worth of wash-gold in a day. In the province of Sonora the Spaniards discovered a plain fourteen leagues in extent, in which they found wash-gold at the depth of only 16 inches; the grains were of such a size that some of them weighed 72 ounces, and in such quantities, that in a short time, with a few labourers, they collected 1000 marks (equal in value to 31,219*l.* 10*s.* sterling), even without taking time to wash the earth that had been dug. They found one grain which weighed 132 ounces. This is deposited in the royal cabinet at Madrid, and is worth 500*l.*—Dr. Black, vol. ii. page 694.

The native gold found in Ireland was in grains, from the smallest size up to between two and three ounces. Only two grains were found of greater weight, one of which weighed 5 and the other 22 ounces. See *Philosophical Transactions* for 1796.

Gold mines were formerly worked in Scotland; and indeed now, grains of this metal are often found in brooks in that kingdom, after a great flood. It has been said, that at the nuptials of James V. covered dishes filled with coins of *Scotch gold* were presented to the guests by way of dessert.

[b] When a projecting part of one of the highest mountains in Paraguay fell down, about thirty years ago, pieces of gold, weighing from two to fifty pounds each, were found in it.—Helms. There are now no less than thirty gold-mines in the vice-royalty of La Plata alone.

[c] Gold has generally been thought susceptible of two degrees of oxidizement; the purple and the yellow oxide: but neither of them is ever found native. See a note on metallic oxides and the formation of metallic salts, chap. xi.

It was formerly imagined that gold could not be oxidized by atmopplying heat[c]; or by dissolving it in nitro-muriatic id, and precipitating it with a solution of potash.

What salts *of gold are there?*

There is only one salt of this metal that is much own to chemists, viz. the *muriate of gold*[d], which is tained in small crystals, and is very soluble in water. Iany other salts may be formed by means of the mu- ate of gold, but nothing at present is known either

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heric air, even in the highest temperature; it has however been proved, at the heat produced by an electrical or galvanic discharge is sufficient effect it, and to convert a piece of leaf-gold to the *purple* oxide.

The attraction of gold and silver for oxygen is so slight, that the rays the sun alone will deoxidize the oxides of these metals.

The oxides of gold may also be reduced by hydrogen gas or sulphurous d gas. If white satin ribbon, or silk, be moistened with a diluted solu- n of gold, and, *while moist*, exposed to a current of either of these ses, the metal will immediately be reduced, and the silk become gilt th a regular coat of gold. In this way any ornamental figures may be d upon silk, the gilding of which will be very permanent. For the ionale of this process consult Mrs. Fulhame's *Essay on Combustion*.

" If gold and silver should, when heated with other metals, undergo a ght degree of calcination by such a process, a stronger heat alone kes them immediately resume their pure and metallic form. The al- ion therefore to this quality of the precious metals, to illustrate the umph of a good heart over misfortune, is peculiarly beautiful; and, this is to be found in the Bock of Job, the discovery of the oxidizement l reduction of these metals must be very ancient."

This salt is formed by dissolving gold in nitro-muriatic acid, and ving the solution at rest for the salt to crystallize. In this process nitric acid affords oxygen to the metal; and as the metal becomes dized the oxide is dissolved by the muriatic acid. Nitro-muriatic acid l oxymuriatic acid are the only acid solvents of this metal. A solution nuriate of gold, when concentrated by evaporation, yields beautiful ow crystals not unlike *topazes*.

f *ether* be added to a solution of muriate of gold, the gold will leave acid, and float upon its surface, combined with the ether. This ethe- l solution has been used by Mr. Stodart and Mr. Savigny for defending ir lancets and other surgical instruments from injury by a damp at- sphere. See Nicholson's *Journal of Natural Philosophy*, &c. It was nerly used in medicine under the name of *potable gold*. In those days redulity it was generally prescribed to all patients who could furnish apothecary with gold enough to make as much of the medicine as he uld pronounce to be sufficient to ensure a cure. The account which n Glauber gives of this celebrated panacea at the end of his Treatise *Philosophical Furnaces*, 1651, page 393, will afford the reader some ertainment.

of their properties or uses. Gold may also be combine with chlorine, with phosphorus, and with sulphur.

What are the uses *of gold?*

Gold is used for jewellery, for plate[a], and for current coin; but for these purposes it is generally alloyed either with copper or silver. It is employed in variou ways in the arts[c]. Gold is also spread over other metals in the process called gilding, to preserve then from tarnishing or rusting, as gold does not becom oxidized by exposure to atmospheric air. The purpl

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[a] Gold seems to have been employed by the monarchs of antiquity i much greater quantity than any of the modern nations have been a customed to. From the 10th chapter of the 1st Book of Kings it appea that Solomon received 27 tons weight of gold in one year; and in th same chapter it is said, "And all King Solomon's drinking-vessels we of gold, and all the vessels of the forest of Lebanon were of pure gold none were of silver; it was nothing accounted of in the days of Solomon The lavish employment of gold and silver by the nations of antiquity recorded by all the early historians. Several of the most remarkab narratives have been collected and printed in the *Chemical Essays*, vol. page 247.

[b] Gold employed in jewellery is generally alloyed with copper. Wh is called pale gold is alloyed with silver. See an interesting paper c the various alloys of gold, by Charles Hatchett, esq. in *Philosophic Transactions*, vol. xciii. page 43.

Standard gold of Great Britain is twenty-two parts pure gold and tw parts of copper, it is therefore called gold of "twenty-two carats fine."

[c] "In France they grind leaf-gold, or the clippings of leaf-gold, wi honey, and then put it into muscle-shells; this they call gold in powde or in the shell. This gold, so prepared, is used for painting in miniature —Monsieur Pomet's *History of Drugs*. Grinding leaf-gold with hone is now commonly practised by some artists in this country.

[d] Gold is also used in a state of solution, for staining ivory and orn mental feathers. It gives a beautiful purple red, which cannot be effaced even marble may be stained with it. The nitro-muriatic acid is th menstruum used for this purpose. The potters dissolve gold in this wa to be applied to the common kind of porcelain. Bismuth or zinc w precipitate gold from this solution. Tin will precipitate it of a beautif purple, called the *purple precipitate of Cassius*. This also is used by th potters in printing on porcelain. Sulphuret of potash will likewise di solve gold. Some have thought that Moses made use of this process render the calf of gold, adored by the Israelites, soluble in water. Sta wrote a long dissertation in order to prove that this was the case. Se Additional Notes, No. 29.

xide of gold is employed in staining glass, and for namenting porcelain [d].

What is the origin of silver ?

SILVER is found in various parts of the world [e], par- cularly in Peru, and Mexico [f]; in Saxony, Bohemia, wabia, and Hungary; in Norway, Sweden, Russia, d Siberia. This noble metal occurs in a metallic ate; also in that of an alloy; of a sulphuret, of a lt, and in that of an oxide [g]. A considerable quan- y of silver has also been obtained from some of the ad-mines in Great Britain and Ireland [h].

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[e] Silver was used in commerce eleven hundred years before the foun- tion of Rome. Genesis xxiii. 16.

[f] The silver mines of Mexico and Peru far exceed in value the whole the European and Asiatic mines: for we are told by Humboldt, that ese mines in the space of three centuries afforded 316,023,883 pounds y of pure silver; and he remarks that this quantity would form a solid be of silver 91,206 English feet in diameter.—Jameson. Mr. Helms of opinion that the Andes if properly examined would afford silver ough to overturn our present commercial system; by making silver as mmon as copper.

[g] Native silver is found chiefly in the mines of Potosi. Sulphuret of ver occurs in the silver-mines of Germany, Hungary, Saxony, and eria. Oxides of silver are also common in some of the German silver- nes. Native silver has lately been found in a copper-mine in Cornwall. e Mr. Hitchen's paper in *Philosophical Transactions*, vol. xci. page 159; d a memoir by Mr. Carne in the 1st vol. of the *Trans. Roy. Geol. Soc.* *Cornwall*, page 118.

There are no less than eleven distinct ores of silver, besides several b-species, known to mineralogists: viz native silver; auriferous silver; imonial silver; arsenical silver; bismuthic silver; corneous silver- ; compact sulphuret of silver; brittle silver-glance, or antimonial phuret of silver; *red* silver-ore; *white* silver-ore; and carbonate of ver, or *gray* silver-ore.

It may be ascertained whether an ore contains silver, by pulverizing and dissolving it in nitric acid, and afterwards adding a little muriatic id. Should it contain any silver, the muriatic acid will instantly com- e with the whole of it, and precipitate it from the nitric solution in ite flakes of muriate of silver. In order to know the proportion of ver in any given quantity of ore, collect this precipitate on a filter, at it red, and then weigh it accurately. Every 100 grains of the pre- itate will contain 75 grains of pure silver

[h] In the county of Antrim in Ireland there is a mine so rich that every

What is the nature *of silver?*

Silver is a heavy, sonorous, brilliant[a], white metal, without either taste or smell; it is only moderately hard[b], but exceedingly ductile, and of great malleability and tenacity. It possesses these latter properties in so great a degree, that it may be beaten into leaves much thinner than any paper[c], or drawn out into wire as fine as a hair, without breaking. Under certain circumstances it is capable of combustion[d]. It melts when heated to about 1000° of Fahrenheit[e],

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thirty pounds of lead-ore is said to produce one pound of silver. "In the museum of the Academy of Sciences at Petersburg is a piece of *native* silver from China, of such firmness that coins have been struck from it without its having passed through the crucible." See Storch's *Picture of Petersburgh*, page 330.

By the silver which was produced from the lead-mines in Cardiganshire, Sir Hugh Middleton is said to have cleared two thousand pounds a month, and that this enabled him to undertake the great work of bringing the new river from Ware to London. In 1637, a mint was established at Aberystwith for coining Welsh silver.—Bishop Watson's *Chemical Essays*.

Aristotle says, that some shepherds discovered the method of working the silver-mines of Spain; for, having occasion to clear a quantity of land by burning down the wood, they found fused silver produced by the operation of the fires.

[a] This is the most brilliant metal we have. Nothing surpasses it in splendour, except steel when highly polished.

[b] Silver possesses more hardness than gold, tin, or lead; but it is softer than iron, platina, or copper.

[c] Fifty square inches of silver-leaf weigh not more than a grain. The silver wire used by astronomers is no more than half as thick as a fine human hair.

[d] Silver, gold, and platina require the heat of a powerful burning lens in order to put them in a state of combustion, unless the fire be urged by a stream of hydrogen and oxygen gases. Thus treated, silver burns with rapidity, and gives out a pale green flame. A silver wire also burns with great splendour by means of the galvanic battery, and exhibits a beautiful spectacle.

Silver has such an affinity for muriatic acid, that this acid is employed as a test for discovering silver in solution.

Silver readily combines with sulphur. According to Mr. Hatchett, those who rob the public, by diminishing the current silver coin, make use of the following method. "They expose the coin to the fumes of burning sulphur, by which a black crust of sulphuretted silver is soon formed, which, by a slight but quick blow, comes off like a scale, leaving the coin d on cooling crystallizes in four-sided pyramids. Its ecific gravity is 10.474. It forms alloys with many the other metals[f].

What is the effect of oxygen *upon silver?*

Silver cannot be oxidized by atmospheric air, un-s exposed to an intense heat; but the oxide of silver ay be procured by dissolving the metal in an acid[g], d then precipitating it by lime-water or by an alkali. e brown oxide of silver is the only one that is known th certainty[h].

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little affected, that the operation may sometimes be repeated twice or ice, without much hazard of detection."—*Philosophical Transactions*, . lxxxviii.

o know when silver is pure, heat it in a common fire, or in the flame a candle: if it be alloyed, it will become tarnished; but if it be pure er, it will remain perfectly white.

Gasto Claveus, whom I have spoken of in treating upon gold, kept ounce of silver in a state of constant fluidity in a glass-house furnace two months, and upon re-weighing it found that it had lost only one-lfth of its weight. It has however been proved, that if silver be heated a stream of oxygen gas the whole of it may be volatilized.

An alloy of silver with gold was formerly employed for gold coin. dern silver coin is an alloy of silver and copper. An amalgam of silver requently employed for covering the surface of copper, or other me-. It is a process inferior in its effect to that of plating.

The proper solvent for silver is the nitric acid; and if the silver be e, the solution will be colourless. If it contain gold, that metal will precipitated as the silver dissolves. In dissolving dollars, I have etimes seen a considerable quantity of gold precipitated. The Spanish lars, I believe, always contain gold.

Mr. Keir invented a compound acid for dissolving silver, which is a d of nitro-sulphuric acid. It is much employed at Birmingham for arating the silver from old plated goods. It is known to the work-n by the name of *stripping aquafortis*.

ilver is dissolved in nitric acid for forming the metallic tree. It is a asing experiment attended wth very little expense. A metallic cry-lization somewhat similar may be made by suspending a piece of zinc solution of acetate of lead. See Gren's *Principles of Modern Che-try*, vol. ii. page 382; or Dr. John Thomson's edition of Fourcroy's *ments of Chemistry*, vol. ii. page 487.

This oxide is a compound of about 100 of silver and 7.3 of oxygen.

ilver, when reduced to a liquid amalgam with mercury, is liable to oxidized at the temperature of the atmosphere. This is owing to its ing lost its natural coherence by that operation. The same may be d of an amalgam of gold.

What salts *are there of silver?*

The nitrate of silver[a] is best known ; but in analysis the sulphate of silver is also a most useful test : many other salts of this metal[b] may likewise be formed The muriate and the carbonate of silver are both found native[c]. Silver may also be combined with chlorine[d], with iodine, with phosphorus[e], and with sulphur[f].

What are the uses *of silver?*

Silver is used chiefly for ornamental work, for domestic utensils[g], and for current coin : but for thes

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[a] This salt is kept in chemical laboratories as a test for the muriati acid. When melted, and run into moulds, it forms the lunar caustic o the apothecary. When dissolved in water and left at rest, it crystallize in brilliant transparent plates of different forms. Though the solution i as pale as pure water, it will stain the skin and other animal substance of an indelible black. It is employed to dye human hair; for stainin marbles and jaspers; and for silvering ornamental work. This salt i the most powerful antiseptic known. One ounce of it dissolved in 12,00 ounces of water will preserve the water from putrefaction for ever, an it may any time be separated therefrom in a few minutes, by adding small lump of common salt. Dr. Black, vol. ii. page 661. An ingeniou method of silvering ivory by the solution of this salt may be seen in Coun Rumford's *Philosophical Papers*, vol. i. page 22.

A solution of nitrate of silver mixed with a little gum water forms, i conjunction with an alkali, the *indelible ink* used in marking linen.

[b] Hyperoxygenized muriate of silver has been used in making fulminating powder. If this salt be mixed with half its weight of sulphur and struck slightly, it detonates with prodigious violence. The flash i white and vivid, and the silver is reduced.

What is usually called *fulminating silver* is made by a different process; but as it is so dangerous an article, it was thought best to omi giving directions for preparing it in a work designed principally for th use of the young and the inexperienced. It is so dangerous, that a minute quantity only can be made at a time with safety, and even that coul not be removed to a phial, without the utmost risque of shattering th glass into ten thousand pieces by its detonation.

[c] Muriate of silver, called horn-silver and corneous silver-ore, has bee found massive and crystallized in Saxony and in South America. Carbonate of silver has been found in masses in Swabia. It is composed o oxide of silver 72.5, carbonic acid 12, oxide of antimony 15.5.

[d] The chloride of silver is a compound of about 81 oxide of silver an 19 muriatic acid; or on the system of chlorine, about 75½ of silver an 24½ of chlorine.

urposes it is generally alloyed with copper[h], without hich it would not have sufficient hardness to sustain uch wear[i].

What is the history and origin of palladium?

PALLADIUM was discovered by Dr. Wollaston in e year 1803[k]. It exists in the ores of platina, both ose from Peru and the Brazils. It is procured by ssolving crude platina in nitro-muriatic acid, and ecipitating the saturated solution by a solution of ussiate of mercury. The precipitate, when washed, ied, and exposed to a strong heat, is converted into

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[e] The proportions of silver and iodine in the iodide of silver are not actly known. The phosphuret of silver is a white crystalline substance onsisting of 80 of silver and 20 of phosphorus.

[f] Sulphuret of silver is somewhat similar to lead in its texture, but of violet colour. According to Vauquelin it is a compound of silver 100, lphur 14.59. Sulphuret of silver is found native.

[g] Pliny observes, that such was the luxury of the Romans, that it was nply reckoned a piece of elegance to consume in the ornament of aches, and in the trappings of horses, metals which their ancestors uld not use even in drinking-vessels, without being astonished at their n prodigality. Nero and his wife shod their favourite horses with gold d silver. Silver was formerly of more value when compared with gold an it is at present. Herodotus informs us that in his time the relative lue of gold and silver in Persia and Greece was as 13 to 1. Plato, who urished fifty years after Herodotus, says that the value of gold in eece was to that of silver as 12 to 1: and Menander, who wrote about ee hundred years before Christ, estimates the value of gold to that of ver at 10 to 1. In Great Britain, calculating from the value of the cur- t coin of the realm, gold is now rather more than 15 times the value silver.

[h] Our standard silver is formed with about 37 parts pure silver and 3 ts copper. One pound of standard silver is coined into 62 shillings.

[i] Silver is also used for plating other metals, for silvering dial-plates, . An account of these different processes may be found in Imison's *ements of Science and Art.*

[k] When Dr. Wollaston had discovered palladium, he contrived to have offered for sale in London, without affording the public any informa- n respecting its origin, and with a very imperfect account of its pecu- r properties as a distinct and separate metal. This induced Mr Che- vix, who supposed it to be a compound substance, to examine it; and gave it as his opinion, that the new substance was an alloy of platina l quicksilver. Soon afterwards Dr. Wollaston announced that he had covered the new metal in the ore of platina, and that he believed it be a simple substance.

palladium[a]. This metal was named palladium merely because it was obtained in a separate state at the time that the new planet was discovered which had been named *Pallas*[b].

What is the nature of palladium?

Palladium is a hard, malleable metal, of a white colour like platina, and susceptible of being polished. It fuses with difficulty, and is not altered by exposure to the air in common temperatures. It has but little elasticity, and when broken discovers a crystalline texture. It enters into combustion when heated intensely by means of oxygen gas, and affords a brilliant spectacle. The specific gravity of some specimens was found to be 11, of others 11.3 up to that of 12.0, according to the different methods by which they were prepared. Its melting point is not known. It is soluble in nitro-muriatic acid, and affords a beautiful red solution[c]. Its oxide assumes a chesnut brown colour, and is soluble in muriatic acid[d]. This metal has

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[a] Metallic palladium and the other metals from the ore of platina may be purchased of Messrs. Richard and George Knight, Foster-Lane, London.

[b] Since then, Dr. Wollaston has discovered a native ore of palladium, consisting of that metal alloyed with a minute portion of platina and of iridium. It is found in grains, along with the grains of native platina, in the alluvial gold districts in Brazil.

[c] Green sulphate of iron precipitates palladium from an acid solution, in a metallic state. Recent muriate of tin may be considered to be a test of palladium, as it precipitates this metal from its neutralized solutions of a brown or dark orange colour. Prussiate of potash occasions an olive-coloured precipitate.

[d] According to Berzelius the oxide of palladium consists of palladium 87.56, oxygen 12.44.

[e] Palladium has been combined with gold by Dr. Wollaston for the graduation of the circular instrument constructed by Mr. Troughton for Greenwich observatory. It has the colour of platina, but is much harder, which fits it peculiarly for receiving the graduations. For further information respecting palladium I must refer to the volumes of the *Philosophical Transactions* for 1803, 1804, and 1805.

itherto been obtained but in small quantities, and onsequently has scarcely been applied to any use[e].

What is the history and origin of rhodium?

RHODIUM was discovered by Dr. Wollaston in the ear 1804[f]. He obtained it by a peculiar process from he ore of platina, or rather from the nitro-muriatic olution which remained after the platina had been recipitated as far as possible by means of muriate of mmonia[g]. When the metal was obtained, the Doctor oon perceived that the salts formed with it gave rose-oloured solutions; and considering this to be the ost striking characteristic of the new substance, he amed it *rhodium*.

What is the nature of rhodium?

Rhodium is a white metal, with a tint of yellow, omewhat similar to silver: it is as hard as iron, but ore brittle; and excepting iridium, it is more infusi-le than any other metal[h]. It readily combines with rsenic or sulphur, and in either of these states of ombination melts readily. It is insoluble in all the

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[f] For a considerable time after Dr. Wollaston had announced the dis-overy of rhodium, it was very much doubted whether this was really a w metal, or merely a metallic alloy, until Descostils undertook the vestigation and confirmed every thing which Dr. Wollaston had as-rted. For particulars consult *Journal de Physique*, tome lxi. page 399.

[g] The clear liquor separated from the precipitate was acted upon by a d of zinc. By the zinc a black powder was thrown down, which was ashed with very diluted nitric acid. This black powder was redissolved dilute aqua regia; to this solution some common salt was added: the hole was then evaporated to dryness and washed with alcohol until it d dissolved all the soluble matter; there remained behind a deep red bstance, which when dissolved in water and acted on by a rod of zinc, forded a metallic powder, which intensely ignited with borax gave a etallic button of rhodium.—Davy.

[h] This metal is so infusible that Dr. Wollaston, who discovered it, has ver been able to melt it so completely as to produce a solid button of etal free from cavities or hollows.

pure acids. It will form alloys with all the metals except mercury, and for the most part these alloys are soluble in nitro-muriatic acid. The specific gravity of rhodium is 10.649[a].

What effect has oxygen upon rhodium?

When rhodium is reduced to powder and heated in an open crucible, it readily absorbs oxygen from atmospheric air and becomes converted to an oxide. By different modes of treatment three distinct oxides may be formed with this metal[b]. The first, or protoxide, is *black*, the deutoxide is a light *brown*, and the peroxide dark *red*.

What is the history and origin of iridium?

IRIDIUM was discovered in the year 1803 by Mr. Smithson Tennant, and also by a foreign chemist of the name of Descostils, who soon afterwards published an account of his experiments in the Annales de Chimie. This peculiar substance was found in connexion with another new metal called osmium, in the black powder[c] which remains undissolved when the ore of platina has been digested in nitro-muriatic acid[d]. It was named iridium from *iris* the rainbow,

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[a] An alloy which had been formed with one part rhodium and two parts lead was found of the specific gravity of 11.3, from whence we may presume that the real specific gravity of rhodium is very nearly the same as that of lead.

[b] Berzelius supposes the oxygen in these oxides to be in the proportions of 1, 2, and 3, and conceives them to be composed as follows:

	METAL.		OXYGEN.
Protoxide of rhodium . . .	100	+	6.71.
Deutoxide	100	+	13.42.
Peroxide	100	+	20.13.

[c] For the method of obtaining iridium from this powder, I must refer the reader to Sir Humphry Davy's *Elements of Chemical Philosophy*, page 436.

[d] In the year 1805 Dr. Wollaston discovered a native ore of iridium, composed of that metal and osmium alloyed together: it occurs in allu-

ı consequence of the variety of colours which are ob-
ervable in the different solutions of its several salts[e].

What is the nature of iridium?

This is a white metal, very similar in appearance
› platina. It is brittle, and extremely infusible[f]. It
soluble in the muriatic acid, but neither the nitric
ɔr sulphuric acid has any action upon it[g]. It forms
lloys with several of the other metals, and in all cases
e hardness of the several metals is greatly increased
the addition of the iridium. It is remarkable that
large portion of this singular metal may be united
gold without the colour of the gold being sensibly
ıpaired by it. It unites with oxygen in two propor-
ons, forming a deep *blue* or protoxide, and a dark
d which is thought to be the peroxide of iridium.
sulphuret of this metal may be also formed[h]. The
ecific gravity of iridium, according to Mr. Children,
18.68.

*Having thus examined the nature of the several
tals, endeavour to recapitulate the* general *proper-
of this class of bodies.*

The metals are simple substances[i], distinguishable

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soil in South America in the form of small white grains along with
ore of platina. It is heavier than crude platina, having a specific
ity of 19.25, whereas the native ore of platina has a specific gravity
ɔm exceeding that of 17.6.

From the colours of the solutions of iridium connected with the re-
of some experiments, Vauquelin asserted that the residual black
der of platina contained chromic acid; but this notion has been found
erroneous.

Mr. Children fused some iridium by means of his stupendous gal-
battery; but the metallic globule was porous, and manifested that
had been a deficiency of temperature in its reduction.

When iridium was digested in nitro-muriatic acid, it required 300
of the acid to dissolve one part of that metal.

This sulphuret is a compound of 100 iridium and 33.3 of sulphur. It
be prepared by means of an ammoniacal muriate of iridium, as has
shown by Vauquelin. *Annales de Chimie*, tome lxxxix. page 236.

The ancient chemists supposed the metals were *compound* bodies.

from all other bodies by their lustre, and generally by their great specific gravity; by their perfect opacity; and by their superior power of conducting electricity.

What are the obvious advantages which we derive from these bodies?

The metals are the great agents by which we are enabled to explore the bowels of the earth, and to examine the recesses of Nature; their uses are so multiplied, that they are become of the greatest importance in every occupation of life. They are the instruments of all our improvements, of civilization itself, and are even subservient in the progress of the human mind towards perfection[a].

You can doubtless offer some reasons why one metal possesses such opposite and specific differences from another[b]*?*

Their undecompounded nature was first suspected by Mayow, an ingenious physician who flourished in the middle of the seventeenth century, and appears to have had a notion of oxygen nearly a hundred years before it was discovered by Scheele and Priestley. See *Tractatus quinque Medico-Physici, &c. Studio Joh. Mayow, LL.D. &c.* Oxford 1674.

[a] The metals are seldom afforded by Nature otherwise than in a state of great impurity. It is to the use of our reasoning faculty that we owe the possession of any of them in a state fit for use. If we consider for a moment what would be the situation of the world if society were deprived of this class of bodies, we should then have some idea of the obligations we owe to the sciences of metallurgy and chemistry.

——————" Serene philosophy,
Effusive source of evidence and truth!
Without thee, what were unenlighten'd man?
A savage roaming through the woods and wilds,
Rough clad, devoid of every finer art
And elegance of life." THOMSON.

The best information respecting the analysis of metallic ores may be had from Klaproth's *Essays*, to which I refer the reader.

[b] Much information on the nature of many of the metals may be collected from Mr. Hatchett's valuable paper on Gold, in the *Philosophical Transactions* for 1803.

[c] " That beautiful law of Nature, whereby the different unorganized productions are impressed with regular forms, doth not cease to exist even under the hands of man in his various experiments. He finds the metallic ores under determinate forms, or geometrical figures of different kinds; and, when by art he reduces them to a metallic state, the same

This variety is not to be attributed to chance, but must certainly be the effect of consummate wisdom and contrivance[c]. These metals differ so much from each other in their degrees of hardness, lustre, colour, elasticity, fusibility, weight, malleability, ductility and tenacity, that Nature seems to have had in view all the necessities of man, in order that she might suit every possible purpose his ingenuity can invent, or his wants require.

By what means are these bodies rendered so important to us?

We not only receive this great variety from the hand of Nature, but these metals are rendered infinitely valuable by various other properties they possess. By their combustibility[d], their solubility in fluids, their combinations with hydrogen, chlorine, phosphorus, sulphur[e], and carbon, and by their union

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disposition still manifests itself." Thus, when the surface of a melted metal begins to congeal, if the crust be broken and the part still in a fluid state drawn off, the parts which had cooled will exhibit a regular metallic crystallization.

[d] Some of the metals are so combustible that they will burn before they acquire a heat sufficient to fuse them. This is the case with iron and zinc. A thin shaving of zinc, as we before noticed, will burn without melting, if held in the flame of a candle. The combustion of iron in oxygen gas is an interesting and beautiful experiment.—See an account of the method of managing it in the chapter on Combustion.

A very singular phænomenon takes place on the mixture of the metals with melted sulphur; for, as soon as the union commences, the temperature increases, and a considerable glow of light is extricated, similar to what happens in combustion. The same effects take place in hydrogen gas, and carbonic acid gas, and even in vacuo. These experiments have been adduced as objections to the modern theory of chemistry; but they merely tend to show that, in common cases of combustion, the *light* comes in part from the combustible, and not the whole of it, as has been imagined, from the atmospheric air. Light and heat attend other combinations as well as those of oxygen.

[e] Most of the metals will unite with sulphur by fusion. But the natural sulphurets contain more sulphur than the artificial ones; they must therefore have been formed by Nature by other means than those we employ to produce these compounds.

with each other[a], whereby compounds or alloys are formed, extremely useful in a variety of arts, manufactures, and other requisites of life.

By what other means does Nature render these bodies subservient to our wants, and capable of ministering to our comfort and gratification?

Nature has furnished us with a variety of acids, in some of which the most refractory metals may be dissolved[b] and purified, and thus rendered fit for a variety of purposes, to which they could not otherwise be applied. By combining the metals with oxygen[c] we can invest them with *new* properties, and are enabled to employ these to promote the progress of the fine-arts, by imitating the master-pieces of creation in the production of artificial salts, gems, and crystals, of every colour and of every shade[d].

How does oxygen produce these changes in metals?

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[a] Several of the metals have a very strong affinity for each other, as may be shown by direct experiment. Mercury will dissolve lead, bismuth, zinc, and some other metals. If a piece of lead and a piece of bismuth, each alloyed with mercury, be melted together, they form when cold a solid metallic mass; but from their affinity for mercury they have acquired so much fusibility that they will melt by the heat of boiling water. See note, page 318.

[b] The alchemists were in search of an universal *solvent*, which they termed *alkahest*, and which was to dissolve not only every metal, but all substances in nature:—Sir H. Davy has however remarked, that if such a solvent really existed, nothing would be so much dreaded by modern chemists. It would prevent the analysis of every mineral into which it entered, and would be like the fabled water of the Styx, which petrified every thing it touched. How different are the views of the scientific chemist from those of the ancient adepts, who concealed their knowledge with the greatest care, and who appear to have had no other object but how to surprise an ignorant and credulous multitude!

[c] This is exemplified in a striking manner by the metal called chromium. When acidified and combined with lead, the metallic salt that results is of a beautiful orange yellow; whereas chromat of mercury is of the colour of vermilion; chromat of silver, of a carmine red; chromat of zinc and bismuth, a bright yellow.

[d] If phosphoric acid be united with silica by fusion, artificial precious

Different metals, by their union with oxygen, acquire different colours, and the same metal attains a different hue, according to the portion of oxygen combined with it[c]; so that this wonderful substance seems destined not only to render us the most important services, but to embellish the works of creation, by the beatiful tints which it imparts to almost all subjects, whether of the animal, vegetable, or mineral kingdom[f].

You seem to think that the changes which metals undergo by their absorption of oxygen are the most surprising phænomena of Nature:—can you recollect some other properties of oxygen, to serve as a comparison, and to elucidate its importance?

When I consider, in addition to the multiform effects of oxygen upon metals[g], that no animal can exist, few of the acids, earths, or alkalies can be formed,

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ones may be prepared with the compound, which may be coloured to itate any particular kind, by one or other of the metallic oxides.

In making enamels and artificial gems, the processes of Kunckel may depended upon more than those of any other writer. He was the perintendant of several foreign glass-houses.

The oxide of iron is an eminent example of this change of colour. ny distinct colours, besides a great variety of shades, are observed in nerals containing iron: and to the iron in most cases is the colour to ascribed. Black in the obsidian. Green in the euclase. Blue in the ulite. Red in the garnet and ruby. Yellow in the topaz. Brown in tourmalin. While the somnite, which contains iron, is totally devoid colour, it being a *white* mineral. See Dr. Bancroft *on Permanent Co- rs*, article *Iron*, and Sir John Hill's translation of *Theophrastus's His- y of Stones, &c.* 8vo. 1774.

I would recommend to the preceptor the perusal of an interesting er on Oxygen, by Fourcroy, in one of the volumes of the *Annales de imie*. A more comprehensive idea of the nature and operation of this derful substance may be acquired by reading that essay, than from st other treatises on that subject.

It is no unusual thing for chemistry to be called by its votaries a inating science. That it is the most useful of all sciences cannot be ied; nor can there be the least doubt but that it has a strong tendency enchant those who devote their attention to it. It serves as a powerful no combustion can take place[a], nor even the smallest vegetable perform its proper functions, without the agency of this most astonishing substance; I cannot but exclaim—We want no further proofs to demonstrate, that the organization of the world has been effected by consummate wisdom and goodness—attributes belonging to HIM only, who has thus supplied our wants, and ministered to our comforts, and even to our luxuries. Other instances might be enumerated in which oxygen is indispensably necessary. Its importance is, however, too eminently conspicuous to be overlooked in the formation of WATER; nearly *nine-tenths* of every particle of which, whether we consider it in the ocean, or in the lakes, rivers, and fountains, that pervade every corner of this material world; or contemplate the immense quantity always floating as vapours in its atmosphere; we shall find to consist of this one important *simple* substance, OXYGEN[b].

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stimulus to youth, as it occupies their time so satisfactorily to themselves, and renders all low and unworthy pursuits truly detestable. But amidst the great variety of subjects, which this science embraces, the changes which the metals undergo, by their absorption of oxygen, are perhaps more eminently calculated than any other of its departments, to give a relish for chemical pursuits, and to engage the young mind in the unremitted examination of the works of creation.

————"The philosophic youth
To NATURE's voice attends, from month to month,
And day to day, through the revolving year;
Admiring, sees her in her *every* shape;
Feels all her sweet emotions at his heart;
While TRUTH, divinely breaking on his mind,
Elates his being, and unfolds his powers." THOMSON.

[a] The instances of combustion in chlorine gas, and in the vapour of iodine, occur so seldom, and then only in philosophical experiments, that it has not been thought worth while to alter the text on account of these exceptions.

[b] It is also remarkable, that all the liquids that are conductors of electricity and galvanism contain oxygen as one of their elements.—See Mr. Cruickshank's paper in the 4th volume of Nicholson's *Journal*, in quarto.

CHAPTER XI.

OF OXIDES.

WHAT is an oxide?

Any metal or combustible body which is combined with less oxygen than is sufficient to render it *acid*, is usually called an *oxide*.

What substances are capable of forming oxides?

The mineral, the animal, and the vegetable kingdoms, all furnish matters which are convertible into oxides by an union with oxygen[a].

In what way do metals become united to oxygen?

There are several ways in which metallic oxides are formed, the chief of which are by the access of atmospheric air[b], by the decomposition of water, and by the decomposition of acids.

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[a] The oxides appear to range themselves into two classes. There are oxides which are permanently such, and there are others which seem to possess only a kind of intermediate state between combustibles and acids, being convertible into acids by a further portion of oxygen. This will appear as we proceed.

According to the old theory, metals were supposed to be converted to *calces*, as metallic oxides were then termed, by the loss of an imaginary substance called phlogiston; and when these calces were reduced to a metallic state, it was imagined that they recovered their phlogiston from the carbonaceous matter employed in their reduction. Those persons who have not been in the habit of reading the works of the older chemists may understand their phraseology by attending to the following particulars: In most cases, all that is necessary is to substitute the word *oxygen* for *phlogiston*, with a slight inversion of the language. For, the effects which they attributed to the combination of phlogiston, appear to be due to the extrication of oxygen; and what they supposed to be owing to the loss of phlogiston, was really occasioned by the absorption of oxygen. See Kirwan's *Essay on Phlogiston*, octavo, 1787.

[b] Iron may be mentioned as a familiar example of a metal becoming oxidized by atmospheric air. It is well known that when this metal is

Will all metals become oxidized by exposure to the air?

No: gold, silver, and platina, cannot be oxidized, unless in a very high temperature; though iron[a], copper, and lead, merely by long exposure to the air, will become oxidized in the coldest atmosphere. Manganese, by such exposure, will in a few hours be converted into a perfect oxide.

Are metals ever exposed to the air with the design of converting them into oxides?

The common red lead of the shops, which is a true oxide of lead, is made by melting that metal in ovens[b] so constructed as to have a free access of atmospheric air[c].

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exposed to air and moisture, it acquires rust, or in other words its surface is converted to an oxide. If thin shavings of iron be thus submitted to the united action of air and water until the whole is completely oxidized, the metal will be found to have acquired an increase of nearly half its original weight by its absorption and solidification of oxygen; it will have become pulverulent, and have lost the property of being attracted by the magnet. 34.5 parts of iron + 10 of oxygen = 44.5 of green oxide of iron; and the same quantity of iron + 15 of oxygen are = 49.5 red oxide.

Some of the metals combine so readily with oxygen, that they become converted to oxides at common temperatures, even in air which has been deprived of its hygrometric water. The metals of the alkalies and the earths are of this nature, to which arsenic and manganese may be added, and perhaps some others.

[a] Metals not only become oxidized by atmospheric air, but sometimes, by exposure to its action, pass from a lower to a higher degree of oxidizement. Thus, if a solution of the common sulphate of iron be exposed to the atmosphere, the oxide of iron acquires a further dose of oxygen, and by degrees a portion of the metal, in a higher state of oxidizement, is precipitated.

[b] Here it may be proper to remark that a different degree of temperature is generally requisite for the oxidizement of each metal, and sometimes for the production of different oxides of the same metal. Thus, in one temperature lead is converted to massicot, and in a higher temperature becomes minium. Gold and platina may be oxidized by the high temperature which is produced by a galvanic battery; and yet they may be exposed for weeks to the continued heat of a glass-house furnace without undergoing any alteration.

How is it known that the change of common lead to d lead is caused by the absorption of oxygen?

This is known by the increase of weight which the etal acquires during the operation[d]; and to confirm e fact, the oxide may be again reduced, and the iginal quantity of metal recovered unaltered.

Do all metals increase equally when converted into ides?

No: it has already been mentioned that each comnes with a proportion of oxygen peculiar to itself[e]; d this original quantity is in some metals subject to regular increase; and they differ not only in their pacity for oxygen, but also in their attraction for it; that one will often rob the other, thus reducing the st oxide to its primitive metallic form[f].

Some of the metallic solutions cannot be formed but in contact with ospheric air or oxygen. Thus, copper or lead, placed in acetic acid, excluded from the air, does not form any solution; but if the mixe be exposed, oxygen is absorbed, and the solution takes place.

The following account of the manufacture of red lead, from Watson's *mical Essays*, will be a satisfactory proof of this doctrine. In the ufactories of red lead in Derbyshire, the melted lead is exposed to ospheric air: the surface soon becomes covered with a dusky pel; this pellicle being removed, another is formed; and thus, by oving the pellicle as fast as it forms, the greater part of the lead is nged into a yellowish green powder. This powder is then ground fine in a mill, and, when washed and properly dried, is thrown back the furnace, and by constant stirring for 48 hours, so as to expose y part to the action of the air, it becomes red lead, and is taken out se. Twenty cwt. of lead generally give 22 cwt. of red lead; so that vt. of oxygen is absorbed from the atmosphere during the process.

The increase of a metal by the absorption of oxygen may be shown keeping a given weight of iron-wire red hot for some time in an iron e, or in the bowl of a common tobacco-pipe, and weighing the iron be and after it has been submitted to the experiment.

If the red oxide of mercury be heated in conjunction with filings of , the latter metal will abstract the oxygen from the mercury, and the ksilver will be restored to its metallic state.

inc, by its powerful attraction for oxygen, decomposes a great numof metallic solutions, and precipitates the metal from them in a llic form. This may be exemplified by the experiment of the metal-

What metals are oxidized by the decomposition o water?

Iron, zinc, tin, and manganese have the property o decomposing water, and become oxidized by the process. Thus the rust which forms upon polished iro is occasioned by the iron imbibing the oxygen of th water which it decomposes[a], as it meets it in the atmosphere. This metal, when heated, decompose water with great rapidity[b].

How do these metals operate in thus decomposin water?

This effect, like most of the operations of Nature depends on chemical affinity. These metals having greater affinity for oxygen than oxygen has for hydro

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lic tree, which has been attributed to Dr. Black. For the method of conducting it, see the Chapter of Experiments, No. 170.

Sir Humphry Davy has found that whenever one metal precipitate another from its acid solution, the body that falls down is usually fre both from acid and oxygen ; and that the whole of the oxygen and th acid is transferred from one metal to the other. Davy's *Elements of Chemical Philosophy*, vol. i. page 121.

The pin-manufacturers whiten their pins on the same principle. The fill a pan with alternate layers of pins and grain tin, into which they pou a solution of super-tartrate of potash, and then boil the whole for fou or five hours. In this process the tartaric acid first dissolves the tin, an then gradually deposits it on the surface of the pins, in consequence o its greater affinity for the zinc, of which the *brass* wire is composed.

[a] An increase of nearly 30 per cent. may be given to iron, by heatin it red hot, and passing a continued stream of the vapour of water ove it when in that state. This increase of weight arises from its decomposing the water, and imbibing its oxygen.

[b] The metals, which are capable of decomposing water, effect it muc sooner when assisted by heat than without. In this case the caloric unite with the hydrogen of the water, and carries it off in hydrogen gas ; whil the oxygen, the other component part of water, unites with the meta Hydrogen requires a very large portion of caloric to give it the gaseou form. This perhaps accounts for the necessity which there is of employing heat in making some kinds of metallic solutions.

[c] See the account of an experiment with zinc, page 85, which explain the operation of metals in the decomposition of water.

[d] This principle has sometimes been resorted to for the analysis of th different kinds of iron and steel ; for, if these be dissolved in diluted su

en, the oxygen of the water unites with the metal to rm a metallic oxide[c], while the hydrogen, the other gredient of the water, escapes in the form of gas[d].

Is it known what proportion of oxygen each metal quires, in order to its being converted to an oxide?

Most of the metals are capable of uniting with dif- rent proportions of oxygen[e], according to the mode which they are oxidized[f]; and the energy with hich a metal retains its oxygen is generally in an in- rse ratio to the proportion of oxygen which is com- ned with it[g].

In what instances are acids used to oxidize metals?

Many instances of this mode of forming metallic xides might be adduced: thus, common white lead

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uric acid, it is evident that the hydrogen which is evolved will be in act proportion to the real metal contained in them.

[e] When there are two or more distinct oxides of the same metal, they ay not only be distinguished by the different colours which they assume, t also by their chemical relation to other bodies. Thus, the salts formed th the *black* oxide of iron give a *white* precipitate with triple prussiate potash, while the salts composed with the red oxide yield a precipitate an intense *blue* colour.

[f] In the oxidizement of metals by acids, though there be no oxygen s sensibly present by which it is effected, oxygen exists in the acids, o in the water with which the acids are diluted; and the effect is owing the passage of a portion of oxygen from one of these substances to the etal; and the increase in weight which the metal acquires, is always ual to the weight of the oxygen absorbed. Whenever a metallic oxide ssolves in an acid, it causes the acid properties to disappear exactly as an alkali had been employed; and saturates corresponding quantities the different acids.

[g] If the black oxide of manganese be exposed to a strong heat, it gives oxygen gas, and becomes brown; but no heat as yet applied is capa- e of depriving it of the whole of its oxygen. Several similar instances ve been enumerated by Sir H. Davy. Thus the carbonate of soda, hich contains two proportions of carbonic acid to one of soda, gives off lf its carbonic acid with great facility by heat, but obstinately retains e other half. Nitric acid is easily brought to the state of nitrous gas the abstraction of oxygen: nitrous gas with more difficulty is con- rted into nitrous oxide; but nitrous oxide is still less decomposable an nitrous gas.

is made by exposing sheet lead to the fumes of acetic acid[a]; and the oxide of tin, by submitting that metal to the action of the nitric acid[b].

What are the properties *of metallic oxides?*

They are in general friable and pulverulent; have greater absolute weight than the primitive metal; and

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[a] The manufacture of white lead is conducted in the following manner: A number of earthen crucibles, holding from three to six quarts each, and nearly filled with vinegar, are placed in hot beds of tan: upon these crucibles thin sheets of lead, rolled up in coils, are placed, one coil over each crucible. The heat of the bed occasions the vinegar to rise in vapour, which attaches itself to the lead, and oxidizes its surface to a considerable depth. At a certain time the oxide which has been thus formed is scraped off, and the coils of lead replaced; in this manner the operation is repeated, till the whole of the metal is oxidized. This oxide, which contains a portion of carbonic acid, is afterwards *washed*, and ground for sale. See Mr. Hume's Observations on this subject in the *Medical and Physical Journal* for March 1805.

[b] The metallic oxides have generally the property of combining with alkalies, and with some of the earths, similar to the acids.—Hence originated the terms plumbate of potash, plumbate of lime, argentate of ammonia, &c. These terms, however, are certainly improper.

[c] The nature of the combination of oxygen with a metal, the subsequent solution of the metal in an acid, and its revivification, may be shown in a satisfactory manner by the following process: Take some clippings of copper, heat them in a mixture of 8 parts of water, 3 of sulphuric acid, and one of nitric acid, and when the copper is dissolved, dilute the solution with water, and set it aside to crystallize. The crystals thus produced will be the true sulphate of copper, and will exemplify the formation of a metallic salt. If these crystals be now dissolved in a little water, and the polished blade of a knife be immersed in the solution, the copper will be revived, and appear of its natural colour upon the knife. The oxygen having a greater affinity for the iron than the copper, passes to the iron, by which the copper becomes de-oxidized, and consequently insoluble in the acid: it therefore precipitates itself from the solution, and attaches itself to the knife in a metallic form. In the formation of sulphate of copper by this process the oxidizement of the metal, and its solution in the acid, seem to be only one operation; but the metal is undoubtedly *first* oxidized by the oxygen of the nitric acid, and *then* becomes soluble in the sulphuric acid.

[d] Not only acids but solutions of the alkalies will dissolve metallic oxides, and in some cases act upon the metals in a metallic state. If muriate of tin be treated with a solution of caustic potash, the tin will be precipitated; but on agitating the mass this will be re-dissolved. This preparation has been employed in the arts under the name of *stannate* of potash.

There is also a class of substances which is formed by the union of ammonia with metallic oxides, known by the name of *ammoniurets*. Some th the alkalies and the different acids form metallic ts[c].

Is it necessary to oxidize the metals that are in- ded to be formed into metallic salts?

All metals are incapable of dissolving in acids, alkalies[d], until they are combined with oxy- n[e]. This is a fact of great importance[f] to be

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hese have been employed in manufactures with great advantage. y are all decomposed by a strong heat. When the ammoniuret of is thus decomposed, the decomposition is accompanied by a very explosion.

It is not only true that all metals must be oxidized before they can issolved in acids, but they must contain a certain proportion of oxygen, h proportion varies according to the nature of the metal to be dis- ed, and the acid that is employed. On the other hand, if a metal has bined with more oxygen than the necessary proportion, it will pre- ate itself from the acid, and be incapable of forming a salt. The s are often perplexed by the operation of this principle. In making solutions of tin, if they add the tin to the acid too hastily, or in too quantities, and the aqua-fortis be not exactly of the best kind for purpose, the tin becomes, by the violent action of the acid, more ized than it ought to be, and precipitates itself instead of remaining e solution. To guard against this, the workmen generally add a tity of common salt, which being decomposed by the nitric acid, uriatic acid which is liberated dissolves the highly oxidized tin which d otherwise have been precipitated from the nitric acid. In some metallic solutions, such as that of the black oxide of manganese, &c. necessary to add a third substance, for the purpose of depriving the llic oxide of part of its oxygen, in order to prevent a precipitation.

t ought also to be remembered, that if there are two oxides of the metal, that which contains the most oxygen will saturate the most Dr. Henry has exemplified this chemical axiom in the following er. Corrosive muriate of mercury, says he, is composed of the red of that metal, united with muriatic acid; and the sub-muriate nel) consists of the black oxide, combined with the same acid. Now remarkable that, according to the experiments of Thenard, the n in the red oxide is just double of that in the black; and that the n the corrosive muriate is also precisely double that in the sub- ite.

nilar facts have been ascertained by Proust, with respect to the two ites of copper, as appears from the following statement:

vhite muriate consists of	100.00	parts of copper
	12.28	of oxygen
	41.59	of acid.
reen muriate consists of	100.00	of copper
	24.56	of oxygen
	83.18	of acid.

ain, the *solubility* of the metallic salts bears a proportion to the remembered: it is a truth to which there is no exception[a].

Is there any instance of the stronger acids being made use of by manufacturers to dissolve metals?

Yes: the manufacturers of sulphate of copper, commonly called makers of Roman vitriol, boil the oxide of copper in strong sulphuric acid[b], and dissolve it by that operation[c].

What other instances are there of manufacturers using the mineral acids for dissolving metals?

Silver is dissolved in nitric acid, by the refiners, in the business of parting[d]; gold is dissolved in nitro-muriatic acid, for painting china; and the dyers use

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quantity of oxygen in the oxides, and consequently to the quantity of acid with which the oxide is combined. Salts, in which the metal is at the minimum of oxidation, are generally those which are most insoluble.

[a] It is now proved that metallic salts can be formed with the metal in certain states of oxidizement only. Thus, the salts of iron have been supposed to consist of the metal in determinate degrees of oxidizement one, the green sulphate, containing it at the *minimum*; the other, the red sulphate, at the *maximum*; and that between these there are no intermediate combinations. Berthollet has indeed remarked (see *Chemical Statics*), that in the crystallization of sulphate of iron, the firs crystals are nearly without colour; those which succeed in the subsequent crystallizations assume more and more colour, to a deep green and at last there is a liquor not capable of crystallizing, and which contains the metal in the state of the highest oxidizement. This proves says he, that some metallic salts have not fixed proportions of oxygen but pass by insensible gradations from one state to the other. Notwithstanding this great authority, it is now generally admitted that the appearances which Berthollet notices may be explained, by supposing tha these intermediate colours are owing to nothing but different mixtures of the sulphate of iron with the super-sulphate of that metal.

