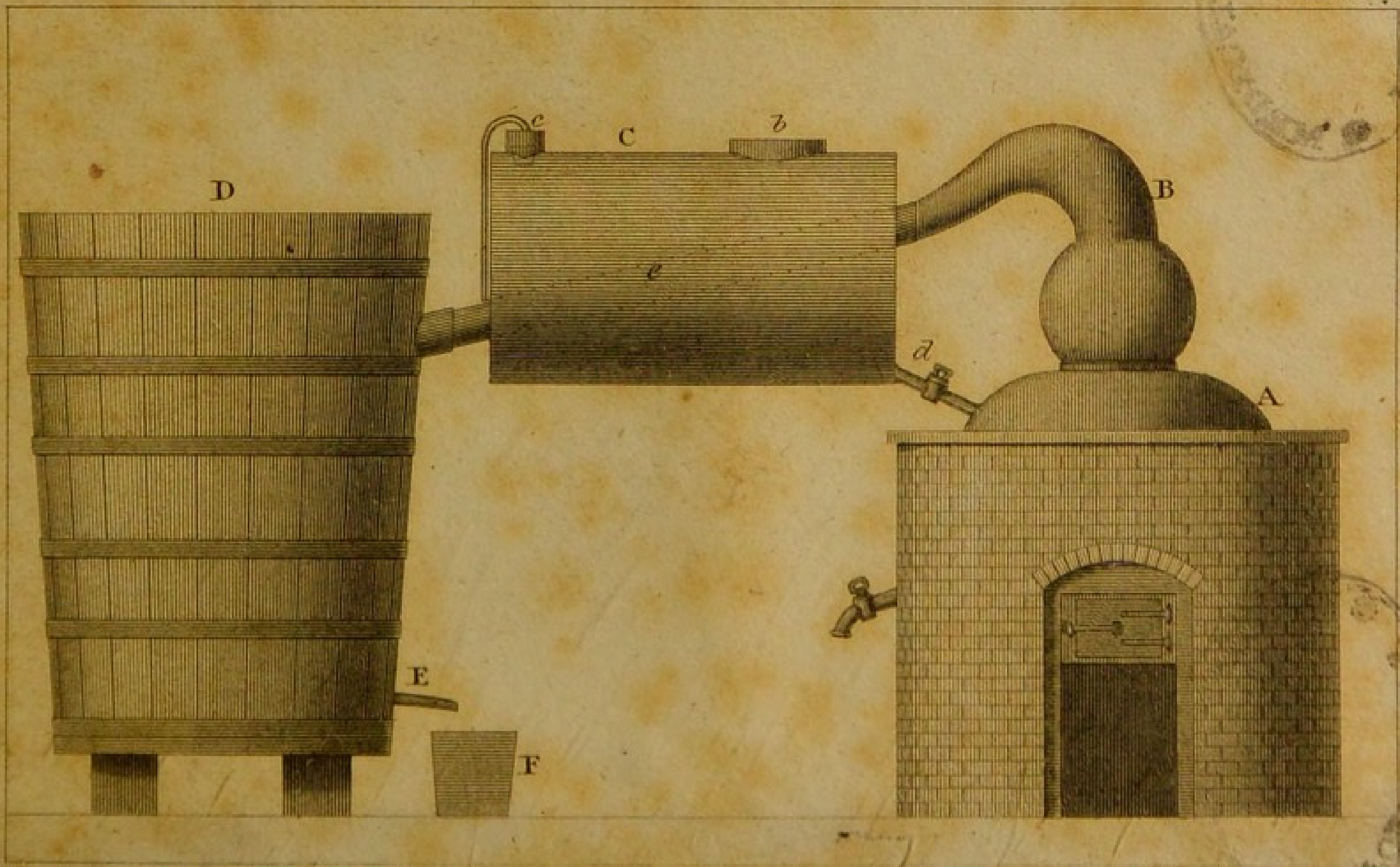
Plate V.

# ECONOMICAL STILL.



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# CHEMICAL ESSAYS,



E/a.

PRINCIPALLY RELATING TO

THE ARTS AND MANUFACTURES OF THE BRITISH DOMINIONS.

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BY

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IN FIVE VOLUMES.

VOL. I.

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*Richard and Arthur Taylor,*
*Printers, Shoe Lane.*

# PREFACE.

Nothing can be of more importance to the people of a manufacturing country than the cultivation of a taste for chemical and philosophical inquiries. Manufactories cannot be conducted without the employment of a variety of artificial as well as natural productions, and it behoves the workmen as well as their employers, to become acquainted with the intimate nature and properties of the respective materials on which they have occasion to operate.

To enable such persons to pursue these investigations with advantage, it is requisite that they should not only possess a knowledge of the elements of chemical science, but acquire also a constant habit of observing the effects which different bodies have upon each other, and hence learn to understand the causes of the various appearances which take place in the several operations that come under their own daily observation or particular superintendance.

To promote this desirable end, nothing would perhaps be so effectual as the dissemination of several distinct and familiar treatises on the most important manufactures of the country, and on the nature of the materials employed in them. The Essays of Bergman, Scheele, and Watson, are of this nature; and these have contributed in no small degree to the information of the public mind, and to that growing taste for chemical pursuits which is one of the characteristics of the present age.

The subjects on which these eminent Essayists have so ably written, are, however, comparatively few, and much remains to be done before an inquirer into the nature and extent of the British manufactures can obtain solid and sufficient information respecting the staple products of the country.

In the course of his business as a manufacturing chemist, the author of the following work has, for many years, been in the habit of visiting the principal manufactories of the kingdom;—of associating occasionally with the most intelligent artists in a great majority of the counties of England;—and of taking notes of every thing that he saw or heard in the course of his journeys which he esteemed worth registering:—he therefore flattered himself that he possessed the means of increasing the stock of general knowledge, and that he might, without presumption, aspire to the honour of treading in the footsteps of those illustrious predecessors above mentioned.

In selecting the subjects, the author has fixed upon those which seem to have been the least examined by other chemical writers, and in all cases due attention has been paid to the improvement of the manufactures of the kingdom.

A complete essay on any of these topics has not however been attempted, since this must have rendered the present work too bulky for common use; the object having been merely to offer such hints as were likely to be most useful to the superintendants of manufactories, and such as should induce a correct chemical investigation of the nature of all those concerns in which persons of this description are usually engaged.

To attain this object, it has been found necessary to recite many chemical axioms, and to impress these upon the minds of artificers and workmen, though such may appear to the expert chemist to be little more than mere truisms or trite observations. In like manner, some of the details are given with no other view than to inform those who are beginning the study of chemistry; and this may be instanced in the enumeration of the many cases in which a knowledge of specific gravity is essential, and where the author's sole aim is to induce such persons to direct their attention to this particular and important subject.

The superintendants of some manufactories may perhaps deem it superfluous to have described their processes so much in detail, because they themselves are already quite familiar with them; but such individuals should consider that others may profit by the perusal, and that those who are engaged in very different occupations, by reading such accounts may perceive that the improvements which are suggested for the adoption of other establishments can, with considerable efficacy and saving, be applied to their own, and thus in the end a great mass of improvement may be gained by the community at large.

It is an excellent opinion of the writer who obtained a prize from the Economical Society of Berne, for an Essay on the best means of instructing the public, that "a labourer executes easily and exactly all his works in proportion to his knowledge;—that the ignorance of the people always throws an indolence on the persons of a more elevated order;—and that the intelligence of the artist necessarily excites the emulation of the gentry and the nobility."

Many years having now elapsed since the author began to register every thing of importance that he saw or read respecting the British manufactures, it has become impossible for him in some instances to ascertain whether the facts were obtained from books, or from observation during his intercourse with artists and their employers; and at this distant period he is unable in some cases to discover even whether the language itself is his own, or that of others. He has, however, endeavoured to make his readers amends for this uncertainty, by referring them on every subject to the best writers within his knowledge; being ambitious that his work should be received as a book of reference to the most eminent chemical authors, so far as these have any thing applicable to the subjects on which he treats. It must always be an acceptable service to those who have chemical subjects to investigate, to be directed to original authorities, or otherwise to faithful translations which can always be procured by many readers with greater ease than those works which are printed abroad, or even than any of the foreign journals.

Notwithstanding the space which is occupied by such allusions and authorities, the author hopes that these volumes will be found to contain as large a proportion of original matter as any chemical work of the present day; and it is impossible in this advanced state of the science to write on any chemical subject, without recapitulating many facts which have been already established by a host of predecessors in the same walk of science. "Do not blame me," said Macrobius, an interesting Latin writer and eminent critic of the 4th century, "if what I have collected in reading shall frequently be expressed in the very words of the authors from whom I have taken it; for my view in this work is, not to give proofs of my eloquence, but to collect and digest, into some regularity and order, such things as I thought might be useful to be known to the public*."

In accomplishing a similar task the author is aware that he is liable to mistakes and misconceptions, especially in his reasonings and remarks on the conduct of those manufactures in which he has never been personally engaged: he is however convinced, as Dr. Priestley has observed, "that a person who means to serve the cause of science effectually, must often hazard his own reputation so far as to risk mistakes in things of small mo-

* Præfat. ad Saturnalia.

ment*." And if it behoves one in the service of *general* science to risk that which is so valuable to every man, surely those branches of knowledge which are more intimately connected with the commerce of these dominions have the most imperious demands upon us; for "what can touch us more nearly than the improvement of our manufactures, on which the riches of our country, and the daily bread of the greatest number of its inhabitants depend†?"

* Preface to Priestley's Observations on Air, Edit. 1781, vol. i. page 9.

† Experiments on Bleaching, by Francis Home, M.D. page 147.

An apology is due to the public for the extent and abundance of the notes which appear throughout the work, because they interrupt the narrative, and in some measure divert the attention of the reader; but in consequence of the various occupations of the author, their introduction became unavoidable. Deeply engaged in a manufactory, which demands great attention and often requires the aid of tedious experimental investigation, little time could be afforded for preparing these volumes, except in those hours which the generality of men devote to relaxation or repose.

The greater part of these Essays were, therefore, necessarily composed during the intervals of business, and often when the author could have no access to his own library, or to books of any kind to which he might refer for authority or elucidation respecting the numerous facts which always offer themselves to the attention when treating on philosophical or chemical subjects.

From these circumstances, the Essays were at first written without any illustrations or references whatever, and the notes were appended occasionally, wherever further explanation seemed to be essential, and whenever the reading or the memory of the author furnished him with any facts of importance to which he had not already alluded. It must however be remarked, that this mode of essay-writing, though it may perhaps give a little more originality to the complexion of the composition, has entailed upon the author the very laborious task, of subsequently collecting and examining numerous authorities, in order to enable him to direct the chemist or artisan to the most authentic sources from whence he could derive additional and often very valuable information.

To avoid the inconveniences which would otherwise result from these numerous appendices, it may perhaps be advisable, first, to read the Essay without the interruption of the notes, and afterwards to consult these as may be found necessary.

To render these Essays more useful, the author has taken considerable pains to procure drawings of all the modern apparatus to which he has referred. These drawings were in general either sketched by himself, or by those proprietors of the several manufactories who were anxious to contribute to the work, and whose kind assistance he hereby acknowledges with gratitude.

Thus all the plates were engraved from *original* drawings, with the exception of the sal-ammoniac apparatus, which is copied from the second volume of the Journal de Physique. This it appeared desirable to describe, because it has not yet excited that attention which its importance and utility deserve, and few persons in this country have access to the early volumes of the foreign journal from whence it was obtained.

Great care has also been taken in describing all these plates; and in order to enable the reader to construct any of the apparatus for his own use, accurate admeasurements have been given wherever there appeared to be a probability of their being useful.

The pleasure which arises from the discovery of any facts not generally known;—any new elucidation of interesting truths;—or the acquisition of any scarce treatise which might afford important hints to the reader;—and the prospect of completing a work which is likely to be useful to the public, have been constant incitements to the author to persevere in the labour of research with unremitting zeal and ardour.

As a considerable mass of materials still remains with the author, he may perhaps be inclined, should it meet with the approbation of the public, to compose at some future period an additional volume of these Essays. At all events he will continue to employ the latter years of his life in the same kind of investigations, always keeping in view the examination of every new improvement in the management of the national manufactures, well knowing that the acquisition of one new idea often gives birth to others of very superior importance.

Cardinal Farnese one day found Michael Angelo, when an old man, walking alone in the Colosseum, and expressed his surprise at finding him solitary amidst the ruins; to which he replied, "I go yet to school that I may continue to learn." Whether the anecdote be correctly true or not, it is evident that he entertained this feeling, for there is still remaining a design by him, of an old man with a long beard in a child's go-cart and an hour-glass before him, emblematical of the last stage of life;

and on a scroll over his head, ANCHORA INPARO in Roman capitals, denoting that no state of bodily decay or approximation to death was incompatible with intellectual improvement. "He established it as a principle," says Mr. Duppa*, who has given us these anecdotes, that to live in credit was enough, if life was virtuously and honourably employed for the good of others and the benefit of posterity:—and thus he laid up the most profitable trea-

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* The Life of Michael Angelo Buonarroti, with his Poetry and Letters, by R. Duppa, Esq. 4to, London 1806.

sure for his old age, and calculated upon its best resources;—making all nature interested in the length of his days."

*London,*
*July 8th,* 1815.

# DESCRIPTION OF THE PLATES

IN

# THE FIRST VOLUME.

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## PLATE I.

### CONTAINING MISCELLANEOUS ARTICLES.

Fig. 1 is a delineation of a glass instrument invented by Dr. Wollaston for producing ice in a peculiar way artificially. He calls it a *cryophorus*. For a further account of this little implement see page 387 of this volume.

Figs. 2 and 3 represent an iron hopper for a furnace with its iron stopper, both of which are described at page 305, &c.

Figs. 4 and 5 are furnace bars, and these are fully described at page 313.

Fig. 6 represents a method of building the end of the fire-place of a reverberatory furnace so that the bars may easily be drawn out for the purpose of clearing away the scoria of the coals, ashes, &c. For some account of the conveniences attending this peculiar construction see page 316.

Fig. 7 is the representation of a bar of iron to be laid within the brick-work of a furnace, to prevent the masonry giving way in consequence of the force of the fire. For some further account of its uses see page 323.

## PLATE II.

Is a highly finished likeness of the Lord Chancellor Bacon, engraved by an eminent artist, from an original portrait in the possession of the author, and on purpose for a frontispiece to Essay I. The lines underneath it were taken from a poem addressed by Abraham Cowley to the Royal Society, on its first formation, and printed in Sprat's History of the Society.

## PLATE III.

This plate is the representation of a new Apparatus for the distillation of rum in the

West Indies, contrived for the purpose of economising fuel.

A is a still of the usual form.

B is a vessel called the preparatory vessel. The design of this is to prepare the wash by giving it a high degree of temperature, from the waste heat of the still, during the time the still is at work. At the commencement of the operation this vessel and the still are both filled with the cold fermented wash, and the still has a fire placed under it. By inspecting the drawing it will be perceived that this apparatus is so constructed that the fire, after performing its office underneath and round the sides of the still, passes under the preparing vessel B in a reverberating manner, instead of going off in a direct way, as is usual, to the chimney. This is effected by means of a slight partition wall, brought up underneath the preparing vessel, (as will appear by reference to the ground plan,) and which occasions the flame to take a circuitous turn under that vessel before it passes to the chimney, as already mentioned; the flues being provided with dampers to direct the flame and the heated air either way as the case may require. During the time the still is at work, the wash within the preparing vessel will by this contrivance be brought to nearly a boiling heat.

The design of this construction is, that when the still is worked off, and has been emptied of the aqueous phlegm, the operator can open the cock of the connecting tube, fixed between the still and the preparing vessel, and thus, with little trouble, recharge the still with fresh wash, which will be of such a temperature that the distillation will recommence almost immediately. In this way the still is charged time after time without the head being removed; and if the preparing vessel be regularly refilled with cold wash, this will become heated in like manner for the next or any future operation. The separate parts of the apparatus may be thus described:

a is the flue under the preparing vessel.

b the man-hole, which is steam-tight and securely fastened down.

c a safety valve.

d the cock which opens or cuts off the communication between the still and the preparing vessel.

g the passage to the chimney.

h the entrance to the fire-place.

## PLATE IV.

Is an *improved* Still, with its preparatory vessel as lately introduced in some of the West India Islands for the distillation of rum.

On an inspection of the ground plan of this apparatus it will be perceived that the still, A, is of a square form : but as the bottom and the crown of this still are both curved in the same manner as a round one, the principle on which this acts is nearly the same as that described in Plate III. except in the following particulars :

The flues under this still reverberate in the direction of the arrows, as shown in the ground plan, and are then taken up on each side of the still into the side flues, from whence the fire or flame proceeds under the preparing vessel B, round a slight partition of brick-work called a *bonnet*, then into an aperture at the bottom of the perpendicular flue or tube, C, which passes through the centre of the liquor in the preparatory vessel, and from thence directly into the chimney D.

In common stills the heat from the fuel is not sufficiently expended under the bottom, as explained at p. 294, but quickly passes off to the sides, whereby the sides of the vessel are very soon burnt through. By this contrivance, however, the light materials which are burnt for fuel in the West Indies are nearly all consumed under the bottom of the still; and whatever waste heat there may be, this is afterwards expended in raising the temperature of the wash contained in vessel B.

In this apparatus, like the former, b is the man-hole for clearing out the preparatory vessel, c the safety valve, and d the cock for opening or shutting the tube by which the still is filled with heated wash from the preparatory vessel B. The principal difference in the two stills, viz. the one in Plate III. and the one now under description in Plate IV., is in the manner in which the liquor of the preparatory vessel of each is heated. That in the former is heated by the flame passing underneath it, and the latter by a heated tube which is fixed within the centre of the liquor itself, as is more particularly described at page 338.

## PLATE V.

The elevation of an *Economical* Still for general purposes.

A is a still in the usual form. B the copper head with a long pipe passing through the condensing vessel C, to the worm E, fixed within the cask or worm-tub D.

The condensing vessel C, which lies in a horizontal position, and may be supported from the ceiling or the floor, as may be most convenient, answers two important ends in distillation which deserve attention. This preparatory vessel being filled with wash, or any other liquor intended to be distilled, materially cools the gas arising from the still, and condenses the vapour into a liquid, as it passes along the pipe c, before it reaches the worm itself; and this intermediate reduction of temperature is so considerable, that one-fourth of the water usually employed in the worm-tub is found sufficient. The second advantage arising from this peculiar construction is, that so much caloric passes off from the tube e, into the wash contained in the intermediate vessel c, that the liquor soon becomes heated to 170° or 180° of Fahrenheit; and hence is in a very desirable state for replenishing the still. This is done merely by turning the cock d, in the pipe, which passes from the preparatory vessel to the still. Each end of the pipe passing through the intermediate vessel is secured with cement, that the vessel may at any time be taken off if required.

The orifices b and c, and the cock d, have the same uses as those in Plates III. and IV. marked with similar letters. F is the vessel placed on the ground for the reception of the product of the still. This apparatus is referred to at page 337 of this volume.

# CONTENTS

OF

THE FIRST VOLUME.