[b] Concentrated sulphuric acid at the temperature of the atmosphere has very little action on any of the metals. In like manner, strong nitric acid produces no sensible effect upon iron; but if a few drops of wate be added to the acid, the iron will immediately commence its oxidizemen and be dissolved with rapidity.

[c] This is common blue vitriol. The mode of its manufacture may be collected from a former note.

[d] For an account of this business, consult Lewis's *Commerce of th Arts*, page 135 &c.

large quantities of tin dissolved in a peculiar acid prepared for that purpose.

Is it possible to recover metals which have been dissolved in acids?

The attraction of the different metals for oxygen is so various, that several of them, when dissolved, may be precipitated even in a metallic form, by the addition of metals that have a greater affinity to oxygen than the dissolved metal[e].

What is the usual mode of reducing metallic oxides?

Charcoal is the agent usually employed, on account of its superior affinity for oxygen[f].

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[e] This is exemplified by the refiners in their operations. When the lver is dissolved in aqua-fortis, they recover it by placing plates of coper in the solution. The copper absorbs oxygen from the silver, and he latter is precipitated in a metallic state. All metals have the power f de-oxidizing gold and silver; copper will take oxygen from mercury; nd iron will reduce an oxide of copper. The degree of attraction for xygen, which the different metals possess, seems to be in the following rder: manganese, zinc, iron, tin, antimony, arsenic, nickel, cobalt, coper, bismuth, mercury, silver, gold, platina.

[f] The usual mode of procedure is to mix a quantity of charcoal with e metallic oxide, and subject the mixture to an intense heat in crucibles. he oxygen combines with the charcoal, and with a portion of caloric, and es off in carbonic acid gas; the metal then falls to the bottom of the ucible, and runs into a solid mass.

The reduction of metallic oxides, by submitting them to the action of e, probably gave rise to the fable of the Phœnix, a favourite emblem th the old chemists:

> "Whene'er Arabia's bird, by age opprest,
> Consumes delighted on his spicy nest,
> A filial phœnix from his ashes springs,
> Crown'd with a star; on renovated wings
> Ascends exulting from his funeral flame,
> And soars and shines, another and the same." Darwin.

It is not a new idea that combustion does not destroy the matter on hich it operates. I have seen an old engraving of sundry chemical pparatus, with a phœnix in the midst of its flames, with this superription:

"Naturæ regna instar Phœnicis per ignem reviviscunt."

Are you acquainted with any other agent which is capable of effecting the de-oxidizement of a metal?

Yes: some of the metals have so slight an union with oxygen, that even light[a] will separate it, and reduce the oxides to their original metallic state[b]. Hydrogen gas[c] and some other compounds will effect the same purpose, when assisted by heat[d].

What oxides are there besides metallic oxides?

We are acquainted with an oxide of each of the following simple combustibles[e], phosphorus, hydrogen, and carbon, and with two of nitrogen.

What is the origin of the oxide of phosphorus?

If phosphorus be not preserved entirely from the access of atmospheric air it soon becomes first white, and then of a dark brown colour, by its union with oxygen. In this state it is *oxide* of phosphorus[f].

What is the nature of the oxide of hydrogen?

Hydrogen differs from the other two simple combustibles in being capable of combining only with one dose of oxygen, whereas *they* form acids as well as

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[a] Oxygen gas is composed of oxygen, caloric, and *light*. Without a chemical union with light it would not be in the state of gas.

[b] Sennebier discovered that the rays of light have not all the same chemical effects;—that the violet rays, for example, will blacken recent muriate of silver in 15 seconds, though the red will not produce the same effect in less than 20 minutes. Sir Humphry Davy has found that "a solution of chlorine in water becomes a solution of muriatic acid most rapidly, when placed in the most refrangible rays in the spectrum." Davy's *Elements of Chemical Philosophy*, page 212. Respecting some other properties of light, see Additional Notes, No. 21.

[c] Mrs. Fulhame has explained the operation of hydrogen in this process very satisfactorily. See her *Essay on Combustion*, printed for Johnson, 1794.

[d] If the red oxide of lead be put into a receiver of hydrogen gas, and the oxide be heated by means of a glass lens, the oxygen of the metal will combine with the hydrogen to form water, and the metal will be completely revived.

[e] All the products arising from the union of the simple combustibles with oxygen are either oxides or acids.

oxides. The combination of oxygen with hydrogen produces water[g].

What is the nature of the oxide of carbon?

The oxide of carbon is in a gaseous form, and is called *carbonic* oxide.

How is carbonic oxide prepared?

Carbonic oxide, which was one of the last discoveries of Dr. Priestley[h], is procured by heating charcoal with metallic oxides or earthy carbonates; by which means the charcoal absorbs sufficient oxygen to convert it to the state of gas.

What is the difference in the composition of carbonic oxide *and carbonic* acid?

Carbonic *oxide* contains about 57, and carbonic *cid* about $72\frac{1}{2}$ per cent. of oxygen[i].

What are the properties of carbonic oxide?

Carbonic oxide, like most other gases, is invisible nd elastic; its specific gravity is somewhat less than hat of atmospheric air; its smell is offensive; it has he property of uniting with chlorine[k], and it is highly ombustible[l]; but it is a gas that will not itself

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Phosphorus, when newly prepared, always contains some oxide of osphorus mixed with it; but this may be easily separated by plunging mass into water heated to about 100. The phosphorus melts, while oxide remains unchanged, and swims upon the surface of the melted osphorus.

For the nature and properties of water, see Chapter iv. page 78.

Dr. Priestley first exhibited the carbonic oxide, but we are in-ted to Mr. Cruickshank for the true explanation of its nature and perties.

Carbonic oxide is composed of 57 parts oxygen and 43 carbon. A ndred cubical inches of this gas weigh about 30 grains. Carbonic contains $72\frac{1}{2}$ oxygen and $27\frac{1}{2}$ carbon.

For an account of this singular compound, which has been called *sgene gas*, see Note, page 155.

Carbonic oxide burns with a lambent blue flame in atmospheric air; it burns with more rapidity and brilliancy when mixed with oxygen support combustion, neither is it fit for animal respiration[a].

What are the oxides of nitrogen?

The first degree of oxidizement produces *nitrous* oxide; a further portion of oxygen forms *nitric* oxide. Both these oxides are in the state of gas.

What is the origin of nitrous *oxide; and how is it procured?*

Nitrous oxide is another of the gases discovered by Dr. Priestley[b]. It is readily procured by exposing crystals of nitrate of ammonia in a retort, to the heat of a lamp[c], by which means the ammoniacal salt is decomposed, and this gas evolved.

What are the properties of nitrous oxide?

This gas, in the proportions of its constituent parts[d], bears the nearest resemblance of any other to atmospheric air. It will support combustion even better than

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[a] According to some French chemists, birds drop down dead immediately on being put into this gas. These chemists attempted to breathe it themselves; but it produced giddiness and faintness.—*Annales de Chimie*, tome xxxix. page 56.

[b] Dr. Priestley discovered this gas about the year 1776, and called it *dephlogisticated* nitrous gas. For further information respecting its properties consult Davy's *Chemical and Philosophical Researches*. Sir Humphry Davy investigated it with great care, and pointed out its nature and properties.

[c] The heat should not be less than 340°, nor above 400°. One pound of dry nitrate of ammonia, well decomposed, will produce rather more than four cubic feet of air, or about 32 gallons wine measure. Its specific gravity, according to Sir Humphry Davy, is to that of hydrogen, nearly as 21 to 1. 100 cubical inches of it weigh about 49 grains.

Nitrous oxide, or the gaseous oxide of nitrogen, as it is sometimes called, is composed of 63 parts nitrogen and 37 oxygen by weight. Nitric oxide is formed with 47 parts nitrogen and 53 parts oxygen.

[d] See Note, page 41.

[e] Persons who have inhaled this gas have felt sensations similar to those produced by intoxication. Its effects on some people are truly ludicrous, producing involuntary muscular motion, and a propensity to leaping and running; on others, involuntary fits of laughter; and in all, high spirits, and the most exquisitely pleasurable sensations, without

common air; it is respirable for a short time[e]; it is absorbed by water; and is capable of forming salts of a peculiar nature, by its combination with alkalies[f] and metals. Its specific gravity is much greater than that of common air.

What is the origin of nitric *oxide; and how is it procured?*

Nitric oxide, or nitrous gas as it has usually been called, was also discovered by Dr. Priestley, during some of his first experiments on air[g]. It is procured by dissolving copper or mercury in diluted nitrous acid, and collecting the gas which rises during the solution.

What are the properties of nitric oxide?

Nitric oxide is an invisible gas, which assumes an orange colour whenever it comes in contact with atmospheric or any other air that contains oxygen. It

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y subsequent feelings of debility. When Mr. Robert Southey, the et, inhaled it, he declared that it produced in him sensations perfectly w and delightful; and for several hours afterwards he imagined that taste and smell were more acute than usual. In a poetical rhapsody, remarked, that he supposed the atmosphere of the highest of all posle heavens must be composed of this gas. See Davy's *Chemical and ilosophical Researches*; and Nicholson's *Journal of Natural Philoso-*, vol. iii. 4to, 446.

The substance usually called *red precipitate* is a compound of nitrous de and mercury. Its most appropriate name, therefore, would be the *ous oxide of mercury.*

This gas was used by Dr. Priestley for purposes of eudiometry. The t eudiometer was made in consequence of his discovery, that when rous gas is mixed with atmospheric air over water, the bulk of the xture diminishes rapidly, in consequence of the combination of the with the oxygen of the air, and the absorption of the nitric acid, thus med, by the water. Whenever nitrous gas is thus mixed with atmoeric air, the diminution will be in proportion to the quantity of the gen; of course this gas will always indicate the measure of oxygen sent in any portion of air submitted to trial. In consequence, howr, of some inconveniences attending the use of this eudiometer, others e been invented by Scheele, De Marti, Humboldt, Seguin, Berthollet, Davy.

produces suffocation in those animals which are made to breathe it, though some substances will burn in it. Its specific gravity is somewhat greater than that of common air[a].

What compounds are formed by means of nitric oxide?

Nitric oxide gas, when mixed with oxygen gas, forms nitric *acid*. The nitric acid of commerce owes its red colour to its holding this gas in solution.

What other oxides are you acquainted with?

Sugar and indigo are both vegetable oxides; and common soap owes its perfection to the absorption of oxygen[b].

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[a] If phosphorus be previously inflamed, it will continue to burn in this gas with as much splendour as in oxygen gas.

Dr. Priestley found, by experiment, that 100 measures of nitric acid, of a moderate strength, absorbed in two days ninety of nitrous gas; that when about 7 parts were absorbed, the acid assumed an orange colour, when 18 parts were absorbed a green colour, and when the 90 were combined it became red and fuming.

According to Sir Humphry Davy, the specific gravity of nitrous gas is to that of hydrogen as 14 to one: 100 cubical inches of it weigh 32 grains.

[b] In the essay prefixed to the first edition of the Chemical Catechism, page 19, I suggested to the manufacturers of soap an advantage that would arise from properly oxidizing the soap while boiling: the *late* experiments of some French chemists have established the truth of this theory, and demonstrated that this curious compound of oil and alkali is indebted in some measure to oxygen for its consistence.

[c] Seed oils are sometimes oxidized artificially for the purposes of painting. Linseed oil is thus boiled with the red oxide of lead. In this operation the oxygen of the metal combines with the oil, imparting to it the property of drying quickly. Oil thus prepared is called *drying* oil.

[d] All the oxides with which we are acquainted may be thus classed: I. That arising from the combustion of hydrogen, by which water, the oxide of hydrogen, is formed. II. Metallic oxides. III. Acidifiable oxides; or such as by an addition of oxygen pass from the state of oxides to that of acids. The oxides of phosphorus and nitrogen, with four of the metallic oxides, admit of this change. IV. Various combinations of carbon and hydrogen in the animal and vegetable kingdoms. To this class common charcoal, oils, gums, resins, wax, sugar, yeast, &c. belong.

[e] All organized beings, whether vegetable or animal, possess the materials of which they are composed only for a limited time: life itself

As you have mentioned several cases in which im- ortant and beneficial effects are produced by the ab- rption of oxygen, are there none in which it acts fferently?

Yes: butter, dried salt meats, and most of the oils[c] ecome rancid by absorbing oxygen from the atmo- here[d]; so that oxygen not only performs for us an finite number of valuable and important offices, but ppears to be one of the grand agents of decomposi- n and destruction[e].

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boon which is only *lent*, to serve the purposes of infinite beneficence. the proper period, *oxygen*, or some other powerful agent, effects the composition of the curious fabric, and sets all the elementary particles liberty, to form other equally perfect and complicated existencies[*]:

"Which *thus* alternating with death, fulfil
The silent mandates of the ALMIGHTY's will;
Whose hand, unseen, the works of nature dooms,
By laws unknown, — WHO GIVES AND WHO RESUMES." DARWIN.

[*] See Additional Notes, No. 26.

CHAPTER XII.

OF COMBUSTION.

What is combustion?

Combustion[a] may be defined to be a process by which certain substances decompose oxygen gas, absorb its base[b], and suffer its caloric to escape in the state of sensible heat. It has, however, of late years been discovered that combustion may take place without the agency or intervention of oxygen[c].

Are all substances capable of being burnt?

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[a] Lavoisier and other French chemists defined combustion to be the combination of any body with oxygen. This definition, however, has very properly been objected to; for there are many instances of oxygen combining with a body without producing combustion. Indeed, this union is sometimes effected when no combustion can possibly take place. Oxygen often combines with bodies without any sensible extrication of heat or light; but we never, in common language, give the name of combustion to any operation in which heat and light are not liberated.

[b] To render the explanation of this phenomenon more perspicuous, it may be said that oxygen exists in the state of gas in atmospheric air; that when a combustible is heated to a certain degree, it possesses such an attraction for oxygen, that it absorbs it from the air, and fixes it in a solid form; while the light and caloric, the solvents which gave the oxygen its aëriform shape, escape and diffuse themselves among the surrounding bodies. See Additional Notes, No. 36 and 38.

[c] This will be explained as we proceed with the subject; but a remarkable instance of this sort of combustion may be noticed in this place. Potassium in combining with arsenic and tellurium produces heat and light by their mutual chemical action, without the aid of oxygen or any substance that can be supposed to contain oxygen.

[d] The term *combustible* is applied to every body that is capable of being burnt in atmospheric air, or in oxygen gas, and, consequently, of uniting with oxygen, and liberating caloric.

[e] The combustible oxides consist of combinations of the combustible bodies, which have not undergone combustion, or their compounds, with oxygen. This class of bodies is very numerous, as it includes the greater part of animal and vegetable substances. The great combustibility of combustible oxides is probably owing to the weaker affinity by which their particles are united. Hence, they are more easily separated than homogeneous particles, and of course combine more readily with

No: some substances are combustible[d], others in- mbustible.

How are combustible bodies classed by chemists?

Into simple combustibles, compound combustibles, d combustible oxides[e]. In consequence of modern scoveries, the *chlorides* and *iodides* may now be ded to this list.

What do you mean by SIMPLE *combustibles?*

Those combustible substances that have resisted ery attempt to decompose them, are called simple mbustibles[f].

Endeavour to enumerate the simple combustibles.

The simple combustibles with which we are ac- uainted are hydrogen, sulphur, phosphorus, carbon[g], ron, and the metals[h].

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ygen. Those simple combustibles which melt easily, or which are in e state of elastic fluids, are also very combustible, because the cohe- n between their particles is easily overcome. See Nicholson's *Journal* 1802.

[f] For an account of the nature and properties of the simple combus- les, see Chapter ix. page 222.

[g] Some modern writers have enumerated *silicum* among the simple mbustibles distinct from the metals; but as I have, upon the authority Sir Humphry Davy, classed this substance with the metals, I refer r readers for an account of its properties to that chapter. See Chapter x. ge 269.

[h] We may be satisfied that metals are really combustible, by repeating e following simple and beautiful experiment of Dr. Ingenhousz:— Twist a small iron wire into the form of a corkscrew, by rolling it und a small stick; fix one end of it into a cork (which will fit a glass previously filled with oxygen gas), and lap round the other end a all bit of cotton thread dipped in melted tallow. Set fire to the cotton, d immediately plunge the whole into the jar of oxygen gas. The wire ll take fire from the cotton, and burn with great brilliancy, throwing t very vivid sparks in all directions. During the combustion, the iron mbines with the oxygen in the jar, and is converted into an oxide, with augmentation in weight of 35 per cent." Mr. Accum says, that a ick piece of iron or steel, such as a file, may be burned in oxygen gas, it be made very sharp-pointed, and a small piece of wood be stuck upon extremity, and set fire to previous to its being immersed in the gas. e method of suspending the metal in the jar may be seen in plate 4, . 17, of Lavoisier's *Elements of Chemistry*.

What are COMPOUND combustibles?

Compound combustibles are all such as are formed by the union of two or more of the simple combustibles[a]. Common coal is an instance of this combination[b].

What is the nature *of combustion*[c]*?*

The real nature of combustion is understood very imperfectly. Sir Humphry Davy describes it to be "the general result of the actions of any substances possessed of strong chemical attractions, or different electrical relations; and that it takes place in all cases in which an intense and violent motion is communicated to the corpuscles or minute atoms of bodies." It may however be added, that in every case of real combustion, light and heat are evolved.

What effects are generally produced by the process of combustion?

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[a] The compound combustibles have been arranged under the five following heads: 1st, Sulphurets; 2d, Phosphurets; 3d, Carburets; 4th, Alloys; 5th, Sulphuretted, phosphuretted, and carburetted Hydrogen.

[b] Hydrogen and carbon, intimately united in the capillary tubes of vegetables, form bitumens, oils, and resins, which are compound combustibles. See Additional Notes, No. 39.

[c] To the old chemists the process of combustion was quite inexplicable; its nature, indeed, was not at all understood till within these forty years. It is now known to be merely a play of affinities between oxygen, light, caloric, and the base of the combustible body; so that nothing is really lost, but new modifications of the same ingredients take place.

"When a stone, or brick, is heated, it undergoes no change except an augmentation of temperature, and when left to itself it soon cools again, and becomes as at first. But with combustible bodies the case is very different. When heated to a certain degree in the open air, they suddenly become much hotter of themselves, continue for a considerable time intensely hot, sending out a copious stream of caloric and light to the surrounding bodies. This emission after a certain period begins to diminish, and at last ceases altogether. The combustible body has now undergone a most complete change; it is converted into a substance possessing very different properties, and no longer capable of combustion." —Thomson.

[d] The component parts of the oxygen which is furnished by the supporters of combustion are two; viz. *oxygen* and *caloric*. The component parts of all combustibles are likewise two; viz. the *base* and *light*. If the

Combustion appears to be a double decomposition,
which the combustible and the supporter of com-
stion divide themselves each into two portions,
ich combine in pairs, the one forming the product,
other the fire which escapes[d].

What do you mean by SUPPORTERS *of combustion?*

The substances which are called supporters of com-
stion are not of themselves combustible, but are
cessary to the process; that is, no combustion can
r take place without one or other of the supporters
combustion being present.

*What substances are deemed supporters of com-
stion?*

There are only three[e] *simple* substances which are
pporters of combustion; viz. oxygen gas[f], chlorine
s, and iodine[g].

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first are called No. 1 and 2, and the two latter No. 3 and 4, the pro-
t of combustion will be formed by the union of No. 1 and 3, and the
pound which we call fire, will arise from the combination of No. 2
4. Dr. Crichton, I believe, was the first chemist who gave this view
ombustion; and in his public lectures elucidated the theory, by many
ropriate experiments.

To these three, fluorine, the base of fluoric acid, has been added as a
porter of combustion; but it does not appear to me that there is
lence enough at present to justify me in giving it that appellation.

The chief properties of oxygen have been described in the foregoing
ets; the following experiments may however be added to those al-
ly detailed. If oxygen gas be forced out of a bladder, or a gasometer,
n a piece of ignited charcoal, the combustion will be so much in-
sed, that the light thrown off will be too vivid for the eye to endure.
k-crystal that has been exposed to an intense heat in atmospheric
for a very long time, and has suffered nothing in its hardness, trans-
ency, or any other quality, will fuse like other substances when sub-
ted to a stream of oxygen gas.

f one ounce of strong nitrous acid, a compound of oxygen and azote,
nixed with about half its weight of concentrated sulphuric acid, and
red into a little oil of turpentine, the whole will immediately burst
flame. In this experiment it is the oxygen of the nitric acid which
duces the combustion. *The phial from whence the mixed acid is poured,
uld be tied to the end of a long stick, to preserve the operator from be-
injured by the splashing of the materials.*

There is a curious circumstance connected with this class of bodies, *To begin with oxygen,—let me ask you what explanation can be given of the manner in which oxygen supports combustion?*

The agency of oxygen in combustion is attributable to its affinity[a] for combustible bodies. For, whenever such bodies are ignited in circumstances favourable to combustion, they absorb oxygen from the air, or other contiguous substances[b], till the combustible is converted to an incombustible body.

From whence proceeds the heat which we observe during combustion?

In general, the heat produced by combustion arises from the decomposition of the oxygen gas of the atmosphere[c]; for, as the oxygen combines with the combustible body, it disengages the caloric which it held when in the state of a gaseous substance.

Can you explain this operation with more precision?

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which is, that they differ in their electrical relations from all other known simple substances, inasmuch as that they are always attracted to or elicited from the *positive* extremity of the voltaic battery, while all other elementary bodies are attracted by, or given out at, the *negative* extremity.

[a] Combustion, like all other chemical processes, may be explained by the laws of chemical affinity. The combustible having a greater affinity to oxygen than oxygen has to caloric, the oxygen gas is decomposed, and its oxygen combines with the ignited body, while its caloric, becoming free, produces the heat which is diffused among the surrounding bodies. As the oxygen unites with the combustible, it becomes more dense than it was when in the state of gas, consequently it has less capacity for caloric than it had; a portion of it, therefore, must be given out before the oxygen can combine with the new substance that attracts it from its former combination.

[b] We have incontestable evidence, that combustible substances unite with oxygen during combustion: thus, if iron which has been burned in oxygen gas be examined analytically, it will be found to consist of iron and oxygen; in like manner it will be discovered that burned phosphorus consists of nothing but phosphorus and oxygen; burned charcoal, of charcoal and oxygen; and burned sulphur, of sulphur and oxygen.

[c] Though every case of combustion requires that heat should be evolved, yet this process proceeds very differently in different circumstances. Hence the terms *ignition*, *inflammation*, *detonation*, &c.

The act of combustion effects a real analysis of mospheric air ; for while the oxygen combines with e combustible, the caloric, in the form of sensible at, is thrown off in every direction[d].

Does this account for the long continued heat which experience in every common combustion?

Whenever we burn a combustible body in order to ocure heat, a continued stream of atmospheric air ws towards the fire-place[e] to occupy the vacancy t by the air that has undergone decomposition, and ich in its turn becomes decomposed also[f]. Hence upply of caloric is furnished, without intermission, l the whole of the combustible is saturated with ygen.

What other effects are produced by combustion?

As the combustible burns, LIGHT is disengaged, d the more subtile parts of the combustible, now

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The rapid combustion that is occasioned by inflaming combustible stances, mixed with hyper-oxymuriate of potash, is owing to the large ntity of oxygen contained in this singular salt, and which it holds a very weak affinity ; and also to a large portion of caloric which this ious preparation contains in union with its oxygen, and which is lved while its oxygen enters into combination with the combustible. note[f], page 191.

On some parts of the continent rooms are warmed by stoves that e ash-pits without ; so that the combustion is kept up by air which no connexion with the air of the room : consequently there is no cur-t, and the persons who occupy them are not subject to the inconvenice of cold draughts of air.

Upon this principle, that a current of air hastens combustion, the gand's lamp is constructed ; for, in consequence of this perpetual ply of oxygen, the air is renewed every moment, and produces heat icient to burn the smoke as it is formed. The smoke which arises n a common fire is chiefly water in the state of vapour, with a mix-e of carburetted hydrogen and bituminous substances ; part of the er comes from the moisture of the fuel ; the other part is formed ing combustion, by the union of the hydrogen of the combustible h the oxygen of the atmosphere. What takes place in a common fire uld furnish an intelligent parent or preceptor with matter for several resting conversations, which could not fail to rouse the curiosity and templation of the pupil. See Additional Notes, No. 16 and No. 38.

converted by caloric into gas, are dissipated in that state[a]. When the combustion is over, nothing remains but the earthy parts of the combustible, and that portion which is converted to an oxide, an acid, a chloride, or an iodide, by the process[b].

From whence proceeds the light which you say is disengaged during combustion?

It is now generally supposed that the light and

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[a] Part of the caloric which is furnished by the supporters of combustion, generally combines with a part of the combustible, and converts it into gas.

"Thus heat from chemic dissolution springs,
And gives to matter its eccentric wings;
With strong repulsion parts the exploding mass,
Melts into lymph, or kindles into gas." DARWIN.

[b] The product of combustion is always either an *oxide*, or an *acid*, or both, except when the new metals potassium or sodium are ignited, and then an alkali is the produce. But indeed alkalies are now proved to be metallic oxides.

[c] If the light arose from the decomposition of oxygen gas, those combustibles which absorb most oxygen would give out most light; but this is not the case. *Pure* hydrogen in burning combines with more oxygen than any other body, and gives out more heat, yet the light is barely perceptible. Several instances might be adduced, in which the quantity of oxygen combining with the combustible, during this process, is greatest where the light is smallest.

Count Rumford has demonstrated that the light given out by a combustible body is in proportion to the elevation of temperature; in conformity to which he constructed lamps with many wicks, so placed as to communicate heat to each other; and these lamps burn with much more brilliancy, and afford much more light, than the same number of wicks would give if placed in separate lamps.

The existence of light as a constituent part of combustible bodies, seems to have been proved by the experiments of Deiman, Pacts, and others. These chemists exposed a mixture of sulphur and zinc to a high temperature, without any substance being present from which they could derive oxygen. At the instant when the sulphur and zinc formed a *sulphuret*, there was a vivid emission of light; and when the materials were examined, it was found that no oxidizement had taken place. On this subject see Mr. Portal's remarks, *Philosophical Magazine*, vol. xv. page 207, and Dr. John Thomson's Notes to Fourcroy, vol. i. page 190. See also Note[d], page 357 of this volume. It is also a very curious fact, that whenever vegetables are made to grow in the dark, no wax, bitumen, oil, or other combustible substance is formed in them; which shows that combustible substances cannot be produced without the presence of light.

ame which appear during this process proceed from
e combustible body[c], though some philosophers
ave imagined that the light comes in part from the
ecomposition of atmospheric air[d].

What is the origin *of light?*

Light, which is an extremely attenuated fluid mat-
r, is constantly transmitted from the sun[e] to the
rth. It is also found combined with several terres-
ial substances[f].

" That a great part of the light comes from the combustible, is evi-
nt from the colour of the light always depending upon the nature of
e combustible. Carbonic acid burns with a blue flame, carburetted
drogen with a white, charcoal with red, and sulphur with blue or
let." If quick-lime be slacked in the dark, the liberation of light will
very evident. See Additional Notes, No. 40; also note [c] page 234.

[d] The following fact seems to prove that atmospheric air contains
ht. Some time ago a soldier in the French army found that heat was
oduced by the condensation of the air in an air-gun. The experiment
s repeated before the National Institute, and proved satisfactory. If
e air be very rapidly compressed, heat is disengaged by the first stroke
the piston, sufficient to set fire to a piece of fungus match placed
thin the pump; and if the end of the pump be furnished with a glass
s which admits of the inside being seen, a ray of *vivid brilliant light*
l be perceived, on the first compression of the air. See Note, page 86.
Light is generally given out whenever oxygen combines with any
dy; oxygen, therefore, is scarcely ever extricated without the agency
light.

Light is transmitted to us from the sun, in little more than eight
nutes, which is a velocity almost equal to 200,000 miles in a second of
e; but the rays of light and the rays of caloric are distinct from each
er. It has been demonstrated that some rays from the sun produce
at, which have no power of communicating light. For a further elu-
ation of this subject see a paper by Dr. Herschel in the *Philosophical
ansactions*, and an account of the experiments of Sir Henry Englefield
the original volume of the *Journals of the Royal Institution*. The ve-
ity of light will appear truly astonishing, when we consider, that were
annon ball thrown from the sun, it would be more than thirty years
arriving at this earth, though it travelled throughout with the same
ocity that it acquires when first shot from the cannon.

Light is capable of entering into bodies, and of being afterwards ex-
cated without any alteration. Many instances might be adduced of
stances which, after being exposed to the sun's rays, appear luminous
the dark, and emit light for a longer or shorter period. Thus, sulphate
barytes, the shells of marine animals, and several other substances
y be made to absorb light, and emit it in the dark. There was once

What is the nature *of light?*

Light is a peculiar substance, the nature of which is little understood[a], but it possesses several very singular and striking properties[b].

Is the presence of atmospheric air necessary to combustion?

Until lately it was supposed that no combustible body could burn without atmospheric air, or at least without *oxygen* gas, which is a component part of the atmosphere[c]. It has however been discovered

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an instance of a diamond which had been exposed to the sun's rays and immediately covered with black wax, that shone in the dark several years afterwards on the removal of the wax. Light also combines with bodies, and forms one of their component parts. On this subject consult Dr. Hulme's paper in the *Philosophical Transactions* for 1800 and 1801; Dr. Herschel's paper in the former of these volumes, and Dr. Wollaston's in the volume for 1802; all which are extremely interesting. See also Dr. Henry's observations in the fifth volume of the *Manchester Memoirs.* From the following beautiful apostrophe to Light, by Milton, there is some reason to imagine that even in his time some idea was entertained of light being latent in bodies;

> "Hail, holy Light! offspring of Heaven, first born,
> Or of th' Eternal co-eternal beam,
> Bright effluence of bright essence increate——
> Thy fountain who shall tell? Before the sun,
> Before the heavens thou wert; and at the voice
> Of God, as with a mantle didst invest
> The rising world of waters dark and deep."

[a] Sir Isaac Newton described light to be a substance consisting of small particles, constantly separating from luminous bodies, moving in straight lines, and rendering bodies luminous by passing from them and entering the eye. Those who wish to become further acquainted with all the known properties of light, such as the refraction, reflection, inflection, &c. of its rays, may consult Newton's *Optics*, Fourcroy's *System of Chemical Knowledge*, and the several papers by Herschel and Count Rumford in the *Philosophical Transactions.*

[b] Light is decomposable into seven distinct rays of different colours. Some bodies absorb one coloured ray, others another, while they reflect the rest. This is the cause of colour in bodies. A red body, for instance, reflects the red rays, and absorbs the rest. A white body reflects all the rays, and absorbs none; while a black body, on the contrary, absorbs all the rays, and reflects none. Dr. Paley has remarked, "that if light had been made by a common artist, it would have been of one uniform colour; whereas, by its present composition, we have that variety of co-

at this axiom must be received with some limita-ons; as will presently be explained.

Having so far illustrated the nature of the opera-on of oxygen gas in combustion, it is necessary to quire on what account CHLORINE *GAS is arranged ith the supporters of combustion?*

When copper or gold in thin leaves, or tin, zinc, d some other metals in filings are thrown into lorine gas, they burn spontaneously[d], and the mpound which is produced by the combustion

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rs which is of such infinite use to us for the distinguishing of objects; ich adds so much to the beauty of the earth, and greatly augments the ck of our innocent pleasures."

> "Nature's resplendent robe!
> Without whose vesting beauty all were wrapt
> In unessential gloom."

ight has great effect on vegetation. See note[b], page 250. It also sesses the property of deoxidizing several of the metallic oxides, by nbining with their oxygen, to which it gives wings, as it were, to fly in the form of gas.

he glow-worm seems to have the faculty of absorbing light and giving ut at pleasure :—

> "Sweet child of stillness, midst the awful calm
> Of pausing nature thou art pleased to dwell,
> In happy silence to enjoy thy balm,
> And shed through life a lustre round thy cell."
>
> Dr. WALCOTT.

n the *Asiatic Annual Register* for 1802, we are told that there is a rrow of Hindostan, that has the instinct to light up its nest in the t-time with glow-worms, which it collects for this purpose; and it attaches them to the inside of its nest by means of a tenacious l of clay. See Additional Notes, No. 40.

here is an insect common in the United States, called the *lightning* , that is seen sometimes in considerable numbers, shedding its inter-ing light, on summer evenings, in the fields and gardens.

This may be demonstrated by placing a lighted candle under a glass nverted upon a plate of water. It will be seen, that the candle will ut as soon as it has consumed all the oxygen contained in the in-ed air.

If a bit of phosphorus, or a morsel of potassium, be suspended in gas, a similar effect will be produced, without either of these sub-ces being previously ignited, and the combustion will be vivid and sing. If a lighted taper be plunged into a jar of chlorine gas, it will inue to burn with a red flame, and a small portion of light will be ved. See Notes, page 153.

is denominated, in modern chemical language, a *chloride*.

What are the properties and distinguishing characteristics of the chlorides?

A chloride is a compound body formed by the union of a combustible substance with chlorine. By this process the chlorine gas is deprived of its latent heat, and the combustible is entirely altered in its appearance and properties. The chlorides are similar to the dry muriates. Thus, if the muriatic salts be heated red, or in any other way be deprived of water, they will in general be converted thereby to true chlorides[a]. Muriate of soda (common table salt), when reduced to dryness, is a chloride of sodium.

What is it that constitutes IODINE *a supporter of combustion?*

If the crystals of iodine and phosphorus come in contact at the common temperature of the atmosphere, combustion will ensue, and much heat will be evolved[b], but no light. Iodine combines also with oxygen, with chlorine, with sulphur, with most of the metals, and with some other substances. These compounds are called *iodides*.

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[a] This is not universally the case, because there are instances in which a metallic muriate may be heated and the muriatic acid driven off without decomposition; though, in general, the hydrogen of the acid unites with the oxygen of the metal to form water, and the chlorine thus divested of its hydrogen unites with the metal and forms a metallic chloride. Thus it is with common salt, or muriate of soda, when heated to dryness; for the hydrogen of the muriatic acid unites with the oxygen of the soda and they pass off together in the form of water, while the chlorine of the muriatic acid combines with the sodium of the soda, and a chloride of sodium is formed.

[b] If instead of mixing solid iodine and phosphorus, a bit of the latter substance be suspended in the *vapour* of iodine, the propriety of classing iodine with the supporters of combustion will be still more evident; for in this case the phosphorus will burn with great freedom and evolve

What are the peculiar properties of the iodides?

The nature and properties of the iodides are at resent but little known, and their employment in the rts has been extremely limited. The compound of odine and mercury is a red powder of considerable eauty; that of iodine and starch is a substance which akes a brilliant blue colour inclining to purple. Ere ong these iodides will probably be brought into use[c].

In what do combustible bodies differ from each other?

Combustible bodies differ from each other principally in the rapidity with which they absorb oxygen, r the other supports of combustion, and in the proortions of them which they can take up[d], to form the ew compounds.

What is the effect of these properties in the act of ombustion?

In general, the greater the quantity of oxygen gas r of the other supporters, which any combustible body capable of decomposing, the greater will be the deree of heat that is produced by the combustion.

How is it known that oxygen unites with the comustible body in the act of burning?

If a combustible substance be burnt in a sufficient

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uch heat without the intervention of oxygen, or any substance conning oxygen. Potassium will also burn in its vapour under similar cumstances, emitting a pale blue light.

[c] For some further particulars respecting this singular class of bodies efer the reader to the Additional Notes, No. 48.

[d] Almost all the simple substances are capable of combining with vaus doses of oxygen. Thus sulphur forms sulphurous acid and sulphuric d; phosphorus forms oxide of phosphorus, phosphorous acid, and osphoric acid; carbon also unites with different portions of oxygen, d forms carbonic oxide and carbonic acid. When either of these ple combustibles is united to any other, or to either of the alkalies, rths, or metals, the combinations are known by names ending in *uret*, sulphuret of potash, phosphuret of lime, carburet of iron, &c.

quantity of oxygen gas in a close vessel, and the product preserved, the whole will be found to be increased in weight[a] exactly in proportion to the oxygen gas consumed, and the combustible body will then have become incombustible[b].

What is the cause of a body becoming thus incombustible?

It becomes incombustible because it is incapable o combining with any more oxygen, or more of that supporter of combustion in which the process took place some bodies, however, may be rendered combustibl again by depriving them of the oxygen which the absorbed in their former combustion[c].

In the decomposition of atmospheric air by combustion, what becomes of the nitrogen gas?

As the oxygen becomes fixed in the combustibl body, its caloric is disengaged, a part of which combines with the nitrogen, and carries it off in the for of rarefied nitrogen gas.

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[a] Phosphorus is an eminent instance of this increase by combustio If an ounce of phosphorus be properly inflamed, it will produce mo than two ounces of phosphoric acid; the increase in weight arises fro its absorption of oxygen.

[b] A series of curious experiments of this kind may be seen in Lavo sier's *Chemical Elements*, page 495, and following pages.

[c] "This view of combustion authorizes us to divide almost all th productions of nature into two grand classes; one of *combustible* bodie the other of bodies already *burnt*: in the masses and action of the form we discern the causes of inflammable meteors, the perpetual alteratio of the surface of the earth, volcanoes, &c.: in the existence of the latt we perceive the source of the number and diversity of acids, saline con pounds, oxides, and metallic salts, which vary in a thousand ways th appearance of ores, &c. &c."—Fourcroy.

[d] Whenever a substance is converted to an oxide, we say it is *oxidize* but if it becomes an acid by its union with oxygen, we say it is *oxygenize* We are indebted to Mr. Chenevix for this lucid definition of terms t often used indiscriminately.

[e] When oil is burnt in an Argand's lamp, its carbon unites with th oxygen of the atmosphere, and forms carbonic acid gas; while its h

What chemical name is given to burnt bodies?

Such substances are generally said to be *oxygenized*, *oxidized;* that is, changed into acids or oxides[d]. ıt these terms will not apply to the new substances lled *chlorides* and *iodides*.

Does the oxygen become fixed in all combustible dies when burnt?

It is a characteristic property of a combustible body, form a chemical combination with the oxygen that furnished by the supporter of the combustion; and intimate is this union in many instances, that it is ly with extreme difficulty we can again separate the ygen from the combustible body[e].

Is it possible to separate entirely the oxygen from rnt bodies?

Yes: these compounds may be deoxidized in various ys[f]; and in some cases the oxygen may be transrred from the burnt body to a fresh combustible body,

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gen unites with another portion of oxygen, and forms water. Every ounces of oil thus burnt, produce 130 ounces of water. In these lucts of combustion the oxygen is more intimately combined than it with caloric in the gaseous state. Hence we see what a beautiful es of changes and modifications the elements of matter are destined ndergo, and how admirably Nature has provided for the preservation l her productions.

"To me be Nature's volume broad display'd;
And to peruse its all-instructing page,
My sole delight."

hat the combustion of alcohol produced water was known in the time Boerhaave. By presenting a cold vessel to the flame of alcohol he ected water that was without taste or smell, and in every respect like lled water.

Water, as we have shown, is a product of combustion, and its base ydrogen, the most combustible substance we are acquainted with. estore the combustibility of the hydrogen, we have only to abstract oxygen, which may readily be done by mixing iron or zinc filings, sulphuric acid, with the water: by which means the metal becomes ized, and the hydrogen gas is evolved as combustible as ever. This be adduced to show that the simple substances cannot be effectually sted of their own peculiar properties by any of our mixtures, or even nical combinations.

and be made the means of producing a fresh combustion; or it may sometimes be completely separated, and shown in its primitive or gaseous state[a].

What part of bodies is it which is destroyed by combustion?

No part that we know of. We have reason to think that every particle of matter is indestructible, and that the process of combustion[b] merely decomposes the body, and sets its several component parts at liberty to separate from each other, to form other new and varied combinations[c].

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[a] This is frequently done for the purpose of procuring oxygen gas. The oxide of manganese, or of mercury, is exposed to a proper degree of heat, and the gas received in a suitable apparatus as it is extricated.

[b] "When bodies are burnt, none of their principles are destroyed; they had previously formed together one kind of compound, and they now separate from each other, at the high temperature to which they are exposed, in order to form others with the vital air in contact with them: and such of the principles as cannot unite with the vital air, viz. the earth, some saline and some metallic particles, compose the cinder. The new compounds formed, are carbonic acid and water: the proportion of these varies according to the proportion of the carbonic particles, and of the hydrogen that had been contained in the inflammable body." Berthollet's *Chemical Statics*, vol. i. page 163.

[c] "It was said of old, that the Creator *weighed* the dust, and *measured* the water, when he made the world. The first quantity is here still; and though man can gather and scatter, move, mix, and unmix, yet he can destroy nothing: the putrefaction of one thing is a preparation for the being, and the bloom, and the beauty of another. Something gathers up *all* fragments, and nothing is lost." Robinson's *Morning Exercises.* Harlow, 1805, page 422. See Additional Notes, No. 26 and 37.

[d] Perhaps it was in some such light as this that Pythagoras meant the metempsychosis to be understood. It might be a curious inquiry, whether or not he received this doctrine from the Egyptian priests, as they, from the philosophers of India. An ancient Shastre, called the Geeta, has a beautiful stanza upon this subject, in which the varied form that nature assumes is compared to a change of dress. See Halhed's *Account of the Hindoo Laws.* Ovid, in the speech he forms for Pythagoras, compares it to wax, where the substance is always the same, though the outward form is varying. Dr. Darwin pursues the same idea in the following lines:

"Hence, when a monarch or a mushroom dies,
Awhile extinct the organic matter lies;

What is the natural inference from this interesting
ct?

The natural conclusion is, that nothing less than
nsummate wisdom could have devised so beautiful a
stem, and that nothing short of infinite power could
ve so modified matter as to subject it to the opera-
n of such laws; laws which effect so many desirable
rposes, and at the same time so effectually prevent [d]
e destruction of those elementary principles, which
actually essential to the preservation of the world.

But, as a few short hours or years revolve,
Alchemic powers the changing mass dissolve;
Emerging matter from the grave returns,
Feels new desires, with new sensations burns;
With youth's first bloom a finer sense acquires,
And LOVES and PLEASURES fan the rising fires."

CHAPTER XIII.

OF ATTRACTION, REPULSION, AND CHEMICAL AFFINITY.

What is attraction?

Attraction is that unknown force which causes bodies to approach each other[a].

Which are the most obvious instances of attraction?

The gravitation of bodies to the earth[b]; that of the planets towards each other[c]; and the attractions of electricity and magnetism[d].

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[a] Attraction has, by some philosophers, been attributed to an inherent property of matter, and by others to the influence of some foreign agent. The former is perhaps the most probable supposition.

[b] Of this property of matter we know but little. This however is apparent, that the power which a body possesses of gravitating towards the earth depends upon the quantity of matter which is inherent in the body; and it is upon this principle that the common operation of weighing substances by means of a balance is founded.

[c] Sir Isaac Newton demonstrated that the planetary attraction is the same principle as gravitation. To this principle we are indebted for the periodical flux and reflux of the tides, and for other important operations of nature.

"For this the moon thro' heaven's blue concave glides,
And into motion charms the expanding tides;
While earth impetuous round her axle rolls,
Exalts her wat'ry zone, and sinks the poles." FALCONER.

[d] For some account of magnetism see note [b], page 272. In addition to that, it may be remarked that, if a steel needle be rubbed *from* its eye, *to* its point, a few times over the north pole of a magnet, and then stuck in a small cork, to swim on water; the eye will veer towards the north, and the point to the south. In this way the Chinese form their mariner's compass; a guide on which they can rely at all times with perfect safety:

"So turns the faithful needle to the pole,
Tho' mountains rise between and oceans roll." DARWIN.

Are you acquainted with any other instances of traction?

Yes: attraction subsists likewise between the *par- les*[e] of bodies; and it is this kind of attraction ich comes under the more immediate cognisance of emists[f].

How is this kind of attraction defined in chemical nguage?

Whenever the force of attraction operates between rticles of the same species, it is called the attraction *cohesion*[g] or the attraction of *aggregation;* but ien between the particles of different substances, it then called the attraction of *composition*, or chemi- l *affinity*[h].

If common flowers of sulphur and potash be mixed and thrown into er, the sulphur will separate and the potash be dissolved; but if they previously melted together, the union will then be so perfect, that compound will be completely soluble. The design of this experiment is to show that chemical affinity has no sensible action but on the re elementary particles of bodies.

All the operations of chemistry are founded on the force of attraction ch nature has established between the particles of bodies, and by ch force all bodies cohere. The art of chemistry employs different ns to destroy this attraction of cohesion, and to form fresh substances he means of new attractions. Take alumina as an instance:—In this h, as it exists in the sapphire, the attraction of cohesion is so strong, even the most powerful acids have no action upon it. But if the ngth of this cohesion be broken, it then becomes soluble in the weak- acids, and may be held in solution by most, or all of them.

It is from the attraction of cohesion that a drop of water is always erical, and that small particles of quicksilver are constantly of a glo- ar figure. In consequence of the same species of attraction, particles ater and other liquids ascend in capillary tubes. If a small plate of s be laid upon a globule of mercury, the globule, notwithstanding pressure, continues to preserve its round figure. If the plate be lually charged with weights, one after another, the mercury becomes ner and thinner; but as soon as the weights are removed, its globu- figure is restored.

A piece of loaf sugar broken into fine powder, or water in the state apour, is said to have its attraction of aggregation broken; but smallest atom of the powder is still sugar, and the most trifling portion of the vapour is still water. In order to exemplify the latter kind

Can you explain with more precision what is meant by attraction of aggregation[a]*?*

The particles of all bodies are possessed of the inherent property of attracting each other, which causes them to adhere, and preserves the various substances around us from falling in pieces. The nature of this wonderful property is entirely unknown.

What do you understand by attraction of composition, or chemical affinity?

The particles of every simple substance have not only an attraction among themselves, forming the ag-

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of attraction, a little caustic soda may be put into a glass, and muriatic acid added to it. Both these are corrosive substances; but the compound resulting from them will be found to be our common table salt. Here we have an instance of two heterogeneous bodies, producing, by their action on each other, a distinct substance, possessing the properties of *neither* of the bodies which compose it. See Additional Notes, No. 11; also several instances of chemical affinity in the chapter of Experiments at the end of the volume.

If several salts be dissolved in the same water, each particle, when they crystallize, will find its own kind, by a sort of innate polarity. To prove this, dissolve separately equal weights of sulphate of copper and crystals of carbonate of soda in sufficient quantities of boiling water: pour them together while hot into a flat pan, and when the water has evaporated a little, and the whole is suffered to cool, the salts will shoot;—the sulphate of copper in *blue*, the soda in *white* crystals, similar to what they were before they were dissolved.

[a] There are different kinds of aggregation; viz. solid, soft, liquid, and gaseous. A stone is an instance of the first, jelly of the second, water of the third, and atmospheric air of the last.

If we carefully notice two small particles of mercury, while gently moved along a smooth surface towards each other, a mutual attraction of one to the other will be very evident at the moment of their union into one globule. Two small pieces of cork floating in a bason of water, if not nearer to the edge than to each other, will visibly approach, and at last come into contact:—

"Hast thou not seen two pearls of dew
The rose's velvet leaf adorn,
How eager their attraction grew,
As nearer to each other borne?" DRUMMOND.

The force of the attraction of aggregation, in solid bodies, may be measured by the weight necessary to overcome it. Thus, if a rod of metal, glass, wood, &c., be suspended in a perpendicular direction, and egation of that body or substance; but they have o another attraction to such other substances with ich they have an affinity, called elective attraction; d, when presented, unite to them, and form a new npound[b].

What are the laws of chemical attraction[c]?

Chemical attraction can only exist between the par- les of opposite and distinct substances[d]; and this ecies of attraction is exerted with different force, cording to the nature of such substances[e], and fre- ently in proportion to the mass. Most bodies com-

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ghts be attached to its lower extremity till the rod break, the weight ched to the rod just before it broke, is the measure of the cohesive e of the rod.

This power was by Bergman called *elective* attraction, as though ter were endued with the ability to prefer one substance to another. *mical attraction* is a more definite term, and is now in general use.

hose substances which are capable of uniting, are said to have a mical affinity for each other; those which do not form a chemical on, are said to have no affinity. The varied influence of this property matter may be attributed by the atheist to *chance*; but the man of er reflection, who allows the evidence of a mass of facts to have its ral influence upon his mind, will be persuaded that chemical affinity neither be ascribed to accident, nor to a necessity in the nature of gs; for, perceiving that the works of nature and art are all governed this astonishing principle, he will attribute the whole to the contri- ce, to the wisdom, and to the goodness of an intelligent Agent, who varied these operations in a thousand ways, to suit the designs of beneficence, and to promote different and distinct purposes of utility happiness.

There are several laws of chemical affinity, but these may be studied 1 more effect when the elements of the science are thoroughly un- tood. They are well explained by Fourcroy, in his *System of Che- l Knowledge*, vol. i. page 96, &c. But one of the best general views he present state of our knowledge respecting chemical affinity will found in Dr. Henry's *Elements of Experimental Chemistry*, vol. i. e 14—64.

Sir Humphry Davy has shown that all bodies which have a chemical ity for each other are in *opposite* states of electricity; and that che- al affinity depends so much upon electricity, that these natural affini- may be modified or destroyed by inducing a change in the electrical es of bodies by artificial means. See note[d], page 142; Note[c] e 403; and Additional Notes, No. 58.

Chemical affinity is sometimes rendered evident by the heat which bine only in certain proportions[a]:—the new combinations acquire new properties[b], and are incapable of separation by mechanical means.

How are the different kinds of chemical attraction distinguished?

Chemical attraction is of three kinds; viz. simple attraction, compound attraction, and disposing attraction.

What is simple attraction?

When two substances unite merely in consequence of their mutual attraction, they are said to combine by virtue of simple attraction or affinity[c].

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is produced on the mixture of two cold bodies, such as oil of vitriol and water, which, when mixed in equal proportions, instantly acquire the temperature of boiling water. There are indeed instances of flame being produced by the mixture of different bodies when one of those bodies is combustible. Thus, if the metal called potassium be dropped upon ice, the ice will be partially melted, the water decomposed, and a brilliant flame generated by the intensity of action of the two substances upon each other. See the Experiments. The heat which is given out on slacking quick-lime arises from the violence of chemical action and the solidification of the water. In this process 68 parts of lime solidify 32 parts of water; but it is remarkable, that in making what we call lime-water, 500 parts of water are required to dissolve one part of lime.

[a] Thus oxygen and hydrogen combine only in one proportion, and the result is water; nitrogen and hydrogen combine also in one proportion, and ammonia is the result.

[b] If we melt together equal quantities of tin and iron, two malleable and ductile metals, the compound produced will have totally lost the properties which its constituent parts possessed before their union; for the alloy formed will be a very brittle metal. If liquid ammonia and muriatic acid, both fluids of a strong odour, be mixed in proper proportions, a fluid will be produced entirely devoid of smell; viz. muriate of ammonia.

If nitrate of ammonia and sulphate of soda, both in crystals, be rubbed together in a stone mortar in equal proportions, the mixture will be converted to a fluid. A similar result may be produced in a different way. See Experiments on metals. By chemical action two fluids on mixture may produce an homogeneous solid. See Experiments on solids and fluids in the Appendix.

[c] The following experiments will serve to exemplify some cases of simple affinity:—Take a portion of acetate of soda, pour muriatic acid

What is compound affinity?

The action of two compound substances, whereby they mutually decompose each other, and produce two or more new compounds [d].

What do you mean by disposing affinity?

When bodies, which apparently have no tendency to unite of themselves, combine in consequence of the addition of another substance, the union is said to be produced by means of *disposing* affinity.

Give me an example of this disposing affinity.

If concentrated sulphuric acid be poured upon iron, no action will ensue; but if a little water be added to dilute the sulphuric acid, an action will

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upon it in a retort, and distil it to dryness. The acetic acid will be expelled, and the muriatic acid will be found in combination with the soda, united so strongly that the most intense heat will not be able to separate it. This effect is owing to the soda having a greater affinity for muriatic acid than it has for the acetic. If a portion of nitric acid be now added to the muriate of soda, and heat applied, the muriatic acid will be again disengaged, and the nitric acid will be in possession of the soda. Lastly, if to the nitrate of soda sulphuric acid be added, and these exposed to a due degree of heat, the nitric acid will be expelled, and the sulphuric acid will be in possession of the alkali, forming a true sulphate of soda. These changes all take place in consequence of chemical attraction. By this attraction acetic acid combines with soda, and forms a salt called acetate of soda; but muriatic, nitric, and sulphuric acid have each of them a stronger affinity for soda, and their respective affinities are in the order in which they have been named.

[d] If into a solution of sulphate of ammonia there be poured nitric acid, no decomposition is produced, because the sulphuric acid has a stronger affinity than nitric acid for ammonia. But if a solution of nitrate of potash be poured in, we obtain by evaporation two new bodies, viz. *sulphate of potash* and *nitrate of ammonia*. In this case, the sulphuric acid of the sulphate of ammonia attracts the potash of the nitrate of potash at the same time that the ammonia attracts the nitric acid; and to the agency of these united affinities the double decomposition must be attributed. The manner in which these combinations take place has been explained by the following diagram, the idea of which first occurred to Dr. Cullen. In order to understand it, let the affinity of potash to sulphuric acid be $= 62$; that of nitric acid to ammonia $= 38$; that between nitric acid and potash $= 50$; and that of the sulphuric acid and ammonia $= 46$. Now, let us suppose that all these forces are placed so as to

instantly commence, and the iron will soon be dissolved[a].

You spoke of elective attractions, as if inert substances could make choice of this or that body to combine with ;—how do you explain this phraseology?

It often happens, if one body be added to a mixture of two other substances, that it will combine with one in preference to the other. This property which bodies possess of singling out those substances with which they have the strongest affinity has been denominated elective attraction[b].

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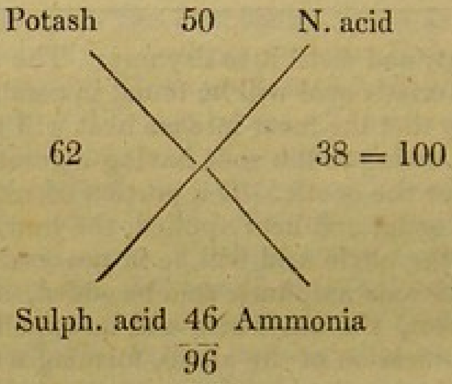
draw the ends of two cylinders crossing one another, and fixed in the middle in this manner :



It is evident, that as 62 and 38 = 100 are greater than 50+46 = 96, they would overcome the other forces, and shut the cylinders.

In like manner acetate of alumina, which is used by the dyers and calico-printers, cannot be formed by the direct mixture of its component parts : for acetic acid exerts no action upon alumina, however its parts may be divided by mechanical means. But if we mix sulphate of alumina with acetate of lead, a mutual decomposition will take place, and the article required will be produced.

[a] If *concentrated* nitric acid be poured upon tin, there will be no union. The component parts of the nitric acid have so great an attraction for each other, that the tin has no power to effect a decomposition. But if a few drops of water be added, the union between the oxygen and nitrogen of the nitric acid will be weakened, part of its oxygen will combine with the tin, a violent action will take place, clouds of nitrous gas will be disengaged in abundance, and the tin will soon be entirely dissolved in the acid. In like manner, if a little oil be put into a phial with a portion of water, and the whole be violently agitated, no union will take place; for when left at rest the oil will be found swimming on the surface of the water, because the water and the oil have no affinity for each

What other terms are employed on the subject of chemical affinities?

There are what are called *quiescent* attractions, and *divellent* attractions.

What do you mean by quiescent attractions?

When two or more bodies are presented to each other, the attractions which tend to preserve their original arrangement of parts are denominated the *quiescent* affinities[c].

What is meant by divellent affinities?

Those attractions which tend to destroy the origi-

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ther; but if some caustic ammonia be added and the phial then agitated, the whole will be united into one homogeneous substance, and an ammoniacal soap formed.

[b] If acetic acid be poured upon a mixture of lime and magnesia, and the acetic acid be no more than is sufficient to dissolve the lime, chemical action will immediately commence and the acid will soon be saturated. But if the whole be afterwards accurately examined, it will be found that the solution contains not a particle of magnesia, but consists entirely of acetic acid and lime, and that the whole of the remaining earth is magnesia. It must however be recollected that the latter earth is also soluble in acetic acid; but when lime is present, that acid selects it in preference to magnesia, and therefore this experiment will be sufficient to show the nature of elective affinity. It is upon this principle that the ingenious process of Dr. Henry for forming Epsom salt from magnesian limestone is founded. The limestone having been pulverized, it is digested in a measured quantity of pyroligneous acid, which dissolves the lime and leaves the magnesia. The latter earth is then formed into Epsom salt by means of sulphuric acid, and crystallized in the usual way for sale.

[c] If a few drops of nitrate of silver be poured into a solution of muriate of soda, two new substances will be formed, viz. nitrate of soda, and muriate of silver; the latter of which, being insoluble in water, will be precipitated. In this experiment the affinity of the nitric acid to the silver, and the muriatic acid to the soda, are the *quiescent* affinities; whereas the affinity of the nitric acid to the soda, and the muriatic acid to the silver, are the *divellent* affinities. Hence no new arrangement of parts in any mixture can take place, unless divellent attraction exist.

Among the affinities of any substance, there is generally at least one peculiar to that substance which stamps it as one of its generic characters; and it is of the utmost importance to the student, in the more early stage of his progress, to imprint these characteristics upon his mind as often as he happens to meet with them. It is these predominating affinities which are more particularly serviceable in the classification of the chemical pro-nal compound, and to form new arrangements, are called the *divellent* affinities.

What advantage do we derive from the study of chemical attractions?

From all that has hitherto been explained, this seems to be beyond doubt the most important part of chemistry; for it is only from a thorough knowledge of the attractions which different substances have for each other, that we shall ever attain a complete analysis of the productions of nature.

How should a pupil proceed to acquire,—what seems so essential to chemistry,—a knowledge of these affinities?

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perties of different substances, and of the chemical phenomena derived from them. Thus, affinity for oxygen distinguishes inflammable substances; and the reciprocal affinity of acids and alkalies constitutes acidity and alkalinity. Thus, barytes has a superior affinity for sulphuric acid, and lime for the oxalic acid, &c. &c.

[a] These will be found in a work entitled *A Dissertation on Elective Attractions*, by Sir Torbern Bergmann, translated from the Latin into English: octavo, London, 1785.

[b] Considerable improvements on the Tables of Bergmann were made by Dr. George Pearson. These were published with the second edition of his translation of the French *Table of Chemical Nomenclature*, quarto, London, 1799.

[c] In the year 1803 Berthollet published some new views respecting the doctrine of chemical affinities in his *Essay on Chemical Statics*, already quoted. Soon afterwards he published *Researches into the Laws of Chemical Affinity*, which were translated from the French by Dr. Farrell. To both these important works I am desirous of referring the reader. An abridged account of the various causes that produce modifications in chemical action will be found in the first volume of Chaptal's *Chemistry applied to the Arts*, London, 1807.

[d] A very remarkable instance of this is observable in the mixture of sulphuric acid and potash. These substances are both very caustic and corrosive, and have each a very peculiar affinity for water; it might therefore be supposed that two such substances when united would form a compound extremely acrid, and powerful in its action upon other bodies; but the exact reverse of this is the case. For, if diluted sulphuric acid be added to a solution of potash, they unite with great violence, and a salt is formed called sulphate of potash; which is neither acrid to the taste, nor caustic to the skin, and which is quite inert in its action upon other bodies. It is moreover remarkable that it has neither

He must practise as well as study the various tables affinities of Bergmann[a], Pearson[b], Berthollet[c], and hers; and endeavour to make himself acquainted ith the changes which take place in the properties bodies, in consequence of their chemical union with ch other[d].

How are chemical attractions noted in these tables[e]*?*

The name of the substance, whose affinities are re- ired, is always placed at the head of the column, d separated generally by a line; below this the other dies are placed in the order of their attraction to the st substance:—thus, in respect to the affinities pe- liar to *sulphuric acid*, it appears that barytes, which

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affinity for water when exposed to a moist atmosphere, nor com- es with any when it crystallizes from its aqueous solution; 100 parts his salt consisting of 54 of potash and 46 of sulphuric acid, without water of crystallization whatever.

The following single example may serve as a specimen of the tables ffinities, and will be sufficient to explain the nature of all others. Let question be Sulphuric Acid, and it will be formed thus:

SULPHURIC ACID.

Barytes.
Strontites.
Potash.
Soda.
Lime.
Magnesia.
Ammonia.
Alumina.
Metallic oxides.
Water.

is table is designed to show that barytes has the strongest affinity ulphuric acid, and will detach it from any of the succeeding sub- es in the list; and that strontites will separate it from potash, &c. Actual experiment will confirm it.

is the nearest, would separate strontites, potash, or any one of the succeeding substances, from sulphuric acid, which prefers barytes to all other bodies whatever.

Are these tables to be depended upon in every case of chemical composition and decomposition?

These tables, notwithstanding some exceptions[a], are so extremely useful, that the study of them cannot be too strongly inculcated; for in most cases they may be safely trusted by the practical chemist.

What is repulsion?

Repulsion is a peculiar property, inherent in the

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[a] The affinities of bodies are affected by the proportions in which they are presented to each other, by the cohesion of their parts, by chemical repulsion, &c. Thus, sulphuric acid decomposes nitrate of potash altogether, by the assistance of heat. The nitric acid is driven off, and there remains sulphate of potash. But if nitric acid be poured into sulphate of potash *in sufficient quantity*, that will be in its turn partially decomposed, and there will be formed a mixture of bi-sulphate or supersulphate of potash and nitrate of potash. In like manner phosphoric acid decomposes muriate of lead, and muriatic acid decomposes in part phosphate of lead.

[b] Sir Isaac Newton found that when a convex lens was put upon a flat glass, it remained at the distance of the $\frac{1}{137}$th part of an inch; that a very considerable pressure was required to diminish this distance, and that no force which can be applied will bring them into actual mathematical contact. Other philosophers have shown that the particles of no body whatever are in such contact; that in every case there is a distance between them; consequently, that the particles of all bodies *repel* each other. According to Boscovich, the atoms, of which all bodies are composed, are mere mathematical points, destitute of extension and magnitude, but capable of acting on each other with a force which differs in intensity, and in kind, according to the distance. At sensible distances the force is *attractive*, and diminishes inversely as the squares of the distance. At the smallest distances the force is *repulsive*; it increases as the distance diminishes; and at last becomes infinite, or insuperable; so that absolute contact, of course, is impossible. The particles of all gases and of atmospheric air evidently repel each other. It is to repulsion that they are indebted for their elasticity.

Some bodies have such a repulsion for water, that it is difficult to wet them. The specific gravity of steel is much greater than that of water; yet if a dry steel needle be placed with care upon the surface of a bason of water, the repulsion of the water will prevent its sinking. Thus, some insects will walk upon water without any of it adhering to them;

"Or bathe unwet their oily forms, and dwell
With feet repulsive on the dimpling well."

articles of all matter, which gives them a constant ndency to recede from each other.

How does this property of matter operate?

It operates both at sensible and at insensible di-ances.

What instances are there of the former kind of pulsion?

The only kinds of repulsion that can be exhibited the senses, are those of electricity[c] and magnet-m[d]; but it is *insensible* repulsion with which che-ists are more particularly concerned.

If two small pith balls be suspended from an insulated body with thread, so as to touch each other, and we charge that body with ctricity, the pith balls will separate immediately. The balls, of course, *el* each other.

Sir Humphry Davy has very satisfactorily shown, that those substances ich are incapable of chemical combination are uniformly in the *same* ctrical states; and that, according to the common laws of electricity, h bodies might be expected to repel, but cannot attract each other. *Philosophical Transactions* for 1807, page 1.

When we present the north pole of a magnet A to the same pole of ther magnet B, suspended on a pivot, and at liberty to move; the gnet B recedes as the other approaches; and by following it with A proper distance, it may be made to turn round on its pivot with consi-rable velocity. There is then a *repulsion* between the two magnets; repulsion which increases with the power of the magnets; and this er has been made so great, by a proper combination of magnets, that he force of a strong man is insufficient to make the two north poles h each other.

he natural magnet is a ponderous iron-stone, of a blackish colour. supposed to derive its magnetic powers from the position in which it n the earth. If one of these natural magnets be broken into pieces, piece will have an attracting and a repelling pole, and the middle veen the poles will neither attract nor repel. The queen of Portugal in possession of one of these natural loadstones, of so large a size it was capable of sustaining a weight of more than 200 pounds. It a present from the emperor of China to John V. king of Portugal. steel needle be rubbed on one of these minerals, as directed in 392, it immediately acquires polarity.

"The obedient steel with living instinct moves,
And veers for ever to the pole it loves." DARWIN.

What instances have you of this latter kind, or of insensible repulsion?

The chief example that we are acquainted with is the repulsion of the particles of caloric[a] amongst themselves; which repulsion would constantly tend to infinite separation, were it not for a chemical union, which, by an irrevocable law of nature, they form with the first surrounding body; for by that law, it seems, the particles of caloric cannot exist in an isolated state.

How does this repulsive force operate upon other bodies?

It diminishes the cohesion of the integrant particles of all heated bodies, in consequence of the particles of caloric repelling each other; so that chemical unions, as well as chemical decompositions, are wonderfully facilitated by this species of repulsion[b].

Endeavour to explain this action of caloric with more precision.

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[a] It is now generally imagined that what is called insensible repulsion is owing to the presence of caloric. It is well known that the elasticity of air and all other gaseous bodies is increased by heat; that is, that the repulsion between the particles of air, the distance remaining the same, increases with the temperature, so that at last it becomes so great as to overcome every obstacle which can be opposed to it.

[b] It is evident, that whatever diminishes the cohesion which exists between the particles of any body, must also tend to facilitate their chemical union with the particles of other bodies. One reason why some bodies require a high temperature to cause them to combine, is, that at a low temperature the attraction of cohesion is in them superior to that of affinity; accordingly it becomes necessary to weaken that attraction by caloric, till it becomes inferior to that of affinity. In like manner bodies combine more easily when held in solution by water, or when they have previously been reduced to a fine powder, as these operations diminish the cohesion which exists among the primitive or integrant particles. Sulphuric acid has no action upon a lump of fluate of lime: but if that earthy salt be reduced to powder, a violent action will ensue on the addition of the sulphuric acid, and the fluate of lime will be decomposed.

[c] The formation of the red oxide of mercury will exemplify the above chemical axiom. If mercury be submitted to a heat little superior to that of boiling water, no new combination will be formed, but the metal

As chemical affinity takes place only between the ltimate molecules of bodies, while the attraction of ohesion remains superior to that of affinity, no other nion can take place; but whenever caloric has suf-ciently diminished this attraction in any substance, the articles are then at liberty to form new combinations, y their union with the particles of other bodies [c].

Is the addition of caloric always necessary to promote hemical affinity?

In order that the attraction of composition may take ace between two bodies, it is generally necessary ther that one of the substances should be in a state fluidity [d], or that heat should be applied; so that loric acts an important part, either sensibly or insen-bly, in all cases of chemical affinity.

Does chemical affinity operate in consequence of the niversal law of attraction?

We have reason to believe that every new compound

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l remain unaltered. If the heat be increased to 600°, or thereabouts, attraction of cohesion of the mercury will be broken; its particles l unite with the oxygen of the surrounding atmosphere; and a new stance, *red oxide of mercury*, will be produced. If this new substance again submitted to the operation of caloric, and the heat be raised 1000°, the combination will again be broken, and new affinities will e place. The affinity of oxygen for caloric will now be greater than t of oxygen for mercury; the oxygen will quit the mercury, unite h the caloric, and be expelled as oxygen gas: thus the mercury will sequently once more appear in its metallic state.

ed lead is formed by long exposure of metallic lead to atmospheric in a high temperature: but by a great increase of temperature, it is le to give out its oxygen in sufficient abundance to be collected in ap-priate receivers in the form of oxygen gas; and the metal is partially ived.

This is so generally the case, that a chemical adage has been founded n it, *Corpora non agunt nisi sint soluta.* But there are exceptions. stallized muriate of lime and snow, if cooled down to 0°, and mixed, act so upon each other as to form a liquid. Crystals of oxalic acid dry lime will also combine on mixture. Again, if pulverized muriate mmonia be mixed with quick-lime, a partial decomposition of the ammoniac will immediately commence, and ammoniacal gas will be ated.

is produced by virtue of the attraction to which all matter is subject, and which is equally operative on the most minute atom, as on a planetary system[a].

How do you imagine that the same force which operates upon the ultimate particles of bodies, so as to produce composition and decomposition, can be sufficient to preserve the planets in their orbits[b]*?*

"We can neither comprehend the one nor the other; nor can we see why the Almighty might not as easily bestow upon one species of matter the power of acting upon another when at a distance[c], as the power of being acted upon and changed by matter when in actual contact[d]."

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[a] The attraction of the particles of bodies for each other is exemplified by small quantities of water, or other fluids, which, when dropped upon a flat surface, form themselves into spherical masses:

"That very law which moulds a tear,
And bids it trickle from its source,
That law preserves the earth a sphere,
And guides the planets in their course." ROGERS.

[b] A passage of Bishop Watson's will perhaps furnish as good a reply to this question as can be given. "We feel," says he, "the interferenc of the Deity every where, but we cannot apprehend the *nature* of hi agency any where. A blade of grass cannot spring up, a drop of rai cannot fall, a ray of light cannot be emitted from the sun, nor a particl of salt be united, with a never-failing symmetry, to its fellow, withou him; every secondary cause we discover, is but a new proof of the necessity we are under of ultimately recurring to him as the one primar cause of every thing."

[c] Dr. Herschel has shown, that not only the planets in our system ar preserved in their orbits by mutual attraction, but that in the sideral systems the double stars are so situated with respect to each other, tha *they* must be subjected to mutual gravitation, and that they can onl preserve their relative distances by a periodical revolution round a common centre. What he calls the *insulated* stars he imagines to be nearl out of the reach of mutual gravitation. He considers our sun and all th brightest stars to be of this class. They are at such immense distance that he calculates that Sirius (the nearest of the fixed stars to us) an the Sun, if the power by which they are preserved in their orbits we withdrawn, would be 33 millions of years in falling together. The sam philosopher has said, that though light travels at the astonishing veloci of 200,000 miles in a second, some of the nebulæ are so far from u that the rays of light must have been nearly two millions of years in pas

Is the consideration of this universal property of natter calculated to produce any peculiar reflections?

The contemplation of this subject has a natural tendency to promote the most profound feelings of awe nd admiration; for the understanding of the highest ntelligences sinks into nothing, when compared with he energy of that Omnipotent Being, who had wisdom o contrive and power to endue the matter which he ad formed with the astonishing ability to operate pon its fellow matter, either in contact, or when se- arated by the infinity of space. Well might a writer f antiquity assert, that "God saw every thing that he ad made, and behold it was very good [e]."

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g from them to our system. According to a writer in the thirty-second olume of the *Monthly Review*, New Series, page 523, astronomers are ow acquainted with no less than 2120 of these nebulous stars. Probably ey are so many distinct worlds, appropriated by the Author of Nature r the reception of intelligent beings, and for the abodes of rectitude d felicity:—

> "Lightnings and storms His mighty word obey,
> And planets roll where HE has mark'd their way."

[d] Dr. Thomson's *Chemistry*, vol. iii. p. 176.

[e] Having now completed my original design, of furnishing the YOUNG ith an elementary treatise on chemistry, it may be necessary to apolo- ize to some readers for the introduction of those moral reflections which frequently occur. This cannot be done better than in the language a late popular writer:—"Every man," says he, "has a particular ain of thought into which his mind falls, when at leisure, from the im- ressions and ideas that occasionally excite it; and if one train of thinking e more desirable than another, it is surely that which regards the phe- omena of nature with a constant reference to a supreme intelligent uthor."—PALEY.

ADDITIONAL NOTES.

I.

Of Specific Gravity.

E common method of taking the specific gravity of the metals,
f any solid body, is by comparing the difference which there is
heir weight when weighed in air and in water; that is, to di-
the *absolute* weight by the *loss*, and the quotient is the specific
ity. Thus, if a mineral, which weighs three ounces in air,
ghs only two ounces when weighed in water, the specific gra-
of such mineral is 3; that is, if water, as it generally is, be
ed 1.000, the substance now examined is 3.000; or, to make it
plainer, if a wine pint of water weigh *one* pound, the same
of such a mineral will weigh three pounds.

more ready way to determine the specific gravity of solids is
ll a phial with water, and note the weight of the whole ac-
ately in grains. Then weigh 100 grains of the mineral or other
stance to be examined, and drop it gradually into the phial of
er. The difference of weight of the bottle with its contents
, and when it was filled with water only, will give the specific
ity of the matter under examination. For example, if the
le weighs 50 grains more than it did when it was filled with
er only, it shows that 100 grains of the mineral displace only
grains of water, and consequently that it is twice the specific
ity of water. See note, page 25.

he specific gravity of fluids is generally determined by an *areo-*
er, which is a graduated glass tube with a bulb, so contrived
it may swim in the fluid in a perpendicular position. The
ific gravity is shown by the degree to which this instrument
s in the fluid to be examined, and this will consequently always
ower in proportion as the liquid is lighter.

he specific gravity of ardent spirits is generally ascertained by
ns of a *hydrometer*, of which various kinds are sold by the ma-
natical-instrument makers; but they all act upon the same
ciple as the areometer just described.

The following method, which was contrived by Dr. Lewis, the celebrated author of the *Commercium Philosophico-Technicum*, was communicated to me many years ago by the amiable Samuel Moore, esq. late secretary to the Society for the promotion of arts, manufactures, and commerce.

In this method the specific gravity of a liquor is estimated from the excess of the weight of a certain measure of it above that of an equal measure of distilled water. A set of weights is made for this purpose, called *carats*, or *cadukes*, in the following manner:—

A convenient bottle being procured, the tare of the bottle is first taken; it is then completely filled with distilled water; the weight of the water is accurately divided into two equal parts, and a weight made equal to one of these parts is marked 64; by continuing the division, are obtained the weights 32, 16, 8, 4, 2, 1, carats; so that a carat is the 128th part of the weight of the water. Another weight is then made which counterpoises the bottle when filled with water; and so many carats as the bottle filled with an alkaline ley, or any other liquor, weighs more than this waterpoise, so many carats strong is the liquor said to be.

In taking the specific gravity of gases or airs, it is usual to procure a glass vessel of a known capacity, and having accurately weighed it when exhausted of air, to fill it with the air or gas which is to be examined; then by weighing again, the actual weight of that volume of the aërial fluid will be determined. Thus, if the vessel should be of the capacity of 100 cubical inches, it will be found to contain $2\frac{1}{4}$ grains of hydrogen gas, or about $29\frac{1}{2}$ of azote, or $30\frac{1}{2}$ grains of atmospheric air, or $33\frac{3}{4}$ grains of oxygen gas. To weigh the gases which are produced in every operation would however be extremely troublesome. Philosophical chemists have therefore contrived to ascertain their quantities by their volumes and by subsequent references to Tables of specific gravities. For this purpose slender glass jars graduated into cubic inches and tenths of an inch are now commonly employed. Such instruments are sold by Mr. Accum, of Compton-street, and also by Messrs. Knight, of Foster-lane, London.

In taking the specific gravity of bodies, an attention should always be paid to their temperature, as the specific gravity of a body when expanded by caloric, will be less than it is when at a low temperature.

II.

Of a curious Property of Charcoal.

A property of which charcoal is very eminently possessed, and which may be regarded as a singular one, is that of absorbing, even when cold, aëriform fluids, and condensing them in its pores, in quantity exceeding many times its own bulk. A very interesting application may be made of this property. The gases which are abbed suffering so great a condensation, two gases introduced at ce into the pores of the charcoal may perhaps be made to com- ne. It appears from the 32d vol. of the *Annales de Chimie,* that ter has actually been formed by this means. The subject de- ves to be prosecuted; and if strong mechanical pressure were plied at the same time, it is probable such combinations might diversified, and carried to a greater extent. More on this sub- t may be seen in Dr. Murray's *System of Chemistry,* second tion, vol. ii. page 456; and in the *Journal de Physique* for 1783.

III.

Of Ebullition.

Under an exhausted receiver, water will boil at the heat of 92° Fahrenheit's thermometer; whereas under the usual pressure of atmosphere, it does not boil till it is heated to 212°; though, the atmosphere varies in density, it occasions some little varia- n in this respect; for Sir George Shuckburgh found by experi- nt, that when the barometer was at 26 inches, water boiled at s than 205 degrees, but when it was at 31 inches it required to heated to nearly 214° before it boiled.

Under the common pressure of the atmosphere

Ether boils at	98°
Alcohol	176
Water	212
Nitric acid	248
Sulphuric acid	546
Phosphorus	554
Mercury	660
Linseed oil	600

Dr. Black made experiments upon several liquids in vacuo, and nd that in general they all boiled with about 140 degrees of heat s than when bearing the weight of the atmosphere. Vitriolic er (if the pressure of the atmosphere be removed) will boil en when 52 degrees below the cold sufficient for freezing water. e note, page 39, and note, page 78.

IV.

Of the Combinations of Caloric.

In addition to the proofs and illustrations already given at page , &c., of the propriety of the term *specific* caloric, and of the fact t the quantity of real caloric is very different in different bodies, hough of the same temperature by the thermometer, I am de- ous of stating that the subject is well illustrated by Professor slie, who has shown that mercury does not contain the 30th part of the quantity of caloric that is combined with an equal weight of water at the same temperature. See Leslie's *Experimental Inquiry into the Nature and Propagation of Heat*, octavo, page 529. Some account of the different means of ascertaining the specific heats of bodies is given by Mr. Dalton in his *New System of Chemical Philosophy*, part i. page 53. A Table of the specific heats of various bodies will be found in the same volume, page 62; and a more extended Table of a similar kind is given by Dr. Thomson in his *System of Chemistry*, 5th edit. vol. i. page 111.

When water is in the state of ice, it combines with caloric, without any rise of temperature being indicated by the thermometer; but the moment the whole becomes fluid, every addition of caloric expands the mercury in the thermometer till the water arrives at 212°, when on a sudden the thermometer ceases to rise, though the water continues to receive and combine with a vast quantity of caloric. On these curious facts Dr. Murray has remarked, "We see no cause why, for a great extent of the thermometrical scale, bodies should receive caloric without entering with it into any intimate combination; why, when the temperature is raised to a certain point in each body, this combination should suddenly take place; and why, after another interval in the thermometrical scale, it should be renewed;—for example, why water at 32°, and, under the common atmospheric pressure, at 212°, and at those points *only*, should contract an intimate union with caloric." It is true, the *cause* which produces these effects is concealed from our investigation, but the uses of this order of things are many and important. See notes, from page 66 to page 77. In addition to the facts there enumerated, other important results, from these seeming anomalies of nature, must present themselves to every contemplative mind, affording it fresh assurances that nothing but beneficence united with consummate wisdom could have dictated such curious and efficacious deviations in the established laws of the universe.

> "'Twas this that guided thy Almighty hand,
> When formless chaos heard thy high command;
> When, pleased, thy eye the matchless work review'd,
> And goodness placid spoke 'that all was good.'"

V.

Of Water.

In addition to what has been said in note [a], page 76, on the peculiar law which water observes during its change of temperature, it is worthy of notice, that as rivers, lakes, &c. give out caloric to the currents of cold air passing over them, the upper stratum of water becomes of greater specific gravity, and therefore sinks, and

: this occasions the rise of a portion of warmer water which es out its caloric in like manner; and that this constant circu- on very much contributes to moderate the rigour of winter oughout the temperate zones. In the ocean and other deep bo- of water, this circulation goes on for a considerable time, and mmense quantity of caloric is thus thrown into the atmosphere: ut if no limit had been put to this process, what would have ome of those innumerable tribes of creatures that inhabit this nent?—The exigency has however been admirably provided by the Author of Nature; for, whenever the whole mass of er arrives at the temperature of 42°—5, its specific gravity no ger increases by the further diminution of its temperature, and circulation that we have been speaking of entirely ceases. How pletely does this simple deviation from a general law answer he purposes for which it was intended!

> "Such the all-perfect hand
> That poised, impels and rules the steady whole."

On the top of a mountain near Lochness, in Scotland, whose per- dicular height is nearly two miles, there is a small lake of fresh er, hitherto said to be unfathomable, which never freezes during coldest winters. Here the depth is so great, that the circu- on is not completed before the return of summer; whereas the hanwyn, or Green lake, 17 miles distant, is perpetually covered h Ice.

VI.

Of Atmospheric Air.

Atmospheric air was once imagined to be a chemical compound xygen and nitrogen gases, but of late years it has been demon- ted to consist of those gases in the proportions of 21 and 79, in a e of mere mechanical mixture. It has been very satisfactorily ved by Mr. Dalton, that whenever two or more of the perma- tly *elastic* fluids come in contact, they penetrate each other, form an equable mixture; and that therefore a lighter gas not for any considerable time float upon the surface of a heavier. The only apparatus which was employed to ascertain this fact, a few phials, and tubes with perforated corks. The tube mostly d was one 10 inches long and of $\frac{1}{20}$th of an inch bore. The phials d the gases that were the subjects of experiment, and the tube med the connexion. In every experiment, the heavier gas was into the *under* phial, and the two, thus fixed one over the other, re placed in a perpendicular position, and suffered to remain so ing the experiment, in a state of rest. Whenever the contents the phials were examined, after having remained a few hours in situation, a mixture of the gases was invariably found in each al. Thus, when a phial of hydrogen gas was inverted over a phial of atmospheric air, the hydrogen, though 12 times lighter than the atmospheric air, gradually descended to mix with the latter, while a portion of the atmospheric air actually ascended to mix itself with the hydrogen. Hence it may be laid down as a principle, that one elastic fluid acts as a vacuum to every other elastic fluid; and thus we obtain a satisfactory explanation of the homogeneous nature of atmospheric air, at whatever altitude, or in whatever climate, it may be examined. An interesting detail of these experiments may be seen in the *Memoirs of the Literary and Philosophical Society of Manchester*, vol. i. of the second series, pages 259—270.

The specific gravity of atmospheric air, and of the gases which compose it, may be explained by the following formula.

79 volumes or cubic inch measures of nitrogen gas $\times 5 = 395$. 21 volumes of oxygen gas $\times 5 = 105$, forming together 500 cubical inch measures of atmospheric air. Now as 395 cubical inches of nitrogen gas weigh 116.92 grains, and 105 cubical inches of oxygen gas weigh 35.43 grains, $116.92 + 35.43 = 152.35$ and 152.50, which is the actual weight of 500 cubical inches of atmospheric air $- 152.35 = 0.15$, which is a difference of less than one sixth of a grain, a mere trifle this in 152.50 grains; and which may be accounted for by the addition of the small quantity of carbonic acid gas always found in atmospheric air. On the temperature of the atmosphere consult Dalton's *New System of Chemical Philosophy*, part i. page 123.

VII.

Directions for procuring Oxygen Gas.

This gas may be procured in any quantity from the black oxide of manganese. It is only necessary to pulverize the manganese, and expose it in an iron retort to a temperature sufficient to make the retort of a white heat. The gas, which will then rise in great plenty from the retort, may be received in gas-holders or any appropriate vessels. One pound of good manganese will furnish about ten gallons of this gas. It may be procured, however, with more ease, and in greater purity, from the oxygenized muriate of potash than from any other substance; but as this is a dear article, manganese will be chosen for all common purposes. And if the manganese be treated with one half its weight of strong sulphuric acid, the gas will be liberated by a much less heat.

VIII.

Of the Effect of Oxygen upon the Blood.

To prove that oxygen gas is really imbibed by the blood in the lungs, Dr. Goodwin opened the chest of a living dog, and exposed ungs and heart to view. It was a striking spectacle to observe *black* blood, in its return from the lungs, and in its passage to eart, change to a bright *vermilion* colour. As the dog became usted, by the pain which the wound occasioned, it was found ssary to inflate the lungs by artificial means. When this was ted, the blood received by the heart was black, and in a little its action ceased. But when the lungs were again made to pse and distend, by the inflation of common air, the blood in ulmonary vessels regained its former crimson colour, and the n of the heart and arteries was excited anew. *Philosophy of icine, or Medical Extracts on the Nature of Health.* See also d, page 49 of the foregoing sheets.

IX.

Of the Circulation of the Blood.

ccording to Dr. Thomson, one principal use of the blood is to sh fibrina to supply the waste of the muscles; for as neither chyle nor the lymph contains fibrina when they flow into the d, there must be a continual decomposition of chyle and lymph e blood-vessels, in order to form this substance. We know carbon and hydrogen are thrown out by the act of respiration; herefore concludes that one use of the air absorbed is to abs- a quantity of carbon and hydrogen from the chyle, by com- d affinity, in such proportions that the remainder becomes fi- a[*]. For the information of young readers, the following account e apparatus for elaborating the blood is copied from Arch- on Paley's *Natural Theology*; London, 1802.

There is provided in the central part of the body a hollow cle, invested with spiral tubes, running in both directions. By contraction of these fibres, the sides of the muscular cavities are ssarily squeezed together, so as to force out from them any which they may at that time contain: by the relaxation of the e fibres, the cavities are in their turn dilated; and, of course, ared to admit every fluid which may be poured into them. Into e cavities are inserted the great trunks, both of the arteries ch carry out the blood, and of the veins which bring it back. is a general account of the apparatus: and the simplest idea s action is, that by each contraction a portion of blood is forced a syringe into the arteries; and at each dilation an equal por- is received from the veins. This produces, at each pulse, a on and change in the mass of blood to the amount of what the y contains, which in a full-grown human heart is about an e, or two table-spoons full. Each ventricle will at least contain ounce of blood. The heart contracts four thousand times in one

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[*] System of Chemistry, 2d edition, vol. iv. page 725.

hour; from which it follows, that there pass through the heart every hour four thousand ounces, or 350lbs. of blood, troy weight. Now the whole mass of blood is about 25 pounds; so that a quantity of blood equal to the whole blood within the body passes through the heart fourteen times in one hour; which is about once every four minutes. Only consider what this is in very large animals. The *aorta* of a whale is larger in the bore than the main pipe of the water-works at London bridge; and the water roaring in its passage through that pipe is inferior in impetus and velocity to the blood gushing from the whale's heart." According to Dr. Hunter, ten or fifteen gallons of blood are thrown out of the heart of a whale at a stroke, with an immense velocity, through a tube of a foot diameter. The whole idea fills the mind with wonder. See Dr. Hunter's account of the dissection of a whale, in the *Philosophical Transactions.*

"It was necessary that the blood should be successively brought in contact or proximity with the air; therefore, as soon as the blood is received by the heart from the veins of the body, and before that it is sent out again into its arteries, it is carried by the force of the contraction of the heart, and by means of a supplementary artery, to the lungs; from which, after it has undergone the proper change, it is brought back by a large vein once more to the heart, in order, when thus prepared, to be from thence distributed anew into the system. (See page 50.)

"An anatomist, who understood the structure of the heart, might say beforehand that it would play: but he would expect, I think, from the complexity of its mechanism, and the delicacy of many of its parts, that it should always be liable to derangement; or that it would soon work itself out. Yet shall this wonderful machine go, night and day, for eighty years together, at the rate of a hundred thousand strokes every twenty-four hours, having, at every stroke, a great resistance to overcome; and shall continue this action for this length of time without disorder, and without weariness."

X.

Of the Combinations of Nitrogen and Oxygen.

Nitrous oxide gas is composed of two volumes or measures of nitrogen gas, and one volume of oxygen gas; and if
200 cubic inches of nitrogen gas = 59.20 grains be mixed with
100 cubic inches of oxygen gas = 33.75 grains
92.95

the 300 cubical inches will be condensed by combination into 200 inches, and consequently 100 cubical inches of *nitrous oxide gas* will weigh 46.47 grains.

Nitrous gas is composed of equal volumes of nitrogen gas and oxygen gas; and if

200 cubical inches of the former = 59.20 grains be mixed with
200 cubical inches of oxygen gas = 67.50 grains

$$\overline{126.70}$$

no condensation will occur during the combination, and therefore 100 cubical inches of *nitrous gas* will weigh 31.67 grains.

Nitrous acid gas is composed of two volumes of nitrogen gas and four of oxygen gas; and if

200 cubical inches of the former = 59.20 grains be mixed with
400 cubical inches of oxygen gas = 135.00 grains

$$\overline{194.20}$$

the 600 cubical inches will condense into 300 inches; consequently 100 cubical inches of *nitrous acid gas* weigh 64.73 grains.

Nitric acid is composed of two volumes of nitrogen gas and five volumes of oxygen gas; but the existence of this acid in the state of gas is very problematical, as has been shown by Sir Humphry Davy in his *Elements of Chemical Philosophy*. By referring to that work, it will be seen that the weights of the several compounds of nitrogen and oxygen which I have thus derived from calculation, agree very nearly with the statements of that eminent philosopher. See Note[g], page 41.

XI.

Examples of Affinity.

Take a little common magnesia, and pour by degrees diluted nitrous acid upon it till the whole of the earth be dissolved. This is an instance of simple chemical affinity. But if a solution of potash be poured upon the former mixture, the potash having a greater affinity for the acid will take it from the magnesia, and the magnesia will again be precipitated.

To a solution of soap add a little weak sulphuric acid. The acid having a stronger affinity for the alkali of the soap than the alkali has for the tallow, the acid will unite with the alkali, and the separated tallow will be seen to float upon the surface of the liquor.

Again,—Dissolve a few ounces of sulphate of iron in water, by adding the salt by degrees till the liquor becomes turbid; then, if a skein of cotton thread be dipped in the solution and shaken a little in it, the thread will take up the whole of the oxide of iron, and render the liquor transparent. This effect is produced in consequence of the great affinity which cotton has for the oxides of iron.

If mercury be put into a *glass* bottle, the surface of the mercury will appear convex, owing to the small affinity which mercury has with glass; but if it be put into a *metallic* vessel, the surface of the mercury will appear concave like that of other fluids, because of its tendency to combine with the sides of the vessel. This may be adduced as a striking proof of metallic elective attraction.

"The phenomena of dyeing may also be referred entirely to chemical principles. The colouring particles possess chemical properties that distinguish them from all other substances; they have attractions peculiar to themselves, by means of which they unite with acids, alkalies, metallic oxides, and earths. The difference in the attractions of the colouring particles for wool, silk, and cotton, is sometimes so great that they will not unite with one of these substances, while they combine very readily with another; thus *cotton* receives no colour in a bath which dyes *wool* scarlet."—Berthollet's *Elements of the Art of Dyeing*, London, 1791, vol. i. page 22. Several curious and instructive instances of the effects of chemical affinity in the art of dyeing may be seen in that work, vol. i. 29, and following pages.

Chemical affinity may be pleasingly illustrated by the composition and decomposition of writing-ink. Take a little tincture of galls, and a little of the solution of green copperas, both colourless liquors, and, if poured together, the mixture becomes black; from the affinity which gallic acid has for the oxide of iron in the copperas. Then pour in a little weak aquafortis, and the liquor will become immediately transparent: this arises from the metal leaving the first acid to unite with the last, to which it has a greater affinity. But if a solution of potash be now added, the nitrous acid will quit the iron, and unite with the alkali: thus the iron, being once more disengaged, will again be caught by the gallic acid in the infusion, and once more produce a black liquor.

Many other instances of chemical affinity will be found in Chap. xiii. and in the Chapter of Experiments.

XII.

Atmospheric Pressure.

The rise of water in a pump was formerly attributed to the horror that nature had of a vacuum. This absurd notion was refuted about the middle of the seventeenth century, by the following occurrence.

The Duke of Florence having occasion to raise water to the height of 50 or 60 feet, ordered a common pump to be made for that purpose; but when it was completed, the workmen were astonished to find that it would not work.

The matter was referred to the celebrated Galileo, but he was unable to account for it. All they could determine was, that water would not rise in a common pump more than from 32 to 35 feet. The fact remained inexplicable until the philosophers of Europe caught the idea of atmospheric pressure from the important expeiments of Torricelli, which were first performed by him in the year 1643, and made known to the world in 1667 by the publication of he *Transactions of the Academie del Cimento.* Since then, the uspension of mercury in the barometer, and water in a pump, have een well understood. See note [d], page 37.

XIII.

Of the Formation of Water.

In 1798 Mr. Seguin made a grand experiment for the compo-ition of water. He expended no less than 25,582 cubic inches or nearly two hogsheads) of hydrogen gas or inflammable air, and 2,457 of oxygen gas or vital air. The first weighed 1039 grains, nd the second 6210, amounting to 7249 grains, and the water ob-ained amounted to 7245 grains, or nearly a wine pint. The loss as only four grains. Another experiment was afterwards made by e Fevre, in which nearly two pounds and a quarter of water were roduced*. Dr. Black was wrong in the weight of the gases, as 5,582 cubical inches of hydrogen gas weigh only 560 grains, little ore than half what he has stated, and the 12,457 grains of oxygen as weigh only about 4200 grains;—but the experiment was a very nportant one, and I was desirous of relating it.

XIV.

Of the Giants' Causeway.

The Giants' Causeway in the county of Antrim in Ireland is the ost remarkable collection of basaltic columns of any in the world. he name of it may naturally convey to us the idea of some stu-endous work of art; and as such it seems to have been considered the days of ignorance, when the name was first applied: modern ilosophy, however, looks on it with a very different eye. To con-ive a proper idea of this unparalleled curiosity, we may imagine n approach to it from the sea: its first appearance is that of a bold ocky shore, with extensive ranges of shelving, calculated for an mense promenade. These rocks, however, instead of being dis-osed in laminæ or strata, form basaltic or angular columns, so osely attached to each other, that, though perfectly distinct from p to bottom, scarcely any thing can be introduced between them. ome account of this stupendous object of curiosity has already een given at page 208; but as the whole is still more curious in s minute parts than in the great, the following additional parti-lars will perhaps not be thought uninteresting.

The columns themselves are not each of one solid stone in an up-

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* Dr. Black's *Lectures*, vol. ii. page 236.

right position, but composed of several short lengths exactly joined, not by flat surfaces, as in works of art, but, what is most extraordinary, they are articulated into each other, as a bone is into its socket, the one end of the joint having a cavity into which the convex end of the opposite is exactly fitted: which is not visible but by disjointing the two stones. The depth of the concavity is generally from three to four inches; and what is still further remarkable, the convexity and the corresponding concavity are not conformed to the external pentagonal figure of the column, but exactly round, and as large as the size of the column will admit. It is still further remarkable, that the articulations of these joints are frequently inverted. In some the concavity is upwards, in others the reverse. A part of one of these columns was exhibited in the Leverian Museum. There is also a part of one in the museum of Mr. James Sowerby of Mead Place, Lambeth, and other specimens are distributed in various parts of the metropolis.

The formation of this curious natural production has been accounted for by supposing that the whole body of the rock was once in a state of fluidity, being no other than the lava of a burning mountain; that the prodigious mass cracked in its cooling into the forms which we now see; that it may since in some measure have been deranged by earthquakes: that these have swallowed up the volcano itself; and that the waters of the neighbouring ocean now roll over the place where it once stood. Some curious and interesting speculations on the origin of volcanoes will be found in Dr. Clarke's new book, entitled "*The Gas Blow Pipe; or, the Art of Fusion by Gases,*" London, Octavo, 1819. Those geologists, however, who have embraced the system of Werner, attribute all these effects to the agency of water. Can any thing be more gratifying to a well informed mind, than the examination of these arcana of nature? "The sensualist may imagine that he enjoys the world; but to enjoy it truly is to be sensible of its greatness and its beauty.

"Presented to the cultured eye of taste,
No rock is barren, and no wild is waste."

XV.

Of Crystallization.

Gahn had observed, that in breaking a pyramidal crystal of carbonate of lime, it afforded rhomboidal fragments, of which it appeared to be entirely formed. Bergman from this conceived the idea, that in every crystal there exists a primitive form, from which the actual forms, having often no resemblance to it, may be generated by the superposition of decreasing laminæ; and that, by the mechanical division of crystals, this form may be detected, and the laws by which it gives rise to the different crystals determined.

This is the basis of the system of Haüy. He demonstrated what Bergman had scarcely more than imagined. He succeeded in showing that in every crystallized substance, whatever may be the difference of figure which may arise from modifying circumstances, there is, in all its crystals, a *primitive* form, the nucleus, as it were, of the crystal, invariable in each substance, giving rise to the actually existing outward forms.

It is well known to those who work on gems, that crystals can be mechanically divided only in certain directions, so as to afford smooth surfaces, and that, if separated in any other way, the fracture, instead of being polished like the others, is rugged and uneven. Ample extracts from the work of the Abbé Haüy will be found in the first volume of the *Philosophical Magazine*. See also Dr. Murray's *System of Chemistry*, vol. i. page 48.

XVI.

Of Combustion.

In addition to what has been said, Chap. xii. of the effects of combustion, it may be remarked, that animal and vegetable substances are converted into water and carbonic acid during this process, by the union of their hydrogen and carbon with the oxygen of the atmosphere; and that, in time, the same water and the same carbonic acid are absorbed by vegetables, and again decomposed in order to set the oxygen at liberty to produce fresh combustions, while the vegetating organs appropriate the hydrogen and carbon to promote their growth and nourishment. A regular circle of compositions and decompositions is thus perpetually going on, and all organized beings are made to surrender in due time, to the general mass, those elementary substances which nature kindly lent them for the preservation of their existence. See pages 84 and 85. Is not this admirable simplicity of nature a conclusive proof of the infinite wisdom of the Deity, and that the greatest possible sum of utility and of happiness was his ultimate object?

> "The whole and every part proclaims
> His infinite good-will;
> It shines in stars, and flows in streams,
> And bursts from every hill.
>
> We view it o'er the spreading plain,
> And heavens which spread more wide;
> It drops in gentle showers of rain,
> And rolls in every tide."