# ESSAY I.

ON

# THE UTILITY OF CHEMISTRY

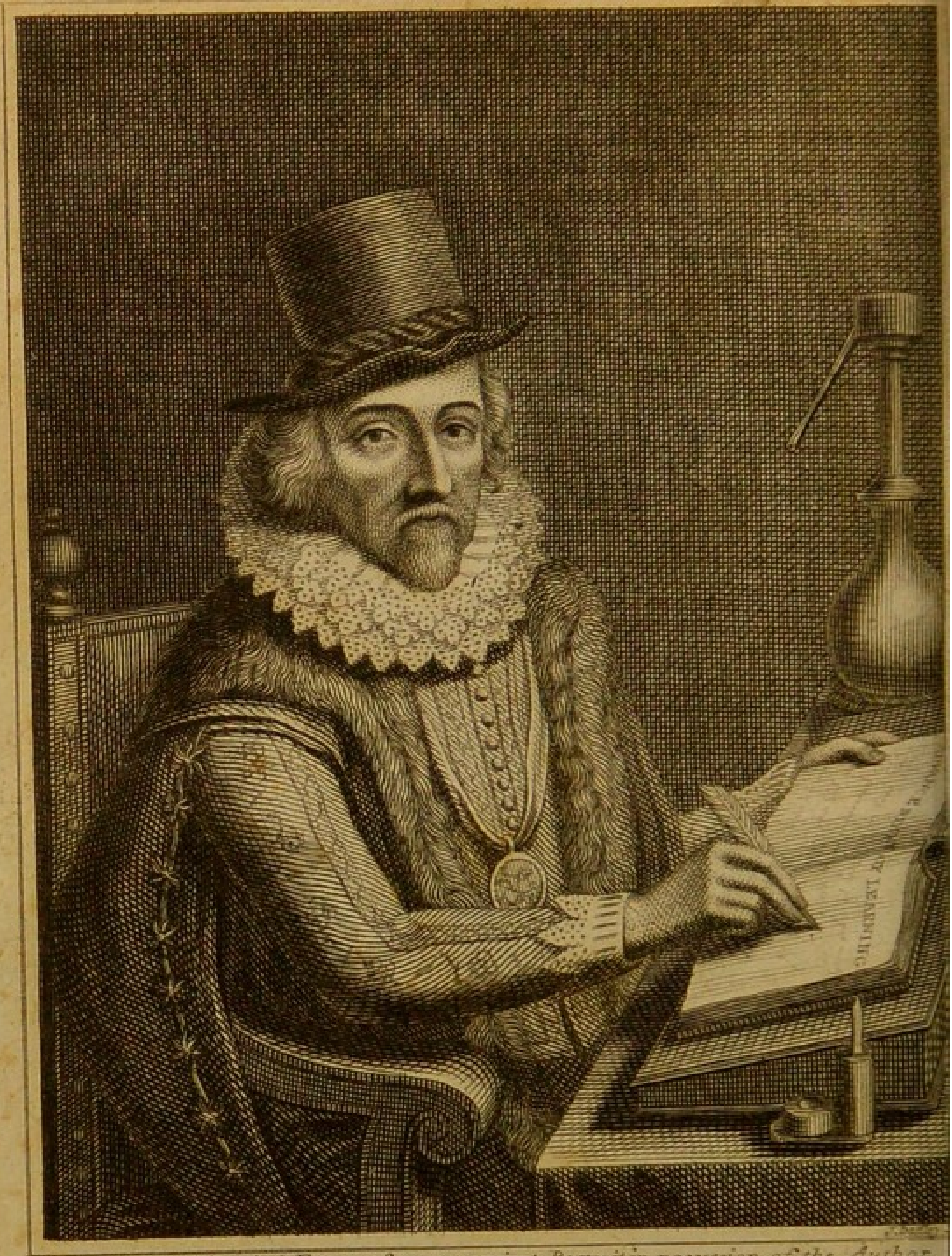
TO

# The Arts and Manufactures.

*ADDRESSED TO PARENTS,*

PARTICULARLY TO THOSE IN THE HIGHER AND MIDDLE RANKS OF LIFE.

Lord Chancellor Bacon.



Engraved for the Chemical Essays from an ancient Portrait in possession of the Author.

Bacon, like Moses, led us forth at last,
The barren wildernefs he past,
Did on the very border stand
Of the blest promis'd land,
And from the mountains top of his exalted wit,
Saw it himself, and shew'd us it.
But Life did never to one man allow
Time to discover worlds, and conquer too. Cowley

# ESSAY I.

ON THE

## *UTILITY OF CHEMISTRY.*[1]

THE discovery of the loadstone and its important application in the construction of the mariners' compass[2],

[1] This First Essay has already been printed in another form; but as it was thought to be a more suitable introduction to this work than to that to which it was formerly annexed, a part of it has been re-written, and so many additions have been made to it, with the view of rendering it more useful and acceptable to the public, that it may now be considered as a new paper.

[2] The mariners' compass was discovered

were the means of producing a general intercourse among nations. The subsequent invention of printing[3] occasioned a rapid progress in that civilization which had thus been much promoted by the increase of

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early in the fourteenth century by Flavio Gioia, of Amalfi, in the kingdom of Naples.

[3] Printing was invented by Peter Scheffer, of Mentz, in the year 1450. It is thus described by a modern poet:

"The storied pyramid, the laurel'd bust,
The trophied arch had crumbled into dust;
The sacred symbol, and the epic song,
(Unknown the character, forgot the tongue,)
With each unconquer'd chief, or sainted maid,
Sunk undistinguish'd in oblivion's shade:
Sad o'er the scatter'd ruins Genius sigh'd,
And infant Arts but learn'd to lisp and died:
Til to astonish'd realms Papyra taught
To aint in mystic colours Sound and Thought,

commerce, and by the consequent interchange and general dissemination of the useful arts.

But these arts consisted of mere processes which had been communicated by the alchemists[4] as secrets

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With Wisdom's voice to print the page sublime,
And mark in adamant the steps of Time."

DARWIN.

[4] So lately as the year 1784, Dr. James Price, F.R.S. of London, attempted to revive the spirit of Alchemy. He produced a red and a white powder, with which he boasted that he could convert mercury into gold or silver. He made several experiments before a number of respectable persons; but when the powders were exhausted, and he was importuned on all sides to renew his powders and repeat his experiments, before men of science, he swallowed laurel water and put an end to his existence. Crell's Chem. Ann. 1784.

from generation to generation, without science, or any theory on which the true knowledge of them might be founded; nor was it till the eminent Lord Chancellor Bacon had shown the necessity of interrogating nature by experiment[5], that any rational system of philosophical inquiry was promulgated.

From this period, however, general science made rapid advances in improvement; and if one branch is more indebted to this great but unfortu-

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[5] This illustrious philosopher was the first writer who seems to have had a just view of the character and the labours of the Alchemist. By showing how little can be done by reasoning on the works of Nature, till a mass of facts is obtained by experiment, he benefited the world more than a host of his predecessors had done by their conjectures and conceits.

nate[6] philosopher than another, it unquestionably is that of Chemistry, which has eminently availed herself of his grand precept, and continued

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[6] While Lord Chancellor, he was impeached by the House of Commons on an accusation of bribery, and was sentenced to pay a fine of forty thousand pounds, and to be imprisoned during pleasure. His conduct has, however, been placed in such different lights that it is at this time difficult to appreciate his true character. A voluminous female historian writes thus:—"Him the rays of science served but to embellish, not enlighten; and philosophy herself was degraded by a conjunction with his mean soul. It is needless for an historian to describe the strength or extent of his genius; his precious bequests to posterity paint them stronger than can any other pen." Macaulay's England, quarto, 1771, vol. i. p. 164, 165.

her unremitting researches till nothing will now satisfy the curious inquirer, but plain facts and lucid deductions from experiment or analogy.

In this state of the public mind, what can be expected throughout Europe but a rapid succession of improvements in the arts and manufactures, and in the personal comforts and conveniences which are so much dependent on chemical knowledge? Hence it appears desirable, that every individual employed in the superintendance of a manufactory should become acquainted with the general principles of Chemistry, in order that he may more successfully apply the great truths of this important science to the various processes which may at any time require his direction.

With this view I cannot but conceive that very important benefits would accrue to these kingdoms, if Chemistry were made a regular branch of education; and I have imagined that I should render an acceptable service to society by showing the advantages which result from the acquisition of this kind of knowledge; for, until its utility be demonstrated, (and a large proportion of the community is not yet apprized of its real value,) that general attention to it which it deserves cannot be expected.

It would, however, be no difficult matter to prove that the world might derive great advantages even from the diffusion of a *theoretical* knowledge of philosophy and chemistry. An instance or two will place this assertion in a clear point of view. Two thousand years ago Archimedes[7] was ridiculed for his attention to mathematics and the abstruse sciences; yet by this knowledge he was enabled to invent such mechanical engines as were sufficient to resist the whole Roman army. And so great was the

[7] There is no evidence that Archimedes had any knowledge of chemistry; for though the transmutation of metals was attempted three or four hundred years after Christ, Geber, who was a Greek Physician of the eighth century, was the first chemical writer whose works were of any value.

dread which the soldiers had of this man's science, that if a rope only were let down from the walls of the city of Syracuse, the whole army would retire from before it in the utmost consternation.

To how many accidents is the general of an army or the admiral of a fleet liable, if he have not a general knowledge of the laws of nature! Julius Cæsar himself relates, that his army was so dismayed on approaching our shores, at the ebbing of the sea from their vessels, supposing it to have been occasioned by a stratagem of the native Britons, that the circumstance had like to have occasioned his total overthrow. In like manner, if Hannibal, the Carthaginian general, had not been acquainted with the effect of acetous acid on calcareous earth, the crag of rock which obstructed the passage of his army through the Alps, would in all probability have remained an insurmountable obstacle [8]."

A further proof of the importance of the dissemination of useful knowledge may be taken from the con-

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[8] It is related of Hannibal, that he opened a passage for his army through the Alps, by applying *fire* and *vinegar* to a part of the rock which opposed his route. Livy informs us that, after the action of the fire and the acid, the soldiers by means of iron instruments readily broke down what stood in their way and obstructed the course of the grand army.

"—When proud Rome the Afric warrior brav'd,
And high on Alps his crimson banner wav'd;

struction of the *Steam Engine.* Mr. Watt often acknowledged that his first ideas on this subject were acquired by his attendance on Dr. Black's *Chemical* Lectures, and from the consideration of his theory of latent heat and the expansibility of steam.

This is certainly a remarkable instance of a great national advantage resulting from the establishment of chemical lectures, for the dissemination of philosophical principles. It

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While rocks on rocks their beetling brows oppose
With piny forests and unfathom'd snows;
Onward he march'd to Làtium's velvet ground,
With fires and acids burst the obdurate bound,
Wide o'er the weeping vales destruction hurl'd,
And shook the rising empire of the world."

DARWIN.

were much to be wished that every subject connected with the trade of the country should also be treated of publicly, and that a considerable number of ingenious men, properly qualified, would follow the example of Dr. Bancroft, but on a more extended scale, and teach the philosophy of manufactures, as he has taught "the philosophy of permanent colours;" or, like Professor Farish of Cambridge, and Dr. Ure of the Andersonian Institution in Glasgow, illustrate the various manipulations by familiar lectures, popular descriptions of processes, and working models of machinery.

The well-informed people of France are so satisfied 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 science we here 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[9].

[9] The celebrated Tycho Brahe not only attended to the motions of the planets, but to the experiments of his laboratory also, in which he worked upon minerals by means of

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[10]. Has he a barren tract of country, which has been unproductive from generation to generation; he will with avidity explore its bowels for hidden treasures, and will

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fire. The great Sir Isaac Newton too, when resting from his immense labours, employed himself occasionally in chemical operations.—Bergman.

[10] Dr. Home, of Edinburgh, was one of the first writers who attempted to apply a rational theory of chemistry to the improvement of Agriculture.—See his treatise on the Principles of Vegetation. Octavo, Millar, London, 1758.

probably not explore it in vain. By analysing the minerals which he discovers, he will ascertain with facility and exactness what proportion of metal they contain, and which of them may be worked to profit [11]. Thus he will operate on sure grounds, and be prevented from engaging in expensive and unprofitable undertakings.

Chemistry will teach him also how to improve the *cultivated* parts of his estate; and by transporting and transposing the different soils [12], how each

[11] Most of the solid substances which encircle our globe are compound bodies, formed by chemical combinations; it therefore must require some skill in chemical operations to be enabled to decompound them with certainty.

[12] Some soils contain a large proportion of iron: I conceive it might be very advantageous

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[13]; a practice the value of which is sufficiently known to every good agriculturist[14].

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to remove a portion of such soil to lands which contain no iron, as by this method both would be improved. Earl Dundonald has satisfactorily explained how this metal promotes vegetation on good soils, though it may be injurious to poor ones. See his treatise "on the intimate Connection of Agriculture and Chemistry," page 52.

[13] According to Dr. Home, hard water promotes the growth of plants in a much greater degree than soft water.

[14] The best paper which I have seen on the

Should he himself occupy the estate, and become the cultivator of his own land; he must of necessity be a chemist, before he can be an œconomical farmer [15]. 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

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subject of irrigation is by the Rev. T. Wright, small 8vo. Scatcherd and Co. 1789. This short essay is deserving the attention of every practical farmer.

[15] In the second volume of the Memoirs of the Imperial Academy of Sciences at Brussels, quarto, 1780, is an ingenious Chemical Essay, by Mons. De Beunie, on Soils, and more particularly on the Cultivation of Heaths. It is divided into fourteen chapters, and occupies 117 quarto pages.

to experiment, before he can avail himself of the advantages which they possess, or before he can be certain of producing any particular effect by their means. The necessity of analysis to the farmer is evident from a knowledge of the circumstance, that some kind of lime is really injurious [16], and would render

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[16] Here I allude to the magnesian limestone, which is common in many districts in England, particularly at Breedon in Leicestershire, where the calcareous earth contains 50 per cent. of magnesia. But, as the Earl of Dundonald has remarked, such lime will be extremely useful on what are called sour soils, or such as contain sulphate of iron, from the decomposition of martial pyrites, as it will unite with the acid of that salt and form sulphate of magnesia, (Epsom salt,) which greatly promotes vegeta-

land which had been hitherto very productive, actually sterile. 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 [17], and at what period to check it, so as to prevent the fertilizing particles be-

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tion. Experiments on the nature of this sort of lime will be found in Professor Tennant's paper in the Philosophical Transactions for 1799. See also Darwin's Phytologia, page 211.

[17] The Earl of Dundonald has remarked, that "vegetable putrefaction can take place only when attended with air, moisture, and a due degree of heat. Water is then decomposed—vital air absorbed—heat disengaged—and new combinations formed."—Treatise on Agriculture, quarto, London, 1803, page 28.

coming effete, and of little value. It will also teach him the difference in the properties of marle, lime, peat, dung, mud, ashes, alkaline salt[18], soap waste, sea water, &c., and, consequently, which to prefer in all varieties of soil. A knowledge of the chemical properties of bodies will thus give a new character to the agriculturist, and render his employment rational and respectable[19].

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[18] Dr. Home in the year 1756 published a valuable treatise on this subject. Indeed he was the first person that we know of, who made direct experiments on the fertilizing properties of saline matters.

[19] Lavoisier cultivated 240 acres of land in La Vendée, on chemical principles, in order to set a good example to the farmers; and his

Are you a practitioner of MEDICINE, and have you acquired great and deserved reputation in your profession, —if you are not a chemist[20], 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

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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.

[20] Boerhaave, more than a century ago, wrote a treatise to show the importance of chemistry to the medical profession, under the title of "*De cognoscendis et curandis Morbis.*"

knowledge of chemistry would have informed you that many of the formulæ in the Pharmacopœia, which are salutary and efficacious, are rendered totally otherwise, not to say often destructive, if given with certain other medicines. Many instances of these chemical changes might be adduced, but one will suffice. Mercury [21] and oxygenized muriatic acid have both been administered by medical men; and *separately*, either of them may be

[21] The vain and conceited Paracelsus, who lived in the sixteenth century, was, I believe, the first who attempted the improvement of pharmacy by the introduction of the metallic oxides. Philip of *Sides* had, indeed, in the 5th century, produced what he called the tincture of Indian iron, but there is no proof that this ever came into general use.

taken without any injury to the animal œconomy: but if a physician, ignorant of the chemical operation of bodies on each other, should give these substances *in conjunction*, the most dreadful consequences might ensue, as the product of this mixture (*oxygenized muriate of mercury*) is a most corrosive poison.

If the profession of medicine be your son's choice, charge him, when he shall walk the hospitals, as it is termed, to pay particular attention to the Lectures on Chemistry, and to make himself master of the component parts of the different salts[22], and

[22] So ignorant were the professors of medicine of the nature of the salts, that no longer ago

of the chemical affinities which subsist between them and the various articles with which they are generally employed[23]. This will inspire him with professional confidence; and he will be as sure of producing any particular chemical effect upon his patient, as he would if he were opera-

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than the year 1765 there was a public dispute between the celebrated Margraff and Mons. De Machy respecting the base of the *super tartrite of potash*, whether or no it was an alkali. See "The History of the Royal Academy of Sciences at Paris, for the year 1765."

[23] M. Deyeux has shown that even the preparation of plasters may be much improved by chemistry. His ingenious paper in the 97th number of the Annales de Chimie contains much curious matter well worth the perusal of medical men.

ting 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 animal physiology, so necessary in the practice of physic, 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[24], the

[24] The use of the blood in respiration was first demonstrated by Priestley. See his paper, which was read to the Royal Society the 25th January 1776, and printed in the 66th volume of their Transactions, page 226.

nature of which it requires the acuteness of a profound chemist to perceive and understand[25]. Neither can a physician comprehend the nature of the animal, vegetable, or mineral poisons without the aid of chemistry[26]. Many thousand lives have been lost by poison, which might have been saved had the physician

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[25] Mr. Brande has written an interesting and very original paper on the colouring matter of the blood. See Philosophical Transactions for 1812, page 90.

[26] All *animal* and *vegetable* poisons are said to destroy by deoxidizing the blood. Substances which contain a large portion of oxygen are the real antidotes to such poison. On the contrary, *metallic* poisons are baneful in consequence of the oxygen they contain. Metals

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

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are for the most part devoid of activity in a metallic state; but when converted into oxides they become poisonous and corrosive, according to the portion of oxygen combined with them. Thus the gray and the white oxides of mercury are only purgative or alterative; while the red oxide is a corrosive poison. Decoctions of bark, having a great affinity for oxygen, have been given to counteract an over dose of antimonial powder, and have produced the desired effect.

medicines as will counteract their baneful effects[27].

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[27] About Christmas 1805 an apothecary in one of the northern counties having drunk some bottled porter, was seized with symptoms which convinced him that he was poisoned; but not knowing what noxious matter he had taken, and being incapable of analysing the remainder, no antidote could be applied, and he gave himself up as lost. A physician had been called in: but neither he nor the patient, nor his partner, could get any information by examining the remaining contents of the fatal bottle; though, I understand, they are all intelligent men, and in great reputation in their profession. In this dilemma what could be done? It was recollected, however, that a neighbouring gentleman had the reputation of being a good chemist. To him the physician and the partner of the patient hastened, to get

If we look to the MANUFACTURES, there is scarcely one of any consequence that does not depend upon

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the dregs analysed, and to learn what ought to be administered. Fortunately, this gentleman had just received Göttling's Book of Tests, which I had procured for his brother, and which had been sent to him but a very short time before. By this book he was enabled to ascertain that the poison was oxide of antimony: and when the patient was informed of it, he recollected that antimonial wine had been kept in a similar bottle some years before; and supposed that the porter must have been bottled without the dregs being properly washed out. This circumstance led to the proper antidote, which was administered immediately; and the life of the unfortunate man was preserved: but in consequence of the loss of time, the poison had so far taken possession of the system as to deprive him of the use of a limb.

chemistry, for its establishment, its improvement, or for its successful and beneficial practice. Though in order to see the real connexion which subsists between chemistry and the arts, it will be useful 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 its conversiou into steel, every operation is the effect of chemical affinities[28]. In the first place,

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[28] Since much valuable iron-ore is raised in districts where charcoal is not to be procured, the proprietors of such mines are generally under the necessity of making their iron with coke, which produces metal of a very inferior quality.

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 pigs. The subsequent processes to convert the metal into malleable iron are entirely chemical, and will be con-

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It is therefore become a desideratum to coke pit coal so as to give it the properties of charcoal, and I think it probable that with some kind of coal this might be effected. The coke which most resembles charcoal of any that I have seen is made at the Duke of Norfolk's works near Sheffield. For a particular description of his furnaces, and of the method of managing them, see the Chemical Catechism, Additional Notes, No. 50.

ducted to the best advantage only by those who have acquired a knowledge of the chemical changes which take place in these operations. The making of CAST STEEL[29], which has been kept so profound a secret, is now found to be a simple chemical pro-

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[29] The ancients, it is believed, had some peculiar method of making steel. This suspicion is grounded on the hardness of some of the statues they have left us, as well as on the nature of the Egyptian obelisks, which are carved with a variety of figures, and yet resist the tools of modern times. Dr. Lister (in a paper read before the Royal Society) complains that this valuable secret is now lost. According to Aristotle and Pliny, the ancient steel was made by keeping forged iron for a certain time in melted cast iron." Lewis's Notes on Neuman, vol. i. page 116.

cess, and consists merely in imparting to the metal a portion of carbon, by means of fusing it in crucibles with carbonate of lime, or by cementation with charcoal powder, in a peculiar kind of furnace constructed for that particular purpose.

Some of the steel-works in the North have these furnaces extremely large, and I have been told that the increase in weight which the iron acquires from the carbon to convert it into steel is amply sufficient to defray all the expenses of fuel and attendance. The German steel is made directly from cast iron by forging it only to a certain point.

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 iron. Indeed, before the smelting of ores was properly understood, great part of the iron was not extracted in the first instance, but was thrown by with the dross: and I have understood that there are heaps containing many thousand tons of such scoria now lying in the forest of Dean, in the county of Gloucester, so rich in iron that the proprietor finds it his interest to work the same over again.

In like manner the founder of printers' types has derived great advantage from a knowledge of the methods of reducing metallic oxides. In this trade fires are kept under the pots the whole day to preserve the metal constantly in a melted state; the consequence of which is, that the surface perpetually oxidizes and must be frequently removed. Formerly these skimmings were called *dross*, and were thrown away as of no value. At length an individual made an experiment upon them, and at this day every manufacturer knows how to convert them to good useful metal. A single manufacturer will now recover from three to four tons of metal annually from these skimmings, worth at least £100 per ton.

If we consider the WOOLLEN, the COTTON, and the CALICO manufactures, of what great importance is each of these trades to the British dominions! 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[30] and

[30] The first account of dyeing that we have in the English language was written by Sir William Petty, at the desire of the Royal So-

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 then surely 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

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ciety, entitled "An Apparatus to the History of the common Practices of Dyeing." A copy of this piece may be seen in the Bishop of Rochester's History of the Royal Society, quarto, London, 1667, page 284.

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[31]; a knowledge of which, and of the different degrees of oxidizement which the several dyes undergo, requires no small share of chemical skill: and

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[31] On this subject some valuable information may be found in Fourcroy's System of Chemistry, vol. viii. pages 70–78.—Berthollet's Elements of the Art of Dyeing, vol. i. pages 45–65, and in a memoir "On the Coloration of Vegetable Matters by Vital Air," in the 5th tom. of Annales de Chimie, pages 80–91.

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[32], and for some of

[32] Dr. Bancroft is of opinion that the ancient Ægyptians employed some of the mordants now in use, and that they were indebted to alum and iron for producing those effects mentioned by Pliny, l. xxxv. § 42.

their most beautiful and brilliant colours[33].

An instance or two will render

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[33] It was not known how to dye wool of a perfect scarlet till the preparation of the nitrate of tin was discovered by a foreigner. Cornelius Drebbelius of Alcmar in the United Provinces, a man in great esteem with one of our kings, made this important discovery; and having left in writing a particular method of making this mordant and of its application in dyeing, Kuster, or Kustelaer, his son in law, brought it to England, and about the middle of the 16th century settled as a dyer, at Bow, near London, where he acquired considerable emolument. See Dallow's Boerhaave, quarto, 1735, vol. i. page 58. According to Dr. Sprat, Drebbelius was a chemist, and not a dyer. Hist. Roy. Society, page 391.

this evident. Formerly a calico-printer required many weeks to produce a printed cotton with some colours, such as an olive ground and yellow figures; a scarlet pattern on a black ground; or a brown ground with orange figures: but, by means of chemical preparations, the whole of this work may now be done in a few days; patterns, more delicate than ever, may be produced; and all with a degree of certainty of which former manufacturers had no idea; the system being now entirely altered. According to the former practice, the mordant[34] was first applied to those

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[34] For an explanation of the action of mordants, see Berthollet on Dyeing, chap. ii.

parts of the cloth that were intended to be olive, brown, or black; it was then necessary for the piece to remain some time before it could be dyed, and afterwards to be exposed in a bleaching-ground a sufficient time to clear those places from the colouring matter of the dye which had not been acted upon by the mordant: a different mordant was then applied by the pencil; and it was necessary to pass the whole piece through the dyeing copper a second time, in order to give the desired colour to those particular parts, and finish the pattern.

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vol. i. page 28; or Bancroft on Permanent Colours, chap. vii. page 167.

Now, all these effects are produced by dyeing the cloth a self colour in the first instance, and afterwards merely printing the pattern with a chemical preparation, which discharges a part of the original dye, and leaves a new colour in its stead. Thus a brown may be changed in an instant to an orange; a dark olive to a yellow; or a black to a bright scarlet. In consequence of similar improvements, rich chintz patterns, which formerly required two years or more to be completed, are now commonly finished in a few weeks.

The art of BLEACHING [35], which is

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[35] The person who has written the largest on this subject is Charmes: his book was translated by Mr. Nicholson into English, and

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 [36] EARTHEN-

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published by Robinsons, 1799, 8vo, pp. 351, with many plates of apparatus, &c.

[36] Dibutades, a potter of Sicyon, first formed likenesses in clay at Corinth, but was indebted to his daughter for the invention. The girl, being in love with a young man who was soon going from her into some remote country, traced out the lines of his face from his shadow on the wall by candle-light. Her father filling up the lines with clay formed a bust, and hardened it in the fire with the rest of his

WARE and [37] 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

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earthen-ware.—Pliny, book xxxv.—See Bergman, vol. iii. p. 58.

[37] Porcelain was made by the Chinese and Japanese some hundred years before it was manufactured in Europe. I understand that no china was made in this quarter of the world before the beginning of the eighteenth century.

ware, to the production of those brilliant colours[38] which give a value to the manufactures by their permanency and beauty.

Mr. Wedgwood was so sensible of the importance of chemistry to these arts, that he not only applied to the study of the science himself, but, upon the death of the celebrated Dr. Lewis (author of the Commercium Philosophico-Technicum), actually engaged his assistant, a Mr. Chisolme[39], to experimentalize with

[38] An account of the respective colours which the different metals produce on porcelain may be seen in the xiiith vol. of the Philosophical Magazine, page 342; and vol. xiv. page 17, &c.

[39] It is but justice to the memory of the late

him, and to devote his whole attention to the improvement of the manufacture by the application of his chemical knowledge, of which perhaps few men in the kingdom at that time had a larger share. A faint idea of the advantages which he derived from these sources may be conceived from the following circumstance:—Dr. Bancroft, in his "Philosophy of Permanent Colours," when treating on iron, says, "I remember

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excellent Mr. Wedgwood to mention that he not only built a comfortable house near the manufactory, for Mr. Chisolme, but when he foresaw that his faithful servant would soon be disabled by age from pursuing his researches he settled a sufficient annuity upon him, which he enjoyed to the day of his death having been told by Mr. Wedgwood, that nearly all the fine diversified colours applied to his pottery were produced only by the oxides of this single metal." This one fact is sufficient to show with what assiduous application he must have studied chemical science, and how insufficient every attempt to bring his manufacture to the perfection which it has now attained, would have been, without this attention.

The sister art, that of making GLASS, is also entirely chemical, consisting in the fusion of siliceous earth with alkali[40] and the oxides of

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[40] It has lately been discovered that sulphate of soda may be applied to the purpose of

lead[41]. In this trade, as well as in many others, the chemical manufacturer, and the man of enlightened experience, will have many advantages[42]. He will not only know how to analyse his alkalies and to as-

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making best flint glass, which opens the prospect of a very considerable saving in this manufactory. See an account of some experiments in Nicholson's Journal, vol. xxxi. p. 357.

[41] In the reign of the Emperor Nero, glass was so scarce at Rome that two small cups made of it sold for the immense sum of six thousand sestertiæ. Pliny, l. xxxvi. c. 26.

[42] Since it has been understood how to apply the oxides of metals so as to produce different permanent colours in vitrifiable substances, some ingenious workers in glass have been enabled to produce several curious imitations of many of the gems and precious stones. The works of Neri and Blancourt contain

certain their exact value before he purchases, but will be enabled on chemical principles to ascertain the exact quantity necessary[43] for any fixed portion of silex, 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[44] is a pro-

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the best directions we have at present in print on this subject.

[34] It has been said that, in the time of Tiberius, it was known how to make glass malleable; but the truth of this is, I think, doubtful: they had anciently a manufactory of glass in the Isle of Lesbos.

[44] There can be no doubt but that leather was prepared in times of remote antiquity; for the contemporaries of Moses not only tanned

cess 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

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leather, but knew also how to colour it. *Skins dyed red* are often mentioned in the sacred books. Pliny attributes the invention of leather to Tychius of Bœotia.

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 a modern chemist[45], 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

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[45] This refers to a discovery made by Mr. Hatchett, an account of which is detailed in the Philosophical Transactions, vol. xcv. for the year 1805, pages 211 and 285, and in vol. xcvi. for the year 1806, page 109. Some valuable remarks by Sir H. Davy on the process of tanning leather are given in the Journals of the Royal Institution.

them, in our laboratories, the article in question, so as entirely to supersede the use of oak bark. This would be an event of great national importance, as the demand at present is so great, that it is not only imported from the continent, but trees, it is well known, have been actually cut down on purpose for the 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. And it is not impossible but he might discover some way of employing to advantage the several refuse articles which a tan yard produces, and which are now put aside as of no value[46]. Chemistry will enable him also to combine the tanning principle with the skins, so as to form leather the most impervious to moisture; and to give the hides the greatest increase of weight in the least possible time:—

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[46] The old tan which is thrown out of the tan pits was considered to be of no use till the arrival of King William III. in this island. He had observed that it was employed in Holland for raising orange trees, and he introduced the use of it here for the same purpose. It has since been brought into general use, and is now in great estimation with most of our gardeners; the great and continued heat which it produces rendering it proper for every species of forcing.

and these are the main secrets on which the profit of the trade chiefly depends[47].

The property which tan has of combining with gelatine, and therewith forming an insoluble precipitate, has lately been applied by Mr. Speer, of Bowling-street, Westminster, to the important purpose of purifying rancid fish oil. This gen-

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[47] The revenue arising to Government from the impost on tanned leather in Great Britain is upwards of two hundred thousand pounds per annum. An ample account of Seguin's improved processes is given in Nicholson's quarto Journal, vol. i. pages 271–279. There is also a memoir by Proust, on the Tanning Principle, in the Annales de Chimie, tom. xxv. p. 225.

tleman has fitted up a very complete apparatus for the business; and by agitating the oil with the tannin and water in a large vessel, to which he gives a rotary motion, the tannin becomes intimately combined with the gelatinous impurities, and afterwards completely subsides. The consequence of this is, that the oil which was fit only for burning in the street lamps, is rendered free from smell, nearly equal to the best spermaceti oil, and fit for burning in the closest chambers.

The manufacturers of MOROCCO LEATHER, an article nearly new as a production of this country, have the utmost reason to regret the want of chemical knowledge. Till within these few 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 reds and yellows are the principal colours for morocco leather, and in these our manufacturers were very deficient, till a Mr. Philippo, a native of Turkey, introduced the eastern mode of management, for which he received the gold medal and 100*l*. from the Society for the Promotion of Arts, Manufactures, and Commerce. Since then we prepare this leather in a manner much superior to any that can be brought from abroad, and large quantities of it have been exported to foreign markets[48]. Notwithstanding this, some colours are still produced by our manufacturers in a tedious and expensive way:—a series of well-conducted and appropriate chemical experiments would no doubt direct them to prepare the same colours, with greater certainty, and by a more œconomical process.

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[48] Transactions of the Society of Arts, &c. vol. i. page 18.

The manufacture of SOAP[49], 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

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[49] The first notice we have of soap is by one of the Hebrew writers: "Though thou wash thee with nitre and take much *soap*, yet thine iniquity is marked before me." Jeremiah ii. 22. Ætius, who flourished about the end of the 4th century, and was the first Christian medical writer, speaks of a black soap; and Paulus Ægineta, a Greek physician, who lived in the early part of the 7th century, says he made an extemporaneous soap from oil and the burned dregs of wine.

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[50]. 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 ba-

[50] The Government of France considered the manufacture of soap to be of so much consequence, that in the year 1795 the Committee of Public Safety engaged those celebrated chemists Mons. Darcet, Lelievre, and Pelletier, to investigate the nature of the art, and to endeavour to ascertain how the various processes might be improved by chemical science. Their report is printed at large in the Annales de Chimie, tom. xix. pages 253–354.

rilla, 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 oxidize the common oils and oil dregs, so as to give them consistence, and render them good substitutes for tallow,—and how to apportion his lime so as to make his alkali perfectly caustic, without using an unnecessary quantity of that article. He will be aware of the advantage to be derived from oxidizing the soap while boiling. 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. Manufacturers of soap, in general, avail themselves of none of these advantages.

An example of the benefit which may arise to the arts from a chemical examination of the nature of bodies, may be seen in the employment of the chemical residuums just mentioned, which were formerly thrown away as useless. The old makers of Glauber's salt regularly threw away the muriatic acid which resulted from the process; and the sulphate of potash, which remains after the distillation of nitrous acid, was formerly thrown into the Thames. Now, these articles are employed in various manufactories, and turn to a good account. I have indeed been told that

Mr. Steer, formerly a very large aqua fortis maker at Birstall, seven miles from Leeds, was for many years accustomed to lay his retorts in a shallow rivulet which ran through his fields, where, in a few weeks, the indurated salt was dissolved, and gradually washed away in the water. By this management he avoided the necessity of breaking the retorts: but from the extent of his business, I am persuaded that the salt thus lost for a number of years would have brought him some thousand pounds, if it had been preserved to the present time.

The manufacture of CANDLES, which is often connected with soap-making, though it is of comparatively small importance, may yet derive advantages from chemistry, which would repay the study[51]. Foreign tallows, which frequently contain a large portion of acid, rendering them inferior to the English, may be

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[51] Candles should be made without any admixture of oil or grease, and when laid up should be preserved from the action of the atmosphere. If tallows are weak, a part soon becomes converted to an acid by exposure to the air, and this renders the whole, when melted together, unfit for candles. I have heard of some persons who were in the habit of keeping their candles closely covered up in bran, and taking them out only as they wanted to use them. I have no hesitation in recommending this practice for general adoption, provided the bran be perfectly dry, and the store-room cool and free from damp.

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.

The mode which naturally presents itself as the best for separating the sebacic acid from tallow, is that of melting it in water containing some alkali; but old tallows may in general be sufficiently purified from their rancidity by melting them upon lime water, and giving a considerable agitation to the whole mixture; for when the water is again suffered to subside, it will be found to be offensive in smell, and to have subtracted most of the impurities of the tallow.

Should the tallow, however, be found not to be sufficiently purified, a repetition of this process would completely effect it.

Where great quantities of candles are required, as in large manufactories, mines, collieries, &c. a great saving would arise from the use of carbureted hydrogen gas, which produces a beautiful intense light, much more cleanly[52] than oil or tallow, and at little or no expense. A slight knowledge of the mode of managing the gases would enable the proprietor

[52] Oils and tallows when burnt with a wick generally produce a portion of soot; but this combustible gas is wholly converted into water and carbonic acid gas, and therefore will soil nothing.

of collieries to procure this gas from the small coal, which is *trodden under-foot,* and to light up his coal-pits with it with the greatest safety, and at NO EXPENSE[53]. If this mode were adopted, the workmen would be lighted much better than they can possibly be by any other means; thousands of pounds would be annually saved to the community; and

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[53] The person who discovered the inflammable nature of this gas was the Rev. Dr. Clayton, more than seventy years ago; but Mr. Murdoch of Birmingham was the first who applied it to the lighting of apartments, &c. For an account of its management and the œconomy of employing it, see Philosophical Transactions, vol. xcviii. for the year 1808, page 124; or the Chemical Catechism, page 457.

the many tons of tallow which are now consuming in these subterranean works might be used in the manufacture of soap; which would tend to lower the price of that necessary article, and render our poor more cleanly and comfortable.

The BREWING OF FERMENTED LIQUORS, a trade of considerable and increasing consequence, is altogether a chemical process[54]. To

[54] Isis and Osiris, it has been said, instructed the countries that were destitute of wine, by what methods they might prepare beer from corn. See Cogan's Diodorus Siculus, page 9. When Tacitus speaks of the ancient Germans making wine from *corrupted* corn, he referred, no doubt, to a process somewhat similar to English Brewing. Basil Valentine, an eminent chemist who flourished in the beginning

those persons whose concerns are so large that it would require a princely fortune to purchase even the *utensils*, it must be surely of the utmost importance to acquire some knowledge of the principles of bodies, and of the nature of those

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of the fifteenth century, wrote expressly on the different methods of brewing malt liquors. For an account of the curious management by which such kinds of beverage were prepared at the time of the Norman Conquest, the reader may consult Du Cange, Gloss. tom. ii. page 662. Some good practical directions for brewing malt liquors will be found in Shaw's Essays, octavo, 1761, page 73, &c. and in a work by Michael Combrune, entitled "The Theory and Practice of Brewing." London, Dodsley, 1762.

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[55]; how the fermentative process converts the saccharine to a *spirituous* substance; and how the latter, by a continuation of the process, becomes changed into *vinegar*. The nature of fermentation (which till lately

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

was entirely unknown) will be studied and understood[56]; and they will not only have learnt 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.

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[56] A Memoir on Fermentation by Fourcroy and Vauquelin has been translated for the Philosophical Magazine, vol. xxv. page 176, &c. and continued page 219 and the sequel.

An ingenious friend assures me, from his own experience, that if new rum be exposed for a night to a severe frost, and then removed to a heated room, and thus alternately

In like manner the DISTILLER[57], the maker of SWEET WINES[58], and the VINEGAR MANUFACTURER[59], will all

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for a week or two, it will in that short time have acquired a flavour equal to fine *old* spirits.

[57] When the Romans had possession of this island the art of distillation was unknown. It is said to have been introduced here in the early part of the reign of Henry II.

[58] It has been aptly remarked by Boerhaave, that "'Tis from the chemical art that we learn how to soften wine, when it is too rough, by a small portion of salt, prepared from the burnt *fæces* of the wine itself, and how to recover it when grown tart." Vol. i. page 72.

[59] Chrysippus, who wrote in the third century before Christ, speaks of the excellence of the Egyptian vinegar. Such was its acidity, that it immediately dissolved the greatest pearl Cleopatra had in her possession. Plin. ix. 35.

receive benefit from the cultivation of the science we are recommending[60]. 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[61]. An acquaint-

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[60] It has been asserted that in wine countries good vinegar may be made in fifteen days. See Phil. Trans. vol. v. page 2003.

[61] An account of the theory of Fermentation must be read and understood, before a manufacturer can know how to conduct this process in a scientific manner. I have seen nothing, however, on the art of making vinegar which is more to the purpose than the directions which were published by Boerhaave near a century ago. See Dallow's Translation, in 2 vols. 4to. London, 1735, vol. ii. page 143.

ance 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[62]. When this is once known, they will soon find by experiment how to oxygenize their wash at the least expense, and in the

[62] When the vinegar is taken out of the sun, it is customary to break up the pipes into small casks and to purchase new wine-pipes to put into their place, from an idea that the *wine* within the wood would add an additional strength to the vinegar; but a knowledge of the cause of the change from the vinous to the acetous fermentation, aided by experience, would inform them that the process will always go on much faster in old vinegar casks.

least possible time[63]. Indeed, when chemical knowledge is more advanced, the process which now takes several months will probably be completed in as many days. The adoption of stoves and some other methods, which might easily be devised, would, I am persuaded, occasion a great saving in this manufactory, besides doing away the necessity of exposing the vinegar in the open air

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[63] William Homberg, a well known chemist of the seventeenth century, filled a bottle, in part, with wine that was not at all acid, and having securely corked it and tied it to the vane of a windmill, it became in three days converted into good vinegar. Might not this idea be improved upon, so as to expedite the process in the great?

to the sun for so many months, as is the present practice, whereby the casks sustain so much injury as to entail a heavy annual expense on the proprietor of every large work, for this article alone.

The REFINING OF SUGAR is also a chemical process; every branch of which depends upon laws well known to chemists[64]. The separation of the

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[64] By the account of Dr. Anderson, in his History of the Origin of Commerce, it would seem that the refining of sugar was not practised in this country until the restoration of Charles II. It is still conducted by Germans, and little or no improvement has been made in any of the processes since that time. The new patent method suggested by M. Cronstat, and for which he required of the London re-

sugar from the molasses; the absorption of the superabundant acid; the granulation of the purified sugar; and the crystallization of candy; will all be conducted most œconomically, 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. To obtain the best and most profitable

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finers 50,000*l.*, appears to me to be entirely inapplicable on a large scale.

esults in the business of parting, it s necessary that the nitrous acid hould be prepared for this express urpose. Some refiners may imaine this to be of no consequence; ecause they purify it, they say, by eans of a solution of silver before ey use it. But I can assure such efiners that it is impossible to pufy some aqua fortis, by means of lver water, as it is usually applied; nd that, when this is the case, a conderable loss in the produce of the old is the inevitable consequence. esides, there is great reason to beeve that a considerable portion of lver is often lost in the process hich succeeds that of *quartation*, by the blue water being removed to the verditer-vats before the whole of the silver has been precipitated. A knowledge of chemical principles would suggest to the refiner a mode by which, without the aid of any apparatus, he might in an instant detect even a tenth of a grain of that metal, if left in the solution.