BROWNE.

XVII.

Of the Effects of Intense Cold.

In Iceland and some other northern countries the thermometer frequently falls to zero, which is 32 degrees below the freezing point. At Hudson's Bay it has been known to sink even 50 degrees lower. When stones or metals, which have been exposed to such degrees of cold, are touched by the tongue, or the softer parts of the human body, they absorb the heat from those parts with such rapidity, that the flesh becomes instantly frozen and mortified, and the principle of life in them is extinguished. Some French academicians who made a journey to the northern end of the Baltic, and wintered under the polar circle, found it necessary to use all possible precautions to secure themselves from the dreadful cold which prevailed. They prevented as much as possible the entrance of the external air into their apartments; and if at any time they had occasion to open a window or a door, the humidity of their breath, confined in the air of the house, was condensed and frozen into a shower of snow; their lungs, when they ventured to beathe the cold air, felt as if they were torn asunder; and they often heard the rending of the timber around them by the expansive power of the frost on the fluid in its pores. In this terrible cold the thermometer fell to 33° *below* zero *. The most intense cold ever known in the neighbourhood of London was on December 25, 1796, when the thermometer indicated 2° below zero. See page 88. Further information on the subject of intense cold will be found in Boyle's *Observations on Cold*; Kirwan *On Temperature*; and in the *Chemical Essays*, vol. i. page 103.

XVIII.

Of the Recession of the Ocean.

At the summit of Mount Perdue, in the Pyrenees, which is nine thousand feet above the level of the sea, a prodigious number of marine productions are found, which indicate that there has been either a great recession of the ocean, or a vast elevation of the mountainous parts of the earth. The former is the most probable supposition. What then has become of this immense body of water? Some have supposed that it has risen into the atmosphere, and remains suspended there; while some others have thought that it has run off and found a permanent bed in the interior of the globe. But since it is known that water is a *compound decomposable substance*, other solutions of this difficult question might be given. Water enters into the composition of most substances; and if it

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* Dr. Black's *Chemical Lectures*, vol. i. page 69.

unite to some without losing its nature, it cannot combine with others unless it be decomposed, and cease to be water. It is thus that it abandons its oxygen to metals, and its hydrogen to plants. These two principles, once separated, cannot unite again to form water, but by a concurrence of peculiar circumstances. M. Poiret, who has written upon this subject, in the sixtieth volume of the *Journal de Physique*, seems to be of opinion, that when the earth was nearly covered with water, a considrable portion of this fluid would necessarily be consumed by marine animals, which would of course be more numerous as the mass of waters was greater. This supposition is strengthened by our knowledge of one circumstance, that hydrogen is the base of animal fat, and that in no animal is fat so abundant as in various species of fish, especially in the cetaceous tribe, of whose substance it often constitutes the principal part. Besides, there existed vast numbers of shellfish, and of polypi, which latter employ themselves in constructing calcareous rocks, that are uniformly composed of the pulverized remains of their shells and their tubes joined together; which, insensibly raising themselves from the sea, have reached the surface of the water. These rocks at first were mere barren islands, but soon afterwards became covered with an abundant vegetation. This great work was thus effected at the expense of the waters, which diminished more rapidly as organized beings became more numerous. He goes on to state, that a vast consumption of water has been occasioned by volcanoes, and by the formation of stony bodies; some of which contain one-fifth of their mass of water. The last cause of the consumption of the water which he mentions, is the vegetation of plants. By this process, water is plentifully and perpetually decomposed, and more and more so in proportion as the surface of the earth increased. If to this fact we add the idea of a vegetation existing for thousands of ages, and of those immense forests which once covered the countries now cultivated; and lastly, the extensive depths of peat, and the thick beds of coal, that are so many vegetable remains, what an idea must we have of the enormous quantity of water necessary for the formation of all these substances, and for the support of such an abundant vegetation for such a period of time! See page 92.

“ Water restrain'd gives birth
To grass and plants, and thickens into earth:
Diffused it rises in a higher sphere,
Dilates its drops, and softens into air:
Those finer parts of air again aspire,
Move into warmth, and brighten into fire:
That fire once more, by denser air o'ercome,
And downward forced in earth's capacious womb,
Alters its particles, is fire no more,
But lies metallic dust, or pond'rous ore.” PRIOR.

XIX.

Morveau's Preservative Phials.

The portable phial contrived by Morveau for preventing contagion may be prepared thus:

Forty or fifty grains of black oxide of manganese in coarse powder, are to be put into a small strong glass phial, with an accurately ground stopper, to which must be added about two drachm measures of nitric acid of about 1.400 specific gravity, and an equal measure of muriatic acid of about 1.134; the stopper is then to be replaced, and the whole secured by inclosing the phial in a strong wooden case, with a cap which screws down so as to keep the stopper safe. It is to be used in hospitals, or other places of infection, or in the chambers of those afflicted with typhus fever, by simply opening the phial, with the nose averted, and replacing the stopper soon after the smell of the oxymuriatic gas is perceived. A phial of this kind, properly prepared, may be used several years without losing its effect. The mixture, however, ought not to occupy more than one-third of the bottle. When a prepared phial of this kind is not at hand, the baneful effects of infectious disease may be prevented by the following expedient:

Mix a few ounces of the pulverized black oxide of manganese and common salt, upon a plate; let the plate thus charged be placed in the house suspected to be infected, and occasionally sprinkle a little sulphuric acid, or oil of vitriol, upon the mixture, which will disengage a sufficient quantity of oxygenized muriatic acid gas to neutralize the putrid miasmata, and render the place salubrious. When this method is adopted in apartments which are inhabited, it will be necessary to add the sulphuric acid only a few drops at a time, with the face averted. An account of a very efficacious method of preserving the workmen of a large manufacturing establishment and their families from infectious diseases may be seen in the *Chemical Essays*, vol. iv. page 163.

XX.

Of Lime and Mortar, and also of Water Cement.

Dr. Watson has remarked, that, "in countries where they have no common materials for making lime, it would be worth while for the farmer to examine the earth which may be met with on the surface of the ground, or at a little distance below it; for that calcareous substances are not always united into hard compact masses, but are sometimes found in the form of loose earth, and that of different colours."

While writing on lime, some persons may be glad to be informed r a cement may be made with common lime, that will harden ler water. What is called *poor* lime has this peculiar property; as this species of limestone rarely occurs, it is often an expen- article The following is a good substitute, and may be used water-cisterns, aqueducts, &c.—Mix four parts of gray clay, of the black oxide of manganese, and ninety of good limestone ıced to fine powder; then calcine the whole to expel the car- ic acid. When this mixture has been well calcined and cooled, to be worked into the consistence of a soft paste with sixty s of washed sand. If a lump of this cement be thrown into er, it will harden immediately. Such mortar, however, may procured at a still less expense, by mixing with common quick- a certain quantity of what are called the *white* iron ores, es- ally such as are poor in iron. These ores are chiefly composed ıanganese and carbonate of lime, or chalk. Common lime and only, whatever may be the proportion of the mixture, will ainly become *soft* under water. Some information, collected ı various sources, respecting the preparation of common mortar building with brick or stone, will be found in the *Chemical ıys*, vol. i. page 389.

XXI.

Of Light.

his work being intended to teach only the first principles of ral and chemical philosophy, I purposely omit entering into a ral investigation of the nature of *light*, as it is a subject which general too abstruse for the comprehension of youth, till they made very considerable proficiency in other branches of know- e. The *velocity* of light is however so admirably calculated to ess the young mind, that I could not resist making the follow- quotation from a work which is well known and esteemed.

It has been demonstrated that light takes about eight minutes ıoving across one half of the earth's orbit: consequently it es at the astonishing rate of 200,000 miles in a second; there- if each of its particles weighed the thousandth part of a grain, rce would be greater than that of a bullet discharged from a et. Were it even the millionth part of a grain in weight, it d destroy every thing against which it struck. If it even hed the millionth part of *that*, it would still have a very sen- force. But how much less must be a particle of light, which es no sensible impression upon so delicate an organ as the We are certain then that no particle of light can weigh $\frac{1}{000,000,000}$th of a grain*." Some further observations on will be found in Chapter xi. on the oxides, page 370.

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* Thomson's *System of Chemistry*, 2d edition, vol i. page 279.

It may be remarked, that light "sets out from the body of the sun with a velocity equalled only by the extent of its journey. It goes from planet to planet, from sun to sun, distributing colours, illuminating and enlivening all nature. It never travels by circuitous routs, like the other great bodies which traverse void space, but passes on in straight lines; and if it does not pass through or combine with the bodies it meets, it is reflected back on other objects. It seems to be destined for the benefit of the whole universe, and consequently travels over all."—Mr. Walter Millar's *Physical and Metaphysical Inquiries.*

XXII.

Of the Nature and Formation of Nitre.

The greatest part of the nitre we have is brought from the East Indies. See page 193. Should this supply fail, it may, after the example of the French, be formed artificially in Europe. During the second and third years of the French republic, the Government required every district to send two intelligent young persons to Paris. This convocation, consisting of nearly eleven hundred individuals, received regular instruction from their first chemists, partly concerning the manufacture of cannon and partly concerning the making of saltpetre for gunpowder. This body of pupils was afterwards distributed among the different establishments in proportion to their abilities, and salt-petre was soon furnished by them in abundance. *Annales de Chimie*, xx. 298.

The theory of the formation of nitre was little known till lately An admirable paper on this subject, by Count Chaptal, occupying 47 pages, may be seen in the *Annales de Chimie*, tome xx. Annexed is a useful paper on the refining of salt-petre, and there i another by Guyton on the same subject, in tome xxiii, of the same work.

A great quantity of nitre is used by the makers of sulphuric acid It is ground small, and mixed with sulphur, in order to afford oxygen to the sulphur while burning. For the same purpose it wa used by the ancients in that destructive composition of antiquit called the *Greek fire.* Sulphur, resin, alcohol, camphor, and othe combustibles, were melted with it, and in this melted mass woolle cords were dipped, which were afterwards rolled up for use. Thes balls being set on fire were thrown into the tents, &c. of the enemy and as the combustibles were furnished with a constant supply o *oxygen* from the nitre, nothing could extinguish them.

When Constantinople was attacked in the reign of Leo, many o the ships of the besiegers were destroyed by this chemical composition. For many centuries the method of making this dreadfu article of destruction was lost; but it has just been rediscovered b the librarian of the elector of Bavaria, who has found a very ol Latin manuscript which contains directions for preparing it.

XXIII.

Of Muriate of Lead.

Muriate of lead, which is readily made, will afford the pupil a
asing example of metallic crystallization. Take common red
arge, pour over it one third of its weight of strong muriatic acid,
stir it well with the litharge. When it has stood 24 hours to
ome dry, melt it in a crucible, and pour it into a *metallic* vessel
state of fusion. The cooled mass will be of a beautiful brilliant
ow, and when broken will exhibit the most regular crystalliza-
that can be conceived. Several other instances of dry crystal-
tion, merely by the loss of caloric, will be found in Note[b], Chap-
3, page 208. A murio-carbonate of lead is found native in Der-
hire, consisting of 85.5 lead, 8.5 muriatic acid, and 6 carbonic
. See Mr. Allan's *Mineralogical Nomenclature*, Table 122,
us 10; and Klaproth's *Analytical Essays*, vol. ii. page 111. It
been said that a native muriate of lead occurs sometimes in
mines of Derbyshire, but this is very doubtful.

XXIV.

Of the Uses of Alum.

lum was not known to the ancient Greeks and Romans, as has
n shown by Professor Beckman in his *History of Inventions and*
coveries, vol. i. page 288, but the present employment of alum
ne arts is very extensive. It is used in dyeing, to fix a variety
egetable colours, which otherwise would be fugitive. By means
is salt we are enabled to obtain the admired colour * of the an-
ts, called the Tyrian purple, which they procured by a different
nt, but which on pain of death none but the Cæsars could wear.
of service in the manufacturing of candles, giving consistence
firmness to the tallow. It is employed in the cod fisheries,
n the fish are prepared for drying, having the property of pre-
ing the salt from deliquescing. In the art of tanning it gives
mness to the skins after they have become flaccid in the lime-
It is used also in other preparations of leather. Its efficacy
reventing the bad effects of damp atmospheric air on preserved
has been mentioned: with the same design it has been used
reparing paper for the preservation of gunpowder; and when
thus, it is of further service by preserving the paper from rea-
taking fire. But one of the most striking advantages of this
ortant salt is in the preparation of acetate of alumina for the
o-printers; an article which, in the present improved state of
arts, the manufacturer cannot dispense with. It is prepared

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the Introduction to Berthollet's *Elements of the Art of Dyeing*, page 19.

with acetate of lead, by a double-decomposition. An easy way to prepare it is related in Berthollet's *Treatise on Dyeing*, and in the *Chemical Essays*, vol. ii. page 137.

XXV.

Of Carbon and its Combinations.

Carbon, whether we regard it in its most simple state, the diamond, or in that of common charcoal, is not only indestructible by age, but in all its combinations, which are infinitely beyond our comprehension, still preserves its identity. In the state of carbonic acid it exists in union with earths and stones in unbounded quantities; and though buried for thousands of years beneath immense rocks, or in the centre of mountains, it is still carbonic acid; for no sooner is it disengaged than it rises with all the life and vigour of recent formation, not in the least impaired by its torpid inactivity during a lapse of ages. Is not the consideration of this subject calculated to afford a strong and satisfactory *analogical* argument in favour of human resuscitation? "Tu perire et Deo credis, si quid oculis nostris hebetibus subtrahitur? Corpus omne, sive arescit in pulverem, sive in humorem solvitur, vel in cinerem comprimitur, vel in nidorem tenuatur, subducitur nobis, sed Deo elementorum custodi reservatur."—*Minucius Felix, edit. Ouzelii*, p. 326.

XXVI.

Of the Chemical Decomposition of Organized Beings.

It is a striking fact that man, the most perfect creature that inhabits the earth, should be dependent upon other animals for hi support and healthy existence; and that the inferior animals in thei turn should be subordinate to and entirely dependent upon plant for the continuance of their lives, and for the ability to perform an of their animal functions. Thus vegetables, which have been place in the great scale of being, as a link, if we may so express ourselves, between the animal and mineral kingdoms, draw from th great storehouse of the earth various substances which they combine and re-combine, until they have rendered them suitable for th aliment and sustenance of the various tribes of animated beings and these again concoct and assimilate them by a variety of unknown processes, until they become fit for the use and maintenance of man. But it is a still more astonishing fact, that the Almighty should have so constituted the world, that the various elements which the several organized beings both animal and vegetabl had converted into the pabulum of life, together with all the materials of which they themselves are constituted, should in due tim estored without loss or deterioration to the general mass of mat- eady to be again converted by the chemical processes of Na- nto fit and proper nutriment for succeeding orders of animated ences. See Notes at page 375 and 390; and Additional Notes, 37.

e changes which matter perpetually undergoes by the destruc- and decomposition of all organized beings, probably gave rise e ancient doctrine of transmigration.

"The sacred seer, with scientific truth,
In Grecian temples taught the attentive youth,
With ceaseless change how restless atoms pass
From life to life, a transmigrating mass;
Whence drew the enlighten'd sage the moral plan,
That man should ever be the friend of man,
Should eye with tenderness all living forms,
His brother emmets, and his sister worms!" DARWIN.

XXVII.

Of the Manufacture of Leaden Shot.

e manufacture of small shot is curious, and will probably e the young reader. In melting the lead, a small quantity senic is added, which disposes it to run into spherical drops. hen melted, it is poured into a cylinder whose circumference rced with holes. The lead streaming through the holes, soon es into drops which fall into water, where they congeal. They ot all spherical; therefore, those that are must be separated, h is done by an ingenious contrivance. The whole is sifted on pper end of a long smooth inclined plane, and the grains roll to the lower end. But the pear-like shape of the bad grains s them roll down irregularly, and they waddle as it were to a while the round ones run straight down, and are afterwards d into sizes by sieves. The manufacturers of the patent shot fixed their furnace, for melting the metal, at the top of a tower eet high, and procure a much greater number of spherical s, by letting the melted lead fall into water from this height, shot is gradually cooled before it reaches the water[*]."

XXVIII.

Of the Incompatible Salts.

ere are certain salts which cannot exist together in solution ut mutual decomposition being produced. It is of great im- nce to the philosophical chemist to have these always in me-

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[*] Dr. Black's *Chemical Lectures*, vol. ii. page 604.

mory. They have been arranged by Dr. Henry in the following order.—*Elements of Chemistry*, vol. ii. eighth edition, page 560.

Salts	*incompatible with*
Fixed alkaline sulphates	Nitrates of lime and magnesia Muriates of lime and magnesia
Sulphate of lime	Alkalies Carbonate of magnesia Muriate of barytes
Alum	Alkalies Muriate of barytes Nitrate, muriate, carbonate of lime Carbonate of magnesia
Sulphate of magnesia	Alkalies Muriate of barytes Nitrate and muriate of lime
Sulphate of iron	Alkalies Muriate of barytes Earthy carbonates
Muriate of barytes	Sulphates Alkaline carbonates Earthy carbonates
Muriate of lime	The sulphates, except of lime Alkaline carbonates Carbonate of magnesia
Muriate of magnesia	Alkaline carbonates Alkaline sulphates
Nitrate of lime	Alkaline carbonates Carbonates of magnesia and alumina Sulphates, except of lime

XXIX.

Of Water-gilding.

Some persons may be glad to be informed how the process of water-gilding is conducted. It is done by previously cleaning copper, intended to be gilt, with sand and weak aquafortis; after which the piece is plunged in a diluted solution of mercury; the mercury leaves its solution, and precipitates itself upon the copper; this causes the amalgam of gold, which is afterwards spread on the piece, to adhere. When the amalgam of gold is uniformly spread, the piece is heated on charcoal, which volatilizes the mercury, and leaves the gold on the copper. See pages 323 and 345. The method practised by the Birmingham manufacturers may be seen in a paper by Mr. Collard, printed in the ninth volume of the *Philosophical Magazine*. The processes for some other kinds of gilding may be

in Gren's *Principles of Chemistry*. A method of gilding silver
out fire is described minutely by Gillert in his *System of Me-*
rgic Chemistry, page 297. And a different mode of water-
ng from the one above related, is given at page 375 of the
work. For common purposes copper is sometimes made to
me the appearances of gold by means of exposing it to the
s of zinc as described by the same author. See page 359. All
modes of gilding as practised at Birmingham will, however, be
d more in detail in Richardson's *Chemical Principles of the*
llic Arts, designed chiefly for the Use of Manufacturers, pages
107. A method of gilding glass and porcelain is also described
ichardson, page 173.

XXX.

Of Tin and Tinned Plates.

n is of use for covering copper and iron culinary utensils. See
281. It is also employed in the formation of tin-plate. These
hin plates of rolled iron, which are covered with tin by the
wing process:—The iron plates, having been thoroughly clean-
r rubbing them with sand, are steeped in water acidulated by
atic acid. They are then heated in an oven to remove whatever
s might be attached to them. In the next place they are ham-
d smooth and passed through a pair of powerful rollers. They
fterwards steeped in a chemical preparation called sours, and
n they have undergone some other preliminary operations, they
mmersed one by one in melted tin; which not only adheres to
urface, but in a great measure penetrates the whole plate. For
ther account of these processes consult La Grange's *Manual of*
nistry, vol. ii. page 80. A more circumstantial account of all
processes in this very curious manufacture will however be
d in a paper which I communicated to the *Literary and Philo-*
cal Society of Manchester, and which is printed in the 3d vol.
v Series) of their *Transactions*.

here are two kinds of tin known in commerce; viz. *block* tin
grain tin. Block tin is procured from the common tin ore,
s usually cast in blocks of about 320 pounds weight; after
h it is taken to the proper offices to be assayed, where it re-
s the impression of a lion rampant, the arms of the Duke of
wall, and which is necessary to make it legally saleable. Grain
found in small particles, in what is called the *stream tin ore*.
pears to have been washed from its original bed in remote ages.
kind of tin owes its superiority not only to the purity of the
but to the care with which it is washed and refined. Tin when
n to be stamped pays a duty of four shillings per hundred weight
e duke. From hence a vast income accrues to the Prince Re-
who is duke of Cornwall. For a particular account of the

management of the Cornish tin mines, consult the sixth volume of Maurice's *Indian Antiquities*, and Mr. John Taylor's communications in the *Philosophical Magazine*.

XXXI.

Wine Tests.

We are told that fraudulent wine-merchants have sweetened their wines and ciders by the addition of lead. Dr. Watson relates that it was at one time a common practice at Paris. He directs how it may be detected. See his *Chemical Essays*, vol. iii. page 369. Methods of detecting this and other adulterations of wine may also be seen in Dr. Willich's *Lectures on Diet and Regimen*, pages 357 to 362. The following is easy of application, and will be found effectual:—Equal parts of oyster shells and sulphur may be heated together, kept in a white heat for 15 minutes, and, when cold, mixed with an equal quantity of cream of tartar: these are put into a strong bottle with common water to boil for an hour; and then decanted into ounce phials, adding 20 drops of muriatic acid to each. This liquor precipitates the least quantities of lead, copper, &c., from wines, in a very sensible black precipitate. As iron might accidentally be contained in the wine, the muriatic acid is added to prevent its precipitation, and its being mistaken for the precipitate of lead. See Note [a], page 308. For an account of the general uses of lead see page 312.

XXXII.

Native Copper.

Native copper occurs occasionally in most of the copper mines. It is usually copper red, but sometimes it is found brown, black, and of various colours. It assumes various forms, and some of the specimens have considerable beauty. It is not often of a large size, though a mass of *native* copper has been found in a valley in the Brazils of 2666 pounds weight. The description of it in the *Memoirs of the Royal Academy of Sciences of Lisbon* is said to be very interesting, as the largest specimen of native copper that had ever been found before this weighs only ten pounds. See *Appendix to Monthly Review*, vol. xxvii. N. S. page 551. The places where native copper is generally found are Siberia, Sweden, Hungary, in some parts of France, and in Cornwall. For a further account of this natural production consult Kirwan's *Mineralogy*, vol. ii. second edition, page 128; or Jameson's *System of Mineralogy*, vol. iii. second edition, page 95.

XXXIII.

Of Iron.

There are several ways of analysing iron ores. An easy method s been suggested by Dr. Higgins; viz. by noting the quantity of drogen gas that is given out, by treating them with the usual ixture of sulphuric acid and water. This method will give, with ry little trouble, a good comparative analysis. One part sulphuric id to eight parts water is the proper proportion for use.

If an iron ore be suspected to contain sulphur, take two measures the hydrogen gas produced by the iron ore in question, and add them one measure of oxygen gas; then inflame these gases by ectricity, and examine the water which is produced from their mbustion. If litmus paper be reddened thereby, it is a proof at it is acidified, and that the ore contained sulphur—otherwise t.

Some valuable information on the manufacture of iron and steel, d on the methods of preparing coke, may be collected from a arce duodecimo volume by a Mr. Horne, entitled *An Essay on on and Steel.* A quarto volume on the same subject, with en-avings of furnaces, &c. has been imported by De Boffe from ris, which is well spoken of.

Iron is found in solution in many natural springs; it gives the aracter to all our chalybeate waters; besides which, there are me springs which contain iron in combination with sulphuric acid. ese are called vitriolated waters. There are several in the king-m; but those at Shadwell near London, and at Swansea in Gla-organshire, I believe are among the most important.

Of all the metals this is certainly the most important, especially it possesses so many properties, exists in so many different states, d is capable of being applied to such a variety of useful purposes.

> "Hail, adamantine steel! magnetic lord!
> King of the prow, the ploughshare, and the sword!
> True to the pole, by thee the pilot guides
> His steady helm amid the struggling tides,
> Braves with broad sail the immeasurable sea,
> Cleaves the dark air, and asks no star but thee."
>
> Darwin.

XXXIV.

Of the Iron Manufactories.

Some idea of the extent and importance of the iron trade (see ge 271) may be conceived from the following account of the iron-orks in South Wales:—" Merthyr Tydvill was a very inconside-ble village till the year 1755, when the late Mr. Bacon obtained a lease of the iron- and coal-mines of a district at least eight miles long, and four wide, for 99 years. Since then, these mines have been leased by him to four distinct companies, and produce to the heirs of Mr. Bacon a clear annual income of ten thousand pounds. The part occupied by Mr. Crawshay contains now the largest set of iron-works in the kingdom. He constantly employs more than two thousand workmen, and pays *weekly* for wages, coal, and other expenses of the works, twenty-five thousand pounds. The number of smelting furnaces belonging to the different companies at Merthyr is about sixteen. Around each of these furnaces are erected forges and rolling-mills, for converting pig into plate and bar iron. These works have conferred so much importance on the neighbourhood, that the obscure village of Merthyr Tydvill has become the largest town in Wales, and contains more than twelve thousand inhabitants."—Abridged from *Malkin's Scenery, &c. of South Wales.*

XXXV.

Of the Diamond.

"It will no doubt be demanded how it happens that pure carbon or diamond is so scarce, while its compounds in different states are so abundantly dispersed? To dispel the astonishment of those who might consider this a ground of distrust, I shall remind them that the aluminous earth is likewise one of the commonest substances, though the adamantine spar, no less rare than the diamond, is nevertheless alumina; that iron exists every where, under every form, excepting in the state of purity, and that the existence of *native* iron is still doubtful. The wonder respecting the diamond consists only in the opposition between facts and our opinions: it disappears in proportion as we discover and appropriate the powers of nature to produce the same effects *." See page 236, &c. A very interesting dissertation on the diamond, will be found in Jameson's *System of Mineralogy*, vol. i. page 1—15.

XXXVI.

Of the Absorption of Caloric.

Dr. Black heated a quantity of water in a strong phial, closely corked, till its temperature rose ten degrees above 212°, its usual boiling point. On drawing the cork quickly, a small portion of water rushed out in vapour, and the temperature of the remaining fluid sunk instantly to 212°. Ten degrees of caloric, therefore, had been absorbed by the quantity of vapour that escaped. Mr. Watt, by heating water under the pressure of a strong iron vessel, raised

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* Dr. John Thomson's *Notes on Fourcroy*, vol. iii. page 201.

temperature to 400°; yet still when the pressure was removed, ly part of the water was converted into vapour, and the tempe- ure of this vapour, as well as that of the remaining fluid, was no ore than 212°.—There were therefore 188 degrees of caloric ab- bed in an instant, by the formation of the vapour, which had no ect on the thermometer. This note is designed to exemplify the ctrine taught at page 79, &c.

XXXVII.

Of the Indestructibility of Matter.

That the Author of nature had so constituted the world that none its elements should be subject to destruction might have been posed by the ancients; but, till the present advanced state of the nce of chemistry, no *proof* of this interesting fact could have n adduced. This is one of the many instances of the tendency ich chemical science has to enlarge the mind, and to establish a onal system of physics. In addition to the facts which have been ady noticed, it may be remarked, that provision has been made n for the restoration of the fallen leaves of vegetables, which rot on the ground, and, to a careless observer, would appear to be lost ever. Berthollet has shown by experiment, that whenever the becomes charged with such matter, the oxygen of the atmo- ere combines with it, and converts it into carbonic acid gas. The sequence of this is, that this same carbon in process of time is orbed by a new race of vegetables, which it clothes with a new age, and which is itself destined to undergo similar putrefaction renovation to the end of time.

> "Link after link the vital chain extends,
> And the long line of BEING never ends."

How insignificant do the most stupendous works of art appear, en compared with the beautiful simplicity of these masterpieces Nature! See page 257.

XXXVIII.

Of the Caloric of Combustion.

r. Crawford determined by numerous experiments, that the ution of caloric which attends combustion is owing to *change pacity*. He found that the capacity of oxygen gas for caloric is h greater than the capacities of combustible bodies; he like- ascertained that the capacity of the compound resulting from combustion is always much less than that of the oxygen gas: therefore evident, that caloric *must* be rendered sensible during bustion, and that it is from the oxygen gas and not from the bustible that it must be evolved. See Crawford's *Experiments nimal Heat, &c.* 8vo. 1788.

XXXIX.

Of Pit Coal.

Naphtha, which is found in great abundance in Persia, is as fluid and transparent as water; but when exposed to the air it becomes yellow, and then brown; its consistence is increased, and it passes into *petroleum.* Petroleum is found native in many countries, and by an exposure to the air becomes *mineral tar.* Mineral tar is also found native, which by exposure to the air passes into *mineral pitch* and *maltha.* By further induration this passes into *asphaltum,* which substance is likewise found native in many parts of the world. Common coal is a composition of some of these bitumens and charcoal. The French jet and the English cannel coal are both so hard that they are susceptible of polish, and are frequently wrought into trinkets. See notes, pages 240 and 241.

XL.

Of the Glow-worm.

In addition to the Notes on Light at page 385, it may be remarked that "the glow-worm is the wingless *female* of a beetle insect. The male is of a dusky hue, without much beauty or peculiarity of markings. The female is more like the larva or grub of a beetle, than a perfect full-grown insect. The light, which is of a beautiful sulphur colour, proceeds from the three last rings of the body. See page 385. From the circumstance of the male being a winged animal, and the female not, it was necessary that some contrivance should be had recourse to for directing the rambler to his sedentary mate. What more beautiful, and at the same time sufficient guide could possibly be contrived, than this self-lighted hymeneal torch?"

"Thine is an unobtrusive blaze,
Content in lowly shades to shine;
How much I wish, while yet I gaze,
To make thy modest merit mine!" Mrs. Opie.

XLI.

Of Siliceous Fossils.

Although this is not professedly a mineralogical work, the following brief account of some of the more common minerals will be useful to the young student.—We begin with those whose chief ingredient is silica.

Quartz is composed for the most part of silica, and forms the chief portion of many of our primitive mountains. It occurs of

rious colours and of a variety of shapes. According to Bergmann
is composed of 93 parts of silica, 6 of alumina, and 1 of oxide of
on. Its specific gravity is 2.6. When perfectly transparent, it is
lled ROCK CRYSTAL, 99 parts in 100 of which are pure silica.
hen quartz occurs of a purple colour it is called amethyst. This
s been found to consist of 97.50 of silica, and the remainder oxide
iron and alumina.

HELIOTROPE is composed of 84 parts of silica, 7.5 of alumina,
0 of oxide of iron, and 2.5 water. This mineral is mostly green
th spots of deep red, and hence it has been called bloodstone. Its
ecific gravity is 2.6.

CALCEDONY is of a gray or brown colour with various shades of
llow, blue, or green, in stalactitical or spherical masses. It con-
its of 84 parts of silica, and 16 of alumina, with a small portion
iron. When of a flesh-red colour, semi-transparent and amor-
ous, it forms CARNELIAN; when stained with dark-coloured
ots or arborizations, MOCHO STONES. The OPAL, the PITCH
ONE, and the HYALITE are fossils of the same family. JASPER
a siliceous fossil which exhibits great variety in its appearances.
is generally composed of about 75 parts silica, 20 of alumina,
d 5 parts of oxide of iron. Its colours are various, and it is sus-
ptible of a high polish. Its specific gravity is 2.7. Where it is
mposed of alternate broad stripes or layers of different colours,
is termed RIBBAND JASPER: the variety which is found in sphe-
idal masses, and exhibits various colours or shades of the same
lour in concentric and alternating stripes or layers, is termed
EGYPTIAN PEBBLE. This mineral was analysed by Weigleb,
d found to consist of 74.58 parts of silica, 15.4 of alumina, and
magnesia.

PUDDING STONE is a collection of rounded pebbles cemented
gether by siliceous matter intermixed with iron. It takes a fine
lish, and possesses a considerable degree of hardness.

GARNET is of a deep red colour, sometimes varying to brown,
ack, or violet. Its specific gravity is from 3.5 to 4.3. The com-
on red kind consists of silica 48, alumina 30, lime 11, iron 10.
EUCITE, or white garnet, is generally in small opaque crystals,
d contains 21 per cent. of potash, 53.75 of silica, and 24.62 of
umina.

LAPIS LAZULI is a stone of a rich blue colour, having little
stre, but susceptible of a fine polish. Its specific gravity is 2.7;
s colour is occasioned by a blue sulphuret of iron. It occurs mas-
ve, and is so hard as to scratch glass. According to Klaproth it is
mposed of 46 silica, 14.5 of alumina, 28 of carbonate of lime,
5 of lime, 3 of oxide of iron, and 2 of water. That beautiful
ne pigment known by the name of *ultramarine* is made from this
ssil.

XLII.

Of Aluminous Fossils.

The aluminous fossils differ from the aluminous earths in having the hardness of stones, and in not falling into powder when immersed in water. The principal are the following.

Corundum, or adamantine spar. This mineral is distinguished from every other by its great hardness, which is such that it is used for polishing even the diamond. Its specific gravity is from 3.9 to 4.01. It consists of 91 of alumina, 5 of silica, and from 1.5 to 6.5 of oxide of iron. The sapphire and ruby are varieties of the same stone.

Lillialite, or **Lepidolite**, is of a violet blue or purple colour, and, when in thin laminæ, of a silvery white; it has a pearly lustre with a slight transparency. Its specific gravity is 2.8. It is composed of about 54.5 parts of silica, 38.25 of alumina, 4 of potash, and 1 of iron and manganese, with 2 of water. Vauquelin analysed a specimen which consisted of 20 alumina, 18 potash, and 4 fluate of lime combined with 54 of silica.

Cyanite is of a blueish gray colour, with streaks of deep blue. Its specific gravity is 3.5. It consists of 55.5 alumina, 43 silica, and 0.5 of iron.

Hornblende. Common hornblende is amorphous, of a gray or black colour, and possesses considerable hardness. Its specific gravity is from 3.6 to 3.8. By heat it may be fused into glass. According to Kirwan, it consists of silica 37, alumina 22, carbonate of magnesia 16, carbonate of lime 2, and oxide of iron 23.

Trap. Under this name are comprehended several varieties of stones, which agree in their general characters. It is found in large masses, of a gray, blue, or purplish black colour, destitute of lustre or transparency, and presenting generally a texture composed of granular concretions. **Whinstone** is a variety of this fossil.

Basaltes is a similar fossil; but it has a greater specific gravity than trap, and is always in large masses of a regular form, generally columnar. According to Klaproth it is composed of 44.5 silica, 17 alumina, 20 oxide of iron, 9.5 of lime, 2.6 soda, and 6 manganese and water. See note [b], page 208, and Additional Notes, No. 14.

Slate, the last of the aluminous stones which I shall mention, is of a blue or grayish colour, with little lustre and scarcely any transparency; it is composed of alumina, silica, lime, magnesia, and oxide of iron, united in various proportions, in the different specimens.

XLIII.

Of Magnesian Fossils.

The magnesian fossils are distinguished by being soft and oily to he touch, and by being more fusible than those of the siliceous enus. The following are some of the varieties.

Chlorite is a fossil of a green colour and scaly texture, without ustre. It occurs both amorphous and crystallized, and consists of agnesia, silica, alumina, lime, iron, and water, in various propor-ons according to the species.

Talc has a plated texture, the lamellæ being easily separated om each other. These lamellæ are flexible, but differ from mica not being elastic: their colour is a greenish white, with some-mes a tinge of red. The laminated variety consists of 62 silica, 7 magnesia, and 1.5 of alumina. Its specific gravity is 2.7 to 2.8.

Steatite, or soap-rock, exists in various states of induration. s specific gravity is 2.6 to 2.8. It always feels soft and greasy; of a yellowish white or greenish gray colour; sometimes spotted r veined; with little lustre or transparency. It is composed of lica, magnesia, alumina, oxide of iron, and water, in various pro-ortions, according to the species and the place whence the spe-imen is obtained. Some curious remarks by Sir H. Davy on the ormation of Steatite, will be found in the first volume of the *ransactions of the Royal Geological Society of Cornwall*, page 43. his mineral occurs at the Lizard Point in Cornwall, and about twelve ons of it are annually raised there, for the porcelain manufactories.

Serpentine is generally of a dark green colour, sometimes raw yellow or blueish gray, with spots or veins of other colours, hrough its substance; without lustre, but susceptible of a fine po-sh Its specific gravity is 2.6. It is always found massive, or morphous. It is composed of silica 31.50, magnesia 47.25, iron .50, carbonate of lime 0.50, oxide of manganese 1.50, alumina 3, nd water 10.50. The precious serpentine contains more silica ith less magnesia and alumina.

Asbestus is distinguished by its fibrous or striated texture. Its olour is greenish white, greenish gray, or yellowish gray. It does ot effervesce with acids. Its specific gravity is from 2.5 to 3.0. Its omponent parts vary, consisting of silica, magnesia, iron, and umina; the silica being in the largest proportion. See note [g], age 95.

Amianthus is a similar fossil, differing from asbestus in its laments being more separated and flexible. According to Mr. henevix it is composed of silica 59, magnesia 25, lime 9.5, alu-mina 3, iron 2.25.

Mountain cork is of a greenish white colour, sometimes of a lood-red, without lustre or transparency, and so light as to swim pon water; its specific gravity being only from 0.68 to 0.99. It onsists of silica 56, carbonate of magnesia 26, alumina 2, car-onate of lime 13, and oxide of iron 3.

Jade, or **Nephrite**, is of a dark leek-green colour, verging often blue. From its supposed medical virtues it was formerly called

Nephritic stone. Its specific gravity is 2.96. It consists of silica 50 5, alumina 31, of magnesia 10, iron 5.50, chrome 0.05, water 2.75. The inhabitants of New Zealand make their hatchets and other edge tools with this stone.

Boracite occurs in small cubic crystals, of a grayish and yellowish white colour. It is a compound of various earths with boracic acid; its proportions being 13.50 of magnesia, 11 of lime, 68 of acid, 2 of silica, 1 of alumina, and 1 of oxide of iron. Its specific gravity is 2.566. This fossil has been found near Luneberg, in Hanover, seated in a bed of sulphate of lime. Westrumb named it *Sedative spar*.

XLIV.

Of Calcareous Fossils.

Gypsum, or **Plaster of Paris,** exists native in considerable quantity, and forms immense strata in various parts of the world. Its specific gravity is 2.3. It consists of 32 parts of lime, 46 of sulphuric acid, and 22 of water. Some of the varieties contain carbonate of lime, alumina, iron, and silica. It occurs in various forms, viz. earthy, fibrous, compact, foliated, and sparry.

Fluor spar is found both amorphous and crystallized; its colours are often very beautiful, and it is susceptible of a fine polish. Its specific gravity is 3.19. A variety analysed by Scheele was composed of 57 of lime, 16 of fluoric acid, and 27 of water. It usually consists of about 68 lime, and 32 acid.

Apatite, which is a phosphate of lime, occurs crystallized and amorphous, but more frequently in crystals. Its specific gravity is 3.2. Its colour is snow-white, gray, green, red, or purple. It consists of 55 of lime and 45 of phosphoric acid. The asparagus-stone is a species of this fossil.

Calcareous spar is crystallized, amorphous, and stalactitical. Its specific gravity is 2.7. It is most commonly white, but it occurs of various colours. The crystals are distinguished by their laminated texture, and by their fragments possessing the property of *double refraction**. They have often the transparency of the siliceous crystals, but want their hardness, being easily scratched

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* ——————————" dissolving shells distill
From the loose summits of each shatter'd hill,
To each fine pore and dark interstice flow,
And fill with liquid chalk the mass below:
Whence sparry forms in dusky caverns gleam
With borrowed light, and *twice refract the beam*;
While in white beds congealing rocks beneath
Court the nice chisel, and desire to breathe;
Or, fused by earth-born fires, in cubic blocks
Shoot their white forms, and harden into rocks." Darwin.

ith a knife. They consist of 56 lime and 44 carbonic acid. *Amorphous* calcareous spar has less transparency and lustre, but its fracture presents distinct granular concretions.

The *Stalactites* are distinguished by their fibrous or striated texture, and their peculiar shapes; being formed at the tops of caverns, by water, loaded with carbonate of lime, filtering through the roof. They are composed of 56 parts lime, 43 of carbonic acid, and 1 of water. Their specific gravity is 2.8. The *Stalagmites* are similar depositions, formed by the water dripping on the floor of the cavern.

Marble is distinguished from the preceding varieties by being amorphous, by existing in large strata, and by greater density and hardness: the latter qualities enable it to take a fine polish. Marbles appear under a variety of forms distinguished by colours, impressions, and fineness of grain. Their specific gravity is from about 2.70 to 2.83.

White marble is nearly pure carbonate of lime; the coloured kinds contain silica, alumina, oxide of iron, and sometimes magnesia and barytes. A pleasing account of the varieties of marble which occur in different parts of the world will be found in Jameson's *System of Mineralogy*, second edition, vol. ii. pages 139—160.

To those persons who are desirous of entering upon the study of mineralogy, the following works, in addition to those which have been repeatedly quoted in the foregoing pages, will be found useful; viz. Jameson *On the Characters of Minerals*; Werner's *New Theory of the Formation of Veins*; Allan's *Mineralogical Nomenclature*; Aikin's *Manual*; Dr. Kidd's *Outlines of Mineralogy*; Brande's *Outlines of Geology*; Mawe's *Mineralogy of Derbyshire*; Bakewell's *Introduction to Geology*, &c.

XLV.

Of Definite Proportions.

It can hardly have escaped the notice of the reader of the foregoing pages, that whenever two or more substances enter into the composition of a body they exist in limited and unvarying proportions. This doctrine is, however, become of so much importance in chemical investigation and analysis, that I am desirous of appropriating a page or two to the more particular consideration of the subject, which can only be rendered plain and perspicuous by offering some examples; and for this purpose I have selected the following.

Sulphur combines with oxygen to form sulphurous and sulphuric acids, but it does not combine with any intermediate quantity of oxygen; and the second dose of oxygen bears a definite and regular proportion to the first, viz. 40 parts of sulphur combine with 40 parts of oxygen to constitute *sulphŭrous* acid, and with 60, or half as much more oxygen, to form *sulphuric* acid.

Copper unites with a certain proportion of oxygen to form the red oxide, and with a defined addition of oxygen to compose the black oxide of that metal; but it never combines with a less quantity of oxygen than that with which it forms red oxide, nor with any quantity intermediate between those with which it forms the two oxides already mentioned, nor with any quantity exceeding that with which it forms the black or per-oxide of copper. To prevent the possibility of being misunderstood, I will add, that 100 parts of this metal unite with $12\frac{1}{2}$ parts of oxygen to constitute the *red* oxide of copper, while 100 parts of copper require 25 parts of oxygen to compose the *black* oxide, and that this metal is never known to combine with oxygen in any other proportions.

Iron is likewise susceptible of two degrees of oxidizement, 69 parts of that metal combining with 20 of oxygen to form the *black* oxide, and with 30 of oxygen to compose the *red* oxide; and it does not unite with oxygen in any other proportions whatever.

Lead differs from iron and copper in this circumstance,—that it has the property of combining with three different portions of oxygen, and forming with them three distinct oxides. The proportions of the oxygen are however as regular and defined in this as in the other instances; the second oxide of lead containing exactly one half more oxygen than the first; and the third oxide exactly four times the quantity of the first oxide: thus 100 parts of lead and $7\frac{1}{2}$ of oxygen form the *yellow* oxide; 100 of lead and $11\frac{1}{4}$ of oxygen compose the *red* oxide; and 100 of lead and 30 of oxygen constitute the *brown* oxide. And lead has never been found to combine with any other than these proportions of oxygen.

Again—if we examine the earthy or alkaline salts, we shall find that the acids and their bases unite with as much regularity; and that the proportions of each may be defined with similar precision. An example or two will render this evident. If we take potash, we shall find that 54 parts of this alkali combine with 46 of dry sulphuric acid to form *sulphate* of potash, and with double that quantity, or 92 parts of a similar acid, to constitute the *bi-sulphate.*

In like manner 59 parts of potash unite with 27.5 parts of carbonic acid to compose the *sub-carbonate* of potash, and with double that quantity, or 55 of carbonic acid, to form the *bi-carbonate* of that alkali; and we have no reason to believe that potash ever unites with carbonic acid in any other than these proportions.

Or if we take ammonia, it will be seen that $21\frac{1}{2}$ of ammonia will combine with $27\frac{1}{2}$ of carbonic acid, forming together 49 of *sub-carbonate* of ammonia, but that the same quantity of this alkali will require exactly a double portion of carbonic acid to constitute the *bi-carbonate* of ammonia. All the salts and metallic oxides with which we are acquainted are formed with the same exactitude of oportions; that is to say, whenever an elementary or compound bstance combines chemically with another substance in more an one proportion, the second or third proportion is always a ltiple or a divisor of the first, and this regularity of composition pears to be observed by Nature in all true chemical compounds, ether solids or fluids, in which no mechanical mixtures have en place.

I have now to observe, that it is entirely owing to this consti- ion of things, that any perfect double decompositions can be ef- ted, and this may be easily demonstrated by one or two exam- s. For instance, if a solution formed with 100 parts of dry phate of soda, equivalent to about 228 parts of crystallized sul- ate, be mixed with a solution containing 186 parts of crystals of rate of barytes, we shall obtain 120 parts of nitrate of soda and 6 of sulphate of barytes; and both the new salts will be as per- tly neutral as the two salts were which were employed to pro- ce the decomposition; and this will always be the case when two tral salts mutually decompose each other; for, if there be a fect interchange of principles, any excess of acid or of basis in resulting compounds will be impossible.

In like manner, if 100 parts of sulphate of potash, which con- 46 parts of dry sulphuric acid and 54 of potash, be mixed with of nitrate of lime, consisting of 32 parts lime and 62 of dry ni- acid, we shall obtain two new salts in the following propor- s; viz. 78 parts of sulphate of lime, consisting of 46 sulphuric d and 32 lime, and 116 parts of nitrate of potash, consisting of nitric acid and 54 potash.

Hence it is evident, that when one body has the power of de- hing another from its combinations, it will always detach the e proportions. Thus, from whatever basis barytes attracts sul- ric acid, it will always detach the same quantity; for, if 100 ts of muriate of barytes (a salt consisting of 26 parts of muriatic d and 74 of barytes) be mixed with a solution containing 100 ts of sulphate of soda, the 74 parts of barytes will separate only parts of sulphuric acid from 68 parts of the sulphate of soda, and remaining 34 parts will be entirely unacted upon, and still con- e to be sulphate of soda as perfect as at the first.

The knowledge of the uniformity and simplicity of these laws, rds the practical chemist a confidence in the results of his expe- ents, which former experimentalists could not attain; and it vinces him that chemical science is now in a fair way for being ablished upon a basis which no future discoveries will ever be to overturn. In justice to Mr. Dalton, I am desirous of re- rking that we are indebted to him for our first ideas respecting important doctrine, on which he has built his atomic theory of chemical constitution of bodies. A brief illustration of this ory may be seen in Dr. Henry's *Elements of Chemistry*, eighth t. vol. i. page 28.

XLVI.

Predatory Insects.

Having already considered (pages 44 and 52) several of those means by which the atmosphere is regularly renovated, it may not be amiss to remark, that the Deity has also provided an innumerable multitude of predatory insects to assist in the accomplishment of the same purpose. These remove the noxious matter that otherwise might rest upon the surface of the earth; and they convert to their own support, even such excrementitious substances as, by the exhalation of their putrid miasmata, would in time totally destroy the whole animal creation.—Is it possible for an unprejudiced mind to avoid being charmed with this beautiful economy of nature; or for those sapient philosophers to escape our pity, who *endeavour* to persuade themselves, that to chance only they are indebted for all these congruities?

"To me, the laurell'd wreath that murder rears,
Blood-nurs'd, and water'd by the widow's tears,
Seems not so foul, so tainted, and so dread,
As waves the nightshade round the sceptic head."
CAMPBELL.

XLVII.

Apparatus for collecting Gases.

The effect of the pressure of the atmosphere in elevating a column of water in the cylinder of a common pump is generally understood, and it is on the same principle that an apparatus has been invented for collecting elastic fluids, or gases. It consists of,

1st. A wooden trough, either square or oval, about 18 inches long, from 9 to 12 inches in diameter and about 6 inches deep. In this trough about 1½ inch below the top is fixed a shelf an inch and half thick, and nearly half the width of the vessel, with holes near its edge 2 or 3 inches asunder, each hole about ¼ of an inch in diameter in the upper surface, and hollowed out in the shape of a funnel in the under surface. This vessel, when in use, is filled with water so as the shelf may be about half an inch below the surface of the water. This vessel is called a pneumatic trough, and a representation of it may be seen in figure 19, plate 5, of the *Rudiments of Chemistry.*

2dly. Cylindrical glass jars of various dimensions from 3 to 12 inches in height, and from 1 to 4½ inches in diameter.

3dly. Phials of flint glass of various sizes, whose mouths are exactly fitted, by grinding, to glass tubes bent in the form of an S.

4thly. Glass funnels of various sizes.