In like manner the reduction of the ores of COPPER[65], LEAD, TIN,

[65] The copper mines in Cornwall were worked to great disadvantage till Queen Elizabeth invited one Daniel Houghsetter from Germany to instruct her subjects in the art of managing them. For an account of the exclusive privileges which the Parliament granted him, see Statutes at Large, in the reign of Queen Elizabeth.

INC[66], and ANTIMONY, and the ma-
ufacture of BRASS, have all been
ery materially improved by the ap-
lication of chemical knowledge, and
ave supplied sources of wealth to
dividuals, an immense revenue to
e government, and a profitable em-
loyment to many thousands of the
ommunity.

The manufacturers of GUNPOW-

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[66] Notwithstanding the vast stores of Cala-
ine with which this island abounds, we were
the habit of importing all our zinc for the
anufacture of brass from India, till Mar-
aaf instructed the chemists of his day in the
ethod of procuring it from this ore. Ac-
ording to Pliny (l. xxxiv.) brass was known
the ancients.

DER[67], ALUM[68], COPPERAS, 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

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[67] It is a curious fact, that "upon our discovery of China, the most eastern part of Asia, we found that nation possessed of gunpowder, a composition which could not have been made without a considerable knowledge of chemistry." See the preface to Delaval's Inquiry respecting Colours, page 62.

[68] The first alum manufactured in England was at Gisborough by one Thomas Chaloner in the reign of Queen Elizabeth. For some particulars of this intrepid man, see Notes to the Chemical Catechism, page 123.

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. Till lately the MAKERS OF ALUM bought alkalies of every description. An accurate analysis of alum has now discovered that potass and ammonia are the only alkalies which enter into the composition of alum; and consequently, that during a long series of years large sums have been expended by the manufacturer for an article comparatively of no use.

The article more particularly referred to here is a refuse product of the soap-works called *black ash*, for which the alum-maker has given from 10 to 15*l.* per ton, though it is composed in a great measure of soda and muriate of soda, neither of which salts is of any use in the manufacture of alum. They must have been as careless in their inquiries as the Spaniard of whom Bowles speaks, who on being asked if he knew how the saltpetre was yearly regenerated in his grounds replied, "I have two fields—in the one I sow wheat, and it grows; in the other I collect saltpetre[69]."

Even science itself is now reaping the benefit of its own discoveries. A

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69 See Bowles's Histoire Naturelle de l'Espagne, page 80.

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[70]. And so easy is the applica-

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[70] This is done by means of oxygenized mu-

tion, 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 expense of only a few pence. These improvements, which, however, are not yet universally practised, will, when chemical science is better understood, probably lead the way to a cheap method of bleaching *coloured* rags also, and enable the bookseller to furnish us with the most common works in

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riate of lime. But I would suggest that no manufacturer should employ it, unless he has an abundant supply of water to wash the pulp frequently and thoroughly after its use.

a style of neatness to which we have not hitherto been accustomed.

In like manner it might be shown that the making of BREAD, SUGAR, STARCH[71], VARNISH[72], and OIL OF VI-

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[71] The success of the starch manufactory depends, in a great measure, upon giving a proper degree of fermentation to the wheat; it is evident then how much the profit might be increased by a scientific attention to this circumstance. See Fourcroy and Vauquelin on the Germination and Fermentation of Corn and Seeds in Phil. Mag., vol. XXV. pages 176, &c. and 219, &c.

[72] In making oil-varnishes it is first necessary to oxygenize the oils by means of metallic oxides, in order to give them the drying property. To do this in the best possible way, requires some chemical skill; and, whether the varnish be made with a resin or a gum-resin, it is of the utmost importance to learn

TRIOL; the felting[73] and fulling of HATS[74], the refining of SALTPETRE,

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the proper solvent for each particular resin, and the best temperature for producing the solution.

[73] Within these few years some manufacturers of hats have introduced a considerable improvement into their manufactories, by treating the fur of the hare and rabbit with a solution of mercury in nitrous acid. As this solution of nitrate of mercury is applied before the fur is removed from the skins, it acts on one side of the hairs only, and renders them crooked, which occasions them to felt much easier than they otherwise would.—See Monge's Annales de Chimie, tome vi. p. 300. I have good reason to believe, however, that this preparation of mercury was in general use by the hatters of America for some considerable time before it was employed in Europe for that purpose.

[74] In the operation of fulling hat-felts, it

and the manufactures of SMALTS, ULTRAMARINE, PRUSSIAN BLUE[75], CO-

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has been customary to employ a large proportion of wine lees or tartar; and it was imagined that the consistence and density which this gives to the felt, was attributable to the alkali of the Tartar; and indeed the author of the French Encyclopédie has affirmed that this is the case. But Mons. Chaussier knowing that tartar is a super-tartrate of potash, suspected that it might be the tartarous *acid* which determined the felting; and by direct experiment he discovered this to be the fact, and that any other acid would produce the same effect. Of late years, therefore, those manufacturers who are aware of this circumstance derive considerable advantage from the substitution of diluted sulphuric acid. See Journal Polytechnique, cahier i. p. 160; or Nicholson's Journal, 4to. vol. i. p. 399.

[75] A large proportion of the Prussian blue

BALT BLUE[76], CUDBEAR[77], ARCHIL, and other colours[78], are all dependent

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which is made in this country goes to China; the captains of the East India Company's ships take it out at the beginning of the year, and it constitutes a part of the private trade to that country. Though the Chinese are ingenious in the manufacture of a variety of permanent and beautiful colours, they have not yet learnt the art of making Prussian blue.

[76] The consumption of cobalt blue by the blue potters and manufacturers of porcelain, is very considerable; and till lately it was made only from zaffre imported from Saxony, though it has long been known that cobalt ores were to be found in some of the English mines. Just now, however, a few enterprising men have accomplished their reduction, and a beautiful colour, worth from two to three guineas per pound, and much better than what is usually made from zaffre, has been produced in considerable quantities.

upon chemistry for their improvement and successful practice[79]:—

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[77] This valuable article in dyeing was discovered by a Florentine merchant about the year 1300, which not only enriched himself, but was so very advantageous to the Florentines, that they gave him an honourable title, which was likewise borne by all his family and descendants. Bergman.

[78] When the science of chemistry was little understood, some colours were extremely rare and valuable. Such was the purple of the ancients, which none but the Cæsars were allowed to wear. At the taking of Susa, Alexander the Great found in the royal treasury purple to the value of 50,000 talents, which had lain there 192 years, and still retained its exquisite beauty.

[79] One Kloeck, a Dutch painter of the 16th century, acquired great skill in the manufacture of colours in the East, and which he trans-

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[80] may receive improvement

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ferred to his own country, where he died in the year 1550. Bergman.

[80] "The country seats of our English gentlemen being removed from the tumults of cities, give them the best opportunity, and freedom of observations. Their stables, their stalls, their kennels, their parks, their ponds, will give them eternal matter of inquiry. Their pastures, their orchards, their groves, *their gardens*, their nurseries, will furnish them with perpetual contemplations. They may not only make their business, but their very sports most serviceable to *experimental* knowledge." Dr. Sprat's History of the Royal Society, page 405.

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[81].

The various operations of Nature[82], and the changes which take

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[81] Natural history is intimately connected with chemistry, as it must depend upon this science for any elucidation of the minute properties of those substances, the outward characters of which it describes; so that what Mr. Dayes has said of the painter may with greater truth be said of the chemist: "The volume of NATURE is laid open to him: his attention is directed to the vast and to the minute; and his imagination clings to perfection with ineffable delight."

[82] "Man should observe all the workmanship and the particular workings of Nature,

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[83].

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and meditate which of these may be transferred to the arts." Lord Bacon's *Advancement of Learning*, book v. 148.

[83] A very remarkable instance of a whole nation availing themselves of advantages presented

Were parents aware of this truth, that sordid maxim *primò vivere, deindè philosophari*, would not be heard: but every youth would be instructed in the first principles of natural philosophy[84] and chemistry, as *the means* of qualifying him for conducting 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, is the most

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to them by chemistry, in a case of the greatest emergency, may be seen in the Chemical Catechism, Additional Notes, No. 22, p. 426.

[84] Thales the Milesian, who flourished 600 years before Christ, used to declare that he preferred the study of Natural Philosophy to all other sciences.

likely way for conducting to opulence, respectability, and rational enjoyment[85].

Moreover, it is the necessary consequence of an attention to this science, that it gives the habit of *investigation*[86], and lays the founda-

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[85] Martini, the author of the Chinese Atlas, relates a story of nine virgin sisters, who passed their lives in celibacy, intent on chemical pursuits.

[86] "If we would lay a good foundation for a philosophical taste, and philosophical pursuits, persons should be accustomed to the sight of experiments, and processes, in early life. They should, more especially, be *early* initiated in the theory and practice of investigation, by which means, in a great variety of articles, very young persons may be induced to engage with peculiar alacrity in pursuits

tion of an ardent and inquiring mind[87]. 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.

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truly original." Preface to Priestley's Observ. on Air, vol. iv. London, 1779.

[87] Boerhaave, who had a botanical garden of eight acres, and who was so intent upon stocking it with every exotic that he could procure, as once to have styled a present of a few American seeds, "munera auro cariora," gifts more precious than gold, was, notwithstanding, so captivated with chemistry, that he sometimes spent whole days and nights successively in the study and processes of the art.

The knowledge of *facts*[88] 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.

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[88] Democritus of Thrace applied himself with so much earnestness to his studies that he was absorbed in philosophy, and declared he would prefer the discovery of ONE CAUSE in the works of Nature, to the possession of the whole Persian monarchy. Bergman.

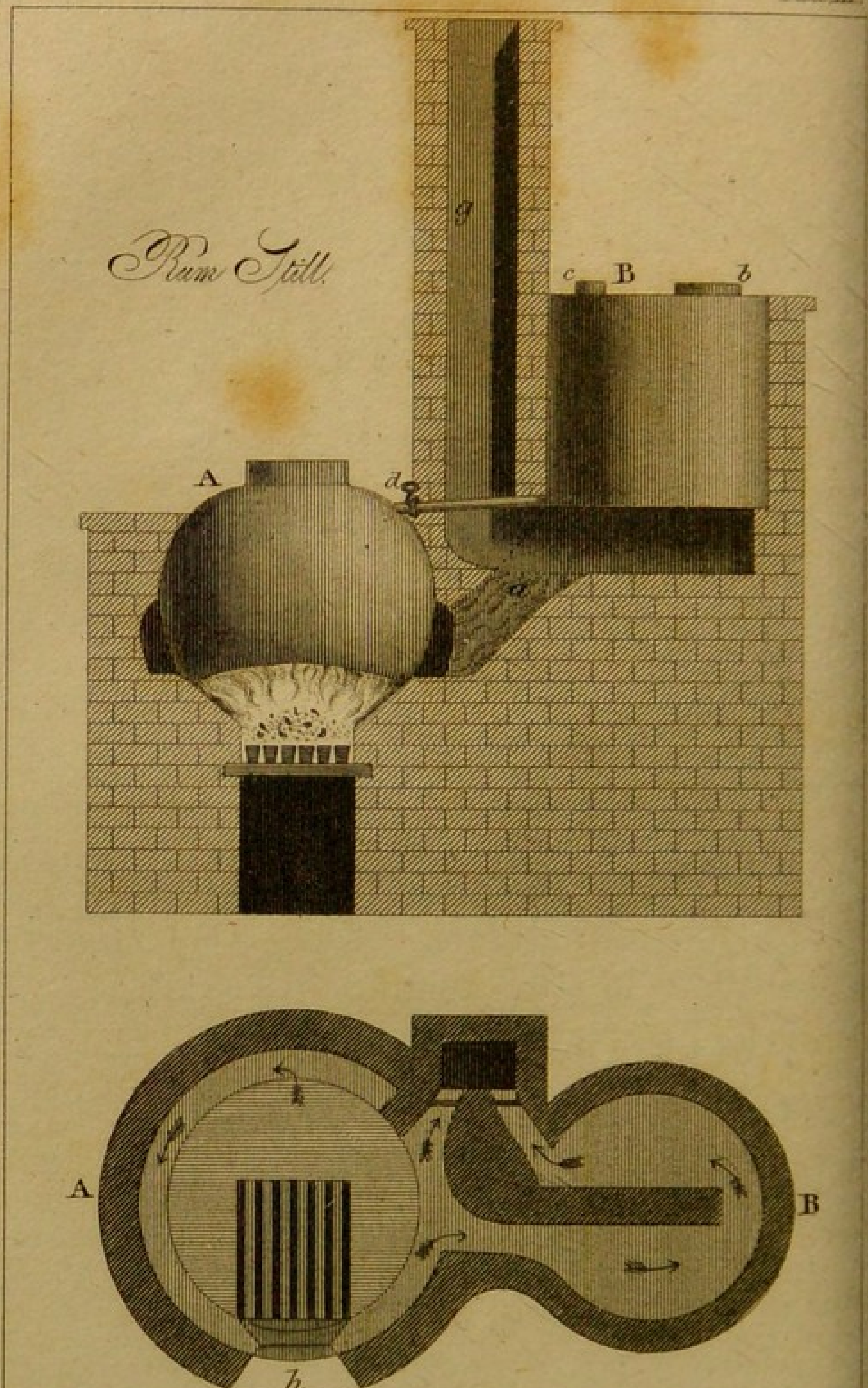
# ESSAY II.

ON

# TEMPERATURE.

## PART I.

Plate III.




Ja.s Davis, sculp.

# ESSAY II.

ON

# TEMPERATURE.

## PART I.

AFTER having given some account ff the Utility of Chemistry to the ts, it occurred to me that there ould be a peculiar propriety in introducing the following Essays to e notice of the reader, by a few marks on Temperature—as there is arcely an operation in chemistry, a process in any of our manufacries, that does not either require a arked attention to the precise degree of heat under which it is conducted, or would produce a better result, were this first to be determined by experiment, and made one of the preliminary conditions of the operation.

Besides, if we contemplate the Works of Nature, it will be difficult to name any substance that, in the œconomy of the world, is of equal importance with the matter of heat. What this matter is, or how it produces the astonishing effects which are attributed to it, we know not; nor have philosophers as yet agreed whether it be really a material ponderable substance[1], or only the con-

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[1] "Very delicate experiments have been made, which show that bodies when heated do

sequence of a particular motion excited among the particles of bodies.

The word TEMPERATURE is usually employed to denote the precise state of any region on the face of the earth, with respect to heat and cold; or the condition of any particular insulated body, produced by the operation of caloric [2], or by the par-

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not increase in weight; but these cannot be considered as decisive, on account of the imperfection of our instruments. A cubical inch of inflammable air requires a good balance to ascertain that it has any sensible weight, and a substance bearing the same relation to this, that this bears to platina, could not perhaps be weighed by any methods in our possession." Davy's Chem. Elements, part I, vol. i. page 96.

[2] This term (caloric) was introduced not from caprice, but for the sake of giving pre-

tial removal of this wonderful and occult power[3].

In order to furnish a complete Essay on Temperature, it would be necessary to give a history of all

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cision to chemical language—for the purpose of distinguishing between this peculiar matter itself, and the effects which are produced by it.

[3] The following is the definition which Sir Humphry Davy has given of the word temperature.

"Temperature," says he, "is the power bodies possess of communicating or receiving heat, or the energy of repulsion; and the temperature of a body is said to be high or low with respect to another, in proportion as it occasions an expansion or contraction of its parts: and the thermometer is the common measure of temperature." Elements of Chemical Philosophy, vol. i. page 76.

he discoveries[4] which have been uccessively made respecting the natter of heat, and to detail the va-ious experiments which have been erformed by the principal philo-ophers of Europe for the last two undred years. This, however, would e incompatible with the design of

[4] What an accession would there soon be the mass of knowledge on temperature and eteorology, if the various governments of urope made these national objects of inquiry! hat excellent prince, CHARLES THEODORE, lector Palatine of the Rhine, not only erected academy which was solely dedicated to ese purposes, but sent collections of the best struments subservient thereto, and fabricated his own expense, to all the academies and iversities of Europe that were willing to em-oy them. See Kirwan's Preface on Climate.

these Essays, and very uninteresting to the class of readers for whom they are more particularly intended.

But, if I can give such a concise and popular view of the general causes of the change of temperature in bodies, as shall enable the most unscientific reader to understand the subject, and shall, at the same time, teach him how to avail himself of the best means of applying his knowledge in the common concerns of life, I shall be abundantly satisfied[5].

To this end it may be most con-

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[5] "For not to know at large of things remote
From use, obscure and subtile, but to know
That which before us lies in daily life,
Is the prime wisdom."

MILTON, Par. Lost, book viii.

venient to divide the subject into two branches, and to treat it under the distinct heads of Natural and Artificial Temperature.

The variety of climate in the different regions of the earth, the effects of caloric on animal and vegetable life, and the nature of its agency on combustible substances, will arrange themselves under the first division of the subject; while that on Artificial Temperature will contain a brief detail of a variety of expedients for procuring fire, for modifying the effects of heat and cold, for œconomizing fuel, and for improving certain operations which have a considerable influence on the success of many of the manufactories of the country.

In regard to CLIMATE, it is not necessary to enter into the disquisition, whether the matter of heat be transmitted to us from an immense globe of fire which we call the sun[6]; or whether it may not be more probable that the necessary quantity of caloric for the wants of the world and its inhabitants, was made inherent in the earth[7] at the time of its forma-

[6] Boerhaave, one of the fathers of chemistry, was of opinion that the sun did not emit caloric. See Dallow's edit. 4to. vol. i. page 150.

[7] "As the earth is the chief source of heat in the atmosphere that surrounds it, distance from the earth is a source of cold. Hence, the highest mountains, even under the equator, are, during the whole year, covered with snow." Kirwan on Climate, 8vo. 1787, pages 6 and 7.

tion, and that this sun is an inhabited world, with a phosphorescent atmosphere that perpetually sends forth rays of light, and that these elicit[8], and, as it were, put in motion the matter of heat belonging to this as well as to the other planets[9].—I say, it is not necessary to adduce argu-

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[8] The sun's rays appear to have no power of giving heat unless they impinge against a solid body. The focus of the most powerful burning glass, if directed on mere air, does not produce the smallest degree of heat. Thus Mons. Charles, the aëronaut, found the air in the neighbourhood of Paris to be 47°; and when he had ascended to the height of eleven thousand feet, only 21°, or 11° below the freezing point.

[9] This theory "enables us to solve the

ments in favour of either the one or the other opinion; for this would open too wide a field of discussion, and would be very unsuitable to that brevity which I am anxious to observe, and to that general UTILITY which I have placed before me as the main object to which I aspire.

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great difficulty concerning the distribution of heat among the different planetary bodies; for, according to this view, those nearest the sun may have no more than those at the most remote distance. We have only to suppose the quantity of caloric to be proportioned to the distance; and if a *small* quantity exists in the planet Mercury, no more heat may be excited than is done by a *larger* quantity in Saturn." Millar's Physical and Metaphysical Inquiries, London, 1806.

That we are indebted to the sun[10] for some of the most beneficial effects of caloric, cannot for a moment be disputed; nor will it be denied that the difference of climate on the various divisions of the earth, is, in a great measure, occasioned by the relative situation of the different regions with respect to that luminary; and that the Author of Nature had an eye to the general felicity, in

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[10] It is evident that there must be other causes besides the sun's rays, which operate in the production of variety of climate; for the hottest days are frequently felt in the coldest climates, and the coldest weather and even perpetual snow are found in countries bordering on, or even immediately under the equator. See Kirwan on Different Latitudes, page 2, &c.

the curious adaptation of the animal and vegetable creation (in their primitive constitutional qualities and texture of parts) to this great variety of situation and climate.

How strange then must that hypothesis of Mons. Buffon appear, which supposes that the earth and all the other planets were once in a state of fusion [11]; that they are now gradually cooling; and that a time

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[11] To some such conceit as this the following lines probably owe their origin:

"When high in ether with explosion dire,
From the deep craters of his realms of fire,
The whirling sun this ponderous planet hurl'd,
And gave the astonish'd void another world:
When from its vaporous air condens'd by cold,
Descending torrents into oceans roll'd;
And fierce attraction with relentless force
Bent the reluctant wanderer to its course."

will come when they will have lost so much of their present heat as to be totally unfit to preserve either animal or vegetable existence! As if the Great Architect of this stupendous whole had neglected to provide against its degenerating into a useless mass of inert matter.

Fortunately, however, we are not obliged, even on the authority of so great a name, to believe this monstrous and incongruous representation. For all history abounds with circumstantial details, which directly contradict the assertion, and tend, on the contrary, to prove that some of the cold regions of the earth have become much warmer than they were eighteen hundred, or two thousand years ago[12].

The following are a very few of the many instances which might be adduced:

In the Augustan age, the Rhine and the Danube were commonly frozen over during several months of the year; and when the Barbarians

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[12] In the year 1719, Mons. de Mairan gave it as his opinion that the earth is more indebted to the matter of heat inherent within itself than to the sun for the degree of temperature which it experiences; and after a lapse of forty-nine years this eminent man embodied his ideas, and published his reasonings on the subject in an elaborate Memoir, which may be seen in the History of the Royal Academy of Sciences at Paris, for the year 1766, 4to. Paris, 1768.

overran the Roman empire, they transported immense weights and innumerable armies across the ice of these rivers[13]; a thing which in the present times would be impossible. The rein-deer[14] and the elk, which flourish only in the coldest climates, were formerly abundant in the Hercynian forest[15], which covered a great part of that vast country lying between Switzerland and the Black Sea[16]. All the rivers throughout this

[13] Diodorus Siculus, lib. v. page 340, edit. Wessel.

[14] The rein-deer is found, not only in the wilds of Siberia, but on the rocks of Spitzberg within ten degrees of the pole.

[15] This forest was said to be sixty days journey in length.

[16] Cæsar de Bel. Gal. vi. 23, &c.

region were perpetually bound up with ice during the whole winter, which usually lasted for eight months[17], and the cold was so excessive that the historians of the time evidently supposed that the countries north of this district must be absolutely uninhabitable. Ovid says that at Tomi, which was seven degrees south of London, the snow continued two years on the ground; and Virgil agrees with him in declaring that the people living on the banks of the Danube were accustomed to cut out their wine with hatchets[18], and to deliver it to their guests in solid por-

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[17] Herodotus, lib. iv. § 28.

[18] Ovid. lib iii; Xenophon. Anabasis, lib. vii. p. 560, edit. Hutchinson.

tions[19]. These, and various other instances, incontrovertibly prove that Europe, at least[20], was formerly much colder than it is at present.

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[19] "But where Mæotis Scythia's waste divides,
And turbid Ister rolls his yellow tides,
There stalls inclose the herds that never stray,
No grass the field, no leaves the wood array;—
There crystal chains at once whole pools confine,
And hatchets cleave the congelated wine."
SOTHEBY'S Georgics of Virgil, book iii.

[20] The same change has also taken place on the continent of America. Formerly the people of Guiana, within five degrees of the equator, could not live without lighting evening fires; and though it is not a century since a part of this country was cleared from wood, the heat in that part is already excessive. Buffon Supplement, 8vo. page 346. The parts of North America which have been cleared are much warmer than they were when the woods were standing.

It has frequently been imagined that difference in climate is occasioned *solely* by the relative situation of the different countries with respect to the sun[21]; but nothing can be more erroneous. On the contrary, I am inclined to think that many an inhospitable clime might be rendered healthy and uniformly temperate, by the resolute exertions of a good

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[21] The state of the Andes is a complete refutation of this idea; for between the base and the summit of these mountains every degree of temperature may be found. The city of Quito, situated about the middle of one of these, experiences a mild and temperate climate, while the sands beneath it are intensely hot, and the ground above it covered with perpetual snow.

government and an enlightened population.

The country on the borders of the Albany River, and the southern parts of Labradore, are in the same latitude with Great Britain[22]; and yet the cold is now so severe, and the snow so perpetually on the ground, that the lands lie entirely uncultivated. The climate of Newfoundland, which is situated still further south than this island, is more like that of the north

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[22] According to the observations made at the house of the Royal Society from the year 1772 to 1780, it appears that the mean annual temperature of London is 52°. The greatest usual cold is 20°, and happens in January; and the utmost degree of heat is generally 81°, which commonly happens in July.

of Russia than England; and those who have travelled in Canada, which lies in the same parallel of latitude with the finest vineyards of France, assure us that the great river St. Laurence is frozen over for many months, while the correspondent provinces in Europe experience the most genial temperature.

Dr. Robertson, indeed, supposes[23] that the difference of temperature between certain parts of Europe and similar latitudes in America is equal to twelve degrees, and that a place thirty degrees from the equator in the latter, is as warm as one situated at eighteen degrees from it in the former.

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[23] Hist. of America, vol. ii. page 472.

There is also nearly as much variation in the climate of some countries situated near the line. Thus, many parts of Peru are mild and temperate, while the correspondent latitudes on the continent of Africa are scorched by the burning heats of the torrid zone[24].

A person accustomed to the examination of the works of Nature, can scarcely avoid being often very much struck with the beauty and excellence of the arrangements which its divine Author has established, for the preservation of the world and

[24] On the road from Senegal to Podor the heat is frequently 111°. At Pondicherry it has been 113° and 115°. Kirwan on Climates, pages 99 and 101.

the various animated beings which inhabit it. Some of these native and original appointments are contrivances of great wisdom. Of this class, the following appears to me to be a most striking instance, though not often adverted to.

Land is capable of receiving much more either of heat or cold, than water[25]. In the neighbourhood of Marseilles, Dr. Raymond often found the land heated to 160°; but the sea was never hotter than 77°, and even this heat it receives chiefly by its communication with land[26]; for in

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[25] Saussure, when the air was at 81°, found the Lake of Geneva at the surface was 62°, and at the depth of eighty-seven feet only 55°.

[26] That the land has an effect on the waters of

July 1765 he found that the part of the bay next the land was at 74°, the middle of the bay 72°, and the entrance of the bay 70°. On the contrary[27], he frequently observed the earth in winter cooled down to 14° or 15°; but the sea never lower than 44° or 45°.

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the vicinity, also lowering its temperature, appears from the fact that some of the inland seas of Europe, even of great extent, have sometimes been entirely frozen over. In 1668 the Baltic was so firmly frozen that Charles the XIth of Sweden and his whole army passed over it. Puffend. Hist. Europe. Mod. Univ. Hist. in 8vo, vol. xxx. page 180. In 1709 the Adriatic was completely frozen over. Mem. Par. 1749.

[27] Mém. de la Société de Méd. de Paris, An 1778, p. 70. Kirwan on Climate, p. 34.

Were it otherwise, and that the waters on the face of the earth had the property of acquiring the same temperature either of heat or cold as the land, the evaporation in summer would be excessive and detrimental; and in winter all navigation would be suspended, and the finny inhabitants of the water would inevitably perish.

Having adverted to this subject, it would be improper to allow it to pass without noticing one or two of the causes which constantly act to modify the temperature of the seas and other large bodies of water. In hot climates, the seas, rivers, and lakes are prevented from acquiring any thing like the heat of the adjacent lands, by the evaporation which is continually going on at the surface, and which carries off the greater part of the heat as fast as it is received. This principle of evaporation producing cold, has been long understood, and will be explained as we proceed.

On the contrary, in winter, whenever the temperature of the atmosphere is so far reduced as to give the waters a tendency towards freezing, those particles of water on the surface which are first cooled, acquire a greater specific gravity, and sinking within the mass, warmer particles of water ascend to supply their place, which are cooled in their turn, and descend also. Thus a circulation between the surface and the lowest depths of the sea and of other large bodies of water is constanly kept up, which often tends, among other important purposes, to preserve them from congealing for a long period after the air is reduced to the freezing point.

As the operation of this principle is uniform, it might be expected that the deepest lakes would remain the longest unfrozen; and this is really found to be the case. Near Lochness in Scotland there is a small fresh-water lake[28] on the top of a

[28] A patriotic writer, when mentioning this and other of our British lakes, recommends it to Government to have them all well stored with the spawn of the various sorts of fish that will not live in rivers; and that this may be done for the support of the poor in their

ery high mountain, the water of which never freezes, owing to the ime between the end of one summer nd the beginning of another not eing long enough to allow of this irculation being completed [29].

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spective neighbourhoods. Campbell's Politi-l Survey, vol. i. page 166. The pedlars of ina, it is well known, carry jars of spawn out from one province to another through e whole empire, for this very purpose of cking every lake with all the different ds of lake-fish.

[29] Near Mohanagh, the seat of Roger Fen-ck, Esq., in the county of Cork, there are o small lakes, that in the hardest winters *ver freeze.* They are very deep, and pro-ce trout of an unusual size. Ancient and esent State of the County of Cork, book ii. ap. iv. page 264.

Whenever this circulation ceases, it might be supposed that as the cold increases the density of the freezing water would continue to increase, and that the ice, as fast as it is formed, would be precipitated. But here, Nature, all bountiful, has made a memorable deviation from her usual course; for no sooner is the water cooled down to 40—5°, than it ceases to increase in density; and, on the contrary, actually becomes of less and less specific gravity, as the caloric is further abstracted by the cold atmosphere.

When this diminution of specific gravity has begun to take place, the water continues enlarging its bulk in regular gradation, till the surface ecomes cooled down to 32°, when, the water be still, a film of ice orms and covers the whole mass. f the cold continues, this covering f ice increases in thickness, and atches itself firmly to the banks[30], so s entirely to cut off all communicaon with the atmosphere, and thus revent that abstraction of caloric, hich otherwise would soon convert e whole mass of water into ice.

No person, who has paid even a ght attention to chemical science, n be ignorant of one of its prinpal axioms, that solids and fluids quire density by the loss of caloric;

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"A crystal pavement, by the breath of heaven
Cemented firm, till, seized from shore to shore,
The whole imprison'd river growls below."

it is therefore surely worth while to inquire why this general law of nature has been departed from in this solitary instance, and to consider, what would have been the result had water been subjected to the same law with other bodies?

It has before been remarked, that as water loses caloric it becomes more and more dense till it is cooled down to about 40°; but if no check had been given to this process, and the density of water had continued to increase till it came down to 32°, the superficial stratum would have continued to descend, followed by others in quick succession, and a body of ice would have first formed at the *bottom* instead of at the *surface* of our lakes and rivers. This would have accumulated with such rapidity, that one severe winter would, in all probability, have converted the whole of most of the rivers of Europe into as many solid masses of ice; which, on account of their great thickness, no future summer would have been able to dissolve.

It is certainly extremely curious that the same cause should thus be made to produce effects which, apparently, are diametrically opposite:—That water, within a certain range of temperature, should have its specific gravity *increased* by the loss of its caloric; and then, on a sudden, that the action should be reversed, and its specific gravity *lessened* by the same operation.

It will now be perceived, that this curious contrivance was absolutely necessary for the preservation of the world; and it is pleasing to reflect how many inconveniences are avoided by this very simple deviation from the usual course of Nature: that the sheet of ice which often covers the small seas, the rivers and lakes, not only preserves a vast body of caloric in the subjacent water, but when it thaws the aquatic race is not annoyed by the cold; for not a particle of the cold surface-water can descend, till a change in the temperature of the atmosphere has taken place, so as to raise the temperature of this water at least ten degrees.

The next branch of our subject embraces the *effects* which are produced on animal and vegetable life by change of temperature; but as these are too various to be even barely enumerated within the compass of an Essay, the mention of a few of the most interesting must suffice.

The first idea which naturally presents itself on this subject is, that nothing but consummate wisdom and goodness could have suggested the formation of such an infinitude of animals and vegetables[31] of various

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[31] Dr. Kirwan has remarked that "every ha-

natures and properties, and all peculiarly adapted to the various climates in which each and every of them are respectively placed:

> "Life buds or breathes from Indus to the Poles,
> And the vast surface kindles as it rolls!"

But it is not a little remarkable, that while every climate on the face of the earth, and almost every situation[32], has a race of animals pecu-

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bitable latitude enjoys a heat of sixty degrees, at least, for two months; which heat seems necessary for the growth and maturity of corn." On the Temperature of Different Latitudes, page 105.

[32] Mons. Humboldt and Mons. Bonpland, in travelling through the province of Quito in South America, perceived fish thrown up alive, and apparently in health, from the bottom of a volcano, in the course of its ex-

liarly fitted for it, and that can flourish and propagate no where so well as in their native quarter of the world, man should be so organized that he can reside, increase and multiply on every part of the habitable globe.

It is also observable, that while the cold-blooded animals vary their animal temperature with every alteration of the medium in which they live[33], the mechanism of the human

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plosions, along with water and heated vapour that raised the thermometer to 210°, being only two degrees short of the boiling point. Recueil d'Observations de Zoologie et d'Anatomie comparée.

[33] To establish the truth of this, many facts might be adduced. Frogs have been frozen so

body is such, that it is capable of preserving nearly an equable temperament, whatever may be its situation, or however great the transition from its accustomed state, to the highest degree of heat that it can endure, or to the most intense cold. That is, the temperature of the human body is nearly the same in all climates.

Of this singular faculty no satisfactory elucidation was afforded till Dr. Crawford, in 1779, published his Experiments and Observations on Animal Heat. This eminent philo-

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hard, as to chip like a piece of ice, and yet by a careful and gradual increase of temperature have been reanimated. On the contrary, worms of the species of Tænia have been taken alive out of the body of a boiled carp.

sopher explained it on the well known chemical principle of different substances having different capacities for caloric; on the property that the matter of heat has of becoming latent; and on the fact, which he discovered, that arterial blood has a greater capacity for the matter of heat than venous blood. But that this may be more clearly comprehended by all classes of readers, it may perhaps be necessary to proceed a little further into this part of our subject.

It was formerly presumed that caloric, in whatever state it might be, could always be measured by the thermometer[34]. But the important

[34] There are four different thermometers

experiments of Dr. Black and others have shown, that besides the caloric which acts upon, and is appreciable by, the thermometer, there are other portions which are in such close union with most bodies, as to occasion no sensible variation in their temperature. That is, caloric may

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employed in Europe. This often occasions much inconvenience. Ours has the scale of Fahrenheit, the zero of which commences at 32° below the point at which water freezes; and between this and the point at which water boils, it is divided into 212 degrees. The late Dr. Kirwan proposed that the use of all these thermometers should be discontinued, and a general one constructed, beginning at the congelation of mercury, and terminating at the ebullition of water, and to be divided into 250 degrees. Mr. Murray of Edinburgh has be so combined with a body, as to have lost all power of affecting the most delicate instrument; yet, when this latent heat is set at liberty, and converted to free caloric, as it is called, this shall be as active, and as energetic, as though it had never been confined[35]. A single example

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since suggested, that it would be convenient to form a scale whose extreme points should be the temperatures of freezing and boiling quicksilver, both which have now been accurately ascertained, and to divide this scale into 1000 degrees. Kirwan on the Temperature of Different Latitudes, 8vo, 1787, preface, page vii. Murray's Chemistry, 8vo, 1809, vol. i. page 139.

[35] A luminous explanation of the doctrine of latent heat may be seen in Dr. Robison's Preface to Dr. Black's Lectures, 4to, p. 34, &c.

will be sufficient to adduce, by the repetition of which any one may satisfy himself of the truth and propriety of this distinction.

Put about half an ounce of cold water into a small phial, and add to it, *very gradually*, about an equal measure of oil of vitriol, gently shaking the phial after every addition of the acid. The consequence of this will be, that the water will immediately begin to give out its latent caloric; and, after as much oil of vitriol has been added as is equal to double the measure of the water, the mixture will assume a degree of heat superior to that of boiling water.

In regard to the operation of this

principle in the act of respiration, it may be said that the oxygen, which is one of the component parts of atmospheric air, has a large portion of caloric thus chemically combined with it, and that a great part of this caloric is taken up by the blood, every time that atmospheric air passes through the lungs[36]; the internal surface of which, according to anatomists, is equal to the external superficies of the whole body; and on this *extended* surface it is that the

[36] Every time we make an inspiration, the bone of the breast rises and the diaphragm sinks. By these two contrivances room is made for a pint and a half, or more, of atmospheric air, at every drawing in of the breath.

arterial blood, through the medium of a thin pellicle, is exposed to the influence of the respired air.

How then is it that the lungs are not injured by this great accession of the matter of heat? Here is the difficulty which Dr. Crawford has so well explained. The arterial blood has the property of arresting this caloric, and of chemically combining with it—that is, it absorbs it in the same way as ice absorbs caloric, without becoming warmer, in the least degree, by the addition.

But when this blood flows from the arteries to the veins, the case is entirely altered, and by some unknown contrivance its capacity for caloric is lessened, the moment it enters these vessels, and what was latent, or combined caloric in the arteries, becomes free[37] caloric, or sensible heat, in the veins[38]; and as

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[37] An example of a contrary effect may be found in the conversion of ice into water. Let one pound of ice at 32° be dissolved in one pound of water heated to 172°, and it will be found that 140 degrees of heat have disappeared, and become latent in the fluid, which assumes a temperature of 32° only; whereas, if a pound of water at 172° be mixed with a pound of ice-cold water at 32°, the temperature of the mixture will be exactly 102°, which is the mean of 32° and 172°. Ice requires 140 degrees of caloric to give it fluidity, and this it receives without the least augmentation of temperature.

[38] If the reader have an opportunity of referring to the third chapter of the Chemical Catechism, pages 73—79, he will find several

these branch out in infinite ramifications to every extremity of the body, the genial warmth is conveyed through these channels to every part. And when the blood returns to the lungs[39], its former capacity is restored, and it again loads itself from the atmospheric stores, and distributes air, as before, to every even the most minute vessel in the animal system.

When this theory was first published, it was naturally asked, What becomes of the azote, which is also

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instances adduced, whereby the difference between latent and free caloric is explained.

39 The blood of the veins is black, or purple; but as it passes through the lungs it deposits charcoal, and becomes, when it enters the arteries, a bright scarlet.

a component part of atmospheric air? and whether the greatest part of the caloric would not be required to preserve this in a state of gas, so that it might be expelled from the lungs when the oxygen was separated from it? And that as a part of this oxygen takes up carbon from the blood, whether the remainder of the inhaled caloric would not be necessary for the formation of carbonic acid gas, which, it is well known, is also thrown off in the act of respiration [40]?

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[40] Lavoisier discovered that atmospheric air abstracted carbon from animal blood. His first paper on respiration was read to the Academy of Sciences on the 3d of May, 1777, and is printed in their volume for the year 1780.

But here another remarkable contrivance presents itself, and one equally necessary to the uniform preservation of animal heat. This I cannot explain more correctly, or with more conciseness, than by transcribing the following note from the Chemical Catechism.

"It is not simple azote or 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 carbonic acid gas 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[41]."

These arrangements for the production of animal heat, and preservation of life, are equally operative in every climate and in every situation in which man is likely to be placed. For, in climes intensely cold, the atmospheric air is more condensed, and consequently more

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[41] Chemical Catechism, 6th edition, chap. ii. page 65.

caloric is taken in at every inspiration[42].

In many of the habitable parts of the Russian empire the cold is often sufficiently intense to freeze mercury[43]; though it is well known that fluid quicksilver does not become a solid till it be reduced to the temperature of 71 degrees below the point at which water becomes frozen[44]. Indeed, when men have been

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[42] "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." Dr. Skrimshire's Essays.

[43] A paper by Dr. Blagden on the Congelation of Mercury in these parts, may be seen in Phil. Trans. 1783.

[44] Some idea of the very low temperature

accustomed to cold climates, so as to know the precautions[45] necessary to be taken, they can endure more severe cold than even this, without sustaining any injury.

Many of the natives of Great

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of frozen mercury may be derived from the circumstance, that if a lump of it be dropped into a small quantity of water at the boiling point, it will abstract the caloric with such rapidity that the hot water will be instantly converted into ice.

[45] One precaution necessary to be observed in such situations, is, not to handle any metallic body; for, if an instrument or utensil of iron, or any other metal, which had been exposed to the cold atmosphere, were touched, a sensation would be felt like that of burning, and the part would, in all probability, be blistered.

Britain make annual voyages to Greenland, and stay there during the fishing season, where the cold is greater than most people would believe. Some idea of it may, however, be formed from the account we have of the masses of ice which are generated there, and float occasionally from thence into the Atlantic ocean. "These mountains of ice," says Dr. Troil, "which are often seen fifty feet or more *above* water, are at least nine times[46] the same depth *below*

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[46] Mr. Boyle found by experiment, that a cylinder of ice floating in water of the same specific gravity as that of which it was made, could rise only one tenth of its height above the surface of the water. Appendix to his History of Cold, page 16.

water[47]. Frequently these immense masses are left in shoal water, fixed, as it were, to the ground, and in that state remain many months, nay years, undissolved[48], chilling all the am-

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[47] The account which Pennant in his Arctic Zoology has given of the ice mountains at Spitzbergen is grand and interesting. The "collision," says he, "of the great fields of ice, in high latitudes, is often attended with a noise that, for a time, takes away the sense of hearing any thing else; and the lesser, with a grinding of unspeakable horror."