Whenever I wish to collect a quantity of gas and confine it by water in the upper part of a glass jar or cylinder, I plunge the cy-

nder sideways into the tub of water. When thus entirely im-
ersed, and consequently full of water, I give it a perpendicular
rection with the open end downwards, and, in that position,
ace it on the shelf, projecting so far over the edge as to admit the
d of a glass tube or the nosle of a retort. The glass jar being thus
aced, and the ingredients which are to produce the gas being put
to one of the phials mentioned above at No. 3, I fix the ground
d of a bent tube into its mouth, and introducing the other end of
e bent tube under the edge of the jar, I leave the phial suspended
ver the side of the pneumatic trough, as shown in plate 5 of the
udiments of Chemistry, above mentioned. Things being thus ar-
nged, and heat applied, if necessary, we shall soon perceive the
as to rise in bubbles through the water, and, collecting in the upper
art of the jar or cylinder, displace a quantity of water equal to its
wn bulk, because air or gas being lighter than water, it must ne-
essarily rise through it and occupy the upper part of the vessel.

If the gas be prepared in a retort, we have only to place the
outh of the retort whence the gas is evolved, under the open end
f the inverted jar containing water, and wait while the gas rises
nto it in the same manner as already described; and while the
outh of the jar continues surrounded with water, the included gas
annot escape, nor will atmospheric air find access to it. In this
ay aëriform fluids may be collected, preserved, and easily submit-
ed to experiment.

When a jar has been thus filled with air or gas, I slide it care-
ully to the back part of the shelf, where it remains until it be
equired for use. I have then room for one or more on the edge of
e shelf, and space, if it be necessary, for two or more of these
perations to proceed at the same time.

Should I have filled several jars with one species of air, which I
ish to collect in one larger vessel, I plunge this vessel sideways
nto the tub, and when thus filled with water, set it on the shelf
ith the open end downwards. If the jars containing the gas stand
pon the shelf, I take them in succession, and sliding the first off
e shelf, I bring its edge below that of the larger vessel, which had
een placed so as to project beyond the edge of the shelf. I then
radually turn the jar which I hold in my hand under water, when
e air which it contains being forced out by the superior weight of
he water, will rise into the upper part of the larger receiver, dis-
lacing its own bulk of water. I then take the other jars and
mpty them in the same manner.

If I want to transfer a particular species of air from a jar on the
helf into a phial, I first fill the phial with water by plunging it
nto the cistern of water. I then place it on the shelf, with its mouth
ver one of the holes already described, through which I introduce
he glass funnel, and sliding the jar, which contains the gas, off the
helf, I bring its edge under that of the funnel, into which I pour

the elastic fluid, by gradually lowering the closed end of the jar. If the holes in the shelf be properly countersunk underneath, the glass funnel will be generally unnecessary. The phial being thus filled with the air, I slide it off the shelf, and cork it whilst I hold it under the water in an inverted and perpendicular position. In this manner, as many bottles as I have occasion for are easily filled in succession.

Some kinds of air, however, such as muriatic acid gas and ammoniacal gas, are rapidly absorbed by water, they must therefore be confined by quicksilver instead of water. A small wooden cistern, with the bottom made cylindrical, may be conveniently used for this purpose, with jars, &c., on a less scale. Such an apparatus is usually called a mercurial trough; and in using it, the trough and the inverted jars are filled with mercury instead of water.

XLVIII.

Iodine.

In the year 1812, Monsieur Curtois, a maker of soda at Paris, having been accustomed to evaporate saline solutions procured from barilla in iron vessels, observed, that whenever the residual liquors which remained after the separation of the carbonate of soda were allowed to continue in the boilers, their surface became very much corroded, which greatly surprised him, and determined him to endeavour to ascertain the cause of so unexpected an appearance; and during this investigation he discovered a new article, which from the colour of its vapour has been named IODINE. This singular substance may be procured in the following manner. Take a solution of kelp or barilla, evaporate the aqueous part so as to obtain the carbonate of soda; and when by repeated evaporations the whole of the soda and neutral salts are separated, remove the remaining liquor to a tubulated glass retort, adapt a receiver to it, and when this is properly luted, pour some concentrated sulphuric acid upon the liquor within the retort, and proceed to distillation. In a short time a beautiful purple vapour will arise and fill the receiver. If the receiver be kept cool, these vapours will condense upon the sides of it in the form of small rhomboidal blackish-coloured crystals. These crystals, which are the iodine in a solid form, may be purified from any portion of sulphuric acid that may be attached to them, by washing them in water in which a little potash is dissolved. The crystals are then to be dried between folds of bibulous paper, and preserved in stoppered bottles for use. It is adviseable to operate upon a considerable quantity of the solution of kelp at once; for if the quantity be small and there should be chlorine in the residual liquor, the chlorine will combine with the iodine and prevent the formation of purple vapour. In this case a little zinc might be sed to arrest the chlorine ; but if more of this metal be employed han is absolutely necessary, hydrogen gas will be evolved by the ecomposition of the water, and hydriodic acid will be formed. hese circumstances have so often occasioned disappointment the result of this process, that the only way of ensuring a good roduce of iodine, is to concentrate a considerable quantity of the elp lixivium at once by boiling, and then to distil the whole of the esidual liquor in one retort.

The following is a brief outline of the properties of this singular bstance.

Iodine is considered a simple body. It is solid at the usual tem- erature of the atmosphere ; it is a non-conductor of electricity, nd like oxygen and chlorine it is evolved from its combinations at e positive extremity of the voltaic arrangement, and is classed ith them as a supporter of combustion. This may be shown by eans of potassium ; for if a morsel of potassium be suspended in e vapour of iodine it will inflame and burn with a pale blue light. hosphorus also burns when heated in iodine vapour.

Water has not been decomposed by iodine in any of the methods hich have hitherto been attempted, neither does it form any com- nation when heated in oxygen gas ; but it unites with hydrogen, rming with it a distinct acid, which has been named the *hydriodic* id. In the capability which it possesses of forming an acid with ydrogen it resembles chlorine, and also in its odour. Hydriodic id gas is colourless ; it readily combines with water ; the satu- ted solution is of the specific gravity of 1.70, and is fuming like uriatic and some other acids. Its compounds are called *hydriodates*.

Iodine combines with chlorine, and with it forms a peculiar acid lled *chloriodic* acid. Although it does not combine with oxygen mere mixture, it may by the intervention of euchlorine be made combine with it, in which case a new acid is formed which Sir umphry Davy calls *oxyiodine* or oxide of iodine. This acid acts pidly on gold, and produces detonations when heated with the ore combustible metals.

Iodine in vapour is 117 times heavier than hydrogen gas, for 100 bical inches of it weigh rather more than 262 grains. The cry- ls of iodine melt at 225° of Fahrenheit, and at 350° are converted to vapour. If water however be present, the vapour is formed a much lower temperature. Although the vapour of iodine has owerful affinity for water, its crystals are very sparingly soluble that fluid. In spirit of wine they dissolve readily.

The action of iodine with the alkalies is very remarkable. If its pour be made to pass over pure hydrate of potash, the alkali is composed, oxygen is disengaged, and the metallic base combines th the iodine and forms a compound similar in every respect to at which is produced by the union of iodine and potassium. By e mixture of iodine and liquid ammonia, a compound of nitrogen and iodine may be formed which will detonate with the slightest friction.

Iodine by means of heat unites with all the metals, forming compounds called *iodurets*, which like sulphurets have the power of decomposing water. In this operation the hydrogen of the water converts the iodine to an acid, which acid unites with the respective metals, and with them forms metallic salts called *hydriodates*. It agrees also with sulphur in another property, viz. that of forming one acid by its union with hydrogen and a different acid when combined with oxygen. The first of these, as already mentioned, is the *hydriodic*, the other the *oxyiodine* acid.

An ingenious French chemist, M. Gaultier de Claubry, has lately ascertained that iodine exists in the sea-weed *before* combustion; he having found it in several of the fuci in the state of hydriodate of potash. And as the hydriodate of potash is very soluble and even a deliquescent salt, this circumstance accounts for its remaining in the mother-liquor during the subtraction of the subcarbonate of soda and other neutral salts from the alkaline lixivium by the usual process of evaporation.

To the last-mentioned chemist we are also indebted for the discovery that starch is a most delicate test of the presence of iodine. The following experiment is interesting and decisive:—Let a solution of iodine be prepared by dissolving a few of the crystals in spirits of wine; then if a drop or two of this solution be added to an aqueous solution of starch, the starch will separate the iodine from the alcohol, and form with it a blue compound which will eventually precipitate. In order to ascertain if iodine be present in the expressed juice of any vegetable, all that is necessary is to add a few drops of sulphuric acid to the fluid in question, and then treat it with a very dilute solution of starch; and if iodine be present, it will be rendered evident by a blue colour appearing in the liquor.

I have not heard of iodine having been employed in the arts, except for the preparation of some peculiar and expensive pigments; but whenever it shall be produced in considerable quantities, it may probably be employed in calico-printing and for various other purposes. That it may, however, come into use for ascertaining the goodness of starch is I think very likely, as I know much of what has been sold under the name of starch, contains but little of that peculiar substance which possesses the chemical properties of real starch.

XLIX.

Manufacture of Sugar.

Having had occasion to mention the refining of sugar at page 115, I thought a short account of its manufacture in the West Indies would not be uninteresting to the young reader. The sugar cane

ords most of the sugar which is consumed in Europe. The ripe
nes are crushed between two iron cylinders placed perpendicu-
rly. The expressed juice falls on a plate beneath, whence it flows
o a caldron, where it is boiled with wood-ashes and lime, and the
m taken off. This boiling with ashes and lime is repeated in
ee other boilers, which process converts it into syrup. It is then
ongly boiled with lime and alum, and when sufficiently concen-
ted is poured into hogsheads pierced at the bottom with many
les, to let off the molasses, which will not crystallize. These
les are afterwards stopped with canes, as we see them when the
gsheads are imported. The sugar, as it cools, becomes solid in
casks, and is called *muscovado* sugar. It afterwards undergoes
Europe several refinings in order to form it into loaf sugar.

t should be remembered that oxygen is absolutely necessary for
formation of sugar, which is a vegetable oxide. If it were de-
ved of the greater part of this oxygen, it would lose its sweetness,
l would be no longer sugar, but a singular kind of substance
sessing properties more analogous to gum than sugar. Mr.
ickshank has effected this change on sugar by means of phos-
ret of lime, which has a very strong attraction for oxygen;
ugh he was not able to reproduce sugar by the union of gum
h oxygen. See page 254. See also an account of these experi-
nts in Dr. Rollo's *Treatise on Diabetes.*

variety of new experiments on the nature of sugar may be seen
Paper, which, in the summer of 1808, I had the honour to read
re a select Committee of the House of Commons, and which was
rwards printed in the Report of that Committee for the use of
members. Those persons who have no means of seeing the
orts of the House of Commons may find an abstract of this
er in the *Philosophical Magazine* for September 1808.

L.

Coak Ovens.

s the success of several manufactures depends on the procuring
l coak, (see note, page 238,) I feel pleasure in having it in my
er to furnish a description of the kind of oven made use of in
orth of England for coaking the refuse small coal, which before
doption of this method was entirely useless.

the Duke of Norfolk's colliery near Sheffield, several of these
s are built on the side of a hill, occupying spaces formed within
ank. Each oven is a circular building, 10 feet in diameter
n, and the floor laid with common brick set edgeways. The
of the oven rises 19 inches perpendicularly above the floor,
he whole is then covered with a brick arch which rises 3 feet
hes more, forming nearly a cone, whose base is 10 feet, and

whose apex is 2 feet, if measured within. This opening of 2 feet at the top, is left for the convenience of supplying the oven with coal, and to serve as a chimney during the process. The whole height of the building from the floor is 5 feet, and the wall, which is 18 inches in thickness, is built with good bricks and closely laid, that no air may get in through any part of the work.

The floor is elevated three feet above the ground, for the convenience of placing a low carriage under the door-way to receive the coak as it is raked from the oven. When the oven is thus finished, a strong perpendicular wall of common unhewn stone is thrown round it, of about 20 inches in thickness, and carried up the whole height of the oven, forming a complete square. The four corners between the circular building and these outward walls are then filled with soil or rubbish, and well rammed to give greater firmness to the work, and the more effectually to exclude atmospheric air.

When these ovens are once heated, the work goes on night and day without interruption, and without any further expense of fuel. It is conducted thus:—Small refuse coal is thrown in at the circular opening on the top, sufficient to fill the oven up to the springing of the arch; it is then levelled with an iron rake, and the door-way built up with loose bricks. The heat which the oven acquires in the former operation is always sufficient of itself to light up the new charge; the combustion of which is accelerated by the atmospheric air that rushes in through the joints of the loose bricks in the door-way.—In two or three hours the combustion gets to such a height, that the attendant finds it necessary to check the influx of atmospheric air: the door-way is therefore now plastered up with a mixture of wet soil and sand, except the *top* row of bricks, which is left unplastered all night. Next morning (when the charge has been in 24 hours) this is completely closed also; but the chimney remains open till the flame is gone, which is generally quite off in 12 hours more; a few loose stones are then laid on the top of the chimney, and closely covered up with a thick bed of sand or earth. All connection with the atmosphere is now cut off, and in this situation the whole remains for 12 hours, to complete the operation. The door-way is then opened, and the coaks are raked out into wheelbarrows, or low waggons, to be carted away. The whole takes up 48 hours; and as soon as the coaks are removed, the ovens are again filled with coal for another burning. About 2 tons of coals are put in for each charge. These coaks are ponderous, extremely hard, of a light gray colour, and shine with metallic lustre. They are used in those manufactures that require an intense heat.

When coak is required to be more of the nature of charcoal, the process is conducted in a different manner. The small-coal is then thrown into a large receptacle similar to a baker's oven, previously brought to a red heat. Here the door is constantly open, and the heat of the oven is sufficient to dissipate all the bitumen of the coals,

e disengagement of which is promoted by frequently stirring
ith a long iron rake. The coak from these ovens, though made
ith the same kind of coal, is very different from that produced by
e former operation; this being intensely black, very porous, and
light as pumice-stone. I am indebted to Mr. Curr, steward to
is Grace the Duke of Norfolk, for these particulars, who very
litely attended me through the works in the year 1802, and as-
ted me in taking the necessary drawings, admeasurements, &c.
is description will be better understood by referring to a copper-
ate engraving of these ovens in the second volume of the *Chemical*
says, viz. Plate 11, page 329.

LI.

Of the Uses of Diamond.

The lapidaries employ a considerable quantity of diamond in pow-
, which they use with steel instruments, to divide pebbles and
cious stones. The small pieces of diamond of which the pow-
is made, are worth 28 shillings a carat. The use of the diamond
this way is very extensive. Had nature withheld the diamond,
the pebble, the agate, and a variety of other stones, would have
en of little value, as no other substance is hard enough to operate
on them. In this way rock crystal from Brazil is divided into
ves, and ground and polished with diamond dust for spectacles,
l other optical instruments. See page 238; also Mr. Mawe's
eatise on Diamonds and Precious Stones, octavo, London, 1815;
the Additional Note No. 35, in this volume.

LII.

Of the Effect of Oxygen upon Colours.

everal of the effects of oxygen have been mentioned in different
s of this work; but its action on some colouring substances has
been noticed, though it is various and striking. When woollen
hs are taken out of an indigo vat, they are of a green colour;
they are scarcely exposed to the atmospheric air for one minute,
re they imbibe a sufficient portion of oxygen to change that
ur to a deep blue. In like manner the whelk (the *buccinum*
innæus), which is used to dye purple, undergoes a change
lly extraordinary. The liquor, though naturally yellow, be-
es oxidized by exposure to the sun and air, passes through
us shades of yellow, green, crimson, &c., and at length be-
es purple. A good *black* cannot be given to cloth, without
ent exposure to the air. Light has a great affinity for oxygen:
e cloths frequently fade and lose their colours by the abstrac-
of oxygen by the agency of light. That part of the furniture

of a bed which has been exposed to the sun will often be entirely faded, while those parts which have not been so exposed will retain their original colours. This probably arises from the loss of oxygen, and that the oxygen which existed in a solid form is rendered aëriform by the rays of the sun, and goes off in the state of oxygen gas. See Bancroft *On Permanent Colours.*

LIII.

Of the Gases emitted in Respiration.

Having shown that sheet of the work which contains page 53 to a friend, an ingenious chemist, he suggested that those remarks on the *levity* of nitrogen gas evolved from the lungs in respiration would have more force, were I to contrast this character with the superior specific gravity of carbonic acid gas, which is ejected at the same instant. For during that *remarkable* interval that always occurs in breathing, there is sufficient time allowed for these noxious fluids to separate; the first to ascend, while the other preponderates, leaving a space for a fresh current of uncontaminated atmospheric air. Thus every thing is prepared without any care or forethought of ours for a new inspiration.

> "The air inhaled is not the gas
> That from a thousand lungs reeks back to thine
> Sated with exhalations rank and fell,
> Which, drunk, would poison the balsamic blood,
> And rouse the heart to ev'ry fever's rage—
> But air that trembling floats from hill to hill,
> From vale to mountain, with incessant change
> Of purest element." Dr. ARMSTRONG.

I am aware that the doctrine which is advanced in one of the former of these Notes (No. 6.) seems to militate against the argument just advanced; but, if it be considered that it requires a considerable time for gases of different specific gravities to form one homogeneous mixture, I think the objection will be removed.

LIV.

Of Lutes.

Glazier's putty is a very good lute for all common purposes, but it is necessary that the whiting be made thoroughly dry before it be mixed with the oil. Linseed oil and sifted slacked lime, well mixed, and made thoroughly plastic, form an excellent coating for retorts: if made thicker, this mixture is an impenetrable luting, that is not liable to crack.

Dr. Black recommends a mixture of four parts sand and one of lay, except where it is to be exposed to an intense heat, and in uch situations to use six parts of sand to one of clay.

For *fire*-lute Mr. Watt directs the use of porcelain clay from ornwall (not pipe-clay) to be pounded small, and mixed up to e consistence of thick paint, with a solution of two ounces of borax a pint of hot water. For want of this peculiar kind of clay, acked quick-lime mixed up in the same manner, may be used. his may be kept ready mixed in a covered vessel. For *cold*-lute e directs to take equal parts by measure of the above clay and heat flour, and to mix them to a proper consistence with cold ater. This is more tenacious than his fire-lute, but does not keep well.

A very excellent lute for many purposes may be made by beating an egg, both the white and the yolk, with half its weight of ick-lime in powder. This lute is to be put upon a piece of linen, d applied as usual. It dries slowly, but becomes very compact, d acquires great hardness.

A mixture of martial pyrites and muriate of ammonia forms a od lute for stopping the cracks in iron utensils; but the follow- g artificial compound is preferred, on account of the exact pro- rtions of the ingredients being more easily ascertained. To two unds of iron turnings or filings, add one ounce of sal-ammoniac, d one ounce of flowers of sulphur; blend the mixture with water l the whole is of a proper consistence, and use it fresh. This lute employed by engineers to stop the joints of steam-engines and er machinery.

Just as this sheet was going to press, I received a letter from an elligent stranger, informing me that a mixture of salt and whiting, perly kneaded with water, makes a very hard and durable lute many purposes, particularly for securing the joints of the appa- us which is employed for the production of carburetted hydrogen .

LV.

f the extreme Hardness of Ice in some Countries.

The following narration will show the solidity that water is ca- le of acquiring when divested of a large portion of its caloric :— ring the severe winter of 1740, a palace of ice, fifty-two feet long, een feet wide, and twenty feet high, was built at Petersburg, ording to the most elegant rules of art. The river Neva afforded ice, which was from two to three feet thick, blocks of which e cut, and embellished with various ornaments. When built the different parts were coloured by sprinkling them over with er of various tints. Six cannons, made of and mounted with with wheels of the same matter, were placed before the palace; a hempen bullet was driven by one of these cannon, in the presence of the whole court, through a board two inches thick, at the distance of sixty paces*.

"No forest fell,
Imperial mistress of the fur-clad Russ,
When thou wouldst build;—no quarry sent its stores
T'enrich thy walls; but thou didst hew the floods,
And make thy marble of the glassy wave.
Silently as a dream the fabric rose;
Ice upon ice the well adjusted parts
Were soon conjoin'd; nor other cement ask'd
Than water interfused to make them one.
Lamps gracefully disposed, and of all hues,
Illumined ev'ry side. Long wavy wreaths
Of flowers, that fear'd no enemy but warmth,
Blush'd on the pannels, which were once a stream,
And soon to slide into a stream again." COWPER.

LVI.

A New Kind of Gunpowder.

Notwithstanding the accident which happened in France in the year 1788 (see note [f], page 191), the French have since, as I have been informed, actually employed, in one of their campaigns, gunpowder made with oxymuriate of potash instead of salt-petre. That this is practicable, has been proved in this country by the Rev. Alexander Forsyth, of Belhelvie, in Aberdeenshire, in Scotland.—This gentleman, who has taken out a patent for a new kind of gun-lock, to be used without a flint, and has contrived to inflame such gunpowder merely by percussion, informed me that many years ago he discovered a method of making this gunpowder; and that he has himself been in the habit of using it ever since in killing game. The gun-lock is calculated for firing cannon as well as musquetry; it is contrived to hold forty primings of such powder; and the act of raising the cock primes the piece. Though each charge of priming contains only an eighth of a grain of oxymuriate of potash, that alone makes a very loud report; and the principle of the lock is such, that it can never possibly miss fire. This effect is entirely attributable to the large portion of oxygen that is condensed in this very singular salt.

LVII.

Of the Efficacy of Water in Vegetation.

That vegetables will grow in woollen cloth, moss, and in other

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* M. de Bomare.

nsoluble media, besides soils, provided they be supplied with water, as been repeatedly shown since the days of Van Helmont and oyle ; but the experiments of a modern author, from their apparent correctness, seem more highly interesting and conclusive.

Seeds of various plants were sown in pure river-sand, in litharge, n flowers of sulphur, and even among metal, or common leaden ot ; and in every instance nothing employed for their nourishent but *distilled water*. The plants throve, and passed through l the usual gradations of growth to perfect maturity. The author en proceeded to gather the entire produce, the roots, stems, leaves, ods, seeds, &c. These were accurately weighed, dried, and again eighed, then submitted to distillation, incineration, lixiviation, nd the other ordinary means used in a careful analysis. Thus he btained from these vegetables all the materials peculiar to each invidual species, precisely as if it had been cultivated in a natural il,—viz. the various earths, the alkalies, acids, metals, carbon, lphur, phosphorus, nitrogen, &c. He concludes this very imortant paper nearly in these extraordinary words: " *Oxygen* and *ydrogen*, with the assistance of solar light, appear to be the only ementary substances employed in the constitution of the whole niverse ; and Nature, in her simple progress, works the most innitely diversified effects by the slightest modifications in the means e employs." See " *Recherches sur la Force assimilatrice dans les égétaux*," par M. Henri Braconnot, *Annales de Chimie*, Fev. et ars, 1808.

Professor Leslie has made many experiments on a variety of rths and stones by means of his improved hygrometers, the results which are highly deserving the attention of all practical agricul-rists. From these researches he has been induced to think it obable, that the fertility of soils depends chiefly on their disposition imbibe moisture. See his *Short Account of Experiments and struments depending on the Relations of Air, Heat, and Moisture*, tavo, pages 94—102.

LVIII.

Of the Agencies of Galvanism.

The experiments of Sir Humphry Davy, published in the first rt of the Philosophical Transactions for 1807, have thrown consi-rable light on the agencies of electricity and galvanism. See te, page 395.

First. In opposition to the assertions of Pachiani and others, he s demonstrated that muriatic acid is not produced in water by the ency of galvanism, but that water " chemically pure is decom-sed into gaseous matter alone, into oxygen and hydrogen."

Secondly. By the agency of galvanism he decomposed sulphate lime, sulphate of strontites, fluate of lime, and other solid bodies, insoluble, or difficultly soluble in water. In each case the earth was found in one vessel and the pure acid in the other. Even glass was decomposed, and part of its alkali exhibited entire. Sulphuric, muriatic, nitric, and phosphoric salts were decomposed with more rapidity; the acids in a certain time collected in the tube containing the positive wire, and the alkalies and earths in that containing the negative.

Thirdly. He connected a small cup, made with sulphate of lime, with a cup of agate, by a piece of asbestus; and, filling both with purified water, made a platina wire in the cup of sulphate of lime transmit the electricity from a power of 100 plates; a wire in the agate cup received it. In about four hours a strong solution of lime was found in the agate cup, and sulphuric acid in the cup of sulphate of lime. By reversing the order, and carrying on the process for a similar time, the sulphuric acid appeared in the agate cup, and the solution of lime on the opposite side.

Fourthly. Acid and alkaline substances passed through water containing vegetable colours, without affecting them; and the usual chemical affinities were so far destroyed or suspended by the agency of galvanism, that sulphuric acid was passed through a solution of ammonia without combining with it. In like manner the alkalies and earths were transmitted through acids, without combination.

From these and similar results, it appears that " hydrogen, the alkaline substances, the metals, and certain metallic oxides, are *attracted* by negatively electrified metallic surfaces, and *repelled* by positively electrified metallic surfaces; and contrariwise, that oxygen and acid substances are attracted by positively electrified metallic surfaces, and repelled by negatively electrified metallic surfaces; and these attractive and repulsive forces are sufficiently energetic to destroy or suspend the usual operation of elective affinity." Sir H. Davy concludes this most important paper by suggesting that this new method of decomposition may, probably, be introduced with advantage into manufactures; and imagines that he shall be able to refer several natural phenomena to this source, which have been hitherto inexplicable.

For an account of his experiments on the alkalies, see Additional Notes, No. 68.

LIX.

Of the Origin of Caloric.

Mr. Walter Millar of Perth, the ingenious author of a modern work, entitled, " *Physical and Metaphysical Inquiries*," imagines that caloric is *not* transmitted from the sun, but that it is a subtile fluid originally belonging to our earth. The arguments by which he supports this opinion appear to me to have great weight; but I must refer the reader to the work itself, and content myself

ith merely copying the conclusion he draws from these premises:
This view of the nature of caloric," says he, "is more corre-
ondent with the general character of matter, than those generally
tertained. It still represents the sun as the great agent in the
oduction of heat, without supposing it to be an enormous mass of
e. We have only to consider the sun as the great storehouse of
ht: a power, indeed, the most active in nature, but no ways de-
uctive. It shows that light produces heat merely by exciting an
sensible action betwixt caloric and the particles of matter con-
ned in bodies, It accounts for the want of heat in the upper
gions of the atmosphere by the want of sufficient matter to pro-
ce the action of caloric. It destroys the absurd opinion concerning
nsmitted and conducted heat, so contrary to the invariable cha-
cters of all the material powers. It shows that caloric is not an
ception to all the other kinds of matter, but that, like its fellows,
exists in other characters besides that of sensible heat. It ena-
es us to solve the great difficulty concerning the distribution of
at among the different planetary bodies; for, according to this
w, those nearest the sun may have no more than those at the
st remote distance. We have only to suppose the quantity of
oric to be proportioned to the distance; and if a *small* quantity
ists in the planet Mercury, no more heat may be excited than is
ne by a *larger* quantity in Saturn."

The coldness of the upper regions of the air seems to contradict
opinion of the sun being the source of caloric. Professor Leslie
ving ascertained, by some delicate experiments, the law which
nnects the capacity for heat with the rarity of the air, was enabled
trace the gradations of cold in the higher atmosphere, and even
mark the precise limit where the reign of perpetual congelation
st commence. Thus he determined, that under the equator the
ndary of the frozen region begins at the altitude of 15,207 feet;
the latitude of London at 5,950; and in that of Stockholm at
18. See Leslie's *Elements of Geometry*, page 495, &c.

Mr. Bell, in his System of Anatomy, denies that animal heat is
served entirely by the inspiration of atmospheric air, and ad-
ces a new theory, which he supports by several striking facts.
Bell's *Anatomy*, vol. ii.—article *Blood.*

LX.

Of the Barometer.

As the mercury in a barometer rises or falls in consequence of
variation in the weight of the atmosphere, this instrument has
n made use of to measure the height of mountains; and, by
onauts, to ascertain the height they ascend in the air. I am
refore desirous of informing those who are inquisitive on such
jects, that the barometer varies about an inch for every 600 feet
scent above the earth's surface. See page 40, and Additional

Notes, No. 12. This important instrument was invented by Mr. Boyle in the year 1659. An account of some very curious experiments that were made with the barometer on its first construction will be found in a work entitled "*A Continuation of New Experiments Physico-Mechanical,*" &c. By Robert Boyle. Quarto, 1669.

LXI.

Of the Colour of the Blood.

The colour which the blood acquires by the absorption of oxygen has usually been accounted for on chemical principles. Blood it has been said contains iron, and this iron is converted into red oxide by the oxygen gas which it receives from the lungs. See page 50, and Additional Notes, No. 8 and 9. If the coagulum of the blood be washed, it may be rendered colourless; but then it will be found by chemical tests to contain no iron. It has been supposed that the colour of the blood is occasioned by a phosphate of iron, that has the property of giving out part of its oxygen to the system, without its being entirely decomposed. This has given rise to the practice of prescribing phosphate of iron in cases where the blood is deficient in red particles. It is, however, proper to add, that since these remarks were first written, Mr. Brande has published a very ingenious paper to contradict the long established theory of the colour of the blood. See the *Philosophical Transactions* for 1812, page 90.

"When air's pure essence joins the vital flood,
And with phosphoric acid dyes the blood,
Contractile tubes the transient heat dispart,
And lead the soft combustion round the heart."

LXII.

Of Copper.

Tin mines, as they deepen, often produce copper; and formerly, when they had occasion to raise this ore in order to obtain the tin, it was thrown aside as of no value, under the name of *poder*. The present race of miners is profiting by the ignorance of their forefathers. This shows of what importance it is to determine, by chemical analysis, the nature of every substance which passes under the miner's observation. See Note, page 302.

An account of the produce of all the copper mines in Cornwall, in ore, copper, and money, for three years; each year ending on the 30th of June.

Year.	*Tons of Ores.*	*Metallic Copper.*	*Value.*
1815	79,984	6,607 tons 12 cwt.	£582,108 7*s.* 6*d.*
1816	82,442	6,988 tons 2 cwt.	537,621 18 6
1817	73,727	6,608 tons	410,936 0 6

See the *Transactions of the Royal Geological Society of Cornwall,* vol. i. page 252—262.

The ores of copper, as sold at the mine, though some of them richer, do not in most instances contain more than one twelfth copper, frequently not one fifteenth, some of them not one twen- th. The accompanying substances are a heterogeneous mixture earths and metals, amongst which arseniates of various kinds en bear a considerable proportion. As a proof of the great dif- ence there is in the value of copper ores, it may be mentioned, t there are many veins in Cornwall which seldom yield it of a ater price than 4*l.* or 5*l.* per ton; and yet a few tons were lately d from the United mines at 100*l.* per ton. The general average haps does not exceed 7*l.* 10*s.* or 8*l.* per ton. See Mr. Phillips's *ection of Facts respecting the Geology of England and Wales,* ge 212 and 229.

LXIII.

f the Nature of the Combinations of Sulphur and Hydrogen with the Earths and Alkalies.

When sulphur is heated with any of the earths or alkalies, a npound is formed which is denominated a *sulphuret*; but if the phur be previously combined with hydrogen so as to form sul- uretted hydrogen, the earthy or alkaline compound is then called *ydrosulphuret*; and if the hydrogen be combined with an addi- nal portion of sulphur, instead of sulphuretted hydrogen, we ob- what is called supersulphuretted hydrogen, and the compounds ich the supersulphuretted hydrogen forms with the alkaline or thy bases, are known by the name of hydroguretted sulphurets. e nature of these combinations will probably, however, be better derstood by an examination of the following tabular represen- on. If potash be taken for an example, that alkali will be found form these various compounds.

44.5 parts of potash and 15.0 parts of sulphur	give 59.5 of sulphuret of potash.
15.0 parts of sulphur and 1.0 part hydrogen	give 16 of sulphuretted hydrogen.
44.5 parts potash and 16.0 sulphuretted hydrogen	form 60.5 parts of hydrosulphuret of potash.

t has just been stated, that if 15 parts of sulphur be dissolved in art of hydrogen gas, we shall have 16 parts of sulphuretted hy- gen. Now if 15 parts more of sulphur be united to the former pound, we shall obtain 31 parts of supersulphuretted hydrogen, posed of

1 part of hydrogen, and 30 parts of sulphur.

And if we combine

44.5 of potash with 31.0 of supersulphuretted hydrogen,	we obtain 75.5 of hydroguretted sulphuret of potash.

LXIV.

Of Twilight.

Whenever the rays of light pass from one medium to another, they do not afterwards proceed in the same straight lines, but are refracted or bent by the attraction of the denser medium, and proceed as though they had been propagated from another point. If the rays of light pass from a dense to a rarer medium, they are refracted, and in their bending they recede *from* the perpendicular; but, when they come from a rarer into a denser medium, as out of a vacuum into air, or out of air into water, they are refracted or bent *towards* the perpendicular, that is, towards a line perpendicular to the surface whereon they fall at the point of incidence*. Agreeably to this law of nature, when the sun has sunk below the horizon, or has not yet attained that altitude, so that his rays cannot directly impinge upon our earth, they fall on the atmosphere, which refracts them towards the surface of the earth. This is sufficient to account for the morning dawn and the evening twilight; and for the sun himself appearing a few minutes earlier or later than he really is. The gases that compose our atmosphere

> "With airy lens the scattered rays assault,
> And bend the twilight round the dusky vault."

In the summer solstice, in the northernmost parts of our island, the sun descends very little below the horizon, and there is no absolute night, for by the twilight a person may distinctly read at midnight. Near the poles of our world, where one day and one night divide the year, there are some weeks of continued twilight, and the sun is several days visible before he actually rises above, and after he has sunk beneath the horizon. See note [c], page 34 of this volume.

LXV.

Of Dyers' Aquafortis.

This article is used for dissolving tin, to form a mordant for fixing some of the most valuable colours on woollen cloths. In employing this acid, the dyers in the metropolis generally proceed thus: A carboy of aqua-fortis is measured out into a large earthen pan, with from one to two quarts of water for every gallon of the acid, and the whole is well mixed by stirring it with a strong wooden spatula.

Supposing single aqua-fortis be used, the quantity of water employed generally amounts to about one third of the whole; but as no fixed rule can be given, this is left to the discretion of the workman, who apportions the quantity according to the nature and strength of the acid he is using. When the aqua-fortis and water are thus

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* See Ferguson's *Optics*, page 204.

ted, a handful or two of grained tin is thrown in, in such a nner as nearly to cover the whole of the bottom of the jar. An ion immediately commences; and if the aqua-fortis be properly pared, and the tin uniformly spread, the solution goes on regu-y, and no more heat is generated than is necessary to keep up a per action.

If a froth appears upon the surface, the whole is well stirred h the spatula for a few seconds, as it is known that this frothing requently occasioned by the tin lying in heaps at the bottom of vessel. When this tin is dissolved, more is thrown in, and rred as before, as occasion requires. If the aqua-fortis be pure, will now be necessary to add a portion either of common salt or ammoniac to the mixture, which is given in such quantities, l at such intervals, as the appearances of the acid suggest. Here discretion of the workman is the only guide;—for in this, as many other cases, practice instructs better than precept.

When rather more than half the usual quantity of tin is dissolved, liquor begins to turn, as it is termed; that is, a portion of yel- oxide collects round the mass of tin at the bottom of the vessel, ich when stirred gives a colour to the supernatant liquor. When aqua-fortis is in a proper state, the colouring always commences he *bottom* of the jar, which increases on the further addition of tin till the whole liquor acquires the colour of rum, or rather bright amber. If the aqua-fortis be good, these appearances al-ys take place: if not, the tin may dissolve, but the liquor, as it comes saturated, will acquire a milky, instead of a yellow ap-rance: which shows that the tin is improperly oxidized by the d, and that such aqua-fortis is totally unfit for use.

Aqua-fortis is employed in a variety of trades, such as brass nders, silver refiners, gilders, leather dyers, and calico printers; such aqua-fortis would be very improper for dyeing woollen ths. Nothing can be better known to the dyers in the large y, than that the majority of the aqua-fortis that is manufactured ntirely unfit for dyeing scarlet.

Formerly, the difficulty of making good dyers' aqua-fortis was great, that the whole which was consumed in these kingdoms s actually imported from Holland, and there are people now ng who remember the time when they never thought of using but Dutch aqua-fortis. Owing however to various causes, the glish dyers are now generally supplied from London, or by some nufacturers in the country who have paid a particular attention he production of this distinct article. For further information Hellot's *Art of Dyeing Wool*, 12mo., 1767.

LXVI.

Of Strontites.

The history of the discovery of this earth having by accident been omitted in the chapter on the Earths, I am reduced to the necessity of giving it a place in the Additional Notes. It is briefly as follows.

About thirty years ago a mineral was exposed for sale by one of the dealers in fossils at Edinburgh, under the name of carbonate of barytes, which he said he had procured from the lead mines of Strontian, in Argyleshire. For some time this mineral was considered to be merely a variety of *witherite*, or carbonate of barytes; and this opinion was adopted by Pelletier, even after he had submitted a portion of the mineral to chemical analysis. However, Dr. Hope, an eminent professor of chemistry at Edinburgh, from some peculiarities which he had observed in the action of the mineral acids upon the substance in question, strongly suspected the truth of this opinion; and in the year 1791 he entered upon a series of appropriate experiments, the results of which fully convinced him that the mineral from Strontian contained an earth different in its properties from every other earth. From the name of the place whence this mineral was obtained, the Doctor gave the new earth the name of *Strontites*, and the mineral, that of Carbonate of Strontites. Dr. Hope must therefore be considered to be the discoverer of this peculiar earth. His memoir on its properties and combinations, with the detail of his experiments, will be found in the fourth volume of the *Edinburgh Philosophical Transactions*, page 44.

The mineral from whence this earth is obtained, occurs massive and crystallized, but it is generally of a fibrous texture and of a pale asparagus green colour, though it has sometimes been found transparent and colourless. It is soft, yielding readily to the knife, and its fragments are generally wedge-shaped. Its specific gravity is 3.675. According to Dr. Hope it is composed of strontites 61.21, carbonic acid 30.20, water 8.50. A similar mineral has been found also at Braunsdorf in Saxony, and at Pisope, near Popayan in Peru. The former of these occurs in acicular six-sided prisms, and was for a long time mistaken for arragonite. The different varieties of carbonate of strontites are however now generally designated by mineralogists by the name of *Strontianite*, while the several varieties of sulphate of strontites are found in cabinets under the name of *Celestine*.

Strontites, when separated from its acid, has a specific gravity less than 2.0. This of itself distinguishes it from barytes, which has a specific gravity of 4.0. For the peculiar properties of Strontites, see the foregoing sheets, pages 109 and 268.

LXVII.

Of the solvent Power of Water.

The power which water possesses of dissolving gases and solids, is so various when exerted upon different substances, and the re-ts of chemical experiments are so often affected thereby, that I desirous of calling the attention of the student to the fact, by exhibition of a few of the most remarkable instances.

At the usual atmospheric temperature.

Measures f Water.	Measures of Gas.
64 dissolve	1 of azotic gas
64 ditto	1 of hydrogen gas
27 ditto	1 of oxygen gas or 1 of nitrous gas or 1 of carburetted hydrogen gas
8 ditto	1 of olefiant gas
1 dissolves	1 of carbonic acid gas or 1 of sulphuretted hydrogen gas or 1 of nitrous oxide gas
1 ditto	2 of chlorine gas
1 ditto	10 of euchlorine gas
1 ditto	670 of ammoniacal gas.

---

nds of ater.	Pounds of Saline Substances.
,,000 required to dissolve	1 of sulphate of barytes
,,000	1 of muriate of silver
,,900	1 of oxalate of strontites
,,200	1 of sulphate of lead
800	1 of sulphite of lime
500	1 of sulphate of lime
400	1 of phosphite of barytes
200	1 of camphorate of lime
100	1 of camphorate of ammonia
50	1 of carbonate of magnesia
20	1 of pure barytes
12½	1 of nitrate of barytes
7	1 of nitrate of potash
5	1 of tartrate of potash and soda
4	1 of phosphate of soda or 1 of sulphate of copper
2	1 of phosphite of ammonia or 1 of sulphate of iron

Pounds of Water.	Pounds of Saline Substances.
1 dissolves	1 of sulphate of magnesia
1	1½ of muriate of strontites
1	2 of muriate of lime
1	4 of nitrate of lime.

Pounds of Water.	Pounds of Crystallized Salts.
8 contained in	100 of native carbonate of strontites
16	100 of muriate of barytes
22	100 of crystals of sulphate of lime
25	100 of crystals of carbonate of magnesia
31	100 of sulphate of ammonia
52	100 of sulphate of magnesia
56	100 of sulphate of soda

Not a particle in crystallized {
nitrate of potash
nitrate of soda
nitrate of ammonia
or
muriate of soda.

LXVIII.

Of the Decomposition of the Alkalies.

In the third edition of the Chemical Catechism, page 531, I gave my readers an abridgement from the *Philosophical Transactions* for 1807, of a very important paper, read by Sir H. Davy before the Royal Society, on the agencies of galvanism in the decomposition of a variety of alkaline and earthy salts. The experiments which he detailed in that paper were sufficient to produce an alteration in all our former ideas of chemical affinity, as they proved decisively that the formation of all chemical compounds may depend on the electrical state of the materials of which they are composed. Since these, he has had the good fortune to make other important discoveries in this ever-fruitful field of research, and in a paper which he read before the Royal Society on the 19th day of November, 1809, he announced that he had succeeded in the decomposition of the fixed alkalies.—Having the permission of the author to make use of this very interesting paper, I now carefully abridge it, in order to give a correct and succinct account of the important matter which it contains.

In the first attempts which Sir H. Davy made for the decomposition of the fixed alkalies, he entirely failed, in consequence of his having acted upon their aqueous solutions only. He afterwards used potash in the state of igneous fusion, and acted upon it by an electrical power, which was produced from a galvanic battery of 100 plates of 6 inches square, highly charged. Here some brilliant phenomena were produced. A most intense light and a column of flame were exhibited, which seemed to be owing to the development of combustible matter; and when the order was changed, so that the alkali was brought in contact with the negative side of the battery, aëriform globules, which inflamed in the atmosphere, rose through the potash. Being, however, unable to collect the products of decomposition by this means, he had then recourse to pure potash in its usual state, and depended on electricity alone for its fusion, as well as its decomposition.

A small piece of pure potash, moistened a little by the breath, was placed upon an insulated disc of platina, connected with the negative side of a battery consisting of 100 plates of 6 inches and 150 of 4 inches square, in a state of intense activity, and a platina wire, communicating with the positive side, was brought in contact with the upper surface of the alkali. Under these circumstances a vivid action soon commenced. The potash began to fuse at both its points of electrization, and small globules having a high metallic lustre, and precisely similar in visible characters to quicksilver, appeared, some of which burnt with explosion and bright flame. These globules, which appear to be metallic, are the basis of potash, that alkali being composed of this peculiar base and oxygen only.

Soda, when acted upon in the same manner, exhibited an analogous result, and these effects equally took place in the atmosphere, and when the alkali was acted upon in the vacuum of an exhausted receiver; but these globules could not in either case be produced from *crystallized* alkalies. When a globule of the base of potash was exposed to the atmosphere, it immediately attracted oxygen, and a white crust formed upon it, which proved to be pure potash. When the globules were strongly heated and then suspended in oxygen gas, a rapid combustion with a brilliant white flame was produced, and these metallic globules were converted to an alkali, whose weight greatly exceeded that of the combustible matter consumed.

When Sir H. Davy had thus detected the bases of the fixed alkalies, he had considerable difficulty to preserve and confine them, so as to examine their properties and submit them to experiments. He found, however, at length, that in recently distilled naphtha they may be preserved many days, and that their physical properties may be easily examined in the atmosphere, when they are covered by a thin film of it.

The basis of potash, at 60° Fahrenheit, is only imperfectly fluid; at 70° it becomes more fluid; and at 100° its fluidity is perfect, so that different globules may be easily made to run into one. At 50° it becomes a soft and malleable solid, which has the lustre of polished silver; and at about the freezing point of water it becomes harder and brittle, and when broken in fragments exhibits a crystalline texture, of perfect whiteness and high metallic splendour.

To be converted into vapour, it requires a temperature approaching that of a red heat. It is an excellent conductor of heat, and a perfect conductor of electricity.

Resembling the metals in all these properties, it is, however, remarkably different from any of them in specific gravity; for it will not sink in double distilled naphtha, whose specific gravity is only .770, that of water being considered as 1.000. Sir H. Davy has determined by experiment that its specific gravity is to that of mercury as 10 to 223, which gives a proportion to that of water nearly as 6 to 10; so that it is the lightest metallic body known. When this substance is introduced into chlorine gas, it burns spontaneously with a bright red light, and chloride of potash is formed. When thrown upon water, it decomposes it with great violence, and instantaneous explosion is produced with brilliant flame, and a solution of pure potash is the result. When a globule is placed upon ice, not even the solid form of the two substances can prevent their union; for it instantly burns with a bright flame, and a deep hole is made in the ice, which is found to contain a solution of potash. When a globule is dropped upon moistened turmeric paper, it instantly burns, and moves rapidly upon the paper, as if in search of moisture, leaving behind it a deep reddish brown trace. So strong is the attraction of the basis of potash for oxygen, that it discovers and decomposes the small quantities of water contained in alcohol and ether, even when they are carefully purified. When thrown into the mineral acids, it inflames and burns on the surface. In sulphuric acid, sulphate of potash is formed; in nitrous acid, nitrous gas is disengaged, and nitrate of potash formed. When brought in contact with a piece of phosphorus, and pressed upon, there is a considerable action; they become fluid together, burn, and produce phosphate of potash. When a globule is made to touch a globule of mercury about twice as large, they combine with considerable heat: the compound is fluid at the temperature of its formation; but when cool it appears as a solid metal, similar in colour to silver. If this compound be exposed to air, it rapidly absorbs oxygen; potash which deliquesces is formed; and in a few minutes the mercury is found pure and unaltered. When a globule of the amalgam is thrown into water, it rapidly decomposes it with a hissing noise, potash is formed, hydrogen disengaged, and the mercury remains free. The basis of potash readily reduces metallic oxides when heated in contact with them. It decomposes common glass by a gentle heat, and at a red heat effects a change even in the purest glass.

In his experiments on SODA, Sir H. Davy has discovered that its base, like that of potash, is white, opaque, and has the lustre of silver. The property of welding, which belongs to iron and platina, at a white heat only, is possessed by this substance at common temperatures. It is very similar in its more obvious properties to the base of potash; but it has greater specific gravity, being to that of water nearly as nine to ten, or as .9348 to 1.0000. In oxygen gas t produces a white flame, and sends forth bright sparks, occasioning a very beautiful effect. In chlorine gas it burns vividly, with numerous scintillations of a bright red colour. In the quantity of $\frac{1}{40}$, it renders mercury a fixed solid, of the colour of silver, and forms an alloy with tin. When amalgamated with mercury, the amalgam will combine with other metals. Sir H. Davy tried this with iron and platina, and had reason to believe that these latter metals remain in combination with the mercury, even when deprived of the new substance by exposure to the air.

The whole of the sixth chapter of this very interesting paper is occupied with the detail of several curious and ingenious experiments to ascertain the proportions of the bases and oxygen in the two fixed alkalies; from whence he concludes that 100 parts of potash consist of about 84 basis, and 16 oxygen; and 100 parts of soda consist of about 76 or 77 basis, and 24 or 23 oxygen; or that potash may be considered as consisting of about 6 parts basis, and 1 f oxygen; and soda of 7 basis, and 2 oxygen.

In reply to the question, whether the bases of potash and soda hould be called metals, it might be said that they agree with metals n opacity, lustre, malleability, conducting powers as to heat and lectricity, and in their qualities of chemical combination. Even heir low specific gravity does not appear a sufficient reason for making them a new class; for amongst the metals themselves there re remarkable differences in this respect, platina being nearly four imes as heavy as tellurium; and tellurium is not much more than ix times as heavy as the basis of soda. Conceiving the bases of the wo fixed alkalies to be metals, Sir H. Davy has named one Potassium, and the other Sodium, adopting that termination which, by ommon consent, has been applied to other newly discovered metals.

In concluding this very important communication, Sir H. Davy emarks that an immense variety of objects of research is presented the powers and affinities of the new metals produced from the lkalies. In themselves they will undoubtedly prove powerful gents for analysis; and, having an affinity for oxygen stronger han any other known substances, they may possibly supersede the pplication of electricity to some of the undecompounded bodies.

In sciences kindred to chemistry, the knowledge of the nature the alkalies, and the analogies arising in consequence, will open any new views; they may lead to the solution of many problems geology, and show that agents may have operated in the formation of rocks and earths, which have not hitherto been suspected exist.

These discoveries certainly form a new æra in the history of Chemistry, and will render the name of Davy ever dear to those who delight in the investigation of Nature.

> "Immortal Newton thus with eye sublime
> Mark'd the bright periods of revolving time;
> Explored in Nature's scenes the effect and cause,
> And, charm'd, unravell'd all her latent laws."

A more extended view of the connexion between electrical and chemical attraction may be seen in Sir H. Davy's *Elements of Chemical Philosophy*, vol. i. page 158—173. See also Note [d], page 142 of the foregoing sheets.

LXIX.

Of the new Gas procured from Oil, for the purpose of lighting Dwelling-houses and other Buildings.

An important improvement has lately been made in the art of illumination, by the discovery of a mode of producing an inflammable gas from the decomposition of oil. As this promises to be a discovery of considerable importance, I am desirous of laying the particulars before the public.