[48] The extreme hardness of these masses of ice is owing perhaps to their having been formed with salt water. There is a memoir on this particular question in the 15th volume of the Phil. Trans. No. 167.

bient part of the atmosphere[49] for many miles round[50]."

Moreover, Mr. Mac Nab, when he was in Hudson's Bay, experienced such cold as sunk his spirit thermometer to 82° below the freezing point, which, if his instrument did

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[49] The Stockholm Memoirs mention a fact which fully corroborates this statement of the effect of mountains of ice or snow on the atmosphere. When a north-west wind blows on the mountains of Norway, it occasions a thaw; but when it has passed these mountains and entered Sweden, it produces the most intense cold. Mem. Stockh. 1757.

[50] Crantz's Hist. of Greenland. Forster's Voyage in 1773, page 69. Troil's Iceland, Lond. 1780, 8vo, page 49.

not deceive him, was eleven degrees below what is required for freezing mercury[51].

On the other hand, whenever an animal body is placed in a medium the temperature of which is considerably high, the usual change of arterial into venous blood does not take place; consequently there will be no evolution of caloric, and the animal heat will not rise much above the natural standard: but the problem has not yet been solved, how high is the degree of heat which the human frame can endure without injury.

Sir Joseph Banks and Sir Charles

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[51] Phil. Trans. vol. lxxvi. page 271.

Blagden once attempted to ascertain this, and, for some time, actually breathed an atmosphere, in a room prepared by Dr. Fordyce, which was 52 degrees higher than that of boiling water [52].

During this time the temperature of their bodies was not at all raised; though their watch-chains, and every thing else metallic about their persons, were so heated that they could not bear to touch them [53]. The ther-

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[52] The oven-girls in Germany have sustained a heat of from 250° to 280°, and one of these girls breathed in air heated to 325° of Fahrenheit for the space of five minutes. Hist. Acad. Sciences, 1764.

[53] "The heat of metals at the temperature of 120° is scarcely supportable; water scalds

mometers which hung in the rooms always sunk several degrees when either of the experimentalists breathed upon them, or touched them; and to prove that there was no fallacy in the degree of heat shown by the thermometer, "we put," says the reporter, "some eggs and a beef steak upon a tin frame in the room, and in 20 minutes the eggs were taken out roasted quite hard, and the beef steak was overdone in 33 minutes."

Water placed in the same room did not acquire a boiling heat till a

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at 150°, but air may be heated to 240° without being painful to our organs of sensation."
Davy's Elem. of Chem. Philosophy.

small quantity of oil was dropped in, when it soon began to boil briskly. The evaporation from the surface of the water prevented it from acquiring the heat of 212°; but when that surface was covered with a film of oil, the evaporation could not go on, and ebullition commenced [54].

There is an axiom in chemical science, that evaporation always produces cold; and this principle ope-

[54] Sir Charles Blagden's relation of these very interesting experiments may be seen in the Phil. Trans. for the year 1775, pages 111 and 484, &c. A series of experiments by Dr. Crawford, on the power that animals possess of producing cold, will be found in Phil. Trans. for 1781, page 479.

rates in the regulation of animal heat. For, whenever the human body becomes oppressed by heat, if it be in a state of health, perspiration commences, and this carries off the superabundant caloric as fast as it is produced.

These beneficial effects of perspiration arise from a well known chemical principle, viz. that water cannot be converted to vapour till it has combined with a very large portion of caloric. Thus, in all oppressive heats, the fluids of the human body are determined to the surface, from whence they escape in the gaseous form, carrying off with them that superabundant heat, which otherwise would soon have become insupportable [55].

That perspiration actually does operate in this way, may be readily conceived by those who know that although a thermometer plunged into steam indicates the same degree as it would in boiling water, yet that steam contains nearly one thousand degrees more of caloric chemically combined with it, that is, in a latent state, and not appreciable by the thermometer.

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[55] Dr. Valangin has written a valuable paper on perspiration: but he has not treated of it chemically. Valangin's Treatise on Diet and the Management of Human Life, 8vo London, 1768.

Indeed, it is this combination with caloric which enables steam to preserve its gaseous form, in which state it occupies a bulk 1800 times greater than that of water[56]; and this is the only way in which we can account for the loss of that continued stream of caloric which is perpetually passing, and often for many hours, through the bottom of an evaporating vessel, or other boiler of water, when placed over an intense fire[57]; because, if the fire be the same, the water actually admits as much

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[56] Murray, vol. i. page 421.

[57] A more detailed, and consequently a more satisfactory, explanation of this may be seen in the Chem. Catechism, page 88.

caloric after it boils, as it did before, although that which it now receives does not, in the least, augment its temperature.

The temperature of boiling water is 212°, and the constant evaporation prevents it from ever acquiring a higher temperature, however intense may be the fire that is placed beneath it. In like manner, the natural temperature of the human body is about 96° or 98°; and whatever may be the degree of heat to which it is exposed, the animal perspiration always carries off the superabundant quantity, and prevents it from ever acquiring a temperature much beyond the usual standard.

These multiplied contrivances for

the preservation of life, by maintaining an uniform animal temperament, were surely not the offspring of chance; their peculiar adaptation shows them to be a part of the great scheme of unerring Wisdom, effected by a Being who wills the convenience and felicity of his creatures.

There is some intricacy respecting the nature of the operation of caloric on combustible substances: to those, therefore, who have had no opportunity of investigating the subject, a short sketch of the modern THEORY[58] OF COMBUSTIÓN may be acceptable.

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[58] The true theory of combustion was first explained by Lavoisier, Mém. de l'Acad. des Sciences pour l'An. 1774 et 1775, page 520.

Some bodies are combustible, others are incombustible. If a body which is formed of combustible materials be heated to a certain degree in atmospheric air, combustion will commence, and its affinity for oxygen will be so great that it will abstract it from the atmosphere. Should the combustible substance be placed in favourable circumstances, with the free access of atmospheric air, this perpetual accession of oxygen will keep up the combustion till the whole of the combustible matter becomes saturated with oxygen, when it is said to be consumed.

The heat, in this process, generally arises from the decomposition of the oxygen gas of the atmosphere, but the light[59] and the flame in most cases proceed from the combustible body itself. In fact, combustion appears to be merely a chemical process; a double decomposition, in which not only two compound bodies are separated into their original elements, but two new compounds are always formed. For while the light, which is extricated from the burning substance, unites with the caloric of the oxygen gas, and forms what is called fire, the oxygen itself combines with the base of the combustible, and

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[59] For an explanation of the different colours of the light which proceeds from different combustibles, the reader may consult Dr. Fordyce in the Phil. Trans. for 1776, and the Rev. W. Morgan in Phil. Trans. for 1785.

forms a new incombustible substance. This incombustible matter will be either water, an acid, or an oxide; or a compound of two or more of these substances.

In this view of the subject, combustion can never take place *in vacuo*; and this is confirmed by experience. Atmospheric air, or some other compound containing oxygen, must be present in every instance of combustion, as has been repeatedly shown by a variety of direct experiments.

But the necessity for the presence of oxygen in combustion is so clearly exemplified in a certain operation on cotton goods, not universally known, that I conceive I need not apologize for adverting to it. The process to which I allude, and which is very common in Lancashire and other calico-printing districts, is called singeing, and has been contrived for the purpose of taking off all the ends of the threads and other downy filaments that are always attached to the piece, and of giving the whole a smooth surface.

To effect this, several pieces of goods, previously fastened together by their ends, are lapped smoothly round a large wooden roller, from which, by a regular motion, they are passed over a large semicircular piece of cast iron, which, by means of a furnace placed immediately beneath it, is constantly kept at a full red-heat.

All brown calicoes, dimities, fustians, &c. are treated in this manner, and the subsequent bleaching takes out any stains which they may have contracted from the fire [60].

To a stranger, this may seem a very destructive operation; but by the regularity and perpetuity of the motion, and by the uniform pressure of the cloth upon the hot iron, the combustion that would otherwise take place is prevented, and nothing is burnt but the loose threads that

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[60] See the Essay on Calico-Printing in these volumes.

rise above the surface of the fabric. The peculiar effect that is here produced, and how the cloth is protected from the red-hot metal, may be thus explained.

The uniform pressure of the piece upon the cylinder, keeps that part of it that is directly over it in close contact, so that there is no space for the intervention of any more atmospheric air than is just sufficient to occasion the combustion of the mere superficial filaments of the cotton or linen, and nothing more is necessary to be burnt off.

This process, which is now universal with the printers of cotton goods, explains why our housewives cannot get up their home-spun linen with so neat a face as that has which is sold in the shops. There are some intelligent laundresses, however, who are fully aware of the principle on which the above-named process is founded: they dismiss all anxiety about the precise degree of heat; for they well know that, however hot their flat-irons may be, if they press them with all their force upon the linen, and that this be smoothly spread, it will never sustain any injury.

It has already been remarked, that combustion cannot occur without the presence of oxygen, and that the oxygen combines with the base of the combustible: but there is another axiom of equal importance to be impressed on the memory of all those who are likely to be engaged in any kind of chemical operations, viz. 'That every body increases in weight by the operation of combustion[61].' This may perhaps require a little explanation, but it is a law to which there is no exception.

Even the incipient combination of oxygen with a body increases its absolute weight, as is well exemplified in the oxides of the metals, which always acquire additional weight by being converted into oxides. Thus,

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[61] Lavoisier, I believe, was the first chemist who proved this by direct experiment. Essays Physical and Chemical, page 297. This work was first published in Paris in the year 1774.

by exposing melted lead to the action of the atmosphere, under a peculiar management, red lead is formed, and a ton of pig lead will yield 22 cwt. of red lead.

But where complete combustion takes place, this increase is generally more considerable: thus, if 100 pounds of zinc are burnt in a proper apparatus, flowers of zinc will be formed, and the product will be 125 pounds. If lamp oil be burnt in a way that the product can be examined, it will be found that the whole is converted to pure water, and that every hundred ounces of the oil will produce 130 ounces of water. In like manner, if phosphorus be burnt by a rapid combustion, it will attract oxygen from the atmosphere, become phosphoric acid, and every pound of the phosphorus thus employed will produce more than two of acid[62].

It would be fruitless to enumerate more instances, though I thought it right to mention a few examples in passing, because I have met with many intelligent people who had never annexed any other idea to combustion but that of absolute de-

[62] It has been remarked, page 163, that we are indebted to Lavoisier for the true theory of combustion; but the full development of the theory was not published, I believe, till the year 1777. See Mémoires de l'Acad. for that year, page 592. It was afterwards further explained in the volume for 1783, p. 505.

struction; and yet I know of no subject connected with the œconomy of the world, which it is of more importance to understand, or which is better calculated to give us exalted conceptions of the contrivances of that Being, who hath not only formed a perfect whole, and pronounced every part to be in itself good, but has so constituted things that none of the materials which he has employed in this goodly fabric can ever be lost or destroyed.

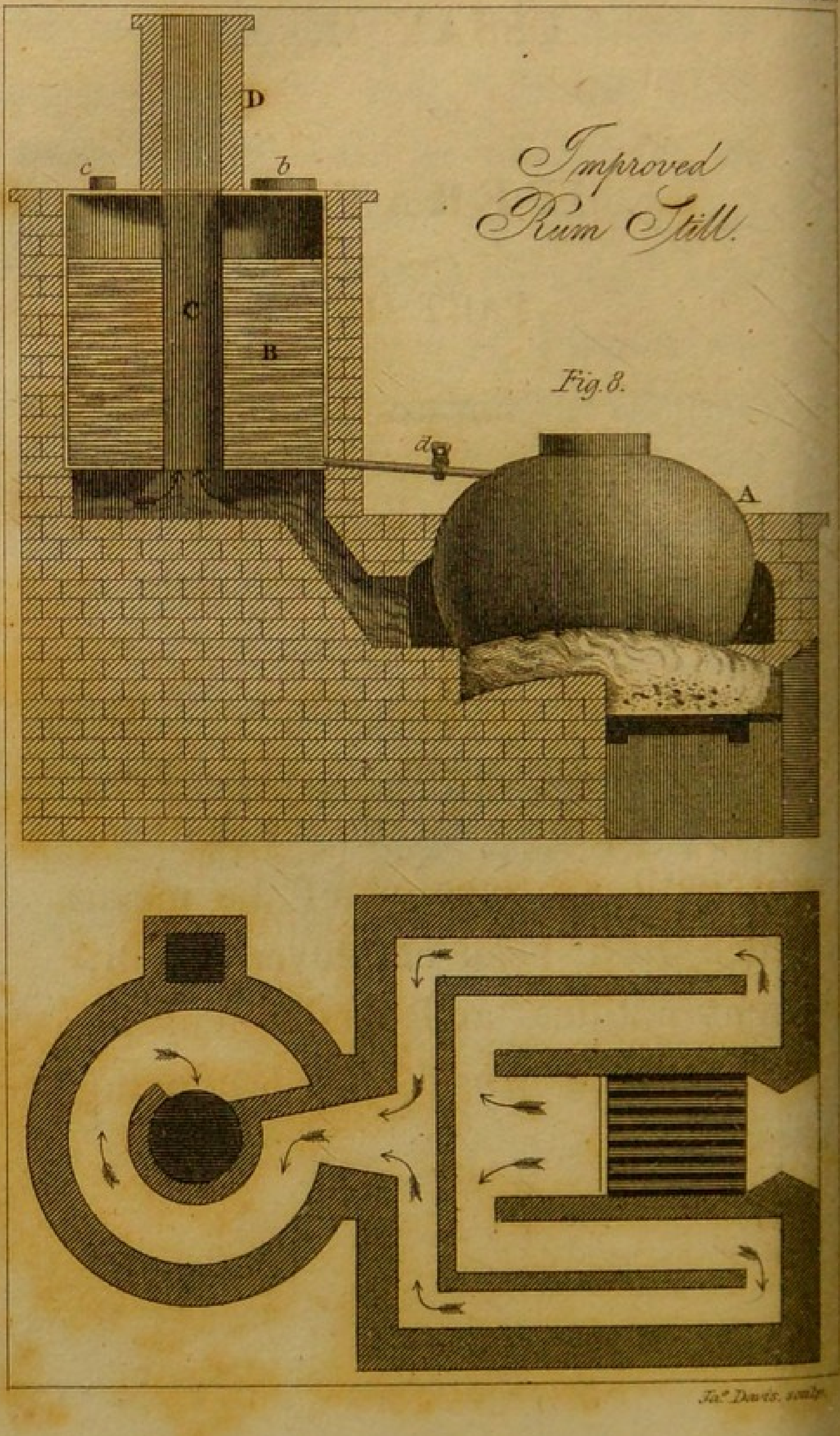
Metals, by means of oxygen, may be converted to pulverulent and even impalpable substances; but, whenever the oxygen is abstracted, every character of the original metal will be restored. All sorts of combustible substances may be employed for the necessary purposes of increasing temperature. The caprice of man may commit many invaluable, as well as worthless substances, to the flames; or the lightning of the heavens may involve a whole district in one general conflagration, in which every thing combustible shall be reduced to ashes:—but let it be remembered, that the act of combustion only separates their particles, and puts them in a state to form a variety of new combinations equally useful and necessary in the order of the Universe.

And shall we be told that such a state of things is the effect of chance? A philosopher of the present day [63]

[63] Sir Humphry Davy, in his Elements of Chemical Philosophy, page 180.

has well remarked, in opposition to such absurdity, that "in the Universe nothing can be automatic, as nothing can be said to be without design. An imperfect parallel," says he, "may be found in human inventions. Springs may move springs, and wheels, indexes; but the motion and the regulation must be derived from the artist. Sounds may be produced by undulations in the air, undulations of the air by vibrations of musical strings; but the impulse and the melody must arise from the master."

Plate IV.




Jas. Davis. sculp.

# ESSAY II.

ON

# TEMPERATURE.

## PART II.

N this part of the Essay, it is pro-
osed to treat of certain expedients
r increasing and diminishing tem-
erature, for œconomizing fuel, and
r improving some of our manu-
cturing processes; and I shall be-
in with an account of the means
hich have been employed by dif-
rent nations, and in different pe-
ods of the world, for producing
re.

FIRE has been known in some part or other of the world in all ages. In ancient times it was always employed in the rites of religion; it consumed the burnt offerings of the Patriarchs; was kept continually burning in the Jewish tabernacle[64]; was looked upon as the origin of life[65], the soul of the world[66], the

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[64] "The fire shall ever be burning upon the altar; it shall never go out." Lev. vi. 13.

[65] Fire was so generally considered as the image of life, that *lighted* torches were usually placed in the hands of the newly married; and at their deaths *extinguished* torches were placed upon their tombs. Essai sur le Feu sacré, &c. 8vo. Amsterdam, 1768.

[66] The fable of Prometheus, who stole fire from heaven to animate his man, seems to have been founded on this idea.

ymbol of Deity; and, considering it as the visible sign of an invisible Being, it has, from time immemorial, been actually worshipped by the Persians, and by some other Asiatic nations[67].

According to Pliny, fire was for long time unknown to some of the ancient Egyptians; and when Eudoxus, the celebrated astronomer, showed it them, they were absolutely in raptures[68].

[67] The sacred fire of the Vestal virgins, among the Romans, was beheld by them with little less than adoration. Numa built a temple to Vesta, the goddess of fire, which in later ages was rebuilt with great magnificence.

[68] Pliny, l. xvi. c. 40. Jonston's Hist. of the wonderful Things of Nature, fol. London, 1657, page 33.

The production of fire by collision, and the use of flint and steel[69], was probably known long before the time of Pliny. A more ancient method, however, of procuring fire was by rubbing two dry sticks one upon the other with violence[70]. The

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[69] The Laplanders begin their contracts of marriage with the fire and flint; for fire with them is the author of life; and the flint, say they, is eternal, for the treasure of fire within it never fails. Scalig. Exerc. 16, § 1. Jonston, page, 33.

[70] "Nymphs! your soft smiles uncultured man subdued,
And charm'd the Savage from his native wood;
Taught the first ART! with piny rods to raise
By quick attrition the domestic blaze."

DARWIN.

A series of experiments on the heat produced by the attrition of different woods

Indians make two pieces of wood fast together, and putting another stick between them, turn the latter swift like a wimble, and thus make the whole take fire. In Apulia they wrap a cane within some cords, and then drawing the cords backward and forward, the cane takes fire by the motion[71].

Fire is also to be procured FROM THE SUN by means of a double convex lens, a concave mirror, or by a combination of a number of plain mirrors[72]. It was by some one of these

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against each other may be seen in Nicholson's Journal, vol. viii. page 218; together with a table constructed on the said experiments.

[71] Jonston's History of Nature, page 34.

[72] By these means wood may by burned to

expedients that Archimedes contrived to set fire to the ships of the Romans during the siege of Syracuse. And that this account is not fabulous, as some writers have imagined, is rendered probable, from the effects which have been actually produced by these contrivances in later ages[73]. The following in-

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a coal, even under water. Hoffman, with the assistance of a concave mirror made by Hoessen, fused the Hungarian asbestos into glass in three seconds. Hopson's translation of Weigleb, page 66.

[73] Father Kircher, and his pupil Schottus, visited Syracuse for the express purpose of investigating the truth of this story; and they proved by direct experiment that Archimedes, by a combination of mirrors, might easily have destroyed the fleet of Marcellus at the

stances will be sufficient to enumerate.

At the beginning of the last century Mr. Tschirnhausen, a member of the Royal Academy of Sciences, made several burning glasses, which were each three or four feet diameter, with a focus one inch and a half diameter at the distance of twelve feet. One of these, which was convex on both sides, and weighed one hundred and sixty pounds, was used by Homberg, who communicated the

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distance at which the ships must have lain from the walls of the city; and also the possibility of the success of Proclus, who is said to have destroyed a fleet at Constantinople in the same manner. Philos. Trans. vol. xlviii. page 621.

result of his experiments to the Academy, and announced the following facts.

"All sorts of wood," says he, "though ever so hard or green, will be fired by it in a moment. Water in a small vessel will boil immediately. Tiles, slates, pomice stones, grow red in a moment, and vitrify. Any metal, put into the crevises of a coal, melts in a moment. Lead and tin volatilize entirely. The ashes of herbs and wood become transparent glass in an instant[74]."