The inventors are Messrs. John and Philip Taylor, the very ingenious civil engineers of Bury Court, St. Mary Axe, London. These gentlemen have for some time been occupied in pursuing experiments with this gas, and they have succeeded in forming a very simple and convenient apparatus for its production. This apparatus may be adapted to buildings of any size, but is particularly applicable to private establishments, as it is easy to manage, and produces a gas of great brilliancy, free from the admixture of sulphuretted hydrogen, which is so often found to be an inconvenience in the use of the coal gas.

The superior purity of this new gas renders it peculiarly fitted for dwelling-houses, or mansions where plate, furniture, or pictures might suffer from the use of imperfectly purified coal gas, as it has been demonstrated that the most costly decorations can be in no danger from the burning of the gas procured from oil, because this leaves no offensive residuum whatever, after combustion, the use of it being equally cleanly with that of wax candles, while the light which it affords is infinitely more brilliant.

This gas is conducted and distributed by pipes in the same manner as the common coal gas, and it may be exhibited in a variety of beautiful forms according to the taste of the proprietors of the buildings which are intended to be lighted thereby. Messrs. Taylors have already erected their apparatus in several considerable establishments in the metropolis, and at the seats of some gentlemen in the country. The magnificent house lately erected for the United

Service Club in Waterloo Place, is lighted in all the principal rooms in this manner, and the stage of Covent Garden theatre derives a great brilliancy of effect from the same cause.

I understand the process is usually conducted by the use of a small iron stove containing a retort, and that this retort is fixed in such a manner that it may receive a regulated and uniform supply of oil from a vessel which is adapted to it. The operation may be begun or discontinued at pleasure; and whenever the retort is sufficiently heated, the gas is rapidly produced, and is made to pass immediately through a proper condenser, which separates any oil that may be volatilized in an undecomposed state, and which by an ingenious contrivance is made to re-enter the oil cistern. The gas in its way to the gasometer is washed by being conducted through a small quantity of water, which is the only purification it requires; and the gasometer, which is hung in the usual way, may, in every case, be adapted, in respect of size, to the quantity of gas which is required.

I confess I was surprised to find how small a volume of oil gas is required to produce a given degree of light when compared with the usual consumption of coal gas—a circumstance which renders it economical, especially as it serves to lessen materially the bulk of the apparatus. This may, however, be accounted for by the consideration that this gas is in all probability nearly a pure olefiant gas, whereas the gaseous products from the distillation of coal consist only of a *portion* of olefiant gas mixed with common hydrogen and sulphuretted hydrogen. And it is the olefiant gas alone which produces light, the common hydrogen affording very little light, although during combustion it gives out very great heat, and is therefore an inconvenient mixture: moreover, the sulphuretted hydrogen is usually but imperfectly separated by the process of passing the gas through lime water, and what remains is undecomposed during combustion, and escapes into the air of the rooms in which it is employed, where, unless rapid ventilation be provided, its noxious effects are soon apparent.

On many accounts therefore it is probable that oil gas will be found a valuable addition to our means of obtaining a perfect and convenient mode of illumination; and it only remains to state what appear to me to be the facts upon which its economy is grounded.

From inquiries which I have made of the patentees themselves, I find that a gallon of common whale oil will produce about 90 cubic feet of gas, and that a large Argand gas burner will require a cube foot and a half per hour to maintain a perfect light; consequently a gallon of oil made into gas will afford such a light for sixty hours. From these data I calculate that the expense of it at an average price of oil with a competent allowance for coals, &c., will be about three farthings an hour.

Such a burner will be equal in intensity of light to about two

Argand oil lamps, or to about 10 mould candles of the common size.

The comparative cost of the different modes of lighting will therefore stand thus:—

With oil gas in a large Argand burner -	0*s*.	0¾*d*.	per hour.
With Argand lamps and spermaceti oil -	0	3	do.
With common candles - - - - - -	0	3½	do.
With wax candles - - - - - - - -	1	2	do.

From the information which I have been enabled to obtain, I am inclined to think that this newly discovered oil gas is very likely to come into use on the continent, where coal is not abundant, and where simplicity in the construction of the apparatus would be a powerful recommendation; especially as I understand that the *vegetable oils*, which are in many places cheap and abundant, have been found to produce a very excellent and brilliant light by the use of the new apparatus.

There is, however, one circumstance attending the formation of this gas which is at present unaccountable: but the question which it involves is so purely chemical, and at the same time so curious, that it would be unpardonable to omit mentioning it. The retorts which the patentees employ are of cast iron; but they found to their astonishment, that when these had been in use for a few weeks, they lost the power of decomposing the oil, and no gas could be procured from them. After a variety of experiments, however, it was discovered that by inclosing various substances in the retorts to present new surfaces to the oil in its passage, the perfect decomposition of the oil might be effected; and that by changing these substances as often as the retorts are fresh charged, the power may be continued without difficulty. The material which upon the whole answers the best, is hard brick broken into pieces; and whenever this is put into the retorts in proper quantity, it restores to them the power of decomposing the oil, and of furnishing the gas in as great abundance as in the first instance. The time which was expended in encountering these difficulties was, however, not entirely lost, as the new ideas which such obstacles furnished, enabled the patentees to give that degree of perfection to the apparatus which it would otherwise probably never have attained.

Having been accustomed to look upon those scientific men as the greatest benefactors to the community, who devote their time to inquiries which tend to the promotion of human comfort, or to improve the condition of civil society, I consider myself bound to give every discovery which bears this character a place in the passing editions of the Chemical Catechism; and I doubt not but the present communication will be as acceptable as many others of a similar description which have preceded it.

A Correction of Note [d], *page* 268.

Having received a letter from Mr. Hume, intimating that in a Note on Silicum, page 294 of the 8th edition of this work, I had misstated his opinion on silica, inasmuch as that I had mentioned Mr. Smithson as having first announced that "Silica possessed the properties of an acid," whereas he considered himself to be entitled to the honour of that discovery; and as this letter was not received until I had reprinted the note in question, in the present edition, (see page 268,) and as I should be sorry not to do every gentleman complete justice, I am constrained to notice this communication in a place where it would not otherwise have appeared. Agreeably to Mr. Hume's desire I have, however, now examined the books to which he has referred me, and the following is the result of the inquiry.

In the papers on Silex in the 30th volume of The Philosophical Magazine, Mr. Hume has attributed to silica the properties of an acid; and Mr. James Smithson in his Memoir "On the composition of Zeolite," in The Philosophical Transactions, has held the same language; but upon looking to the dates of both papers, I perceive that Mr. Hume's was printed in the year 1808, and Mr. Smithson's in the year 1811. This certainly does entitle Mr. Hume to the claim of priority in promulgating that idea. Had I been acquainted with these dates when the first part of the present edition was sent to the press, I would not have reprinted the note which I am now anxious to correct; but as some of the most respectable chemical writers had given this discovery to Mr. Smithson, I did not suspect that I was committing an error in republishing their opinion.

CHEMICAL TABLES.

No. 1.

ble of the Quantities of Acids and Bases which mutually neu- tralize each other: from the Tables published by Richter, every number being altered to correspond with recent discoveries.

Bases.	
Magnesia	36
Ammonia	31
Lime	51
Soda	56.5
Potash	86
Barytes	141
Strontites	100
Oxide of silver	200
Oxide of iron	64.5
Red oxide of iron	72
Oxide of zinc	74
Litharge	202

Acids.	
Carbonic	40
Muriatic	49.5
Sulphuric	72.5
Nitric	98

Note. The intention of this table is, that if an article in one of ese two columns is taken—for example, Potash—to which the mber 86 corresponds, the numbers of the other column will show w much of each acid is required to neutralize these 86 parts of tash; viz. they will require 40 parts of carbonic acid, or 49½ of uriatic acid, or 72½ of sulphuric acid, &c. In like manner, if an ticle of the second column be taken, the first column will show w much earth, alkali, or metallic oxide will neutralize it. By eans of the rule of three this table may be applied to any quan- y of either of the above substances.

No. 2.

A New Table of the Quantities of real Acid taken up by Alkalies and Earths, according to Dr. Wollaston's Table of Chemical Equivalents.

100 Parts.	Carbonic.	Muriatic.	Sulphuric.	Nitric.
Barytes - -	28½	35	51½	69½
Strontites -	40	49½	72½	98
Potash - -	46½	57½	84½	114
Soda - -	70½	87	128	173
Lime - -	78	96	141½	191
Magnesia -	112	139	204	275
Ammonia -	128	159	233	314

No. 3.

A New Table of the Quantities of Alkalies and Earths taken up by 100 Parts of real Nitric, Sulphuric, Muriatic, and Carbonic Acids, when saturated.—Compiled from the above.

100 Parts.	Ammo.	Magn.	Lime.	Soda.	Potash.	Stron.	Baryt.
Nitric - -	32	36½	52½	58	88	102	144
Sulphuric	43	49	71	78	118½	138	194
Muriatic	63	72½	104	115	174	203	285
Carbonic	78	90	129	142	216	250	352

No. 4.

Table of the Boiling Point of sundry Liquids, &c.

Ether - -	98°	Phosphorus -	554°
Aqua ammonia -	140	Oil of turpentine	560
Alcohol - -	176	Sulphur - -	570
Water - -	212	Sulphuric acid -	590
Muriate of lime -	230	Linseed oil -	600
Nitric acid - -	248	Mercury - -	660

No. 5.

TABLE FOR REDUCING THE DEGREES OF BAUMÉ'S HYDROMETERS TO THE COMMON STANDARD.

umé's Hydrometer for Vinous Spirits, or other Liquid slighter than Water. Temperature 55° Fahrenheit.

grees.	Sp. Grav.	Degrees.	Sp. Grav.	Degrees.	Sp. Grav.
10 =	1·000	21 =	—·922	32 =	—·856
11	—·990	22	—·915	33	—·852
12	—·985	23	—·909	34	—·847
13	—·977	24	—·903	35	—·842
14	—·970	25	—·897	36	—·837
15	—·963	26	—·892	37	—·832
16	—·955	27	—·886	38	—·827
17	—·949	28	—·880	39	—·822
18	—·942	29	—·874	40	—·817
19	—·935	30	—·867		
20	—·928	31	—·861		

No. 6.

umé's Hydrometer for Liquids heavier than Water. Temperature 55° Fahrenheit.

egrees.	Sp. Grav.	Degrees.	Sp. Grav.	Degrees.	Sp. Grav.
0	1·000	27	1·230	51	1·547
3	1·020	30	1·261	54	1·594
6	1·040	33	1·295	57	1·659
9	1·064	36	1·333	60	1·717
12	1·089	39	1·373	63	1·779
15	1·114	42	1·414	66	1·848
18	1·140	45	1·455	69	1·920
21	1.170	48	1·500	72	2·000
24	1·200				

No. 7.

Table of the Effects of Heat, showing the Degrees of different Thermometers (omitting Fractions) at which some chemical Phenomena occur.

	Fah.	Reau.	Cent.	Wedg.
Greatest cold produced by Mr. Walker .	— 90	— 54	— 68	
Nitric acid freezes	— 66	— 44	— 55	
Mercury freezes	— 39	— 32	— 39	
Brandy freezes	— 7	— 17	— 14	
Cold produced by mixing equal parts of snow and muriate of soda .	0	— 14	— 18	
Strong wines freeze	20	— 5	— 6	
Water freezes	32	0	0	
Vinous fermentation begins	59	12	15	
Ditto rapid, and acetous begins . .	77	20	25	
Acetous fermentation ceases	88	25	31	
Ether boils	98	29	36	
Spermaceti melts	112	36	45	
Tallow melts	127	42	53	
Ammonia separates from water . .	130	44	54	
Bees' wax melts	142	49	61	
Camphor sublimes	145	50	63	
Bleached wax melts	155	55	69	
Sulphur evaporates	170	61	77	
Alcohol boils	176	64	80	
Water boils	212	80	100	
Sulphur melts	234	89	111	
Nitrous acid boils	242	93	116	
Sulphur burns slowly	303	120	150	
Tin melts	442	182	227	
Sulphuric acid boils	590	248	310	
Lead melts	612	258	325	
Mercury boils	656	277	347	
Zinc melts	680	288	360	
Iron a bright red in the dark . . .	750	315	384	
Hydrogen gas burns	800	341	427	
Iron red in the twilight	884	380	475	
—— red hot in a common fire . .	1050	448	560	
—— red heat in day-light	1077	462	577	0
Enamel colours burnt	1807	757	986	6
Diamond burns	2897	1451	1814	14
Brass melts	3807	1678	2100	21
Copper melts	4587	2024	2530	27
Silver, melting point unknown				
Gold, ditto ditto.				
Delft ware fired	6507	2880	3580	40
Cream-coloured stone-ware fired . .	12257	5370	6770	86
Flint glass furnace greatest heat . .	15897	7025	8770	114
Smith's forge	17327	7650	9600	125
Cobalt melts—Cast iron melts . .	17977	7975	9850	130
Nickel melts	20577	9131	11414	150
Iron melts	21637	9602	12001	158
Manganese melts	21877	9708	12136	160
Platina melts	23177	10286	12857	170
Greatest heat observed	25127	11100	13900	185

No. 8.

irwan's Table of the Component Parts of Salts, corrected by modern Discoveries.

Salts.	Basis.	Acid.	Wate	State.
earl-ash - - - -	60	24	16 & im.	Dry
arbonate of potash	68	32	- -	Crystallized
-carbonate of ditto -	47	44	Wat. 9	Ditto
arbonate of soda -	59	41	- -	Dry
--carbonate of ditto -	37	59¼	10¾	Crystallized
arbonate of barytes -	78	22	- -	Dry
——— strontites	62	30	8	Native
——— lime	56¼	43¾	- -	Dry
——— magnesia	25	50	25	Crystallized
——— common do.	45	34	21	Dried at 86°
ulphate of potash -	54½	45½	No wat.	Dry
--sulphate of ditto -	38	62	- -	Ditto
ulphate of soda - -	44	56	- -	Dried at 710°
tto ditto - - -	19¼	24¾	56	Crystallized
i-sulphate of ditto -	28¼	71¾	- -	Dry
ulphate of ammonia -	40	60	- -	Ditto
Ditto	14	55	31	Crystallized
——— barytes -	66	34	- -	
——— strontites -	58	42	- -	Native
——— lime - -	42	58	- -	Dried in red heat.
——— lime - -	32	46	22	Crystallized
——— magnesia -	33	67	- -	Fully desiccated
——— magnesia -	18	38	44	Crystallized
lum - - - - - -	21	34	45	Ditto
lum - - - - - -	64	36	- -	Dried at 700°
itrate of potash - -	46¾	53¼	No wat.	
——— soda - -	36¾	63¼	ditto	
——— ammonia -	24	76	ditto	
——— barytes -	59	41	- -	Dry
——— strontites -	49	51	- -	Ditto
——— lime - -	34½	65½	- -	Ditto
Muriate of potash - -	63½	36½	- -	Dried
——— soda - -	53½	46½	- -	Ditto
——— ammonia -	32	50	18	Sublimed
——— ammonia -	39	61	- -	Dry
——— barytes -	74	26	- -	Ditto
——— barytes -	64	20	16	Crystallized
——— strontites -	40	18	42	Ditto
——— strontites -	69	31	- -	Dried
——— lime - -	51	49	- -	Dried at red heat.
——— magnesia -	43	57	No wat.	
arbonate of ammonia	44	56	- -	Dry
i-carbonate of ditto -	28	72	No wat.	

No. 9.

TABLES OF THE PRINCIPAL FRIGORIFIC MIXTURES CONTAINED IN MR. WALKER'S PUBLICATION OF 1808, AS ARRANGED BY DR. HENRY.

Table I. consisting of Frigorific Mixtures, having the Power of generating or creating Cold, without the aid of Snow or Ice, sufficient for all Useful and Philosophical Purposes, in any Part of the World at any Season.

Mixtures.	Thermometer sinks.	Deg. of Cold produced
Muriate of ammonia 5 parts Nitrate of potash - 5 Water - - - 16	From + 50° to + 10°	40
Muriate of ammonia 5 parts Nitrate of potash - 5 Sulphate of soda - 8 Water - - - - 16	From + 50° to + 4°	46
Nitrate of ammonia 1 part Water - - - - 1	From + 50° to + 4°	46
Nitrate of ammonia 1 part Carbonate of soda - 1 Water - - - - 1	From + 50° to — 7°	57
Sulphate of soda - 3 parts Diluted nitric acid - 2	From + 50° to — 3°	53
Sulphate of soda - 6 parts Muriate of ammonia 4 Nitrate of potash - 2 Diluted nitric acid - 4	From + 50° to — 10°	60
Sulphate of soda - 6 parts Nitrate of ammonia 5 Diluted nitric acid - 4	From + 50° to — 14°	64
Phosphate of soda - 9 parts Diluted nitric acid . 4	From + 50° to — 12°	62
Phosphate of soda 9 parts Nitrate of ammonia 6 Diluted nitric acid - 4	From + 50° to — 21°	71
Sulphate of soda - 8 parts Muriatic acid - - 5	From + 50° to 0°	50
Sulphate of soda - 5 parts Diluted sulphuric acid 4	From + 50° to + 3°	47

N.B. If the materials are mixed at a warmer temperature than that expressed in the Table, the effect will be proportionably greater: —thus, if the most powerful of these mixtures be made when the air is + 85°, it will sink the Thermometer to + 2°.

No. 10.

ble II. consisting of Frigorific Mixtures, composed of Ice, with Chemical Salts and Acids.

Mixtures.	Thermometer sinks.	Deg. of Cold produced
w. or pounded ice 2 parts riate of soda - 1	From any Temp. to—5°	*
w or pounded ice 5 parts riate of soda - 2 riate of ammonia 1	to—12°	*
w or pounded ice 24 parts riate of soda - 10 riate of ammonia 5 rate of potash - 5	to—18°	*
w or pounded ice 12 parts riate of soda - 5 rate of ammonia 5	to—25°	*
w - - - - 3 parts ted sulphuric acid 2	From +32° to—23°	55
w - - - - - 8 parts riatic acid - - 5	From +32° to—27°	59
w - - - - - 7 parts ted nitric acid - 4	From +32° to—30°	62
w - - - - - 4 parts riate of lime - 5	From +32° to—40°	72
v - - - - - 2 parts t. muriate of lime 3	From +32° to—50°	82
w - - - - 3 parts sh - - - - - 4	From +32° to—51°	83

. B. The reason for the omissions in the last column of this le, is, the thermometer sinking in these mixtures to the degree tioned in the preceding column, and never lower, whatever be the temperature of the materials at mixing.

No. 11.

Table III. consisting of Frigorific Mixtures, selected from the foregoing Tables, and combined so as to increase or extend the Cold to the extremest Degree.

COMBINATIONS OF FRIGORIFIC MIXTURES.

Mixtures.	Thermometer sinks.	Deg. of Cold produced.
Phosphate of soda - 5 parts Nitrate of ammonia 3 Diluted nitric acid - 4	From 0° to—34°	34
Phosphate of soda - 3 parts Nitrate of ammonia 2 Diluted mixed acids 4	From—34° to—50°	16
Snow - - - - 3 parts Diluted nitric acid - 2	From 0° to—46°	46
Snow - - - - 8 parts Diluted sulphuric acid 3 Diluted nitric acid - 3	From—10° to—56°	46
Snow - - - - 1 part Diluted sulphuric acid 1	From—20° to—60°	40
Snow - - - - 3 parts Muriate of lime - 4	From+20° to—48°	68
Snow - - - - 3 parts Muriate of lime - 4	From+10° to—54°	64
Snow - - - - 2 parts Muriate of lime - 3	From—15° to—68°	53
Snow - - - - 1 part Cryst. muriate of lime 2	From 0° to—66°	66
Snow - - - - 1 part Cryst. muriate of lime 3	From—40° to—73°	33
Snow - - - - 8 parts Diluted sulphuric acid 10	From—68° to—91°	23

N.B. The materials in the first column are to be cooled, previously to mixing, to the temperature required, by mixtures taken from either of the preceding Tables.

Let it be remembered that the salts ought in all cases to be fresh crystallized, and reduced to very fine powder, and the mixtures made in very thin vessels as quickly as possible.

A TABLE of the PROPERTIES of several of the SALTS, arranged in each Class according to the Affinities of their Radicals for the Acids.

Salts.	*Origin.*	*Taste.*	*Form of their Crystals.*	*Action of the Air.*	*Action of Heat.*	*Solubility in 100 Parts of Water.*	
						60°	*Boiling.*
Sulphate of barytes	Native	None	Rhomboidal tables	None	Decrepitates	Insoluble	Insoluble
—— potash	Artificial	Bitter and acrid	Six-sided prisms	Ditto	Ditto	6	20
—— ditto super	Ditto	Sharp and hot	Ditto	Little	Fusible	50	100
—— soda	In sea water	Bitter and cool	Ditto grooved	Effloresces	Aqueous fusion	37	125
—— strontites	Native	None	Rhomboidal prisms	None	Fusible at a high temperature	Insoluble	Insoluble
—— lime	Ditto	Hardly perceptible	Quadrangular prisms	Ditto	Calcines and melts	Nearly inso.	Nearly insol.
—— ammonia	Artificial	Sharp and bitter	Six-sided prisms	Attracts moisture	Aqueous fusion	50	100
—— magnesia	In sea water	Bitter and cold	Four-sided ditto, ending in pyramids	Slightly efflorescent	Ditto	100	133
—— ditto & ammonia	Artificial	Ditto and acrid	Octahedrons	None	Ditto	Little solu.	Little soluble
—— alumina	Ditto	Astringent	Thin pearly crystals	Little	Dries to powder	Moderately	Moderately
—— super ditto and potash	Ditto	Ditto and styptic	Octahedrons	Ditto	Melts and dries	5	133
Sulphite of barytes	Ditto	Little	Tetrahedrous	Ditto		Insoluble	Insoluble
—— lime	Ditto	Sulphureous	Six-sided prisms	Effloresces	Dries to powder	⅛th of a part	
—— potash	Ditto	Ditto sharp and acrid	Various	Ditto	Decrepitates	100	Still more
—— soda	Ditto	Ditto and cool	Four-sided prisms	Ditto	Watery fusion	25	100
—— ammonia	Ditto	Cool and sharp	Six-sided ditto, and various	Deliquesces	Decrepitates	100	
—— magnesia	Ditto	Sweet and earthy	Flat transparent tetrahedrons	Effloresces	Softens and dries	5	
—— alumina	Ditto	Sulphureous & earthy	In white powder	Changes to sulphate	Decomposes	Insoluble	Insoluble

(Table continued.)

Salts.	*Origin.*	*Taste.*	*Form of their Crystals.*	*Action of the Air.*	*Action of Heat.*	*Solubility in 100 Parts of Water.*	
						60°	*Boiling.*
Nitrate of barytes	Artificial	Hot, acrid, and rough	Octahedrons	Little	Decrepitates	9	30
——— potash	Native	Cool and bitter	Various	None	Melts	14	200
——— soda	Artificial	Ditto	Rhomboidal cubes	Softens	Decrepitates	33	100
——— strontites	Ditto	Cool and penetrating	Octahedrons	None	Ditto	100	200
——— lime	Ditto & native	Acrid, hot, and bitter	Six-sided prisms	Deliquesces	Fuses and decomposes	400	Unlimited
——— ammonia	Artificial	Acrid and bitter	Various	Ditto	Watery fusion	50	200
——— magnesia	From mother waters of nitre	Bitter	Small needles and four-sided prisms	Ditto	Fusible	100	100
——— alumina	Artificial	Astringent	Does not crystallize	Ditto	Decomposes	Extremely soluble	
Muriate of barytes	Ditto	Pungent	In tables and octagons	Unalterable	Decrepitates	18	20
——— potash	Ditto	Pure saline taste	Cubes	Moistens a little	Ditto	33	
——— soda	Sea and rocks	Ditto	Ditto	Ditto and dries again	Ditto	35	36
——— strontites	Artificial	Pungent	Fine prisms	Unalterable	Melts	120	Unlimited
——— lime	Mineral waters	Ditto	Needle-like ditto	Very deliquescent	Ditto	200	
——— ammonia	Native	Bitter	Various	None	Fusible and volatile	30	100
——— magnesia	In waters	Ditto and disagreeable	In powder, or jelly	Deliquesces	Ditto and decomposes	100	
Oxygenized muriate of potash	Artificial	Cool and harsh	Square thin plates	None	Ditto and ditto	6	40
Phosphate of barytes	Ditto	Insipid	Heavy powder	Ditto	Fusible in great heat	Insoluble	Insoluble
——— strontites	Ditto	Ditto	White ditto	Ditto	Ditto	Ditto	Ditto
——— lime	Native	Ditto	Various prisms	Ditto	Ditto with difficulty	Ditto	Ditto
——— ditto super	Artificial	Sour	Plates or silky threads	Moistens a little	Softens and dries		
——— soda	Ditto	Mild, saline, and alkaline	Various	Effloresces outwardly	Aqueous fusion	25	50

(Table continued.)

Salts.	Origin.	Taste.	Form of their Crystals.	Action of the Air.	Action of Heat.	Solubility in 100 Parts of Water.	
						60°	Boiling.
Phosphate of ammonia	Artificial	Salt and urinous	Four-sided prisms, ending in pyramids	None	Aqueous fusion	40	60
——— ditto and soda	In urine			Effloresces			
Phosphite of lime	Artificial	Acid	Small needles	None	Decomposes	Sparingly	
——— barytes	Ditto	Insipid	White powder	Ditto	Melts	Ditto	
——— magnesia	Ditto	Ditto	Flaky crystals	Effloresces	Ditto	¼th of a part	
——— potash	Ditto	Sharp	Four-sided prisms	Little	Decrepitates and melts	33	33
——— soda	Ditto	Mild and cool	Irregular ditto	Effloresces	Melts	50	50
——— ammonia	Ditto	Sharp	Needles and prisms	Deliquesces	Ditto and decomposes	50	50
Fluate of lime	Native	None	Various	None	Decrepitates	Insoluble	
——— soda	Artificial	Bitter	Cubes	Ditto	Ditto	Difficult	
Borate of lime	Ditto & Native	Insipid	White powder			Ditto	
——— ditto & magnesia	Native	Ditto	Polyhedron with 22 faces	None	Decrepitates	Insoluble	
——— soda	Ditto	Alkaline and sweet	Irregular	Effloresces	Aqueous fusion	8½	17
Carbonate of barytes	Ditto		Striated masses	None	Decomposes	Nearly inso.	Nearly insol.
——— strontites	Ditto	None	Striated ditto	Ditto	Ditto and decomposes	Ditto	Ditto
——— lime	Ditto	None	Various	Ditto	Decrepitates	Insoluble	Ditto
——— potash	Ditto & artificial	Mild alkaline	Square prisms terminated by square pyramids	Crystals effloresce	Aqueous fusion	25	80
——— soda	Native	Ditto	Irregular octahedrons	Ditto much	Ditto	50	100
——— magnesia	Artificial	None	Small prisms	Ditto	Decrepitates	Cryst. 2	
——— ammonia	Ditto	Little acrid	Irregular	Unalterable	Sublimes	30	100

EXPERIMENTS.

Nothing tends to imprint chemical facts upon the mind so much as the exhibition of interesting Experiments. With this view the following selection has been made, in which such experiments as may be performed with ease and *safety*, have uniformly been preferred. The rationale of each will generally be found in the foregoing sheets at the pages referred to.

I. *Experiments on Change of Temperature.*

No. 1. Take a small phial about half full of cold water; grasp it gently in the left hand, and from another phial pour a little sulphuric acid very gradually into the water. A strong SENSATION OF HEAT will immediately be perceived. This, by the continued addition of the acid, may be increased to many degrees beyond that of boiling water. See pages 59 and 68.

2. Take a small phial, in one hand, containing some pulverized muriate of ammonia; pour a little water upon it, and shake the mixture. In this instance a SENSATION OF COLD will immediately be felt. See page 61.

3. If the student be in possession of an air-pump, the following experiment may be easily performed:—Let him fix a small tin cup of *ether* within a large watch-glass containing a little water, and place both under the receiver of the air-pump. The exhaustion of the receiver will cause one of the fluids to BOIL, and the other to FREEZE AT THE SAME INSTANT. See note, page 39.

4. Place a phial of water, inclosing a thermometer, in a frigorific mixture, and by avoiding agitation cool it some degrees below the freezing point. If it be now agitated, it immediately becomes solid, and its temperature instantly rises to 32°, an instance of a change of form occasioning an EXTRICATION of CALORIC. See page 58.

5. Fill a small glass matrass, or flask, holding about half a pint, with any kind of coloured water, having previously put in a few tea-spoonfuls of *ether:* then invert the flask in a shallow vessel of water, and by degrees pour boiling water upon its bulb. By the sudden accession of heat the ether will be changed into vapour, which will force out the coloured water and fill the whole of the vessel. This experiment will afford an example of a liquid being converted into an ELASTIC VAPOUR BY CALORIC. See note, page 71.

6. For want of a proper glass vessel, a table-spoonful of ether may be put into a moistened bladder, and the neck of the bladder closely tied. If hot water be then poured upon it, the ETHER WILL EXPAND, and the bladder become inflated. See note, page 71.

7. Take a glass tube with a bulb in form of a common thermometer; fill it with cold water, and suspend it by a string. If the bulb be frequently and continually moistened with pure sulphuric ether, the water will presently be FROZEN, EVEN IN SUMMER. See note, page 78.

8. Dissolve five drachms of muriate of ammonia, and five drachms of nitre, both finely powdered, in two ounces of water. A thermometer immersed in the solution will show that the temperature is reduced below 32°. If a thermometer tube, filled with water, be now suspended within it, the WATER will soon be AS EFFECTUALLY FROZEN as in the last experiment. See note, page 59.

9. If a small thermometer be placed in a glass vessel containing about an ounce of a solution of soda; on adding a sufficient quantity of muriatic acid to saturate the soda, the mercury in the thermometer will expand; affording an instance of HEAT being produced by THE FORMATION OF A SALT. See page 61.

10. Let the last experiment be repeated, with the *carbonate* of soda instead of pure soda; the mercury will now sink in the thermometer. Here, though the SAME KIND OF SALT is formed, COLD IS PRODUCED. See note, page 70.

11. Fill a thermometer tube with tepid water, and immerse it in a glass vessel of water of the same temperature, containing a mercurial thermometer. If the whole be now placed in a bed of snow, or in a frigorific mixture, the water in the tube will suffer a progressive diminution of volume, until it arrives at about 40°; it will then begin to expand gradually until it becomes solid. This shows

how ICE is enabled to SWIM ON THE SURFACE OF WATER. See pages 75 to 77.

12. Another example on this subject may be shown. Fill a thermometer tube with cold water, at about 32°, and immerse it in a vessel of warm water. In this case, the water in the tube will contract in volume till it arrives at about 42°; when it will appear for a time nearly stationary. If the heat be now continued, the effect will be reversed, for the water in the tube will *expand* as its temperature is increased. This is a curious instance of a CHEMICAL ANOMALY. See note, page 76.

13. Charge a small glass retort with strong muriatic acid, and insert its beak into a tubulated receiver containing a little water; then into this receiver insert two small thermometers, the one immersed in the water, the other suspended above it. By applying the heat of a lamp to the retort, muriatic acid gas will be disengaged in abundance; and if the thermometers be examined, that which is suspended in the gas will be found to have risen only a FEW DEGREES, while that which was immersed in the cold water has acquired a BOILING HEAT. See note[f], page 61.

14. Take a glass of cold water, pour a little sulphuric ether upon its surface, and inflame it by a slip of lighted paper. The ether will burn for a considerable time, and produce a large volume of flame, but when it is extinguished the water will be found not to have increased in temperature. The design of this experiment is to show that WATER IS A BAD CONDUCTOR OF CALORIC, and that when we wish to heat water, the heat ought not to be applied at its surface. See part of note[d], page 73.

15. Dip the bulb of a thermometer in melted rosin so as to coat the glass with it, and suffer it to cool completely. If the flame of a taper be now applied to the bulb, so as to melt the rosin, the MERCURY in the thermometer will not rise at the approach of the taper, but WILL actually be seen to CONTRACT AS THE ROSIN BECOMES LIQUID. See note, page 68.

16. Put into a wine-glass about a scruple of the oxidized manganese and nitrate of potash, prepared as directed page 288, and an equal quantity of the same compound into another glass. On one pour hot, and on the other cold water. The HOT SOLUTION will exhibit a BEAUTIFUL GREEN colour; the COLD ONE, a DEEP PURPLE.

17. If a small portion of the same compound be put into several glasses, and water at different temperatures be poured upon each,

the contents of each glass will exhibit a different shade of colour. This experiment affords another instance of METALS PRODUCING VARIOUS COLOURS according to their different modes of TREATMENT. For the means of varying this experiment, see note, page 288.

18. If a flat bar of iron be hammered briskly on an anvil, its temperature will soon be so increased, that a piece of phosphorus laid upon it would instantly be inflamed. This experiment is designed to show that CALORIC may be EVOLVED merely BY PERCUSSION; and that, when evolved, it is as active and energetic as though it had never been latent. See page 57.

19. In two or three wine-glasses, each containing some distilled water, diffuse a little newly prepared *white* prussiate of iron, and exclude the action of the air, by covering the contents of each with a thin layer of oil. If these colourless liquids be now exposed to different degrees of cold, it will be perceived that whenever the water in either of them freezes, the WHITE PRECIPITATE will become BLUE.

II. *On the Gases.*

20. Put about an ounce of marble grossly pulverized into an eight-ounce phial, with about an equal quantity of water. Pour upon it a little sulphuric acid, and CARBONIC ACID GAS will be evolved *. See page 252.

21. Put some iron wire into a phial with about three or four ounces of water; pour a little sulphuric acid upon the contents, and HYDROGEN GAS will be evolved. See notes, page 85.

22. Pour water into a small glass retort so as to occupy about one third of its capacity, lute its beak into the end of a gun barrel, the middle of which must be kept red hot in a furnace, or by a chafing-dish: then if a lamp be applied to the retort so as to cause the water to boil, the steam will pass through the red-hot iron tube, and the water in this case also will be decomposed; for, as the oxygen combines with the iron, the HYDROGEN GAS will be liberated, and may be collected in the usual way. See page 85.

23. Put some sulphuret of iron into a phial, pour a little diluted

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* The cheapest receiver for the collection of this and other gases is a moistened bladder, with a piece of tobacco-pipe firmly tied into its neck, and twisted in such a manner as to expel all the common air. This may easily be adapted to any vessel by means of the pipe, which may be fixed in the cork, and closely luted in the usual way.

sulphuric acid over it, and attach a bladder, prepared as directed for Experiment No. 20, to the phial. SULPHURETTED HYDROGEN, a gas extremely fetid and disagreeable, will immediately be evolved : though the ingredients here employed were destitute of smell. See page 224.

24. Put an ounce or two of the black oxide of manganese into a small glass retort, pour a little concentrated sulphuric acid upon it, and apply the heat of a lamp. OXYGEN GAS will be disengaged in abundance. See Additional Notes, No. 7.

25. If the leaves of a plant, fresh gathered, be placed in the sun as directed page 53, very pure OXYGEN GAS may be collected.

26. Into a small glass retort put a mixture of two parts of quicklime, and one of muriate of ammonia, both in powder. Apply the heat of a lamp, and AMMONIACAL GAS will come over. See page 137.

27. Pour a little sulphuric acid upon a small quantity of quicksilver in a glass retort, apply heat, and SULPHUROUS ACID GAS may be collected. See page 148.

28. Take some copper-wire or a few shreds of copper, and pour over them a little diluted nitrous acid, in the proportion of about three parts of water to one of acid. The gas evolved in this case is NITROUS GAS. See page 157.

29. Upon an ounce or two of nitrate of potash in a glass retort pour some sulphuric acid; give it heat by means of a lamp, and collect NITRIC ACID GAS. See page 156.

30. Treat muriate of soda in the same manner with sulphuric acid, and MURIATIC ACID in the gaseous form will rise from the retort. See note, page 150.

31. Convey some muriatic acid gas into a glass jar containing a portion of the gas produced in Experiment 26. From the mixture of these two invisible gases a SOLID SUBSTANCE will be produced, viz. the common sal ammoniac; this may be perceived to deposit itself upon the sides of the vessel in a neat crystallized form. See pages 137 and 138.

32. Convey some carbonic acid gas into a a glass jar containing a portion of ammoniacal gas. The instant the two gases come into

contact a great absorption will take place, and SOLID CARBONATE OF AMMONIA will be formed on the inner surface of the jar. See page 137.

33. Whenever uncombined muriatic, or any volatile acid is suspected to be present in any chemical mixture, it may be detected by ammonia. A single drop of ammonia on a feather, or small slip of paper, held over the mixture, will immediately render the VAPOUR VISIBLE.

34. Ammonia in solution may in like manner be detected by a single drop of muriatic, or acetic acid, which will produce very evident WHITE FUMES. This is merely the reverse of the former experiment. See note, page 139.

35. Procure a bladder furnished with a stop-cock, fill it with hydrogen gas, and then adapt a tobacco-pipe to it. By dipping the bowl of the pipe into a lather of soap, and pressing the bladder, soap-bubbles will be formed, filled with hydrogen gas. These bubbles will rise into the atmosphere, as they are formed, and convey a good idea of the principle upon which AIR-BALLOONS are inflated.

36. Procure a bladder similar to that described in the last experiment, and charge it with a mixture of oxygen and hydrogen gases. With this apparatus blow up soap bubbles as before, and touch them with a lighted match. The bubbles as they rise will EXPLODE WITH A SMART NOISE. See note, page 222.

37. Fill a bladder (similar to that directed in the Note for Experiment No. 20.) with hydrogen gas; apply a lighted match to the end of the tobacco-pipe, and press the bladder gently. A PENCIL OF FLAME, extremely beautiful, will be seen issuing from the pipe, till the whole of the hydrogen gas is consumed. See note, page 84.

38. Place some small phials on the shelf of the pneumatic tub filled with water, and inverted as usual for receiving gases. Now fill these with mixed *oxygen and hydrogen gases* from the bladder, as described in Experiment 20. A lighted match will cause any one of them to EXPLODE WITH VIOLENCE. When the phials are used, it will be prudent to fold them round with a handkerchief, to prevent any injury being received from the glass in case of bursting; but if small bladders be employed in place of the phials, this precaution will be unnecessary. See note, page 222.

39. Procure a glass jar, such as is generally used for deflagrating

gases, and fill it with oxymuriatic acid gas. If nickel, arsenic, ismuth in powder, be thrown into this gas, and the tempera- of the atmosphere be not lower than 70°, the metal will in- e, and continue to burn with the most BRILLIANT COM- STION. See note, page 152.

0. Put a small piece of phosphorus into a crucible, cover it ely with carbonate of lime or pulverized common chalk, so as ll the crucible. Let another crucible be inverted upon it, and subjected to the fire. When the whole has become perfectly hot, remove them from the fire; and when cold, the carbonic of the chalk will have been decomposed, and the BLACK ARCOAL, the basis of the acid, may be easily perceived ngst the materials. See page 248.

1. Place a lighted wax taper within a narrow glass jar, then a jar or phial of carbonic acid gas, and cautiously pour it into jar containing the taper. This being an *invisible* gas, the ope- r will appear to invert merely an *empty* vessel, though the ta- will be as effectually and instantaneously EXTINGUISHED water itself had been used. See note, page 250.

2. Let sulphuric acid be poured into a saucer upon some ace- of potash. Into another saucer put a mixture of about two s of quick-lime, and one of sal ammoniac, both in powder, ng to these a *very small* quantity of boiling water. Both saucers le separate will yield *invisible* gases: but the moment they are ght close together, the operator will be ENVELOPED IN RY VISIBLE VAPOURS. Muriate of soda, in this experi- t, may be substituted for acetate of potash. See page 139.

3. It is an interesting experiment to place a glow-worm within of oxygen gas, in a dark room. The insect will shine with h greater brilliancy than it does in atmospheric air, and appear e alert. As the luminous appearance depends on the will of animal, this experiment probably affords an instance of the MULUS which this gas communicates to the ANIMAL STEM.

4. Paste a slip of litmus paper within a glass jar, near the om, then fill the jar with water, and invert it on the shelf of a umatic trough. If as much nitrous gas, previously well washed, assed into the jar as will displace the water below the level of paper, the colour of the litmus paper will still remain unaltered; on passing up atmospheric air it will immediately be reddened; wing THE FORMATION OF AN ACID, by the MIXTURE TWO GASES. See page 373.

45. Take a few grains of citric acid, and twice as much dry ca
bonate of potash, or of soda, both in powder; mix them, and p
them into a dry glass. No chemical change will take place i
either of these salts; but the moment water is poured upon them
an effervescence and extrication of gas will ensue, affording an i
stance of the necessity of WATER to promote SOME CHEM
CAL DECOMPOSITIONS. See page 18.

III. *On the Formation and Crystallization of Salts*

46. If common Glauber's salt be dried and reduced to powde
as directed note, page 209, and then dissolved in three times i
weight of boiling water, it will not only be found to crystalliz
again on cooling, but the crystals will assume the identical form
which they exhibited before they were pulverized. This exper
ment is designed to show that a DETERMINATE FIGURE h
been instamped upon every INDIVIDUAL SALT.

47. Dissolve $\frac{3}{4}$ of an ounce of Glauber's salt in two ounces
boiling water, pour it while hot into a phial and cork it close.
this state it will not crystallize, even when perfectly cold; but
the cork be now removed, the crystallization will be seen to com
mence and proceed with rapidity; affording an instance of the e
fect of ATMOSPHERIC AIR on CRYSTALLIZATION. S
page 207.

48. Repeat the experiment with a small thermometer immers
in the solution, and closed so as to exclude the atmospheric air.
the solution be suffered to cool completely under these circu
stances, the thermometer will be seen to rise on the removal
the cork. This experiment is designed to show that saline so
tions give out CALORIC in the act of CRYSTALLIZATIO
See note, page 61.

49. Put half an ounce of quicksilver into a wine-glass, and po
about an ounce of diluted nitrous acid upon it. The nitrous ac
will be decomposed by the metal with astonishing rapidity; t
colour of the acid will be quickly changed to a beautiful gree
while its surface exhibits a dark crimson: and an effervescence
describably vivid and pleasing will go on during the whole time t
acid operates upon the quicksilver. When a part only of the me
is dissolved, a change of colour will again take place, and the ac
by degrees will become paler, till it is as pellucid as pure wat
This is one instance of a METALLIC SOLUTION by means
an ACID; in which the opacity of a metallic body is complet
overcome, and the whole rendered perfectly transparent.

50. Take the metallic solution formed in the last experime

little more quicksilver to saturate the acid; then place it at
distance, over the flame of a lamp, so as gently to evaporate
of the water. The new-formed salt will soon be seen to be-
shoot into needle-like prismatic crystals, crossing each other
ry possible direction; affording an instance of the FORMA-
I of a METALLIC SALT.

Pour a small quantity of strong nitrous acid into a wine-
add twice its quantity of distilled water*, and, when mixed,
a few very small pieces of granulated tin into it. A violent
escence will take place, the lighter particles of the tin will be
n to the top of the acid, and be seen to play up and down in
uor for a considerable time, till the whole is dissolved. This
ther example of a TRANSPARENT LIQUID holding a
AL IN SOLUTION.

Dissolve one ounce of quicksilver *without* heat in ¾ of an
of strong nitrous acid, previously diluted with one ounce and
of water. Dissolve also the same weight of quicksilver, *by*
of heat, in the same quantity of a similar acid, and then to
of these colourless solutions add a solution of potash. In the
ase, the metal will be precipitated in a *black*, in the other, in
ish yellow powder, affording an example of the difference of
of metallic oxides, arising from DIFFERENT DEGREES
XIDIZEMENT. See page 358.

Take an ounce of a solution of caustic soda, pour upon it
n ounce of sulphuric acid; lay the mixture aside, and when
crystals of sulphate of soda will be formed in the liquor.
a MILD SALT has been FORMED from a mixture of two
ve substances. See page 122.

Take carbonate of ammonia (the common volatile *smelling*
and pour upon it muriatic acid so long as any effervescence
ues. The produce will be a SOLID SALT, perfectly *inodo-*
nd of little taste. See page 138.

Take caustic soda one ounce; saturate it with muriatic acid,
of these corrosive substances. The produce will be our COM-
I TABLE SALT. See page 122.

Mix in a wine-glass equal quantities of a saturated solution
riate of lime, and a saturated solution of carbonate of potash,
transparent *fluids*: stir the mixture, and a SOLID MASS
e the product. See page 211.

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here distilled water is not at hand, clean *rain* water will answer nearly
for most purposes.

57. Take the substance produced in the foregoing experiment, and pour a very little nitric acid upon it. The consequence will be, the solid matter will again be taken up, and the whole exhibit the appearance of one homogeneous fluid. An instance of a solid *opake* mass being converted by a chemical agent to a TRANSPARENT LIQUID. See pages 110 and 213.

58. Take a transparent saturated solution of sulphate of magnesia, (Epsom salt,) and pour into it a like solution of caustic potash or soda. The mixture will immediately become almost SOLID. This instance of the sudden conversion of two fluids to a solid, and that related No. 56, have been called *chemical miracles.* See page 213.

IV. *Experiments on Colours.*

59. Pour boiling water upon a little red cabbage sliced, and when cold decant the clear infusion. Divide the infusion into three wine-glasses. To one add a solution of alum, to the second a little solution of potash, and to the third a few drops of muriatic acid. The liquor in the first glass will assume a purple, the second a bright green, and the third a beautiful crimson. Here is an instance of THREE DIFFERENT COLOURS from the same vegetable infusion, merely by the addition of three *colourless* fluids. See pages 122 and 142.

60. Prepare a little tincture of litmus. Its colour will be a bright blue with a tinge of purple. Put a little of it in a phial, and add a few drops of diluted muriatic acid; its colour will change to a *vivid red.* Add a little solution of potash; the red will now disappear, and the *blue* will be restored. By these means, the liquor may be changed alternately from a red to a blue, and from a blue to a red, at pleasure. An instance of the effects of acids and alkalies in CHANGING VEGETABLE COLOURS. See page 122.

61. Make an infusion of red roses, violets, or mallow flowers; treat it with solution of potash, and it will become *green*; the addition of diluted muriatic acid will convert it immediately to a *red.* This experiment may be as frequently varied as the last, and furnishes an excellent TEST FOR ACIDS AND ALKALIES.

62. Add a drop or two of solution of potash to tincture of turmerick. This will change its original bright *yellow* colour to a dark *brown*: a little colourless diluted acid will restore it. By this tincture we can detect the most minute portion of any ALKALI IN SOLUTION.

63. Into a wine-glass of water put a few drops of prussiate of

sh; and a little dilute solution of sulphate of iron into another
s; by pouring these two *colourless* fluids together, a BRIGHT
EP BLUE COLOUR will be immediately produced, which is
true prussian blue.

4. Put some prussiate of potash into one glass; into another a
e nitrate of bismuth. On mixing these COLOURLESS fluids,
ELLOW will be the product.

5. Pour a little prussiate of potash into a glass containing a *co-*
less solution of sulphate of copper, and a REDDISH BROWN
be produced, being a true prussiate of copper. See page 306.

6. Prepare a phial with pure water and a little tincture of galls;
another with a weak solution of sulphate of iron; then mix
e transparent COLOURLESS fluids together, and they will in-
tly become BLACK. See page 172.

7. Pour a little tincture of litmus into a wine-glass, and into
her some diluted sulphate of indigo; pour these two BLUE
ds together, and the mixture will become perfectly RED.

8. Drop as much sulphate of copper into water as will form a
urless solution: then add a little ammonia, equally COLOUR-
SS, and an intense BLUE COLOUR will arise from the mix-
.

9. Take water holding carbonate of iron in solution, and add
e diluted prussiate of potash: PRUSSIAN BLUE will be
ned by the mixture. See page 175.

0. Take some of the same water as that used in the last expe-
ent; boil it, and now add prussiate of potash. In this case NO
LOUR will be produced.

1. Take some water impregnated with carbonic acid, and add
a little BLUE tincture of litmus. The whole will be changed
RED. See page 122.

2. Take some of the same carbonated water, and boil it. Then
a little tincture of litmus, and the blue colour will experience
CHANGE.

3. Take some of the black liquid described in Experiment 66,
by degrees muriatic acid to it, and the COLOUR WILL BE
CHARGED. Now drop in a little solution of potash, and
black colour will be RESTORED. Some nicety is requisite

in adding the acid and alkali: for if they be given in excess the effects will not be so apparent.

74. Take the blue solution formed by the Experiment No. 68, add a little sulphuric acid, and the colour will *disappear*; pour in a little solution of caustic ammonia, and the BLUE COLOUR WILL BE RESTORED. Thus may the liquor be alternately changed at pleasure. See pages 122 and 142.

75. If a spoonful of good alcohol and a little boracic acid be stirred together in a tea-cup, and then set on fire, they will produce a very beautiful GREEN FLAME. See page 164.

76. If alcohol be inflamed in like manner with a little pure strontites in powder, or any of its salts, the mixture will give a CARMINE FLAME. See note, page 109.

77. If barytes be used instead of strontites, we shall have a brilliant YELLOW FLAME. See text, page 107.

78. If alcohol contains muriate of magnesia, it has the property of burning with a REDDISH YELLOW FLAME.

79. Evaporate to dryness a solution of gold, made with nitro-muriatic acid, and dissolve the crystals in a sufficiency of pure water to prevent the crystallization of the metallic salt.—Thoroughly moisten a little magnesia with this aqueous solution, and place the mixture in the sun's rays. A change of colour will soon be apparent. It will first take a FAINT VIOLET hue, and in a few hours the whole will have acquired a very DEEP PURPLE. See pages 369 and 370.

80. Moisten a little magnesia with some of the solution as before, and then dry the mixture in the *dark*. If it be then submitted to the action of the sun's rays, it will acquire only a FAINT VIOLET, even by SEVERAL HOURS exposure. See note, page 344.

81. If the mixture employed in the last experiment be now thoroughly *wetted* with pure water, and again placed within the rays of the sun, its colour will RAPIDLY CHANGE, and it will acquire a DEEP PURPLE approaching to CRIMSON. See page 344.

82. Moisten a piece of white riband with the aqueous solution of gold, described at No. 79, and dry it thoroughly in the dark: then suspend it in a clean, dry, transparent phial, and cork it close with a dry cork. Expose the riband, thus secured, to the strong

ght of a bright sun, for half an hour, and only a FAINT ap-arance of CHANGE OF COLOUR will be perceived.

◆

83. Take the riband out of the phial that was employed in the st experiment, and *wet* it well with distilled water. If it be now posed to the sun's rays, it will instantly CHANGE colour, and ill quickly be stained of an INDELIBLE PURPLE.

V. *On Dyeing and Calico-Printing.*

84. Pour a little solution of indigo in sulphuric acid into a glass water, and add about an equal quantity of solution of *carbonate potash.* If a piece of white cloth be dipped in this mixture, it ll come out a BLUE. If a piece of yellow cloth be dipped in, will become a GREEN, or a red will be converted to a PUR-E. A slip of blue litmus paper immersed in it will immediately come RED.

85. If a little fustic, quercitron bark, or other dye, be boiled in ter, the colouring matter will be extracted, and a coloured solu-n formed. On adding a small quantity of dissolved alum to s decoction, the alumina, or base of the salt, will attract the co-uring matter, forming an INSOLUBLE COMPOUND, which a short time will subside, and may easily be separated. See Ad-ional Notes, No. 11.

86. Boil a little cochineal in water, with a grain or two of cream tartar, (supertartrate of potash,) and a dull kind of crimson so-on will be formed. By the addition of a few drops of nitro-riate of tin, the colouring matter will be PRECIPITATED OF BEAUTIFUL SCARLET. This, and some of the former in-nces, will give the student a tolerably correct idea of the general cess of dyeing woollen cloths. See note, page 282.

7. If a few strips of dyed linen cloth, of different colours, be pped into a phial of oxymuriatic acid, the colours will be quickly harged; for there are few colours that can resist the energetic ct of this acid. This experiment may be considered as a com-e example of the process of BLEACHING coloured goods. notes, page 153.

8. Having found a piece of blue linen cloth, that will bleach xygenized muriatic acid, dip the tip of the finger in a solution *uriate of tin,* and press it while wet with the solution, upon a of this cloth. After an interval of a few minutes immerse the h in a phial of liquid oxymuriatic acid, and when it has remained the usual time, it will be found that the spot which was pre-

viously wet with muriate of tin, has preserved its ORIGINAL COLOUR, while the rest of the cloth has become WHITE. See note, page 279.

89. Dip a piece of white calico in a strong solution of acetate of iron; dry it by the fire, and lay it aside for three or four days. After this, wash it well in hot water, and then dye it black by boiling it for ten minutes in a strong decoction of Brazil wood. If the cloth be now dried, any figures printed upon it with a *colourless* solution of muriate of tin, will appear of a BEAUTIFUL SCARLET, although the ground will remain a permanent BLACK. See note, page 282.

90. Dissolve 4 drachms of sulphate of iron in one pint of cold water, then add about 6 drachms of lime in powder, and 2 drachms of finely pulverized indigo, stirring the mixture occasionally for 12 or 14 hours. If a piece of white calico be immersed in this solution for a few minutes, it will be dyed GREEN; and by exposure to the atmosphere only for a few seconds, this will be converted to a PERMANENT BLUE. See Additional Notes, No. 48.

91. If a piece of calico be immersed in a solution of sulphate of iron, and when dry washed in a weak solution of carbonate of potash, a PERMANENT COLOUR will be produced, viz. the BUFF of the calico-printers.

92. Boil equal parts of arnotto and common potash in water till the whole are dissolved. This will produce the PALE REDDISH BUFF so much in use, and sold under the name of NANKEEN DYE.

93. If muriate of tin, newly made, be added to a solution of indigo in sulphuric acid, the oxygen of the indigo will be absorbed, and the solution instantly converted to a *green*. It is on the same principle that muriate of tin is employed in cleansing discoloured leather furniture; as it absorbs the oxygen, and the LEATHER IS RESTORED TO ITS NATURAL COLOUR.

94. Take a piece of very dark olive-coloured linen that has been dyed with iron and quercitron bark, or weld, and spot it in several places with a *colourless* solution of muriate of tin. Wherever the cloth has been touched with this solution, the original colour will be discharged, and spots of a BRIGHT YELLOW will appear in its stead.

95. Dip a piece of white calico in a cold solution of sulphate of iron, and suffer it to become entirely dry. Then imprint any fi-

res upon it with a strong solution of colourless citric acid, and
ow this also to dry. If the piece be then well washed in pure warm
ater, and afterwards boiled in a decoction of logwood, the ground
ll be dyed either of a slate or black colour, according to the
ength of the metallic solution, while the printed figures will re-
ain beautifully white. This experiment is designed to show the
FECT OF ACIDS in DISCHARGING VEGETABLE CO-
OURS. See page 170.

96. If lemon juice be dropped upon any kind of buff colour,
dye will be instantly discharged. The application of this acid
means of the block, is another method by which calico-printers
e the WHITE SPOTS or FIGURES to PIECE-GOODS. The
stallized acid is generally used for this purpose. *These few ex-*
iments will give the student some idea of the nature of calico-
nting.

VI. *Of Combustion and Detonation.*

97. Spread a piece of tinfoil, such as is used for coating electri-
jars, upon a piece of thick paper; spread some powdered cry-
ls of nitrate of copper upon it, and sprinkle it with water. Fold
p quickly, and wrap it round carefully with the paper, more
ectually to exclude the atmospheric air. Place it then upon a
, and in a short time *combustion* will commence, and the TIN
ILL INFLAME.

98. Take three parts of nitre, two of potash, and one of sulphur;
of these should be thoroughly dry; then mix them by rubbing
m together in a warm mortar: the resulting compound is
ed *fulminating powder.* If a little of this powder be placed up-
a fire-shovel over a hot fire, it gradually blackens, and at last
ts. At that instant it EXPLODES WITH A VIOLENT
PORT. *Note, This mixture is not dangerous, like the metallic*
inating powders; none of which should be intrusted in the hands
oung people.

9. If a few pounds of a mixture of iron filings and sulphur be
le into paste with water, and buried in the ground for a few
rs, the water will be decomposed with so much rapidity, that
MBUSTION AND FLAME will be the consequence.

00. Put a little *fresh calcined* magnesia in a tea-cup upon the
rth, and suddenly pour over it as much concentrated sulphuric
as will cover the magnesia. In an instant sparks will be thrown
, and the mixture will be COMPLETELY IGNITED.

01. Make a little charcoal perfectly dry, pulverize it very fine,

and put it into a warm tea-cup. If some strong nitrous acid be now poured upon it, COMBUSTION and INFLAMMATION will immediately ensue. See note[1], page 237.

102. If strong nitrous acid be poured upon a small quantity of a mixture of oxymuriate of potash and phosphorus, FLASHES OF FIRE will be emitted at intervals for a considerable time. See page 192.

103. Put a bit of phosphorus into a small phial, then fill it one-third with boiling olive oil, and cork it close. Whenever the stopper is taken out in the night, LIGHT WILL BE EVOLVED sufficient to show the hour upon a watch.

104. Burn a piece of iron wire in a deflagrating jar of oxygen gas, as directed page 377, and suffer it to burn till it goes out of itself. If a lighted wax taper be now let down into the gas, this will burn in it for some time, and then become extinguished. If ignited sulphur be now introduced, this will also burn for a limited time. Lastly, introduce a morsel of phosphorus, and combustion will also follow in like manner. These experiments show the RELATIVE COMBUSTIBILITY of different substances. See page 381.

105. When antimony is heated to whiteness in a crucible, and in this state agitated, in contact with the air, it inflames with a sort of explosion, and presents while burning a very singular kind of WHITE FLAME, forming what have been formerly called *argentine flowers.*

106. When antimony is well fused upon charcoal, and if, at the moment when its surface is not covered with any particle of oxide, we throw it suddenly upon the ground, the globules into which it divides in its fall, BURN with a very LIVELY FLAME, throwing out on all sides BRILLIANT SPARKS, different from that of any other metal. See note, page 315.

107. Mix five or six grains of sulphuret of antimony with half its weight of oxy-muriate of potash, and then, if a sudden stroke be given to the mixture, upon a steel anvil, it fulminates with a loud report, emitting, according to Fourcroy, a FLAME as brilliant and RAPID AS LIGHTNING.

108. Into a tea-cup, placed upon a hearth, and containing about a table-spoonful of oil of turpentine, pour about half the quantity of strong nitrous acid, previously mixed with a few drops of sulphuric acid. The moment the acids come in contact with

the turpentine, heat and FLAME will be produced. *In performing this experiment it is advisable to mix the acids in a phial, to tie the phial to the end of a stick, and, at arm's length, to pour its contents into the oil, as the sudden combustion sometimes occasions a part of the liquids to be thrown out of the vessel.* See note, page 60.

109. Pour a little pure water into a small glass tumbler, and put one or two small pieces of phosphuret of lime into it. In a short time FLASHES OF FIRE will dart from the surface of the water, and terminate in ringlets of smoke, which will ascend in regular succession. See page 233.

110. Put thirty grains of phosphorus into a Florence flask, with three or four ounces of water. Place the vessel over a lamp, and give it a boiling heat. Balls of fire will soon be seen to issue from the water, after the manner of an artificial fire-work, attended with the most beautiful coruscations. An experiment to show the extreme INFLAMMABILITY OF PHOSPHORUS. See note [g], page 233.

111. Into an eight-ounce retort pour four ounces of pure water, add a little solution of pure potash, and give it a boiling heat with a lamp. When it boils, drop a small piece of phosphorus into it, and immerse the beak of the retort in a vessel of water. Bubbles of PHOSPHURETTED HYDROGEN GAS will issue from the retort, rise through the water, and take fire the moment they come in contact with atmospheric air, somewhat similar to the appearance mentioned at Experiment No. 109. See page 227.

112. Fix a small piece of solid phosphorus in a quill, and write with it upon paper. If the paper be now carried into a dark room, the writing will be BEAUTIFULLY LUMINOUS.

113. Pour a little phosphuretted ether upon a lump of sugar, and drop it into a glass of water, a little warm. The surface of the water will soon become luminous; and if it be moved by blowing gently with the mouth, beautiful and brilliant undulations of its surface will be produced, exhibiting the appearance of a LIQUID COMBUSTION.

114. If any part of the body be rubbed with liquid phosphorus, or phosphuretted ether, that part, in a dark room, will appear as though it were ON FIRE, without producing any dangerous effect, or sensation of heat.

115. Take two grains of oxymuriate or chlorate of potash, and one grain of flowers of sulphur; rub them together in a mortar,

and a smart DETONATING NOISE will be produced. Continue to rub the mixture hard, and the reports will be frequently repeated, accompanied with vivid flashes of light. If the same mixture be wrapped in paper, laid on an anvil, and smartly struck with a hammer, the report will be as loud as what is usually produced by a pistol. See page 192.

116. Take two grains of the oxymuriate or chlorate of potash, and one grain of phosphorus. Treat this mixture as in the last experiment, and very VIOLENT DETONATIONS will be produced. It is advisable *never to exceed* the quantity of phosphorus that is prescribed here, and in other similar experiments.

117. Take a similar quantity of oxymuriate of potash with three or four grains of flower sulphur, and mix the ingredients very well on paper. If a little of this mixture be taken up on the point of a knife and dropped into a wine-glass containing some sulphuric acid, a beautiful COLUMN OF FLAME will be perceived, the moment the powder comes in contact with the acid.

118. Put a little oxymuriate of potash and a bit of phosphorus into an ale-glass, pour some cold water upon them cautiously, so as not to displace the salt. Now take a small glass tube, and plunge it into some sulphuric acid: then place the thumb upon the upper orifice, and in this state withdraw the tube, which must be instantly immersed in the glass so that, on removing the thumb, the acid may be immediately conveyed upon the ingredients. This experiment is an example of a very singular phenomenon, COMBUSTION UNDER WATER.

119. Proceed in all respects as in the last experiment, and add a morsel of phosphuret of lime. Here, besides the former appearance, we shall have COMBUSTION also ON THE SURFACE OF THE WATER.

120. Prepare a mixture of equal parts of lump sugar and oxymuriate of potash; put a small quantity of this mixture upon a plate or a tile; then dip a piece of sewing thread into a phial of sulphuric acid, so as to convey the smallest quantity of the acid: with this touch the powder, and an immediate BURST OF FLAME will be the consequence.

121. Mix, without much friction, ten grains of oxymuriate of potash with one grain of phosphorus, and drop the mixture into concentrated sulphuric acid. This is an instance of DETONATION AND FLAME being produced, by the mixture of a powder with a *cold* liquid. See page 192.

122. Add a few grains of oxymuriate of potash to a tea-spoonful or two of alcohol, drop one or two drops of sulphuric acid upon the mixture, and the whole will BURST INTO FLAME, forming a very beautiful appearance. See page 191.

123. A mixture of oxymuriate of potash and arsenic furnishes a detonating compound, which takes fire with the utmost rapidity. The salt and metal, first separately powdered, may be mixed by the gentlest possible triture, or rather by stirring them together on paper with the point of a knife. If two long trains be laid on a table, the one of gunpowder and the other of this mixture, and they be in contact with each other at one end, so that they may be fired at once; the arsenical mixture burns with the RAPIDITY OF LIGHTNING, while the other burns with comparative SLOWNESS. See page 191.

124. Into an ale-glass of water put a few pieces of zinc, and a small bit of phosphorus; then drop a little sulphuric acid upon the mixture by means of a glass tube, as described at No. 118, and phosphuretted hydrogen will presently be disengaged, which will INFLAME on rising to the SURFACE OF THE WATER. See page 227.

125. Take a small piece of phosphuret of lime a little moistened by the air, and let a single drop of concentrated muriatic acid fall upon it. In this case phosphuretted hydrogen will also be evolved, accompanied by SMALL BALLS OF FIRE darting from the mixture, and the most intolerable fetid smell that can be conceived. See page 227.

126. If 20 grains of phosphorus, cut very small, and mixed with 40 grains of finely granulated zinc, be put into 4 drachms of water, and 2 drachms of concentrated sulphuric acid be added thereto, bubbles of inflamed phosphuretted hydrogen gas will quickly cover the whole surface of the fluid in succession, forming a real AQUEOUS FOUNTAIN OF FIRE. See pages 233 and 234.

127. If any light substance capable of conducting heat, be placed upon the surface of boiling water, and a bit of phosphorus be laid upon it, the heat of the water will be sufficient to set the PHOSPHORUS ON FIRE. See page 233.

128. If one grain of dry nitrate of bismuth be previously mixed with a grain of phosphorus, and then rubbed together in a metallic mortar, a LOUD DETONATION will be produced. See Additional Notes, No. 22.

129. Drop a piece of phosphorus about the size of a pea into a tumbler of hot water, and from a bladder, furnished with a stop cock, force a stream of oxygen gas directly upon it. This will afford the most BRILLIANT COMBUSTION UNDER WATER that can be imagined. See page 233.

130. Put a little alcohol in a tea-cup, set it on fire, and invert a large bell-glass over it. In a short time an aqueous vapour will be seen to condense upon the inside of the bell, which, by means of a dry sponge, may be collected, and its quantity ascertained. This may be adduced as an example of the formation of WATER BY COMBUSTION. See page 389.

131. Take a small piece of pure potash, gently breathe on its surface, and place it on an insulated plate connected with the negative side of a powerful galvanic battery in a state of intense activity. Then bring a metallic wire from the positive side of the battery in contact with the upper surface of the alkali, and soon a very vivid action will be observed. Small globules, having a high metallic lustre, and of the appearance of quicksilver, will be seen, some of which will burn with explosion and a bright flame as soon as they are formed. Thus POTASH may be DECOMPOSED, AND ITS metallic BASE RENDERED VISIBLE in a separate state.

132. Take the metallic substance formed in the last experiment, called potassium, make it very hot, and confine it in a small glass vessel of oxygen gas. Here a rapid combustion, with a brilliant white flame, will be produced, and the metallic globules will be converted into a white and solid mass, which will be found to be REGENERATED PURE POTASH.

133. Place a small piece of potassium within a dry wine-glass, and in order to acquire an idea of its specific gravity pour a little alcohol, ether, or naphtha upon it; when, quitting the bottom of the glass, it will immediately rise to the surface of the liquid, it being, notwithstanding its metallic appearance, the LIGHTEST FLUID BODY KNOWN.

134. If a little potassium be dropped into a jar of oxymuriatic gas, it BURNS SPONTANEOUSLY, and emits a bright red light. In this experiment a white SALT IS FORMED, being a TRUE MURIATE OF POTASH.

135. If a globule of potassium be thrown upon water, it decomposes it with great violence: an instantaneous EXPLOSION IS PRODUCED with brilliant flame, and a SOLUTION of PURE POTASH IS THE RESULT.

136. If a similar globule be placed upon ice, it will spontaneously BURN with a bright flame, and perforate A DEEP HOLE IN THE ICE, which will contain a solution of potash.

137. Take a piece of moistened turmeric paper, and drop a globule of potassium upon it. At the moment that it comes into contact with the water, IT BURNS and MOVES rapidly UPON THE PAPER, as if IN SEARCH OF MOISTURE, leaving behind it a deep reddish brown trace.

138. When a globule of sodium is thrown into *hot* water, the decomposition of the water is so violent that small particles of the metal are thrown out of the water, and actually BURN WITH SCINTILLATIONS and FLAME IN PASSING THROUGH THE ATMOSPHERE.

VII. *Sympathetic Inks.*

139. Write upon paper with a diluted solution of muriate of copper; when dry it will not be visible, but on being warmed before the fire the writing will become of a beautiful YELLOW.

140. Write with a solution of muriate of cobalt, and the writing, while dry, will not be perceptible; but if held towards the fire, it will then gradually become visible; and if the muriate of cobalt be made in the usual way, the letters will appear of an elegant GREEN colour. See page 301.

141. Write with acetate of cobalt, or with a muriate of cobalt, previously purified from the iron which it generally contains. When the writing is become dry, these letters will also be invisible. Warm the paper a little, and the writing will be restored to a beautiful BLUE. See note [f], page 301.

142. Draw a landscape with Indian ink, and paint the foliage of the vegetables with muriate of cobalt, the same as that used in Experiment No. 140, and some of the flowers with acetate of cobalt, and others with muriate of copper. While this picture is cold it will appear to be merely an outline of a landscape, or winter scene; but when gently warmed, the trees and flowers will be DISPLAYED IN THEIR NATURAL COLOURS, which they will preserve only while they continue warm. This may be often repeated. See note, page 301.

143. Write with dilute nitrate of silver, which when dry will be entirely invisible; hold the paper over a vessel containing sulphate of ammonia, and the writing will appear very distinct.

The letters will shine with the METALLIC BRILLIANCY of SILVER. See page 369.

144. Write with a solution of nitrate or acetate of lead. When the writing is dry it will be invisible. Then having prepared a glass decanter with a little sulphuret of iron strewed over the bottom of it, pour a little very dilute sulphuric acid upon the sulphuret, so as not to wet the mouth of the decanter, and suspend the writing, by means of the glass stopper, within the decanter. By an attention to the paper the WRITING WILL BECOME VISIBLE by degrees, as the gas rises from the bottom of the vessel. See page 310.

145. Write with a weak solution of sulphate of iron, let it dry, and it will be invisible. By dipping a feather in tincture of galls and drawing the wet feather over the letters, the writing will be RESTORED and appear BLACK. See page 172.

146. Write with a similar solution, and when dry wash the letters in the same way with prussiate of potash, and they will be restored of a BEAUTIFUL BLUE. See note, page 273.

147. Write with a solution of sulphate of copper, wash as before with prussiate of potash, and the writing will be revived of a REDDISH BROWN colour. See note, page 306.

148. Write on paper with a solution of nitrate of bismuth; when this is dry the writing will be invisible; but if the paper be exposed to sulphuretted hydrogen gas, the words will be DISTINCTLY LEGIBLE. See page 317.

149. A letter written with a diluted solution of bismuth, becomes, when dry, illegible: but a feather dipped in a solution of sulphuret of potash, will instantly blacken the oxide, and REVIVE THE WRITING. See note, page 317.

VIII. *Some Experiments with the Earths.*

150. Pour a little lime-water into a wine-glass, and put some solution of oxalate of ammonia, equally transparent, into another glass. If the two clear liquors be poured together, a white precipitate of OXALATE OF LIME will immediately become visible. See note, page 169.

151. Pour a little lime-water into a phial, and throw some carbonic acid into it. The carbonic acid will seize the lime, and precipitate it in the state of CARBONATE OF LIME.

152. Take the phial made use of in the last experiment, with its contents, and convey an additional portion of carbonic acid into it. The carbonate of lime will now be RE-DISSOLVED, and the liquor rendered TRANSPARENT. See note, page 110.

153. Take the transparent liquid produced in the last experiment, and give it heat. The earth will now be precipitated in the state of CARBONATE OF LIME, as before.

154. Pour some lime-water into a wine-glass, and a little solution of carbonate of potash into another glass. When these two transparent fluids are thrown together, an abundant precipitate of CARBONATE OF LIME will be the consequence. See page 133.

155. Proceed as in the last experiment, but instead of carbonate of potash, pour a solution of Epsom salt into one of the glasses. When these transparent fluids are poured together, a mixed precipitate of CARBONATE OF MAGNESIA and SULPHATE OF LIME will be produced. See page 112.

156. For another experiment, take in the same manner, separately, lime-water and a solution of alum. The union of these solutions will produce a mixed precipitate of ALUMINA and SULPHATE OF LIME.

157. If a strong solution of caustic potash and a saturated solution of Epsom salt be mixed, the union of these transparent fluids will produce also an abundant precipitate. But this will consist of MAGNESIA and SULPHATE OF POTASH.

158. To a glass of water suspected to contain carbonic acid, add a small quantity of any of the other acids. If carbonic acid be present, it will become visible by a SPARKLING APPEARANCE on the sides of the glass and surface of the fluid.

159. Prepare two glasses of pure water, and into one of them drop a single drop of sulphuric acid, and mix it with the water. Pour a little muriate of barytes into the other glass, and no change will be perceived; pour some of the same solution into the first glass, containing the sulphuric acid, and a white precipitate of SULPHATE OF BARYTES will be produced. See note, page 110.

160. Prepare two glasses of water as before, conduct the experiment in the same way as the last, but instead of muriate of barytes, use *nitrate of lead*. In this case SULPHATE OF LEAD will be precipitated. See page 311.

161. Fill a glass tumbler half full of lime-water; then breathe into it frequently, at the same time stirring it with a piece of glass. The fluid, which before was perfectly transparent, will presently become quite white, and if suffered to remain at rest, REAL CHALK will be deposited. See note, page 111.

IX. *Experiments with the Metals.*

162. Prepare two glasses of rain-water, and into one of them drop a single drop of sulphuric acid. Pour a little *nitrate of silver* into the other glass, and no change will be perceptible. Pour some of the same solution into the first glass, and a white precipitate of SULPHATE OF SILVER will appear.

163. Prepare two glasses as in the last experiment, and into one of them put a drop or two of *muriatic acid*. Proceed as before, and a precipitate of MURIATE OF SILVER will be produced. See note, page 350.

164. Take two glasses, as in Experiment 162, and into one of them put a drop of sulphuric acid, and a drop or two of muriatic acid: proceed as before with the *nitrate of silver*, and a MIXED precipitate will be produced, consisting of MURIATE OF SILVER and SULPHATE OF SILVER.

165. Take the glass containing the mixed precipitate of the last experiment, and give it, by means of a lamp, the heat of boiling water. The sulphate of silver, if there be a sufficiency of water, will now be re-dissolved, and the muriate of silver will remain separate at the bottom of the vessel. This experiment exhibits a method of SEPARATING these METALLIC SALTS whenever they occur in a state of mixture.

166. Mix one ounce of litharge of lead with one drachm of pulverized muriate of ammonia, and submit the mixture to a red heat in a clean tobacco-pipe. The increase of temperature will separate the ammonia in the form of gas, and the muriatic acid will combine with the lead. When the compound is well melted, pour it into a metallic cup, and you will have a true MURIATE OF LEAD of a bright yellow colour, the brilliancy of which may be much heightened by grinding it as usual with oil. In this state it forms the colour called PATENT YELLOW. See note, page 208.

167. Take one ounce of red lead, and half a drachm of charcoal, in powder, incorporate them well in a mortar, and then fill the bowl of a tobacco-pipe with the mixture. Submit it to an intense heat in a common fire, and when melted, pour it upon a slab. The

result will be METALLIC LEAD completely revived. See page 310.

168. Take a little *red-lead*, expose it to an intense heat in a crucible, and pour it out when melted. The result will be metallic glass, and will furnish an example of the VITRIFICATION OF METALS.

169. Drop upon a clean plate of copper, a small quantity of solution of nitrate of silver; in a short time a metallic vegetation will be perceptible, branching out in very elegant and pleasing forms, furnishing an example of METALLIC REVIVIFICATION. See page 369.

170. Dissolve an ounce of acetate of lead in about a quart or more of water, and filter the solution. If this be put into a glass decanter, and a piece of zinc suspended in it by means of a brass wire, a decomposition of the salt will immediately commence, the lead will be set at liberty, and will attach itself to the remaining zinc, forming a METALLIC TREE. See page 363.

171. Procure a phial with a glass stopper accurately ground into it; introduce some copper wire, then entirely fill it with liquid ammonia, and stop the phial so as to exclude all atmospheric air. If left in this state, no solution of the copper will be effected. But if the bottle be afterwards left open for some time, and then stopped, the metal will dissolve and the solution will be colourless. Let the stopper be now taken out, and the fluid will become blue, beginning at the surface, and spreading gradually through the whole. If this blue solution has not been too long exposed to the air, and fresh copper filings be put in, again stopping the bottle, the fluid will once more be deprived of its COLOUR, which it will RECOVER ONLY BY THE RE-ADMISSION OF AIR. These effects may thus be repeatedly produced. See note, page 365.

172. Pour concentrated nitric acid upon pieces of iron, and very little action will be seen: but if a few drops of *water* be added, a most violent effervescence will immediately commence; the acid will be decomposed with rapidity, clouds of red nitrous gas will be evolved in abundance, and a perfect SOLUTION OF THE METAL effected.

173. Take any solution of iron, a chalybeate water for instance, and add a small quantity of succinate of ammonia; in a little time a precipitate will be visible, being succinate of iron. By this test the QUANTITY of iron in any solution may be ACCURATELY ASCERTAINED. See page 212.

174. In like manner add sulphuretted hydrogen to a solution of lead, and a deep brown precipitate will be occasioned. This is an effectual mode of DETECTING this and some other PERNICIOUS METALS. See Additional Notes, No. 31.

175. Dissolve some quicksilver in nitrous acid, and drop a little of the solution upon a bright piece of copper. If it be then gently rubbed with a bit of cloth, the mercury will precipitate itself upon the copper, which will be completely silvered. This experiment is illustrative of the PRECIPITATION OF ONE METAL BY ANOTHER. See page 369.

176. If a little nitro-muriate of gold be added to a fresh solution of muriate of tin, both being much diluted with water, the gold will be precipitated of a purple colour, forming that beautiful pigment called POWDER OF CASSIUS. See note, page 345.

177. Take a phial with a solution of sulphate of zinc, and another containing a little liquid ammonia, both transparent fluids. By mixing them, a curious phenomenon may be perceived:—the zinc will be immediately precipitated in a white mass, and if then shaken, almost as INSTANTLY RE-DISSOLVED.

178. If a colourless solution of galls be added to a solution of bismuth in nitric acid equally colourless, a *brown* precipitate will be produced. This is a distinguishing CHARACTERISTIC OF THIS METAL. See page 317.

179. If a colourless solution of arsenic in caustic potash be poured into a colourless solution of copper, a *green* precipitate will be produced, forming an arseniate of copper similar to an ore found in the Cornish mines. These metals may be thus RECIPROCALLY DETECTED. See page 305.

180. Alloy a piece of silver with a portion of lead, place the alloy upon a piece of charcoal, attach a blow-pipe to a gasometer charged with oxygen gas, light the charcoal first with a bit of paper, and keep up the heat by pressing upon the machine. When the metals get into complete fusion, the lead will begin to burn, and very soon will be all dissipated in a white smoke, leaving the silver in a state of purity. This experiment is designed to show the FIXITY of the NOBLE METALS. See note, page 312.

181. If oxide of cobalt be dissolved in ammonia, a RED SOLUTION will be produced, different in colour from that of all other metallic oxides. See page 301.

82. If nickel be dissolved in nitric acid, a beautiful GREEN LUTION will be formed. The oxide of this metal is used to e a delicate grass green to porcelain. See page 298.

183. When colourless prussiate of potash is added to a solution itanium, this metal will be precipitated also of a GREEN CO- UR.

184. Add a little colourless solution of galls to a clear solution ntimony in nitro-muriatic acid, and the metal will be precipi- d of a PALE YELLOW COLOUR. See page 314.

185. If a solution of tungstate of potash be poured into a solu- n of the green sulphate of iron, A YELLOW PRECIPITATE l fall down. By this experiment the distinguishing character- ic of this metal is exhibited.

186. If a solution of the green sulphate of iron be dropped into itro-muriate of gold, the last metal will be immediately precipi- ed. In this state it is often employed in GILDING CHINA. page 346.

187. If flowers, or any other figures, be drawn upon a riband silk with a solution of nitrate of silver, and the silk, moistened h water, be then exposed to the action of hydrogen gas, the sil- r will be revived, and the figures, firmly fixed upon the silk, will ome visible, and shine with METALLIC BRILLIANCY. page 369.

188. By proceeding in the same manner, and using a solution gold in nitro-muriatic acid, silks may be PERMANENTLY LT at a most trifling expense, and will exhibit an appearance most beautiful that can be conceived. See page 369.

189. To a similar solution of gold add about a fourth part of ier; shake them together, and wait till the fluids separate; the per stratum, or ethereal gold, is then to be carefully poured off o another vessel. If any polished steel instrument or utensil be pped into this solution, and instantly plunged into water, the sur- e will have acquired a coat of pure gold, being a very elegant and onomical mode of PRESERVING POLISHED STEEL FROM JST. See note, page 345.

190. If nitro-muriate of platina be mixed with a fourth part of bulk of ether, and the mixture suffered to settle, the ethereal ution of platina may be decanted as in the preceding experiment. lished brass, and some other metals immersed in this solution,

will be COVERED WITH A COAT OF PLATINA. This process may be applied to many useful purposes. See notes, page 340.

191. Prepare a very dilute and colourless solution of platina by dropping a small quantity of the nitro-muriate of that metal into a glass of water. If a single drop of the solution of muriate of tin be added to this, a bright red precipitate will be instantly produced. A more DELICATE TEST than this of any metal cannot be conceived. See page 339.

192. If a morsel of the dried crystals of nitrate of silver (not the lunar caustic) be laid on a piece of burning charcoal, the metallic salt will immediately deflagrate, throw out the most beautiful scintillations that can be imagined, and the surface of the CHARCOAL will be richly COATED WITH METALLIC SILVER. See page 369.

193. To a colourless solution of nitrate of mercury, add an equally colourless solution of sûb-borate of soda. This will produce a double decomposition, and form a bright yellow precipitate of borate of mercury: giving an instance of DIFFERENCE OF COLOUR IN METALS, by their union WITH DIFFERENT ACIDS. See page 358.

194. Into a diluted solution of sulphate of copper, pour a little liquid caustic ammonia. This will precipitate the copper of a blueish white. During its examination, however, the precipitate will be re-dissolved, and a beautiful blue liquid, called AQUA CELESTIS, will be the result. See page 305.

195. Dissolve a few crystals of nitro-muriate of gold in about eight times their weight of pure water; place a thin slip of charcoal in the solution, and heat the whole by means of a sand-bath. When the solution has acquired nearly a boiling heat, the gold will precipitate itself on the charcoal, in its metallic splendour, forming a singular and beautiful appearance. This experiment is designed to show that METALS become INSOLUBLE, the moment they IMPART THEIR OXYGEN to foreign bodies. See page 344.

196. Proceed as in the last experiment, and submit the vessel with its contents to the rays of the sun. Here the metal will be reduced, and the charcoal as effectually gilt as before, This is illustrative of the DEOXIDIZING POWER OF THE SUN'S RAYS. See note, page 370.

197. Drop a little leaf gold into nitro-muriatic acid, and it will
stantly disappear. This experiment is designed to show the great
OLUBILITY OF THE METALS, when submitted to a pro-
er menstruum. See page 345.

198. Pour a little purified nitric acid into one wine-glass, and
uriatic acid into another; and drop a little leaf gold into each.
ere neither of these corrosive acids will act at all upon the metal,
HE GOLD WILL REMAIN UNTOUCHED. Now pour
e whole contents of the two glasses together, and the metal will
sappear, and be as effectually dissolved as in the last experiment.
e note, page 345.

199. If a little metallic arsenic in powder be mixed with a few
nc filings, and then treated with diluted sulphuric acid, ARSE-
URETTED HYDROGEN GAS may be collected, which
rns with a peculiar kind of lambent white flame.

200. If a portion of this gas, issuing from a very small tube, be
t on fire, and then immersed in a large glass receiver of oxygen
s, and the stream of arsenuretted hydrogen kept up by the pres-
re of the bladder, a BLUE FLAME of uncommon splendour
ll be produced. See note, page 327.

201. Take an amalgam of lead and mercury, and another amal-
m of bismuth, let these two SOLID AMALGAMS be mixed
triture, and they will INSTANTLY BECOME FLUID.
e page 69.

202. If a little pure WHITE calomel be rubbed in a glass mor-
with a little colourless solution of caustic ammonia, the whole
ll become INTENSELY BLACK. See page 358.

203. A little of the solution of sulphate of manganese being ex-
sed in a glass phial to the light of the sun, its rose colour will
irely fade. This is another experiment to show the DEOXI-
ZING POWER OF THE SUN'S RAYS. If the phial be
moved into a dark room, the original COLOUR of the solution
ll be RESTORED. See note, page 369.

204. Dissolve about a drachm of pulverized sulphate of copper
a little boiling water, and an equal quantity of powdered mu-
te of ammonia in a separate vessel, in hot water. By mixing
contents of the two glasses, a quadruple salt will be formed,
ich gives a YELLOW colour to the solution WHILE HOT,
l becomes GREEN WHEN COLD.

205. Mix three grains of sulphur with nine grains of dry nitrate

of silver, and lay the mixture in a small heap on an anvil, or on any piece of solid metal. If the mixture be now struck smartly with a *cold* hammer, the sulphur will inflame, but no detonation will ensue. This is an instance of a METALLIC SALT being decomposed, and a combustible substance INFLAMED BY PERCUSSION.

206. If the experiment be repeated, and the mass be struck with a *hot* hammer, THE MIXTURE DETONATES, and the SILVER IS REDUCED.

207. Pour a solution of nitrate of silver into a glass vessel, and immerse a few slips of copper in it. In a short time a portion of the copper will be dissolved, and all the silver precipitated in a metallic form. If the solution, which now contains copper, be decanted into another glass, and pieces of iron added to it, this metal will then be dissolved, and the copper precipitated, yielding a striking example of PECULIAR AFFINITIES. See note, page 367.

208. Melt a portion of grain tin, and pour it into a metallic cup. Allow it to cool till it is congealed to some depth, then pierce the solid crust, and carefully pour out that portion which is still liquid. If what remains in the vessel be suffered to cool entirely, it will present RHOMBOIDAL CRYSTALS of considerable size, formed by the assemblage of a great number of small needles longitudinally united. See note, page 208.

209. Treat silver in the same way, and we shall procure a metallic mass crystallized in QUADRANGULAR OR OCTOHEDRAL PRISMS. *These two experiments will succeed better if the metal be poured into a vessel with an orifice in the bottom, which must be stopped with a proper plug, and this removed as soon as the upper crust hardens; the liquid metal will then run out, and that which is congealed will exhibit a regular crystallization.*

210. Form an amalgam with four parts of silver leaf and two of mercury, and dissolve this amalgam in diluted nitric acid. Then add water to the solution, equal to 30 times the weight of the metals employed, and put the whole aside for use. If an ounce of this solution be at any time poured into a phial, and a small piece of soft amalgam of silver be dropt in, filaments of reduced silver will shoot from it, and extend upwards, in the form of a shrub. The appearance of arborescence is called THE TREE OF DIANA. See page 364.

211. If two parts of sulphate of copper, and three of carbonate

f ammonia, (the one a blue, the other a white salt,) be rubbed
ogether in a glass mortar till the carbonic acid be expelled, the
ass will become soft and humid, and, when dried, forms a cry-
alline powder of a most beautiful DEEP VIOLET colour. This
ompound was formerly called CUPRUM AMMONIACUM.

212. If a little colourless and recently prepared muriate of tin
e poured into a rich GREEN solution of muriate of copper, the
opper will be deprived of a portion of its oxygen, and a WHITE
URIATE OF COPPER PRECIPITATED. See note, page 280.

213. Into the phial containing the white muriate of the last ex-
eriment, pour a little muriatic acid. The precipitate will quickly
e dissolved, and THE SOLUTION WILL BE COLOURLESS.
ee page 365.

214. Procure some solution of sulphate of iron at the *minimum*
oxidizement, by digesting iron filings with the common sul-
ate. Into this, when filtered, drop a little of the solution of
ussiate of potash, and a WHITE PRUSSIATE OF IRON will
e precipitated. See note, page 358.

215. If a very little colourless nitric acid be added to a solution
sulphate of iron prepared as in the last experiment, the addition
the prussiate of potash will produce not the white, but the
LUE PRUSSIATE OF IRON. See page 358, and note,
ge 361.

216. Pour some pure nitric acid on the black oxide of manga-
se, and no solution will be effected. But if a little sugar be added,
e SUGAR will ABSTRACT a part of the OXYGEN from the
ric acid, and then the acid will be enabled to dissolve the metal.
e note, page 366.

217. Expose an ounce of nitric acid for an hour, in an open
ial, to the direct rays of the sun, and pour another ounce of the
ne acid, that has not been so exposed, into another phial. If a
le of the black oxide of manganese be now put into each, THE
XIDE in the *first phial* will be DISSOLVED, while that in *the*
er will NOT BE AFFECTED by the acid. See page 156, and
e, page 366.

218. If a piece of bright silver be dipped in a solution of sul-
ate of copper, it will come out unchanged: but if the blade of a
an penknife, or any piece of *polished* iron, be dipped in the
ne solution, the IRON will intstantly put on the APPEAR-
NCE OF COPPER. See note, page 305.

219. Take the piece of silver employed in the last experiment, hold it in *contact with the iron*, and then, in this situation, dip them into the same solution, and BOTH will be COVERED WITH COPPER.

220. Dissolve some oxide of nickel in caustic ammonia, which will produce a solution of a rich BLUE colour. By exposure to the air this gradually changes to a PURPLE, and lastly to a VIOLET. The addition of an acid will, however, convert the whole to a GREEN.

221. Take the GREEN solution of the last experiment, and pour caustic ammonia upon it. The original BLUE colour will now be reproduced.

222. Prepare a colourless solution of tartrate of potash and antimony (the common emetic tartar), and pour into it a little liquid sulphuretted hydrogen. This will combine with the metallic oxide, and form an ORANGE COLOURED precipitate.

223. Melt together equal parts of copper and antimony, the one a yellow, the other a white metal, and the alloy that results from this mixture will take the COLOUR OF THE VIOLET.

224. If the gray sulphuretted oxide of antimony be fused in a crucible, we procure a beautiful transparent glass, which is called the *glass of antimony*. This takes THE COLOUR OF THE HYACINTH.

225. Dissolve dry nitrate of silver in pure water; add a little oil of turpentine, shake the mixture, and cork it close. Submit the phial with its contents to the heat of boiling water for an hour, when the metal will be revived, and the inside of the phial, where the oil reposed on the aqueous solution, will be beautifully SILVERED, the revived metal forming a METALLIC RING, extending quite round the phial. See page 369.

226. Immerse a slip of white silk in a solution of nitro-muriate of gold in distilled water, and dry it in the air. Silk thus prepared will not be altered by hydrogen gas: but if another piece of silk be dipped in the solution, and exposed while *wet* to the same current of hydrogen gas, instant signs of metallic reduction will appear; the colour will change from yellow to green, and a brilliant film of REDUCED GOLD will soon glitter on its SURFACE.

227. If a piece of silk be immersed in a solution of nitrate of

silver, and dried in a dark place, and then submitted to hydrogen gas, the silver will not be reduced; but if exposed while *wet* to a stream of the same gas, the surface will quickly be coated with reduced silver; various colours, such as blue, purple, red, orange, and yellow, will accompany the reduction, and the THREADS of the SILK will look like SILVER WIRE.—*During these experiments the silk should be constantly kept wet with distilled water.*

228. Dissolve some crystals of muriate of tin in distilled water, then dip a piece of white silk in the solution, and dry it in the air. If this be now immersed in hydrogen gas, no change will be observed; but if it be exposed while *wet* to the same current of gas, the reduction will soon commence, attended with a great variety of beautiful colours, as RED, YELLOW, ORANGE, GREEN, and BLUE, variously intermixed.

229. Prepare a strong solution of phosphorus in sulphuric ether, and dip a piece of white silk in the solution; then, when the ether has evaporated, and the phosphorus begins to fume, apply a solution of nitro-muriate of gold, made by dissolving the crystals of that salt in distilled water; the silk will in an instant be covered with a SPLENDID coat of METALLIC GOLD.

230. Proceed as in the last experiment, and instead of the solution of gold, apply, with a camel's-hair pencil, a solution of nitrate of silver. Here the silver will instantly be restored to its METALLIC BRILLIANCY, and frequently attended by SPANGLES of a beautiful BLUE.

231. If a bit of white silk be immersed in an ethereal solution of gold, and dried, the application of phosphorized ether will only impart a BROWN colour to the silk; but if, as soon as the phosphorus begins to fume, it be placed on the palm of the hand, and breathed on for a considerable time, the BROWN will be succeeded by a PURPLE TINGE, and the METALLIC LUSTRE of the GOLD will soon begin to appear.

232. " An aqueous solution of nitro-muriate of gold," says Mrs Fulhame, " was poured into a china cup containing some phosphorized ether; instantly the gold began to assume its metallic splendour, attended with a variety of colours, as PURPLE, BLUE, and RED, the beauty of which cannot be described; but which depend on the DIFFERENT DEGREES of the reduction.

233. With a needle pass a thread through a small bit of phosphorus, previously freed from moisture by immersing it in alcohol.

If this be suspended in an aqueous solution of nitro-muriate of gold, in a few minutes the PHOSPHORUS will become covered with PURE GOLD.

234. If a piece of white SILK be dipped in an aqueous solution of nitro-muriate of gold, and exposed while wet to sulphurous acid gas, the whole piece will in a few seconds be covered with a coat of REDUCED GOLD, which remains PERMANENT.

235. If a piece of white silk be immersed in an aqueous solution of nitrate of silver, thoroughly dried in the dark, and then exposed to sulphurous acid vapours, it will suffer no change; nor, if it be wetted with *alcohol* and then replaced in the vapour, will any sign of reduction appear; but if it be wetted with pure *water*, and then exposed to the vapour, METALLIC SILVER will immediately be seen on its surface.

A glass funnel is a convenient apparatus for these experiments. The silk may be suspended by a thread passed through it, and made fast to the funnel with a cork. The funnel is then to be placed on a table, and by moving it a little over the edge of the table, a lighted match may be readily introduced, and when the glass is full of vapour the match may be withdrawn. The vapour is confined by sliding the funnel back upon the table; and thus the phenomena of the experiment may be easily observed.

236. Dip a piece of white calico in an aqueous solution of acetate of lead, and then drop a little solution of sulphuret of potash upon it. If this be now placed in the palm of the hand, the LEAD will be observed gradually to revive, and will soon be reduced to its METALLIC STATE.

237. Dissolve some sulphuret of potash in alcohol, and immerse a slip of white silk in the solution. If a drop of an aqueous solution of sulphate of manganese be now applied, films of METALLIC MANGANESE, bright as silver, will instantly appear.

238. If a bit of silk be immersed in diluted acetate of lead, and exposed while *wet* to a stream of sulphuretted hydrogen gas, a brown tinge will instantly diffuse itself, like a passing shadow, over the whole surface of the silk, accompanied with a bright coat of REDUCED LEAD, resembling silver.

239. If a piece of silk be immersed in an aqueous solution of muriate of tin, and exposed while *wet* to a stream of the same gas, REDUCED TIN of great brightness will immediately cover the

surface, and in a little time this will be accompanied by various colours, such as BLUE, ORANGE, and PURPLE.

240. A piece of silk, treated in the same way, but dipped in an aqueous solution of muriate of arsenic, will be covered with resplendent METALLIC ARSENIC, attended with a CITRON YELLOW COLOUR.

241. Prepare two glasses of very dilute nitrate of copper; into one drop a little liquid ammonia, and into the other some diluted arseniate of potash. The addition of these two *colourless* solutions will produce very different effects; for the one glass will have an abundant precipitate of a brilliant SAPPHIRE BLUE, and the other a precipitate of a beautiful GRASS GREEN.

X. *Miscellaneous Experiments*.

242. Take a slip of blue litmus paper, dip it into acetous acid, and it will immediately become red. This is a test so delicate, that, according to Bergman, it will detect the presence of sulphuric acid, even if the water contain only one part of acid to thirty-five thousand parts of water. Litmus paper which has been thus changed by immersion in acids, is, when dried, a good test for the alkalies; for, if it be dipped in a fluid containing the smallest portion of alkali, the red will disappear, and the paper be restored to its ORIGINAL BLUE COLOUR. See note, page 142.

243. Take a slip of turmeric paper, and dip it into any alkaline solution; this will change the yellow to a deep brown. In many cases turmeric is preferable to litmus paper for detecting alkali in solution, as it suffers no change from carbonate of lime, which is often found in mineral waters. This paper will detect the presence of soda, though it should amount to no more than $\frac{1}{2200}$dth part of the water. The paper thus changed by an alkali, would, if dried, be still useful as a test for acids, as these restore its ORIGINAL YELLOW.

244. Into a large glass jar, inverted upon a flat brick tile, and containing near its top a branch of fresh rosemary, or any other such shrub, moistened with water, introduce a flat thick piece of heated iron, on which place some gum benzoin in gross powder. The benzoic acid, in consequence of the heat, will be separated, and ascend in white fumes, which will at length condense, and form a most beautiful appearance upon the leaves of the vegetable. This will serve as an example of SUBLIMATION.

245. Introduce a little carbonate of ammonia into a Florence flask, and place that part of the flask which contains the salt on the surface of a bason of boiling water: the heat will soon cause the carbonate of ammonia to rise undecomposed, and attach itself to the upper part of the vessel, affording another example of SIMPLE SUBLIMATION. See page 136.

246. Mix a little acetate of lead with an equal portion of sulphate of zinc, both in fine powder; stir them together with a piece of glass or wood, and no chemical change will be perceptible: but if they be rubbed together in a mortar, the two solids will operate upon each other; an intimate union will take place, and a FLUID WILL BE PRODUCED. If alum or Glauber salt be used instead of sulphate of zinc, the experiment will be equally successful. See pages 209 and 212.

247. Pour a little water into a phial containing about an ounce of olive oil. Shake the phial, and if the contents be observed we shall find that no union has taken place. But if some solution of caustic potash be added, and the phial be then shaken, an intimate combination of the materials will be formed by the disposing affinity of the alkali, and a PERFECT SOAP PRODUCED. See page 129.

248. Put a little common sulphur with one-eighth of its weight of nitre, into an iron dish, place it under a jar of oxygen gas, and set fire to it as directed page 143, and sulphuric acid will be formed. This is an example of the formation of an ACID BY COMBUSTION.

249. Take the acid formed in the last experiment, concentrate it by boiling, mix it with a little powdered charcoal, and submit the mixture in a Florence flask to the heat of an Argand's lamp. By this process sulphur will be regenerated, and will sublime into the neck of the flask. An example of the DECOMPOSITION OF AN ACID. See page 144.

250. Melt sulphur in a small iron ladle, and carry it into a dark room in the state of fusion. If an ounce or two of copper filings be now thrown in, LIGHT WILL BE EVOLVED. See page 383.