An instrument still more powerful was constructed in the year

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[74] The History of the Works of the Learned, 4to. London, 1702, vol. iv. page 655.

1773, under the direction of M. de Trudaine, and placed in the garden of the Infanta at the Louvre. It was composed of two large glasses, each four feet diameter, joined at the edges so as to hold alcohol[75]. These glasses, which were without flaw, were two thirds of an inch thick, and formed two portions of a sphere of eight feet radius, leaving between them a vacuum capable of containing thirty-five French gallons of liquid. The focus of this instrument was at the di-

[75] In the Gentleman's Magazine there is an account of some interesting experiments, made with Mr. Villette's concave mirror, of forty-seven inches diameter. Vol. xliv. p. 220.

stance of ten feet ten inches, when filled with alcohol; at eleven feet eleven inches when filled with distilled water; and at seven feet when filled with liquid turpentine. With this apparatus the clippings of bar-iron were melted in an instant[76].

We are informed, however, by Mons. Buffon, who expended a very considerable sum in the construction of different instruments for concentrating the rays of the sun, that the only way by which the sun's rays can be made to produce an intense heat at a great distance, is by the combination of a considerable num-

[76] The History and Memoirs of the Royal Academy of Sciences at Paris, for the years 1774 and 1777.

ber of plain mirrors, so disposed as to throw numerous images of the sun upon the same spot[77].

One of these instruments, which consisted of 360 plain mirrors, each eight inches long and six inches broad, mounted on a frame eight feet high, produced the following among other very powerful effects:

When twelve of the mirrors only were used, light combustible substances were kindled at the distance of twenty feet. At the same distance a large vessel of tin was melted by forty-five of these mirrors, and a thin piece of silver with 117 of

[77] Phil. Trans. No. ccccIxxxiii. pages 493 and 495.

them. With the entire machine all the metals and metallic minerals were melted at the distance of forty feet. Wood was kindled by it, when the sky was clear, at the distance of 210 feet.

Mons. Buffon remarks, that as at the distance of fifty feet the focus, or space in which all the images coincide, is about seven inches broad, metals may be assayed by it[78], and other curious experiments made

[78] There are difficulties in applying this instrument to purposes of general utility which must not be concealed. A cloud passing over the sun during some processes would be a great inconvenience; and when the sun does shine in its full splendour, the motion of the earth will prevent the focus from ever being kept for a minute at a time on one spot.

in the large way, which it is impossible to execute with concave mirrors, in which the focus is inconveniently near or weak, and generally a hundred times less than that produced by this machine.

Among other purposes for which this instrument may be employed, the author has stated that it might be used with advantage in the manufacture of salt, by producing a quick evaporation of the salt-water, without the expense of fuel. An assemblage of twelve mirrors, each a foot square, will, he says, be more than sufficient to give a boiling heat to the liquor contained in shallow pans constructed for this purpose.

Electricity is also capable of

producing powerful effects. The electric matter collected by the friction of a glass plate or cylinder upon a prepared cushion [79] is received on a metallic conductor, as it is generated, and condensed in a collection of glass jars coated with tin-foil [80].

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[79] Electricity is best excited by rubbing the cushion with an amalgam of tin and zinc. The excitation seems to depend upon the ready oxidizement of the metals which form the amalgam; for such metals as are not easily oxidized produce no electricity.

[80] An elegant modern poet, who has endeavoured to "inlist imagination under the banner of science," and has employed Gnomes, Sylphs, and Nymphs for his machinery, has given the following description of this wonderful agent, which I beg leave to transcribe:

By the discharge of one of these electrical batteries, the combustion of various substances may be effected; animal life may be destroyed; and wires of the different metals will be melted in an instant. But notwithstanding these powerful effects, the electric matter may be thrown

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" Nymphs! your fine hands ethereal floods amass
From the warm cushion, and the whirling glass;
Beard the bright cylinder with golden wire,
And circumfuse the gravitating fire.
Cold from each point cerulean lustres gleam,
Or shoot in air the scintillating stream.
So, borne on brazen talons, watch'd of old
The sleepless dragon o'er his fruits of gold;
Bright beam'd his scales, his eyeballs blazed with ire,
And his wide nostrils breathed inchanted fire.
You bid gold-leaves, in crystal lanterns held,
Approach attracted, and recede repell'd;
While paper nymphs instinct with motion rise,
And dancing Fauns the admiring Sage surprise.

*gradually* upon the human body without producing any mischief or inconvenience whatsoever:

" For, if on wax some fearless Beauty stand
And touch the sparkling rod with graceful hand,
Through her fine limbs the mimic lightnings dart,
And flames innocuous eddy round her heart."

By VOLTAIC ELECTRICITY, or galvanism, much more powerful effects may be produced in igniting various substances, and in melting metals,

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You crowd in coated jars the denser fire,
Pierce the thin glass, and fuse the blazing wire;
Or dart the red flash through the circling band
Of youths and timorous damsels, hand in hand.
——Starts the quick ether through the fibre trains
Of dancing arteries, and of tingling veins,
Goads each fine nerve, with new sensation thrill'd,
Bends the reluctant limbs with power unwill'd;
Palsy's cold hands the fierce concussion own,
And life clings trembling on her tottering throne."

DARWIN.

than have ever been occasioned by simple electricity. These, however, depend much on the size and the nature of the apparatus; and though most persons may be acquainted with this property of galvanism, it is impossible for any one to form an adequate idea of the power which may be acquired by an extensive apparatus, in which there is a proper combination of number of plates, and an extended surface, unless he actually witnesses some of the effects produced by it.

"The grandest combination ever constructed for exhibiting the effects of extensive surface *alone*, was made by Mr. Children: it consists of twenty double plates four feet by two; of which the whole surfaces are exposed, in a wooden trough, in cells covered with cement, to the action of diluted acids. This battery, when in full action, had no more effect on water, or on the human body, than one containing an equal number of small plates; but when the circuit was made through metallic wires, the phænomena were of the most brilliant kind."

"A platina[82] wire of one thirtieth

[82] To form an adequate idea of the power of this apparatus, it should be recollected that platina cannot be melted in the most intense heat of an air furnace, nor in a smith's forge, unless oxygen gas be employed; and yet by the silent action of galvanism it became, in this instance, fused in a few seconds.

of an inch in thickness, and eighteen inches long, placed in the circuit between bars of copper, instantly became red hot,—then white hot;—the brilliancy of the light was soon insupportable to the eye; and in a few seconds, the metal fell into globules. Points of charcoal ignited by this power, produced a light so vivid, that even the sun-shine, compared with it, appeared feeble."

"But the most powerful combination that exists, in which number of alternations is combined with extent of surface, is that constructed by the subscriptions of a few zealous cultivators and patrons of science, in the laboratory of the Royal Institution. It consists of two hundred instruments, connected together in regular order, each composed of ten double plates arranged in cells of porcelain, and containing in each plate thirty-two square inches; so that the whole number of double plates is 2000, and the whole surface 128,000 square inches.

"This battery, when the cells were filled with sixty parts of water mixed with one part of nitric, and one part of sulphuric acid, afforded a series of brilliant and impressive effects.

"When pieces of charcoal, about an inch long and one sixth of an inch in diameter, were brought near each other, within the thirtieth or fortieth of an inch, a bright spark was produced, and more than half the volume of the charcoal became ignited to whiteness; and by withdrawing the points from each other a constant discharge took place through the heated air, in a space equal at least to four inches, producing a most brilliant ascending arch of light, broad, and conical in form in the middle.

"When any substance was introduced into this arch, it instantly became ignited; platina melted as readily in it as wax in the flame of a common candle; quartz, the sapphire, magnesia, lime, all entered into fusion; fragments of diamond, and points of charcoal and plumbago, rapidly disappeared, and seemed to evaporate in it, even when the connection was made in a receiver exhausted by the air pump; but there was no evidence of their having previously undergone fusion[83]."

The CLOUDS may be considered another source from whence man has the means of procuring fire. The first idea of the identity of lightning and electricity occurred to the mind of Dr. Franklin[84] in the year

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[83] Sir Humphry Davy's Elements of Chemical Philosophy, part 1. vol. i. page 151.

[84] The following very elegant compliment has been paid to this great philosopher for this his important discovery.

"You led your FRANKLIN to your glazed retreats,
Your air-built castles, and your silken seats;
Bade his bold arm invade the lowering sky,
And seize the tiptoe lightnings ere they fly;

1752; and in the month of June in that year, he elevated a kite for the purpose of ascertaining the fact, and on the first trial he had the satisfaction of finding his conjecture verified and the discovery complete[85].

In the following year the experiment was repeated in France, and on a large scale, by Mons. Romas, which fully demonstrated the powerful effects of elevated metallic con-

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O'er the young Sage your mystic mantle spread,
And wreathed the crown electric round his head.—
Thus when on wanton wing intrepid LOVE
Snatch'd the raised lightning from the arm of JOVE;
The immortal Sire, indulgent to his child,
Bow'd his ambrosial locks, and Heaven relenting smiled."

DARWIN.

[85] Priestley's History of Electricity, 4to. London, 1767.

ductors in drawing off the electric matter.

The kite which he employed had a wire interwoven in the hempen string, and the following were some of the signs of electricity which it exhibited soon after its elevation in the atmosphere. "Electrical sparks three inches long and a quarter of an inch thick were drawn at the distance of a foot from a tin conductor, connected with the apparatus, the snapping of which was heard at 200 paces. On the falling of a little rain, the appearances increased amazingly, and a continual rustling noise was heard, like that of a small forge bellows."

The remainder of the account

which Dr. Priestley has given of these very interesting experiments[86] is too long to be introduced here; but I have no hesitation in saying that those of my readears who may have an opportunity of seeing it, cannot fail of being highly gratified by its perusal.

By this discovery of Dr. Franklin's we have learnt how to secure houses and other more elevated buildings, and ships at sea, from damage by lightning; and are taught that a very small metallic conductor, if elevated above the highest part of an edifice, and connected with the

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[86] In his History of Electricity, quoted before.

earth, is capable of conveying a very large quantity of electric matter from the clouds to the earth, without noise, and leaving no signs of its having been present.

But whoever may be desirous of repeating the experiments with an electrical kite, ought not to attempt the thing without the utmost caution, and a thorough knowledge of the science of electricity, lest he should share the fate of professor Richman, who through ignorance or inadvertence lost his life, in the midst of his family, during a series of experiments similar to those of which we are now speaking.

This ingenious and industrious man, who was professor of natural philosophy at Petersburg[87], had elevated an insulated metallic rod, and prepared a considerable apparatus[88] to collect the aërial electricity, as Dr. Franklin had previously done at Philadelphia; and as he

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[87] Professor Richman was born on the 11th of July 1711, after the death of his father, who was treasurer to the king of Sweden. He was made a member of the Imperial Academy in 1735, and professor of experimental philosophy in 1745.

[88] An engraving, and an ample description, of the apparatus employed by professor Richman may be seen in the xlviiith vol. of the London Philosophical Transactions; also a drawing of the apartments of the house, marking the room and the exact situation in which the professor stood when he received the fatal stroke.

was observing with Mr. Sokolow, engraver to the Royal Academy at Petersburg, the effects of electricity upon the balls of his electrometer, during a thunder storm[89] on the 6th[90] of August, 1753, approached too near the conductor, and receiving

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[89] He was attending the usual meeting of the Academy on the 6th of August, 1753, when hearing it thunder at a distance, he hastened home, in company with Mr. Sokolow, to witness its effects upon his apparatus, and in less than an hour became a corpse.

[90] In the xlviiith vol. of the Philosophical Transactions, the 6th of August is given as the day on which this accident happened ;—but in the xlixth vol. of the Transactions it is said to have occurred on the 26th of July: probably one is calculated from the old, the other from the new style.

the lightning in his head, was instantly struck dead by the side of his philosophical friend above mentioned.

The explosion, which attended this dreadful catastrophe, was as loud as the report of a pistol, the stroke was given at a foot distance from the rod; and from the description of Mr. Sokolow, the electrical spark which struck the professor must have been of a size several inches in diameter. The metallic rod was broken in pieces; and the melted fragments being thrown upon Mr. Sokolow's clothes, left the mark of their form and dimensions upon them.

The professor had seventy rubles

of silver in his left coat-pocket which were not in the least altered. But a clock which stood in an adjoining room was stopped, the door of one of the chambers was broken, and the ashes from the hearth were thrown about the room.

Mrs. Richman, on hearing the loud stroke of the thunder, hastened into the chamber, and found her husband past sensation, sitting upon a chest, which happened to be placed behind him, and leaning against the wall, which situation must have been occasioned by his falling back upon receiving the electrical charge. He was no sooner struck, than killed. There were not the least appearances of life. The surgeons opened a vein of the breathless body twice, but no blood followed. They endeavoured to recover sensation by violent friction, but in vain[91].

Fire produced by COLLISION, particularly when flint and steel are the media, arises from the sudden extrication of the *latent* caloric forced out by percussion, then becoming

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[91] Philosophical Transactions, vol. xlviii. page 765, and vol. xlix. page 61.

"When RICHMAN rear'd, by fearless haste betray'd,
The wiry rod in Nieva's fatal shade;
Clouds o'er the Sage with fringed skirts succeed,
Flash follows flash, the warning corks recede;
Near and more near HE eyed with fond amaze
The silver streams, and watch'd the sapphire blaze;
Then burst the steel, the dart electric sped,
And the bold Sage lay number'd with the dead!"

free and perceptible to our senses. It was first suggested by Mr. Hume[92], and his opinion is now found to be correct, that oxygen exists in a very large proportion and in a most condensed state in flint and all other siliceous stones. Were I, therefore, to hazard a theory upon the phænomena that take place in this instance, I should say,——the latent caloric thus set free had been previously combined with the steel, and perhaps with this condensed oxygen; and that the new compound, the spark which flies off, and is oxide

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[92] First edition of the Chemical Catechism, 8vo, 1806, page 151, and Philos. Magazine, vol. xxx. page 165.

of iron, requiring less latent heat for its composition, permits what is now superfluous to become *free* and active, and to pass to the tinder, gunpowder, or any other combustible substance to which it may be exposed.

This application of flint and steel to each other has lately been employed not only for procuring fire, but for another very important purpose.

The late Mr. Spedding, who was an engineer to some large collieries in the North of England, having observed that the coal-damp could only be kindled by flame, and was not liable to be set on fire by red-hot iron, invented a machine, in which, while a steel wheel is turned round with very rapid motion, flints are applied to it, and by the abundance of sparks emitted the miners are enlightened, and enabled to carry on their work in places where the flame of a lamp or candle would be likely to occasion dreadful explosions[93].

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[93] Mr. Beaumont, writing on the collieries near the Mendip hills, says, "Scarce a pit fails having this fire-damp, yet our colliers still pursue their work. To prevent mischief, they keep their air very quick, and use no candles in their works but of a single wick, and those of sixty or seventy to the pound, which nevertheless give as great a light there as others of ten or twelve to the pound in other places, and they always fix the candles behind them, and never present them to the breast of the work." Philosophical Collections for the years

Without some invention of this sort, the working of such mines would have been utterly impracticable[94].

PHOSPHORUS may be mentioned as another agent by which fire may be produced extemporaneously, at any hour and in any season. All that is necessary is to rub a morsel of it for a second or two, with a match or other small piece of wood, upon a piece of cork, and inflammation will quickly take place, and continue till the whole of the phosphorus be consumed. This peculiar substance is

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1679 to 1682, published by the Royal Society of London, page 7.

[94] A more particular account of this expedient may be seen in the Tradesman's Magazine, vol. ii. page 445.

chiefly of animal origin, though it be still doubtful whether it is not derived from the mineral kingdom, thence to vegetables, and so on to the animal system, where it is most abundant.

Phosphorus was discovered either by Brandt or Kunkel about the year 1669[95]. The product of its combustion is either phosphorous or phos-

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[95] " Nymphs! you disjoin, unite, condense, expand,
And give new wonders to the Chemist's hand;
With sudden flash vitrescent sparks reveal,
By fierce collision from the flint and steel;
Or mark with shining letters KUNKEL's name
In the pale Phosphor's self-consuming flame.
So the chaste heart of some enchanted Maid
Shines with insidious light, by Love betray'd;
Round her pale bosom plays the young Desire,
And slow she wastes by self-consuming fire."

DARWIN.

phoric acid, according to the mode in which the combustion has been conducted, and the quantity of oxygen absorbed.

Fire may also be procured with great facility from a saline compound, called " The HYPER-OXYGENIZED MURIATE OF POTASS." This salt contains so large a portion of condensed oxygen and caloric, that, if it be intimately mixed with any of the highly combustible substances, and the salt be then decomposed, fire and combustion will be the consequence.

A preparation of this sort may very conveniently be made by mixing some of the salt with about an equal portion of loaf sugar, both in fine powder. This is a mixture which may be kept ready prepared and preserved in a phial for any length of time, with perfect safety. Whenever fire is required, all that is necessary is to put a few grains of this mixture upon a bit of tile or on a plate, and then to drop upon it the most minute quantity of concentrated sulphuric acid, which will occasion an immediate burst of flame, increasing in size till the whole mass enters into actual combustion.

A composition of this kind has been lately employed for coating the ends of matches instead of sulphur; and these are more convenient for procuring fire, or an instantaneous light, than any thing which has ever before been offered to the public. In using them, all that is necessary is to dip the coated end of one of them into sulphuric acid, or into a phial of asbestos impregnated with that acid, and it will take fire immediately. The asbestos is put in to prevent the acid from spilling, as cotton in a common inkstand. The fire in this case is produced in consequence of the decomposition of the hyperoxymuriatic salt by the sulphuric acid, which seizes the base of the salt, and liberates its oxygen and caloric, which occasion this curious phænomenon.

By mixing this salt with other combustibles, such as sulphur and charcoal, in proper proportions, a preparation will be formed which will inflame merely by percussion or friction; and an ingenious Scotch chemist has taken advantage of this property of the hyperoxymuriate of potash, and employed it in the manufacture of a new kind of gunpowder, which, for the use of sportsmen and some other purposes, is preferable to common gunpowder. An eighth of a grain of it is sufficient for priming a fowling-piece or a musket, and this of itself makes a very loud report[96].

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[96] A more particular account of this new gunpowder, and which I received myself from the patentee, will be found in the Chemical Catechism, Additional Notes, No. 56.

To these methods of procuring fire may be added that of COMPRESSION. It is a general maxim in chemical science, that extension and rarefaction[97] occasion cold, but that condensation and compression generally produce heat.

[97] This principle is well exemplified in a machine erected at one of the mines in Hungary. In this apparatus the air within a large cylinder is very forcibly compressed by a column of water 260 feet high. Therefore whenever a stop-cock which is attached to the lower part of the cylinder is opened, the compressed air rushes out with great violence, and its expansion is so sudden and considerable that the moisture which was contained in the compressed air is immediately condensed, and falls in a shower of snow. Dr. Wolfe has given a drawing and an ample description of this machine in Phil. Trans. vol. lii. page 547.

Some time ago a soldier in the French army discovered that light and heat are produced merely by the compression of atmospheric air. This curious discovery has been acted upon in various parts of Europe, and is likely to be of use in common life. By adapting a moveable air-tight cap to the bottom of a common syringe, and placing within it a small piece of common tinder, and then depressing the piston with a sharp quick motion, heat will be produced sufficient to inflame the tinder. The use of the screw cap at the end of the syringe, is not only to render the instrument air-tight, but for the purpose of receiving the fungus or tinder to be placed within it.

These syringes are now sold by most of the philosophical-instrument-makers in London; and since the exhibition of this small but useful apparatus, it has been proposed to make walking-sticks furnished with similar syringes, (though for this purpose these syringes must be inverted,) and so contrived that a single stroke of the walking-stick on the ground would be sufficient to inflame the tinder, and afford the traveller a light in any emergency.

There is another mode of procuring fire, viz. by PERCUSSION; and this may be exemplified by the brisk hammering of malleable iron[98].

[98] FRICTION, which seems to be only a

Nothing is more common in some countries, where fuel is dear and fires are not kept up during the night, than for a smith to procure a light

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succession of percussions, will also produce intense heat. Mr. Thomas Wedgwood held the edge of a piece of window-glass against the edge of a revolving grit stone, and the part in contact with the stone became red hot and threw off particles which fired gunpowder. Phil. Trans. for 1792, pages 45 and 270. Since then Count Rumford suspended a metallic cylinder within a quantity of cold water measuring eighteen pints, and caused it to revolve, pressing against a boring instrument, at the rate of thirty times in a minute; and in the course of two hours and thirty minutes it generated heat enough to make the water actually boil. See an Inquiry concerning the Source of the Heat which is excited by Friction. Phil. Trans. for 1798, page 80.

in the morning by laying a bar of iron across an anvil and hammering it incessantly till it become hot enough to set fire to tinder. Here, a portion of the caloric which is naturally latent in the iron, and tends to give it malleability, is forced out by the continued hammering, and becomes free and efficient heat.