251. Fuse a small quantity of nitre in a crucible, and, when in complete fusion, throw pulverized coal into it by small quantities at a time. The carbonaceous matter will decompose the nitre,

and the bituminous part will burn away without acting upon it. This experiment will exhibit a mode of ANALYSING COAL; for every 100 grains of nitre that are decomposed in this way, denote ten grains of carbon. See note, page 192.

252. If hot water be poured into a glass jar of cold water, it will remain on the *surface*; but if cold water be poured upon hot water, it will sink to the *bottom* of the vessel. This experiment may be rendered more obvious by colouring that portion of the water which is poured in. The design of this experiment is to show the CHANGE of the SPECIFIC GRAVITY of the *same* body, merely by the AGENCY of CALORIC.

253. Into a glass of water containing a small portion of common salt, drop some of a clear solution of nitrate of silver, and an insoluble precipitate of muriate of silver will be produced. This experiment is designed to give the pupil some idea of the method of ANALYSING MINERAL WATERS. Every 100 grains of this precipitate, when dried, indicate 42 grains of common salt. See note, page 350.

254. Into a glass of Aix-la-Chapelle water, or water holding a small portion of potash, drop a little of the solution of nitro-muriate of platina, and an immediate yellow precipitate will be produced. This affords another instance of the nature of the means usually employed to DETECT whatever SUBSTANCES may be DISSOLVED IN MINERAL WATERS. See note, page 128.

255. Into distilled water drop a little spiritous solution of soap, and no chemical effect will be perceived; but if some of the same solution be added to hard water, a milkiness will immediately be produced, more or less, according to the degree of its impurity. This is a good method of ASCERTAINING THE PURITY OF SPRING WATER. See note, page 214.

To read or practise the foregoing Experiments merely for the sake of amusement, may occasionally have its advantages; but a resolution to repeat them, and examine all the phenomena, for the sole purpose of receiving instruction, is what the author would principally inculcate. Let it never be forgotten, that *no effect*, however extraordinary, or even trivial, it may appear to us, can ever happen but in consequence of some previously established law of unerring nature. The following apostrophe of Dr. Darwin to the Fountain of all Goodness may possibly tend to impress this important truth upon the student's mind :—

"Thus, at thy potent nod, *effect* and *cause*
Walk hand in hand, accordant to thy laws ;
Rise at Volition's call, in groups combin'd,
Amuse, delight, instruct, and serve mankind."

A VOCABULARY

OF

CHEMICAL TERMS.

A

ABSORPTION. If muriatic acid gas be thrown into water, the water becomes acidulous, and an absorption of the gas is said to have taken place. When a gas loses its gaseous properties by combination, it is said to be absorbed; but this term is not employed when we speak only of the condensation of a gas, by cold or pressure.

ACCENSION. A term employed by the old chemists to denote sudden inflammation or conflagration, by the mixture of two or more substances.

ACETATES. Salts formed by the combination of any base with the acetic acid.

ACIDIFIABLE. Capable of forming an acid. Thus sulphur is said to be an acidifiable base.

ACIDS. For the nature of acids, see page 142.

ACIDULES. A term applied to the natural combination of some acids with a portion of potash. The oxalic acid and the tartaric are the only acids that have hitherto been found in this state of semi-saturation. See page 186.

ADAPTER. A chemical utensil fixed between a retort and its receiver. Thus a tube fixed at the neck of a retort for the purpose of lengthening it, is called an adapter, and sometimes an adopter. A vessel having two necks when used for a similar purpose bears the same name.

AËRIFORM *fluids*. Fluid substances combined with an additional portion of caloric sufficient to give them the gaseous form. See *Gas*.

AFFINITY, *chemical*. A term used to express that peculiar propensity which different species of matter have to unite with each other, or with portions of matter of their own species. See Chap. xiii.

——— *of aggregation*. A force by which two bodies of the *same* kind tend to combine, and by which an aggregate is formed without the *chemical* properties of the substances being at all changed. See page 394.

AFFINITY *of composition.* A force by which substances of *different* kinds unite, and by which matter is formed whose properties are different from those of the bodies before their combination. This attraction is stronger in proportion as the nature of the bodies is different, between which it is exerted. See page 395.

AGENT. Any substance which has the property of producing chemical action is called a chemical agent.

AGGREGATES. Substances whose parts are united by cohesive, and not by chemical attraction. See *Affinity of aggregation.* See page 394.

ALBUMEN. The modern name for coagulable lymph. It is that peculiar animal substance which forms the serum of the blood, the white of eggs, and other compounds.

ALCOHOL. Rectified spirit of wine. When good, its specific gravity is only 0.836. See page 255.

ALEMBIC. The term formerly given to several stills used by chemists for their distillations. The best description of these various instruments will be found in Macquer's *Elements of Chemistry,* vol. i. page 171—175.

ALKALIES. Peculiar substances which have a burning and caustic taste, and a strong tendency to combination. When united with acids they form mild alkaline salts. See page 122.

ALLOYS. A combination of any two metals, except mercury, is called an alloy. Thus gold is alloyed either with silver or copper, for the purposes of coinage.

ALLUVIAL. By alluvial depositions is meant the soil which has been formed by the destruction of the mountains, and the washing down of their particles by torrents of water. See page 219.

ALUMIUM. The pure base of alumina. See page 269.

AMALGAM. A combination or mixture of mercury with any other metal, is called an amalgam.

AMMONIACAL *salts.* Salts formed by the union of an acid with ammonia, or volatile alkali. See page 138.

ANALYSIS. The resolution of a substance into its constituent parts, for the purpose of examination. See page 19.

ANNEALING. The art of rendering substances tough which are naturally hard and brittle. Glass and iron are annealed by gradual cooling; brass and copper by heating, and then suddenly plunging them in cold water.

APPARATUS, *chemical.* This term is descriptive of all the utensils made use of in a chemical laboratory. The principal are stills, furnaces, crucibles, retorts, receivers, matrasses, worm-tubs, pneumatic troughs, thermometers, &c.

RCANUM DUPLICATUM. An old name of the salt which is now called sulphate of potash.

REOMETER. A graduated glass instrument with a bulb, by which the specific gravity of liquids is ascertained. Baumé's areometer is that which is chiefly referred to when the French writers speak of this instrument. See table, page 475.

RGIL. The name employed by the old chemical writers to denote alumina, or common clay. See page 98.

RGILLACEOUS. A term descriptive of those earths which contain alumina or clay.

ROMA. A term used for the odour which arises from certain vegetables, or their infusions.

RSENIATES. Salt formed by the combination of any base with the arsenic acid. See page 199.

TMOMETER. An instrument contrived by Professor Leslie for measuring the quantity of exhalation from a humid surface in a given time.

TMOSPHERES. We use this term to express the degree of additional pressure given to fluids. Thus, if, in order to impregnate water with any of the gases, I give it a pressure of 15lbs. upon every square inch of surface, I am said to give it *one* atmosphere; if 30lbs. *two* atmospheres, &c. See page 39.

TTRACTION. Chemical attraction is a term synonymous with *affinity*; which see.

ZOTE. A name given by the French chemists to *nitrogen*, to which, being the most proper, the reader is referred.

B.

ALLOON. A term given by the French to their spherical chemical receivers.

ALSAMS. Certain aromatic resinous substances, which are obtained from some trees by incisions. Of this kind are the Canada balsam, the balsam of Copaiva, the balsam of Tolu, &c.

ARIUM. The base of the earth called barytes, See page 267.

AROMETER. An instrument which shows the variation of the pressure of the atmosphere, by the rise or fall of a column of mercury in a glass tube attached to a graduated plate. See page 34.

ASE. A chemical term, usually applied to denote the earth, the alkali, or the metal which is combined with an acid to form a salt.

ATHS. Vessels for distillation or digestion, contrived to transmit heat gradually and regularly.

BATHS, *sand.* Vessels filled in part with dry sand, in which those retorts are placed which require a greater heat than can be given by boiling water. In large works, iron plates are used instead of vessels of capacity. They are often called *sand-heats.*

———, *water.* Vessels of boiling water, in which other vessels containing the matters to be distilled or digested are placed, in order that the same heat may be kept up throughout the whole of any particular process.

BENZOATES. Salts formed by the combination of any base with the benzoic acid.

BITTERN. The mother-liquor which remains after the crystallization of muriate of soda (sea salt). It generally contains sulphate of magnesia, and a small portion of sulphate of soda.

BITUMEN. A generic term, applied to a variety of fossil inflammable substances. See notes, page 240.

BLOW-PIPE. An instrument to increase and direct the flame of a lamp for the analysis of minerals, and for other chemical purposes.

BOLT-HEAD. A round chemical vessel with a long neck, usually employed for digestions. It is also called a matrass.

BORATES. Salts formed by the combination of any base with the acid of borax. See page 198.

BORON. The undecomposable base of boracic acid.

BUTTON. A name given to the small round piece of metal which is found at the bottom of a crucible after a metallic ore or an oxide of metal has been reduced.

C.

CALCAREOUS. A chemical term formerly applied to describe chalk, marble, and all other combinations of lime with carbonic acid. See page 110.

CALCINATION. The application of heat to saline, metallic, or othersubstances; so regulated as to deprive them of moisture, &c. and yet preserve them in a pulverulent form.

CALCIUM. The undecomposable base of the earth known by the name of lime. See page 267.

CALORIC. The chemical term for the matter of heat.

————, *free,* is caloric in a separate state, or, if attached to other substances, not *chemically* united with them. See page 59.

————, *latent,* is the term made use of to express that portion of caloric which is chemically united to any substance, so as to become a *part* of the said substance. See page 60.

CALORIMETER. An instrument for ascertaining the quantity of caloric disengaged from any substance that may be the object of experiment. See page 64.

ALX. An old term made use of to describe a metallic oxide.

AMPHORATES. Salts formed by the combination of any base with the camphoric acid. See page 204.

APILLARY. A term usually applied to the rise of the sap in vegetables, or the rise of any fluid in very small tubes; owing to a peculiar kind of attraction, called capillary attraction.

APSULES, are small saucers of clay for roasting samples of ores, and for smelting them to ascertain their value.

APUT-MORTUUM. A term signifying *dead-head*, being that which remains in a retort after distillation to dryness. See *Residuum*, which is the modern term.

ARBON. The basis of charcoal. See page 235.

ARBONATES. Salts formed by the combination of any base with carbonic acid. See page 194.

ARBURETS. Compound substances, of which carbon forms one of the constituent parts. Thus plumbago, which is composed of carbon and iron, is called carburet of iron. See page 247.

AUSTICITY. That quality in certain substances by which they burn or corrode animal bodies to which they are applied. It is best explained by the doctrine of chemical affinity. See page 123.

EMENTATION. A process by which metals are purified or changed in their qualities by heat, without fusion, by means of a composition called a cement, with which they are covered. Thus iron by being kept a long time in a certain degree of heat, surrounded by charcoal powder, is converted into steel.

HALYBEATE. A term descriptive of those mineral waters which are impregnated with iron. See *Martial*.

HARCOAL. Wood burnt in close vessels: it is an oxide of carbon, and generally contains a small portion of salts and earth. Its carbonaceous matter may be converted by combustion into carbonic acid gas. See page 236.

HATOYANT. A term much used lately by the French chemists to describe a property in some metallic and other substances of varying their colours according to the way in which they are held; as is the case with the feathers of some birds, which appear very different when seen in different positions.

HERT. A term made use of in describing a species of siliceous stones, which are coarser and softer than common flint. It is often found in large masses in quarries of limestone.

CHLORIDES. Compound bodies formed by the chemical union of any substance with chlorine. See page 154 &c.

CHLORINE. A name lately given to the substance usually called oxymuriatic acid. See page 152.

CHROMATES. Salts formed by the combination of any base with the chromic acid. See page 166.

CITRATES. Salts formed by the combination of any base with citric acid. See page 203.

COAL. A term applied to the residuum of any dry distillation of animal or vegetable matters. See page 240.

COHESION. A force inherent in all the particles of all substances, excepting light and caloric, which prevents bodies from falling in pieces. See *Affinity*.

COHOBATION. When a distilled fluid is poured again upon the matter from which it was distilled, in order to make it stronger, it is called cohobation. It is not much practised by modern chemists.

COLUMBATES. Salts formed by the combination of any base with the columbic acid. See page 334.

COMBINATION. A term expressive of a true *chemical* union of two or more substances; in opposition to mere mechanical mixture.

COMBUSTIBLES. Certain substances which are capable of combining more or less rapidly with oxygen. They are divided by chemists into simple and compound combustibles. See page 377.

COMBUSTION. The act of absorption of oxygen by combustible bodies from atmospheric or vital air. The word decombustion is sometimes used by French writers to signify the opposite operation. See page 376.

COMMINUTION. The reduction of hard bodies into small particles. By this process the heaviest substances may be made to float in the lightest fluids.

CONCENTRATION. The act of increasing the specific gravity of bodies. The term is usually applied to fluids which are rendered stronger by evaporating a portion of the water which they contain.

CONDENSATION. The act of bringing the component parts of vapour, or gas, nearer together by pressure, or by cold. Thus atmospheric air may be condensed by pressure, and aqueous vapour by the subtraction of caloric, till it is converted into water.

CRUCIBLES. Vessels of indispensable use in chemistry in the various operations of fusion by heat. They are made of baked earth, or metal, in the form of an inverted cone.

CRYSTALLIZATION. An operation of nature in which various earths, salts, and metallic substances, pass from a fluid to a solid state, assuming certain determinate geometrical figures. See page 206.

CRYSTALLIZATION, *water of.* That portion which is combined with salts in the act of crystallizing, and becomes a *component* part of the said saline substances. See page 208.

CUPEL. A vessel made of calcined bones, mixed with a small proportion of clay and water. It is used whenever gold and silver are refined by melting them with lead. The process is called cupellation.

D.

DECOMBUSTION. Synonymous with *Deoxidizement*; which see.

DECOMPOSITION. The separation of the constituent principles of compound bodies by chemical means.

DECREPITATION. The sudden decomposition of salts attended with a crackling noise when thrown into a red-hot crucible, or on an open fire.

DEFLAGRATION. The vivid combustion that is produced whenever nitre, mixed with an inflammable substance, is exposed to a red heat. It may be attributed to the extrication of oxygen from the nitre, and its being transferred to the inflammable body; as any of the nitrates or oxygenized muriates will produce the same effect.

DELIQUESCENCE *of solid saline bodies*, signifies their becoming moist, or liquid, by means of water which they absorb from the atmosphere in consequence of their great attraction for that fluid. See page 209.

DELIQUIUM, is the state of potash, or any deliquescent salt, when it has so far deliquesced by exposure to the air as to have become a liquid.

DELITE. A term used by some of the French writers, signifying to break, by the action of the air, like a soft stone into layers. See *Annales de Chimie*, tom. xix. page 79.

DEOXIDIZE (formerly *Deoxidate*). To deprive a body of oxygen.

DEOXIDIZEMENT. A term made use of to express that operation by which one substance deprives another substance of its oxygen. It is called unburning a body by the French chemists.

DEPHLEGMATION, is the act of separating the water from chemical liquors.

DEPURATION. The purging or separating any liquid in a state of purity from its fæces or lees.

DETONATION. An explosion with noise. It is most commonly applied to the explosion of nitre when thrown upon heated charcoal. See page 192.

DIGESTION. The effect produced by the continued soaking of a solid substance in a liquid, with the application of heat.

DIGESTOR, *Papin's*. An apparatus for reducing animal or vegetable substances to a pulp or jelly expeditiously.

DISTILLATION. A process for separating the volatile parts of a substance from the more fixed, and preserving them both in a state of separation.

DOCIMASTIC ART. The art of assaying metals.

DUCTILITY. A quality of certain bodies, in consequence of which they may be drawn out to a certain length without fracture. See page 258.

DULCIFICATION. The combination of mineral acids with alcohol. Thus we have dulcified spirit of nitre, dulcified spirit of vitriol, &c.

E.

EDULCORATION. Expressive of the purification of a substance by washing with water.

EFFERVESCENCE. An intestine motion which takes place in certain bodies, occasioned by the sudden escape of a gaseous substance.

EFFLORESCENCE. A term commonly applied to those saline crystals which become pulverulent on exposure to the air, in consequence of the loss of a part of the water of crystallization. See page 210.

ELASTICITY. A force in bodies, by which they endeavour to restore themselves to the posture from whence they were displaced by any external force. See page 34.

ELASTIC FLUIDS. A name sometimes given to vapours and gases. Vapour is called an *elastic* fluid; gas, a *permanently* elastic fluid.

ELECTIVE ATTRACTIONS. A term used by Bergman and others to designate what we now express by the words *chemical affinity*; which see. When chemists first observed the power which one compound substance has to decompose another, it was imagined that the minute particles of some bodies had a *preference* for some other particular bodies; hence this property of matter acquired the term *elective* attraction. See Chap. xiii.

ELEMENTS. The simple constituent parts of bodies which are incapable of decomposition; they are frequently called principles. See *Simple Substances.*

ELIQUATION. An operation whereby one substance is separated from another by fusion. It consists in giving the mass a degree of heat that will make the more fusible matter flow, and not the other.

ELUTRIATION. The operation of pulverizing metallic ores or other substances, and then mixing them with water, so that the lighter parts which are capable of suspension may be poured off, and thus separated from the grosser particles. Most of the metallic substances which are reduced to an impalpable powder are prepared by this process.

EMPYREUMA. A peculiar and indescribably disagreeable smell, arising from the burning of animal and vegetable matter in close vessels.

EOLIPILE. A copper vessel with a small orifice, and partly filled with water. It is made hot, in order that the vapour of the water may rush out with violence, and carry a stream of air with it to increase the intensity of fires. It is an instrument of great antiquity.

ESSENCES. What are called essences, in chemistry and pharmacy, are the essential oils obtained by distillation from odoriferous vegetable substances.

ESSENTIAL SALTS. The saline substances found in plants, and which are held in solution by the water wherein they are infused. They are obtained by evaporation and cooling.

ETHERS. Volatile liquids formed by the distillation of some of the acids with alcohol.

EVAPORATION. The conversion of fluids into vapour by heat. This appears to be nothing more than a gradual solution of the aqueous particles in atmospheric air, owing to the chemical attraction of the latter for water.

EUCHLORINE. A compound of chlorine and oxygen, consisting of about 82 chlorine and 18 oxygen. It may with propriety be called the protoxide of chlorine, as there are three other distinct compounds of these gaseous substances, each possessing more oxygen than euchlorine. See page 154.

EUDIOMETER. An instrument invented by Dr. Priestley for determining the purity of any given portion of atmospheric air. The science of investigating the different kinds of gases is called *eudiometry*.

EXPRESSION. A term used in pharmacy, denoting the act of forcing out the juices and oils of plants by means of a press. By a similar term the *expressed* are distinguished from the *essential* oils.

EXSICCATION. The act of drying moist bodies. It is effected in two ways; by exhaling the aqueous particles by the application of heat or atmospheric air, and by absorbing the moisture with soft and spongy substances. Thus, small matters are dried by chemists with bibulous paper; and larger masses, by spreading them on tablets of chalk.

EXTRACTS. The soluble parts of vegetable substances, first dissolved in spirit or water, and then reduced to the consistence of a thick syrup, or paste, by evaporation.

F.

FAT. An oily concrete animal substance, composed of oil and carbon. Rancid fat and stale tallow generally contain a portion of sebacic acid.

FERMENTATION. A peculiar spontaneous motion, which takes place in all vegetable matter when exposed for a certain time to a proper degree of temperature. For the changes which are effected by saccharine fermentation, see page 253.

FIBRINE. That white fibrous substance which is left after freely washing the coagulum of the blood, and which chiefly composes the muscular fibre.

FILTRATION. A chemical process for the depuration of liquid substances. Bibulous paper supported by a funnel is commonly made use of; but for expensive liquors chemists generally use a little carded cotton lightly pressed into the tube of a glass funnel. The valuable concentrated acids should be filtered through pounded glass.

FIXITY. A term applicable to that property of some bodies of bearing a great heat without being volatilized.

FLOWERS, in chemical language, are solid dry substances reduced to a powder by sublimation. Thus we have flowers of arsenic, of sal ammoniac, of sulphur, &c. which are arsenic, sal ammoniac, and sulphur unaltered except in appearance.

FLUATES. Salts formed by the combination of any base with fluoric acid. See page 197.

FLUIDITY. A term applied to all liquid substances. Solids are converted to fluids by combining with a certain portion of caloric. See page 21.

FLUX. A substance which is mixed with metallic ores, or other bodies, to promote their fusion; as an alkali is mixed with silica in order to form glass.

FOSSIL. See *Mineral,* with which it is partly synonymous.

FULIGINOUS. A term sometimes made use of in describing certain vapours which arise in chemical operations, having the thick appearance of smoke.

FULMINATION. Thundering or explosion with noise. We have fulminating silver, fulminating gold, and other fulminating powders, which explode with a loud report by friction, or when slightly heated. See page 324.

FURNACES. Chemical vessels of various forms for the fusion of ores, or other operations which require heat.

——————, *blast,* are built for making iron, smelting ores, &c. They are so contrived that their heat is much increased by means of powerful bellows. A blacksmith's forge is a kind of blast furnace.

FURNACES, *wind.* Chemical furnaces for intense heat, so constructed that they draw with great force, without the use of bellows.

FUSION. The state of a body which was solid in the temperature of the atmosphere, and is now rendered fluid by the artificial application of heat.

G.

GALLATES. Salts formed by the combination of any base with gallic acid. See page 171.

GALVANISM. A new science, which offers a variety of phenomena, resulting from different conductors of electricity placed in different circumstances of contact; particularly the nerves of the animal body. See page 58.

GANGUE. A term made use of to denote the stony matter which fills the cavities, and accompanies the ores in the veins of metals.

GAS. All solid substances, when converted into permanently elastic fluids by caloric, are called gases. See page 44.

GASEOUS. Having the nature and properties of gas.

GASOMETER. A name given to a variety of utensils and apparatus contrived to measure, collect, preserve, or mix the different gases. An apparatus of this kind is also used for the purposes of administering pneumatic medicines.

GASOMETRY. The science of measuring the gases. It likewise teaches the nature and properties of these elastic fluids.

GELATINE. A chemical term for animal jelly. It exists particularly in the tendons and the skin of animals.

GLASS. Some metallic oxides, when fused, are called *glass*. They have somewhat of resemblance to common glass.

———, *phosphoric.* A vitreous, insipid, insoluble substance, procured by boiling down phosphoric acid to a syrup, and then fusing it by an increased heat.

——— *gall.* See *Sandiver.*

GLUCIUM. The pure base of the earth called glucina. See page 270.

GLUTEN. A vegetable substance somewhat similar to animal gelatine. It is the gluten in wheat-flour which gives it the property of making good bread, and adhesive paste. Other grain contains a much less quantity of this nutritious substance.

GRADUATION. A process, by evaporation, of bringing fluids to a certain degree of consistence, in order to separate more easily the substances they hold in solution.

—————. The division of a scale or measure into decimal, or other regular parts.

GRAIN. The *smallest* weight made use of by chemical writers. Twenty grains make a scruple; 3 scruples a drachm; 8 drachms, or 480 grains, make an ounce; 12 ounces, or 5760 grains, a pound troy. The *avoirdupois* pound contains 7000 grains.

GRANULATION. The operation of pouring a *melted* metal into water, in order to divide it into small particles for chemical purposes. Tin is thus granulated by the dyers before it is dissolved in the proper acid.

GRAVITY. That property by which bodies move towards each other, in proportion to their respective *quantities* of matter. This is the property by which bodies fall to the earth. See Chap xiii.

———, *specific.* This differs from absolute gravity in as much as it is the weight of a given *measure* of any solid or fluid body, compared with the *same measure* of distilled water. It is generally expressed by decimals. See page 25.

GUMS. Mucilaginous exudations from certain trees. Gum consists of lime, carbon, oxygen, hydrogen, and nitrogen, with a little phosphoric acid.

H.

HEAT, *matter of.* See *Caloric.*

HEPAR. The name formerly given to the combination of sulphur with alkali. It is now called sulphuret of potash, &c. as the case may be.

HEPATIC *gas.* The old name for sulphuretted hydrogen.

HERMETICALLY. A term applied to the closing of the orifice of a glass tube, so as to render it air-tight. Hermes, or Mercury, was formerly supposed to have been the inventor of chemistry; hence a tube which was closed for chemical purposes, was said to be Hermetically or chemically sealed. It is usually done by melting the end of the tube by means of a blow-pipe.

HYDRATES. Those substances which have formed so intimate an union with water, as to solidify the water and render it one of their component parts, are called hydrates. Common slacked lime is properly a hydrate of lime.

HYDRO-CARBONATES. Combinations of carbon with hydrogen are described by this term. Hydro-carbonate gas is procured from moistened charcoal by distillation. See page 228.

HYDRIODATES. Compounds formed by the union of certain substances with hydriodic acid. See Additional Notes, No. 48.

HYDROGEN. A simple substance; one of the constituent parts of water. See page 223.

HYDROGEN *gas*. Solid hydrogen united with a large portion of caloric. It is the lightest of all the known gases. Hence it is used to inflate balloons. It was formerly called inflammable air.

HYDROGENIZED *sulphurets*. Certain bases combined with sulphuretted hydrogen.

HYDROGURETS. For an account of these compounds, see the Additional Notes, No. 63.

HYDRO-OXIDES. Metallic oxides combined with water.

HYDROMETERS. Instruments for ascertaining the specific gravity of spirituous liquors or other fluids.

HYGROMETERS. Instruments for ascertaining the degree of moisture in atmospheric air.

HYGROSCOPE. This term is sometimes considered synonymous with *Hygrometer*, but the instruments are different. The account of an improved hygroscope invented by Professor Leslie may be seen in his "Short Account of Experiments," page 106.

HYPEROXYGENIZED. A term applied to substances which are combined with the largest possible quantity of oxygen. We had formerly muriatic acid, oxygenized muriatic acid, and hyperoxygenized muriatic acid. These latter terms are however gradually falling into disuse, and the terms chlorine and euchlorine are adopted in their stead. See pages 152 and 191.

I.

INCINERATION. The burning of vegetables for the sake of their ashes. It is usually applied to the burning of kelp on the sea-coast for making mineral alkali.

INCOMPATIBLE *salts*. For an explanation of this term see the Additional Notes, No. 28.

INFLAMMATION. A phenomenon which takes place on mixing certain substances. The mixture of oil of turpentine with strong nitrous acid is an instance of this peculiar chemical effect.

INFUSION. A simple operation to procure the salts, juices, and other virtues of vegetables by means of water.

INSOLATION. A term sometimes made use of to denote that exposure to the sun which is made in order to promote the chemical action of one substance upon another.

INTEGRANT *particles*. See note, page 220.

INTERMEDIATES. A term made use of when speaking of chemical affinity. Oil, for example, has no affinity to water unless it be previously combined with an alkali; it then becomes soap, and the alkali is said to be the *intermedium* which occasions the union.

IODIDES. Compounds formed by the union of any substance with *iodine.* See page 386.

ITTRIUM. The undecomposable base of the earth which is called yttria. See page 270.

K.

KALI. A genus of marine plants which is burnt to procure mineral alkali by afterwards lixiviating the ashes. See page 132.

L.

LABORATORY. A room fitted up with apparatus for the performance of chemical operations.

LACTATES. Salts formed by the combination of any base with lactic acid. See page 171.

LAKES. Certain colours made by combining the colouring matter of cochineal, or of certain vegetables, with pure alumina, or with oxide of tin, zinc, &c.

LAMP, ARGAND'S. A kind of lamp much used for chemical experiments. It is made on the principle of a wind furnace, and thus produces a great degree of light and heat without smoke.

LENS. A glass, convex on both sides, for concentrating the rays of the sun. It is employed by chemists in fusing refractory substances which cannot be operated upon by an ordinary degree of heat. See note, page 72.

LEVIGATION. The grinding down of hard substances to an impalpable powder on a stone with a muller, or in a mill adapted to the purpose.

LIQUEFACTION. The change of a solid to the state of a fluid, occasioned by the combination of caloric. See page 23.

LITHARGE. An oxide of lead which appears in a state of vitrification. It is formed in the process of separating silver from lead. See page 312.

LIXIVIATION. The solution of an alkali or a salt in water, or in some other fluid, in order to form a lixivium.

LIXIVIUM. A fluid impregnated with an alkali, or with a salt.

LUTE. A composition for closing the junctures of chemical vessels to prevent the escape of gas or vapour in distillation. See Additional Notes, No. 54.

M.

MACERATION. The steeping of a solid body in a fluid in order to soften it, without impregnating the fluid.

MAGNESIUM. The undecomposable base of magnesia. See page 267.

MALATES. Salts formed by the combination of any base with malic acid. See page 170.

MALLEABILITY. That property of metals which gives them the capacity of being extended and flattened by hammering. It is probably occasioned by latent caloric. See page 258.

MARTIAL. An old term for chemical preparations of iron; see *Chalybeate*.

MASSICOT. A name given to the *yellow* oxide of lead, as minium is applied to the *red* oxide.

MATRASS. Another name for a bolt-head; which see.

MATRIX. The bed in which a metallic ore is found. See page 258.

MATT. That mass of metal which separates from the scoriæ in smelting ores without previous roasting.

MENSTRUUM. The fluid in which a *solid* body is dissolved. Thus water is a menstruum for salts, gums, &c., and spirit of wine for resins.

METALLIC OXIDES. Metals combined with oxygen. By this process they are generally reduced to a pulverulent form; are changed from combustible to incombustible substances; and receive the property of being soluble in acids. See page 364.

METALLURGY. The art of extracting and purifying metals. See page 259.

MINERAL. Any natural substance of a metallic, earthy, or saline nature, whether simple or compound, is deemed a mineral.

MINERALIZERS. Those substances which are combined with metals in their ores; such are sulphur, arsenic, oxygen, carbonic acid, &c. See page 259.

MINERALOGY. The science of fossils and minerals.

MINERAL WATERS. Waters which hold some metal, earth, or salt, in solution. They are frequently termed Medicinal Waters.

MINIUM. The red oxide of lead, commonly called red-lead. See page 363.

MOLECULE. The molecules of bodies are those ultimate particles of matter which cannot be decomposed by any chemical means. See page 220.

MOLYBDATES. Salts formed by the combination of any base with the molybdic acid. See page 166.

MORDANTS. Substances which have a chemical affinity for particular colours; they are employed by dyers as a bond to unite the colour with the cloth intended to be dyed. Alum is of this class.

MOTHER-WATERS, or MOTHERS. The liquors which are left after the crystallization of any salts. See page 207.

MUCILAGE. A glutinous matter obtained from vegetables, transparent and tasteless, soluble in water, but not in spirit of wine. It chiefly consists of carbon and hydrogen, with a little oxygen.

MUCITES. Salts formed by the combination of any base with the mucous acid. See page 172.

MUFFLE. A semi-cylindrical utensil, resembling the tilt of a boat, made of baked clay: its use is that of a cover to cupels in the assay furnace, to prevent the charcoal from falling upon the metal, or whatever is the subject of experiment.

MURIATES. Salts formed by the combination of any base with muriatic acid. See page 189.

N.

NATRON. One of the names for mineral alkali, or soda.

NEUTRALIZE. When two or more substances mutually disguise each other's properties, they are said to neutralize one another.

NEUTRAL SALT. A substance formed by the union of an acid with an alkali, an earth, or a metallic oxide, in such proportions as to saturate both the base and the acid.

NITRATES. Salts formed by the combination of any base with nitric acid. See page 192.

NITROGEN. A simple substance, by the French chemists called azote. It enters into a variety of compounds, and forms more than three parts in four of atmospheric air. See page 47.

O.

OCHRES. Various combinations of the earths with oxide, or carbonate of iron.

OIL. A fluid substance well known. It is composed of hydrogen, oxygen, and carbon.

ORES. Metallic earths, which frequently contain several extraneous matters; such as sulphur, arsenic, &c.

OXALATES. Salts formed by the combination of any base with oxalic acid. See page 202.

OXIDE. Any substance combined with oxygen, in a proportion not sufficient to produce acidity.

OXIDIZE. To combine oxygen with a body without producing acidity.

OXIDIZEMENT. The operation by which any substance is combined with oxygen, in a degree not sufficient to produce acidity.

OXYGEN. A simple substance composing the *greatest* part of water, and part of atmospheric air. See pages 46 and 359.

XYGEN *gas*. Oxygen converted to a gaseous state by caloric. It is also called vital air. It forms nearly one-fourth of atmospheric air.

XYGENIZABLE. A term applicable to all bodies that combine with oxygen, and do not emit flame during the combination.

XYGENIZE. To acidify a substance by oxygen. Synonymous with Oxygenate; but the former is the better term.

XYGENIZEMENT. The production of acidity by oxygen. See page 143.

P.

ARTING. The operation of separating gold from silver by means of nitrous acid, and other mediums. See page 368.

ELICAN. A glass alembic, with a tubulated capital, from which two opposite and crooked arms pass out, and enter again at the swell of the vessel. The instrument is designed for operations of cohobation, and is calculated to save the trouble of frequently luting and unluting the apparatus. It is now seldom used.

ELLICLE. A thin skin which forms on the surface of saline solutions and other liquors, when boiled down to a certain strength.

HLOGISTON. An old chemical name for an imaginary substance, supposed to be a combination of fire with some other matter, and a constituent part of all inflammable bodies, and of many other substances. See note, page 361.

HOSPHATES. Salts formed by the combination of any base with phosphoric acid. See page 195.

HOSPHITES. Salts formed by the combination of any base with phosphorous acid. See page 196.

HOSPHURETS. Substances formed by an union with phosphorus. Thus we have phosphuret of lime, phosphuretted hydrogen, &c. See page 234.

HOTOMETER. An instrument contrived for measuring the comparative intensity of light. The one invented by Count Rumford is described in the Philosophical Transactions for 1794, vol. 84; and a later one by Professor Leslie, in his "Short Account of Experiments on the Relation of Heat to Air and Moisture," page 52.

LUMBAGO. Carburet of iron, or the *black lead* of commerce. See page 247.

NEUMATIC. Any thing relating to the airs and gases.

———— *trough*. A vessel filled in part with water or mercury, for the purpose of collecting gases, so that they may be readily removed from one vessel to another. See the last note, page 45.

OTASSIUM. The metallic base of the alkali called Potash. See page 261.

PRECIPITATE. Any matter which, having been dissolved in a fluid, falls to the bottom of the vessel on the addition of some other substance capable of producing a decomposition of the compound, in consequence of its attraction either for the menstruum, or for the matter which was before held in solution.

PRECIPITATION. That chemical process by which bodies dissolved, mixed, or suspended in a fluid, are separated from that fluid, and made to gravitate to the bottom of the vessel.

PRINCIPLES OF BODIES. Synonymous with *Elements;* which see.

PRUSSIATES. Salts formed by the combination of any base with prussic acid. See page 205.

PUTREFACTION. The last fermentative process of nature, by which organized bodies are decomposed so as to separate their principles, for the purpose of reuniting them, by future attractions, in the production of new compositions.

PYRITES. An abundant mineral found on the English coasts, and elsewhere. Some are sulphurets of iron, and others sulphurets of copper, with a portion of alumina and silica. The former are worked for the sake of the sulphur, and the latter for sulphur and copper. They are also called Marcasites and Fire-stone.

——— *martial.* That species of pyrites which contains iron for its basis. See a full account of these minerals in Henckel's *Pyritologia,* already quoted.

PYROMETER. An instrument invented by Mr. Wedgwood for ascertaining the degrees of heat in furnaces and intense fires. See Philosophical Transactions, vol. lxii. and lxiv. and Chemical Catech. note, page 65.

PYROPHORI. Compound substances which heat of themselves, and take fire on the admission of atmospheric air. See an account of a variety of experiments with these compositions in Wiegleb's *System of Chemistry,* quarto, page 622 &c.

PYROSCOPE. An instrument invented by Leslie for measuring the pulsatory commotion of the air, or the intensity of the heat darting continually from the fire into a room. This instrument will also mark the pulsations from a cold surface.

Q.

QUARTATION. A term used by refiners in a certain operation of parting. See Lewis's *Com. Tech.* page 135.

QUARTZ. A name given to a variety of siliceous earths mixed with a small portion of lime or alumina. Mr. Kirwan confines the term to the *purer* kind of silica. Rock crystal and the amethyst are species of quartz.

R.

ICALS. A chemical term for the *Elements* of bodies; which see.

———, *compound.* When the base of an acid is composed of two or more substances, it is said that the acid is formed of a *compound* radical. The sulphuric acid is formed with a *simple* radical; but the vegetable acids, which have radicals composed of hydrogen and carbon, are said to be acids with compound radicals.

GENTS. Substances which are added to mineral waters or other liquids as tests to discover their nature and composition. See Gottling's *Description of a portable Chest of Chemistry,* &c. 12mo. 1791. See *Test.*

LGAR. Red sulphuretted oxide of arsenic.

EIVERS. Globular glass vessels adapted to retorts for the purpose of preserving and condensing the volatile matter raised in distillation.

TIFICATION, is nothing more than the re-distilling a liquid to render it more pure, or more concentrated, by abstracting a part of it only.

UCTION. The restoration of metallic oxides to their original state of metals; which is usually effected by means of charcoal and fluxes. See page 369.

INING. The process of separating the perfect metals from other metallic substances, by what is called cupellation. See page 368.

RACTORY. A term applied to earths or metals that are either infusible, or that require an extraordinary degree of heat to change or melt them.

RIGERATORY. A contrivance of any kind, which, by containing cold water, answers the purpose of condensing the vapour or gas that arises in distillation. A worm-tub is a refrigeratory.

ISTERS. Openings in chimneys, or other parts of chemical furnaces, with sliding doors, to regulate the quantity of atmospheric air admitted to the fire-place, or to open or shut the communication with the chimney at pleasure.

ULUS, in its chemical acceptation, signifies a pure metallic substance, freed from all extraneous matters.

ULSION. A principle whereby the particles of bodies are prevented from coming into actual contact. It is thought to be owing to *caloric,* which has been called the repulsive power. See Chap. xiii. page 402.

IDUUM. What is left in a pot or retort after the more valuable part has been drawn off. Thus the sulphate of potash which remains in the pot after the distillation of nitrous acid is called the residuum. It is sometimes called the *caput mortuum.*

RESINS. Vegetable juices concreted by evaporation either spontaneously or by fire. Their characteristic is solubility in alcohol, and not in water. It seems that they owe their solidity chiefly to their union with oxygen.

RETORT. A vessel in the shape of a pear, with its neck bent downwards, used in distillation; the extremity of which neck fits into that of another bottle called a receiver.

REVERBERATORY. An oven or furnace in which the flame is confined by a dome which occasions it to be beat down upon the floor of the furnace before it passes into the chimney. Some are so contrived that it returns or reverberates upon the matter under operation.

REVIVIFICATION. See *Reduction*, which is a synonymous term: though "revivification" is generally used when speaking of quicksilver.

ROASTING. A preparative operation in metallurgy to dissipate the sulphur, arsenic, &c., with which a metal may be combined.

ROCK-CRYSTAL. Crystallized silica. See page 95.

S.

SACCHOLATES. Salts formed by the combination of any base with saccholactic acid. See page 172.

SAL DE DUOBUS, } Names originally given to the salt which
SAL POLYCHREST. } is now called sulphate of potash.

SALIFIABLE BASES. All the metals, alkalies, and earths, which are capable of combining with acids, and forming salts, are called salifiable bases.

SALINE. Partaking of the properties of a salt.

SALTS, *neutral.* A class of substances formed by the combination to saturation of an acid with an alkali, an earth, or other salifiable base.

———, *triple.* Salts formed by the combination of an acid with two bases or radicals. The tartrate of soda and potash (Rochelle salt) is an instance of this kind of combination.

SAND *bath.* } See *Bath.*
——— *heat.* }

SANDIVER. A matter composed of different salts, which rises as a pellicle on the surface of the pots in which glass is melted. It is used as a flux in the fusion of ores, and for other purposes. The term is probably a corruption of "Selle de verre."

SAP-COLOURS. A name given to various expressed vegetable juices of a viscid nature, which are inspissated by slow evaporation for the use of painters, &c. Sap-green, gamboge, &c. are of this class.

PONACEOUS. A term applied to any substance which is of the nature or appearance of soap. See page 129.

TURATION. The act of impregnating a fluid with another substance, till no more can be received or imbibed. A fluid which holds as much of any substance as it can dissolve, is said to be saturated with that substance. A solid may in the same way be saturated with a fluid.

BATES. Salts formed by the combination of any base with sebacic acid. See page 176.

LENITE. A salt existing in spring water, formed by sulphuric acid and lime. Its proper chemical name is Sulphate of lime. See page 215.

MI-METAL. A name formerly given to those metals which, if exposed to the fire, are neither malleable, ductile, nor fixed. It is a term not used by modern chemists.

ICEOUS EARTHS. A term used to describe a variety of natural substances which are composed chiefly of silica; as quartz, flint, sand, &c.

LICUM. The undecomposable base of rock crystal, or of the earth called silica. See page 269.

MPLE SUBSTANCES. Synonymous with *Elements*; which see. See also page 220.

ELTING. The operation of fusing ores for the purpose of separating the metals they contain, from the sulphur and arsenic with which they are mineralized, and also from other heterogeneous matter.

DIUM. The metallic base of the alkali called soda. See page 263.

LUBILITY. A characteristic of most salts. See *Solution.* See also page 211.

LUTION. The perfect union of a solid substance with a fluid. Salts dissolved in water are proper examples of solution.

ARS. A name formerly given to various crystallized stones; such as the fluor spar, the adamantine spar, &c. These natural substances are now distinguished by names which better denote the nature of each.

ECIFIC GRAVITY. See the word *Gravity.*

ELTER. The commercial name of *zinc.*

IRIT. A term used by the early chemists to denote all volatile fluids collected by distillation.

——, *proof.* A term made use of to describe such ardent spirits as are of the same strength as the brandy of commerce, or of the specific gravity of 0 930, water being 1.000.

ALACTITES. Certain concretions of calcareous earth found suspended like icicles in caverns. They are formed by the oozing of water, through the crevices, charged with this kind of earth. See page 94.

STEATITES. A mineral composed of silica, iron, magnesia, &c. It is also called French chalk, Spanish chalk, and soap-rock.

STRATIFICATION. A chemical operation by which bodies are placed in a condition to act mutually upon each other by being arranged layer by layer, stratum super stratum, as is practised by metallurgists.

STRONTIUM. The undecomposable base of the earth called Strontites. See page 268.

SUB-SALTS. Salts with less acid than is sufficient to neutralize their radicals. See page 186.

SUBERATES. Salts formed by the combination of any base with the suberic acid. See page 225.

SUBLIMATE. A name given to several mercurial preparations.

SUBLIMATION. A process whereby certain volatile substances are raised by heat, and again condensed by cold into a solid form. Flowers of sulphur are made in this way. The soot of our common fires is a familiar instance of this process. See *Flowers.*

SUCCINATES. Salts formed by the combination of any base with the succinic acid. See page 174.

SUGAR. A well-known substance, found in a variety of vegetables, composed of oxygen, hydrogen, and carbon. See page 244.

SULPHATES. Salts formed by the combination of any base with the sulphuric acid. See page 187.

SULPHITES. Salts formed by the combination of any base with the sulphurous acid. See page 188.

SULPHURES, or SULPHURETS. Combinations of alkalies, or metals, with sulphur. See page 224.

SULPHURETTED. A substance is said to be sulphuretted when it is combined with sulphur. Thus we say Sulphuretted hydrogen, &c. See page 225.

SUPER-SALTS. Salts with an excess of acid, as the super-tartrate of potash. See page 186.

SYNTHESIS. When a body is examined by *dividing* it into its component parts, it is called analysis; but when we attempt to prove the nature of a substance by the *union* of its principles, the operation is called synthesis.

SYPHON. A bent tube used by chemists for drawing liquids from one vessel into another. It is sometimes called a *Crane.*

T.

TARTRATES. Salts formed by the combination of any base with the acid of tartar. See page 202.

TELLURETED. This term has been applied to certain compounds formed by the agency of Tellurium. See note page 292. Tellurium and hydrogen unite, and produce a gaseous compound called Tellureted hydrogen gas.

TEMPERATURE. The absolute quantity of free caloric which is attached to any body occasions the degree of temperature of that body. See page 65.

TENACITY, is a term used when speaking of glutinous bodies. It is also expressive of the adhession of one substance to another.

TEST. That part of a cupel which is impregnated with litharge in the operation of refining silver. It is also the name of whatever is employed in chemical experiments to detect the several ingredients of any composition. See *Reagent*.

TEST-PAPERS. Papers impregnated with certain chemical reagents; such as litmus, turmeric, radish, &c. They are used to dip into fluids to ascertain by a change of colours the presence of acids and alkalies.

THERMOMETER. An instrument to show the relative heat of bodies. Fahrenheit's thermometer is that chiefly used in England. (See page 65.) Other thermometers are used in different parts of Europe. For the difference in the scale of these thermometers, see the Table at page 476.

TINCAL. The commercial name of crude borax.

TINCTURES. Solutions of substances in spirituous menstrua.

TORREFACTION. An operation similar to roasting; which see.

TRITORIUM. A vessel used for the separation of two fluids which are of different densities. The same operation may be performed by a common funnel.

TRITURATION. A chemical operation whereby substances are united by friction. Amalgams are made by this method.

TUBULATED. Retorts which have a hole at the top for inserting the materials to be operated upon without taking them out of the sand heat, are called *tubulated* retorts.

TUNGSTATES. Salts formed by the combination of any base with tungstic acid. See page 201.

TUTENAG. An Indian name for zinc. Chinese copper is also called by this name, which is a compound of copper, tin, and arsenic, much resembling silver in colour.

V.

VACUUM. A space unoccupied by matter. The term is generally applied to the exhaustion of atmospheric air by chemical or philosophical means.

VAPOUR. This term is used by chemists to denote such exhalations only as can be condensed and rendered liquid again at the ordinary atmospheric temperature, in opposition to those which are *permanently* elastic.

VATS. Large chemical vessels, generally of wood, for making infusions, &c.

VITAL AIR. Oxygen gas. The empyreal or fire-air of Scheele, and the dephlogisticated air of Priestley.

VITRIFICATION. When certain mixtures of solid substances, such as silica and an alkali, are exposed to an intense heat, so as to be fused, and become glass, they are then said to be vitrified, or to have undergone vitrification.

VITRIOLATED TARTAR. The old name for sulphate of potash.

VITRIOLS. A class of substances, either earthy or metallic, which are combined with the vitriolic acid. Thus there is vitriol of lime, vitriol of iron, vitriol of copper, &c. These salts are now called Sulphates, because the acid which forms them is called sulphuric acid.

VOLATILE ALKALI. Another name for ammonia.

VOLATILE SALTS. The commercial name for carbonate of ammonia. See page 137.

VOLATILITY. A property of some bodies which disposes them to assume the gaseous state. This property seems to be owing to their affinity for caloric.

VOLUME. A term made use of by modern chemists to express the space occupied by gaseous or other bodies.

U.

UNION, *chemical.* When a mere mixture of two or more substances is made, they are said to be mechanically united; but when each or either substance forms a component part of the product, the substances have formed a *chemical* union.

USTULATION. The roasting of ores, to separate the arsenic, sulphur, and whatever else is of a volatile nature that is connected with and mineralizes the metal. When the matter is preserved which flies off, the process is called sublimation; but when this matter is neglected, the operation is called ustulation.

W.

WATER. The most common of all fluids, composed of 85 parts of oxygen and 15 of hydrogen. See page 78.

———, *mineral.* Waters which are impregnated with mineral and other substances are known by this appellation. These minerals are generally held in solution by carbonic, sulphuric, or muriatic acid.

WAY, *dry*. A term used by chemical writers when treating of analysis or decomposition. By decomposing in the dry way, is meant, by the agency of fire.

——, *humid*. A term used in the same manner as the foregoing, but expressive of decomposition in a fluid state, or by means of water, and chemical re-agents, or tests.

WELDING HEAT. That degree of heat in which two pieces of iron or of platina may be united by hammering.

WOLFRAM. An ore of tungsten containing also the oxides of manganese and iron.

WORM TUB. A chemical vessel with a pewter worm fixed in the inside, and the intermediate space filled with water. Its use is to cool liquors during distillation. See *Refrigeratory*.

WOULFE'S *apparatus*. A contrivance for distilling the mineral acids and other gaseous substances with little loss; being a train of receivers with safety pipes, and connected together by tubes. For a full description of this most useful apparatus, see *Philosophical Transactions* for 1767, and *Chem. Catech.* page 149.

Z.

ZAFFRE. An oxide of cobalt, mixed with a portion of siliceous matter. It is imported in this state from Saxony.

ZERO. The point from which the scale of a thermometer is graduated. Thus Celsius's and Reaumur's thermometers have their zero at the *freezing* point, while the thermometer of Fahrenheit has its zero at that point at which it stands when immersed in a mixture of snow and common salt. See Notes, page 66.

ZIRCONIUM. The pure base of the earth called zirconia. See page 270.

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ERRATA.

Page 71, line 21 of the notes, for *acarrazas* read *alcarrazas.*
146, line 16 of the notes, erase the word *most.*
214, line 11, for *ound* read *found.*

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