It is also possible to produce combustion by the mere MIXTURE of some fluid substances. Thus, if certain proportions of nitrous and sulphuric acid be poured into some of the essential oil of turpentine, a rapid combustion and inflammation will be occasioned. This, however, is not a very safe experiment, unless it be conducted with caution and prudence.

It may also be mentioned, that if either of the new discovered metals, POTASSIUM or SODIUM, be placed upon ice, fire will be produced, and the metal by this combustion will be converted to an alkali [99].

Combustion often occurs spontaneously by the DECOMPOSITION OF WATER; of this we have many instances. Hay, clover, weld, or other vegetables, if put up in ricks before they are properly dried, are very apt to ferment, and occasion spontaneous combustion. Substances that are thoroughly impregnated with

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[99] Phil. Trans. for 1808, pages 13 and 14.

animal or vegetable oil, when laid up damp and in large heaps, are also very likely to take fire of themselves from the decomposition of the water and the oil. This happens sometimes to painted oil-cloths, and likewise to woollen cloths [100], which have been laid up in heaps and moist, without having the oil removed which had been employed in dressing them. There are examples of cotton taking fire by being improperly laid up [101]; and the sponta-

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[100] There is a singular account of the spontaneous decomposition of a fabrick of silk, in the Philos. Magazine, vol. xvi. page 92.

[101] Dr. Henry accounts for the fires which have sometimes happened in cotton-mills, from the waste cotton, employed to wipe the

neous firing of a mixture of lamp-black and oil is well known [102]. I believe it is also no very uncommon thing for buildings to be burnt down in consequence of quick lime being incautiously stored in them and water getting access to it.

Again, *peat* laid up in very large heaps for fuel is disposed to take fire [103]; and in coal countries it is

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oil from machinery, having been laid in heaps sufficiently large to occasion combustion. Henry's Chemistry, vol. ii. page 162.

[102] There have been instances in which carburetted earths, being mixed with linseed oil for the purpose of making paints, entered spontaneously into a state of combustion. Gentleman's Magazine, vol. xxi. page 71, and vol. xxii. page 82.

[103] Berthollet on Dyeing, vol. i. page 177.

universally known that if pyritous coal be stacked without having the martial pyrites previously picked out, there is great danger that the first shower of rain may produce heat enough to set fire to the whole mass [104].

This combustion of pyritous coal is probably the cause of many of the

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[104] Dr. Plot relates the case of a person at Ealand in Yorkshire who piled several cart-loads of martial pyrites in a barn, of which the roof being faulty, the rain came upon them, and set fire to the building, and occasioned an alarm for the safety of the whole town. Plot's Staffordshire, page 142.

Dr. Jorden mentions that a heap of coals once took fire at Puddle wharf, London, in consequence of pyrites being mixed with them. Jorden on Mineral Waters, chap. 14.

subterranean fires which appear in every quarter of the globe. Near Baku in Persia, the inflammable vapour which issues from the earth is so considerable that the inhabitants burn their lime by its means. There is a caravansary [105] built on the spot,

[105] "This is a very old vaulted building, and in its walls are many chinks, whereto if a candle be applied, the fire catches instantaneously, and runs wherever the chinks communicate. They have hollow places in the house fitted to their pots, where they boil without any other fuel; and instead of candles they stick reeds into the ground, from the tops whereof, upon applying fire thereunto, a white flame comes forth, and continues to burn without consuming the reeds, until they think proper to extinguish it, by putting little covers over them for that purpose." Phil. Trans. vol. xlv. page 296.

and in this live twelve Indian priests and other devotees who worship this fire, which, according to their traditions, has burnt many thousand years[106].

Dr. Plot speaks of a district near the Staffordshire collieries which was on fire in his time[107]. This spot I have visited myself, more than once, and the mass of coal within the bowels of the earth is still burning, and probably will not cease for ages

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[106] Other curious particulars respecting this subterranean fire may be seen in Mr. Jonas Hanway's account of his travels through Persia.

[107] Plot's History of Staffordshire, chap. iii. page 141, § 53.

yet to come[108]. The poor inhabitants of that neighbourhood call it the *fiery ground,* and felicitate themselves in living so near it, as many of them make considerable sums of money, early in the year, by the produce of their gardens, which are always some weeks forwarder than any other in that part of the kingdom. Some of the esculent vegetables flourish surprisingly on this spot;

"Where, in basaltic caves imprison'd deep,
Reluctant fires in dread suspension sleep;

[108] There is a fountain near Grenoble in Dauphiné; another in Transylvania; a third near Chermay, a village in Switzerland; a fourth in the canton of Friburg; and a fifth not far from Cracow in Poland, the waters of which take fire and burn. Campbell's Political Survey, vol. i, page 73.

Or sphere on sphere in widening waves expand,
And glad with genial warmth the incumbent land."

I have mentioned elsewhere that His Majesty's ship Ajax is supposed to have been destroyed in the Mediterranean entirely by the sudden combustion of a heap of this species of coal, then on board for the use of the ship. I also noticed that a friend of mine had a serious accident from the spontaneous inflammation of a mixture of hyperoxymuriate of potass, charcoal, and sulphur.

All such accidents may be explained, by referring them to the decomposition of water, and the inflammation of its hydrogen [109]. But there are instances on record of another kind of spontaneous combustion, which is not so well understood, viz. that of the human body absorbing oxygen with such rapidity as that the whole became silently consumed to ashes; and this, independent of any outward agent, to which the commencement of the combustion could possibly be attributed.

Several cases of this kind have been

[109] There is an account of a great variety of cases of spontaneous combustion, in the 18th volume of the Phil. Mag. extracted from a memoir by Mons. Bartholdi, in one of the volumes of the Annales de Chimie.

described and well authenticated [110]; though it is remarkable that this has never been known to have happened to any but females, and all these were persons who had long indulged themselves in an inordinate use of spirituous liquors.

The means which have been employed in different parts of the world for MODIFYING the effects of HEAT AND COLD, have been so various, that I can only attempt to enumerate a very small proportion of them. But I shall select those which I do not consider to be very generally known,

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110 Philos. Magazine, vol. vi. page 132; Gent. Mag. vol. vi. page 647; Phil. Transactions, vol. xliii. page 447.

or such as may probably be applied, though in a different way, to some useful purpose in this country.

If we begin with that part of the subject which refers to the MODIFICATION of HEAT, or the reduction of temperature, it must be remarked that this is often effected on different principles, according to situation and circumstances.

In some cases the principle of producing cold by EVAPORATION is resorted to. Thus in India, where the apartments are separated from their courts by curtains instead of walls, slaves are employed in perpetually sprinkling these curtains with water, the evaporation of which, when constantly kept up, will reduce the temperature of the rooms ten or fifteen degrees.

The alcarazas of Spain for cooling wine act on the same principle. These, which are very porous earthen vessels, are prepared for use by soaking them in water for a considerable time, so as to saturate them with that fluid. Within these earthen jars vessels containing the wine are introduced, and the perpetual oozing and evaporation of the water [111] cools the interior of the vessel, and conse-

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[111] The ice-makers at Benares discard all those vessels in which the pores have become stopped by long use, and they find that if the water be exposed in porcelain vessels, no ice is produced. Universal Magazine for 1793, page 420.

quently reduces, in some measure, the temperature of the wine or other liquor placed within it.

These, however, at least all that I have seen, are ill calculated for the purpose; for, being so much larger than necessary, a sheet of air of the temperature of the room envelops the wine bottle, and prevents the proper action of the alcaraza upon it; whereas, if they were made perfectly cylindrical, instead of being bulged, and no larger than just sufficient to admit a bottle of wine within them, they would be much better refrigerators than those which are usually sold for this purpose[112].

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[112] As these utensils lower the temperature of wine only a few degrees, it would be a

This principle of cooling by evaporation is well understood by the caravans who cross the great desert of Arabia. These people have occasion for a large quantity of water, which they carry with them on camels, in bottles of earthen-ware, and which, in passing over the burning sands of that country, would become very disagreeably hot, were it not for the following expedient, which is universally adopted by

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much more effectual method of cooling, merely to plunge the bottles into a vessel of water recently drawn from a very deep well. Indeed, I once knew a gentleman who sunk a large well on purpose to store his port wine in, and he assured me that he found it to be a very advantageous mode of keeping it.

them. When they lay in their stock of water, each bottle is infolded in a linen cloth, and some of the company are appointed to keep these cloths constantly wet [113] during the journey; by which means a perpetual evaporation is produced, and the contents of the bottles are preserved at a cool and refreshing temperature.

In like manner, "in the nights in

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[113] Athenæus relates, that in Egypt the pitchers filled with water, which had become warm by standing all day long in the sun, were kept continually wet during the night by servants destined to that office; and in the morning, to preserve the water at the cool temperature to which this expedient had reduced it, the pitchers were bound round with straw. Deipnosophists, iii. page 124.

Bengal, when the temperature is not below 50°, by the exposure of water in earthen pans upon moistened bamboos, thin cakes of ice are formed, which are heaped together and preserved under ground by being kept in contact with bad conductors of heat[114]."

In performing some delicate chemical experiments, the application of this principle may be found extremely useful. Thus, any fluid body which has been heated by mixture or otherwise, may, in a few minutes, be brought to the desired temperament by frequently wetting the containing vessel with ether, which, by

[114] Davy's Chemical Elements, page 88.

the rapidity of its evaporation[115], and consequent abstraction of caloric, instantly lowers the temperature[116].

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[115] Should any one doubt the efficacy of evaporation in producing cold, let him suspend a thermometer in the air, and, having wet the bulb with ether once or twice, notice its operation as indicated by the scale of the instrument. For an account of an expeditious mode of producing ice by the evaporation of sulphuric ether, see Phil. Trans. for 1795, or Monthly Review, New Series, vol. xxi. page 299.

[116] Evaporation is also a drying as well as a cooling process. When I have wanted a bottle in haste to be thoroughly dry, for taking specific gravities or any other nice philosophical purpose, after washing it with water, and draining that out as well as I could, I have rinsed it with a little ether, and it has been dry in an instant.

But the more ancient, and perhaps the most universal mode of reducing the temperature of bodies, was by means of ICE and SNOW. That these were used for this purpose in the time of Solomon, we have the testimony of some of the most ancient writings[117]; and we are told that Alexander the Great, when he lay before the besieged city of Petra, having an eye to the delicacies of his table, caused thirty trenches to be dug, and filled with snow, which was defended from the sun by oak

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[117] "As the cold of snow in the time of harvest, so is a faithful messenger to them that send him: for he *refresheth* the soul of his masters." Proverbs xxv. 13.

branches, and preserved for a long time[118].

The snow of Lebanon was in high estimation in the days of the prophet Jeremiah[119]; and according to Mr. Harmer, the present inhabitants of Palestine collect snow during the summer months, from the top of the same mountain, and carry it two or three days journey, "that, being (as he says) mixed with wine[120], it may keep it as cold as ice[121]."

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118 Athenæi Deipnos. iii. 124. Beckman, vol. iii. page 344.

119 Jeremiah xviii. 14.

120 According to the writer of the Travels of Anacharsis, the ancient Athenians usually mixed a small quantity of sea water also in their wine.

121 Harmer's Observations on divers pas-

The celebrated Abbé Nollet, who drew up a memoir on the means of supplying the want of ice in warm countries, advises the keeping of wines and other potable liquors in the following manner, in preference to keeping them in wells, cisterns, or cellars. He recommends the digging a hole in the earth about four feet deep, in which the liquor should be placed in bottles, covering them over with a foot of earth, dug from the bottom of the hole, and moistened with a little water, after which he advises the covering up the mouth of the hole with a plank, strewed over with new

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sages of Scripture, vol. ii. page 156, Clarke's edition.

dug earth[122]. In adopting this method it will be essential not only that the liquor should be put into the thinnest bottles, but also that these should be of such a form as to afford the greatest quantity of surface to the refrigerating agent. Hence several thin glass bottles will be much better than only one of thick glass.

Ice and snow in hot countries being applicable to so many useful purposes[123], it was natural for mankind to devise some mode of preserving them in all seasons. Hence ice-

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[122] History of the Royal Academy of Sciences at Paris, for the year 1756.

[123] Thomas Bartholin, physician to the king of Denmark, published a treatise on the medicinal uses of snow. Copenhagen, 8vo, 1661.

houses were built, but the era of their invention is not known. That the ancient Romans were acquainted with them is evident from the writings of Pliny, who passes this severe censure upon them:

"Hi nives, illi glaciem potant, pœnasque montium in voluptatem gulæ vertunt: servatur algor æstibus, excogitaturque ut alienis mensibus nix algeat[124]."

It appears, however, that the practice of cooling liquors, at the tables of the great, was not usual in any

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[124] Lib. xix. c. 4. Martial in one of his epigrams sports with it thus:

"Non potare nivem, sed aquam potare rigentem
De nive, commenta est ingeniosa sitis."

MART. xiv. Ep. 117.

country of Europe, excepting in Italy and the neighbouring states, before the end of the sixteenth century; and there is a direct testimony on record, that in the middle of that century there were no ice-cellars in France[125]. However, before the end of the seventeenth century the luxury of ice was very common in France; for about that time there were many persons who were professed dealers in snow and ice[126]; and in 1676

[125] Beckman, vol. iii. page 356.

[126] Quintine, the celebrated French gardener, relates that once, when no ice could be procured on account of the great mildness of the preceding winter, the merchants at Hamburgh sent a ship to Greenland for a load of it, by which they acquired great profit. Instruction pour les Jardins, Paris, 1730, 4to, i. p. 263.

there were not less than two hundred and fifty shops in Paris alone for the sale of liquors of different sorts cooled with ice[127].

In regard to the receptacles for ice, I have not met with any account of the mode in which the ancient Romans constructed their ice-houses, and therefore I can give only a few particulars respecting the modern practice.

In the first volume of the Philosophical Transactions, to which I am indebted for the passages which I have just quoted from Pliny and Martial, I find the following sentence: " The usual way in Italy

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[127] Beckman, vol. iii. p. 362 and 378.

and other countries, to preserve snow and ice, is set down so punctually by Mr. Boyle, in his History of Cold, that nothing is to be added[128]." I have cursorily examined Mr. Boyle's work, and am indebted to it for some curious information: but my copy is probably a different edition from that used by the writer of this article, for I cannot discover the relation alluded to; and Mr. Boyle's treatise on cold is printed so close, and contains so much abstruse and obsolete matter, that rather than employ unnecessary time in labouring through so many uninteresting pages, I merely mention it, that others may,

[128] Philos. Trans. vol. i. page 140.

if they please, avail themselves of the information.

At Leghorn and in other places in that neighbourhood, they lay the bottom of their ice-pits with a thick covering of corn chaff; and as the ice is placed within them, the chaff is brought up all round the sides, and when the pits are full they are well covered up with the same article. Whenever it is necessary to remove any of the ice to a distance from these pits, it is infolded in similar chaff, and is thus preserved from melting[129].

Sir Robert Barker has given a very particular account of the method of making ice at Calcutta and other

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[129] Philos. Trans. vol. i. page 139.

parts of the East Indies[130] lying between $25\frac{1}{2}$ and $23\frac{1}{2}$ degrees north latitude, where natural ice is never seen. But I shall refer my readers to the paper itself for particulars[131]; and also to any of the modern Encyclopedias for an account of the present mode of building ice-houses in England, as a full description of

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[130] Olearius, in an account of his journey to Muscovy and Persia, relates that at Ispahan the inhabitants have conservatories, which they furnish with solid pieces of ice of a good thickness, only by pouring water at night, at certain intervals, upon a sloping floor of free-stone or marble, where it becomes frozen and attached to the former coat of ice, and in two or three successive nights is brought to a very considerable thickness.

[131] Philos. Trans. vol. lxv. page 252.

them is not compatible with my present plan.

The late Mons. Fourcroy, when treating of temperature, remarks, that "chemists often avail themselves of the privation of caloric, in order to prevent the effect of chemical action[132]; to impede the too powerful energy of solutions, combinations and decompositions; or to

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[132] There is a curious memoir by Gren, in the 27th number of the Journal des Mines, on the formation of sulphate of soda in salt waters, and upon an easy method of disengaging all the deliquescent salts, at a temperature beneath the freezing point of water. An abridgement of this paper is also printed in the 24th volume of the Annales de Chimie, p. 121, and in Nicholson's Journal, 4to, vol. ii. page 91.

prevent those spontaneous changes which do not fail to take place in certain compounds, if they remain for a time exposed to a temperature sufficiently elevated to favour the mutual action of their principles. By these means, namely, by a cold temperature, vegetable and animal substances are preserved [133]; and thus it is that an ice-house is scarcely less

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[133] Captain James, whose ship was frozen up all the winter in one of the coldest regions of the world, writes thus: "We got up our five barrels of beef and pork, and had four butts of beer and one of cyder, which God had preserved for us: it had lain under water all the winter, yet we could not perceive that it was any thing the worse." T. James's Journal, page 74.

useful to the chemist[134] than a furnace at its different degrees of heat[135]."

As it is well known that some decompositions take place at a temperature below 32°, which cannot be effected at one more elevated, it might be worth while for a chemist who has access to an ice-house, to institute a series of experiments, in order to determine the affinities of the simple substances, and some of

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[134] Many uses of cold might be mentioned. Stone bottles grown musty by use, if partly filled with water, and the water thoroughly frozen, become as sweet as ever they were. Boyle, Appendix page 12.

[135] Fourcroy's System of Chem. Knowledge, vol. i. page 190.

their compounds, when submitted to the action of intense cold.

It may also be worth while to inquire whether an ice-house might not be employed with advantage during the summer months in preserving meat[136]. We know that

[136] The Hon. Mr. Boyle relates that the physician to the Emperor of Russia assured him that he had had the venison of elks sent him unsalted, and yet untainted, out of Siberia, which is some hundreds of leagues distant from Moscow, and that beef and other flesh well frozen would keep for a very long time uninjured; and that it will have lost none of its natural flavour, provided it be very gradually and thoroughly thawed, before it be dressed for the table. Experiments on Cold, 4to, London, 1683, page 85.

" At Spitzburg the extreme cold will suffer from the salmon fisheries in Scotland and the north of England, the fish are sent to the metropolis, during the greater part of the season, packed with ice, in boxes about four feet long and eighteen inches deep. When packed, the ice, which is previously broken as small as bay-salt, is put over them and beaten down as hard as can be without bruising the salmon. In this manner they are kept perfectly fresh for two or three weeks [137].

There is another way of modify-

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nothing to putrefy and corrupt, insomuch that buried bodies are preserved entire for thirty years, and inviolated by any rottenness." Bartholinus de Usu Nivis, cap. 12.

[137] The Tradesman's Magaz. vol. ii. p. 520.

ing heat which has not yet been adverted to, and which is comparatively of late invention. I refer to the use of certain SALINE BODIES, which absorb a large portion of caloric during their solutions, and consequently produce a great degree of cold.

The salt which was originally used for this purpose was nitre, and the Italians were the first people by whom it was employed. About the year 1550, all the water as well as the wine drunk at the tables of the great and rich families at Rome was cooled in this manner. It was customary to place the bottle containing the wine within a larger vessel of water, and into this they gradually put as much saltpetre as is equal to one fourth or one fifth of the weight of the water, and during its dissolution the wine was driven round by the hand with a quick motion on its axis, in one direction [138].

After this, other salts were employed; and Lord Bacon, who died in 1626, asserted that, by a mixture of snow with common salt [139], he could freeze water [140]. In the Mineralogy of Aldrovandus, first printed in 1648, it is said "that it was usual

[138] Beckman, vol. iii. page 363.

[139] The iced creams are now, I believe, usually made by plunging the vessel of cream into a mixture of bruised ice and common salt.

[140] Historia Vitæ et Mortis, § 44. Silva Silvarum, cent. i. 83.

in countries where fresh water was scarce, to make deep pits in the earth, to throw rock-salt into them, and to place in them vessels filled with water, in order that it might be cooled."

When snow is mixed with common salt, both substances soon become in some measure liquid[141]. Now it is well known that solids can never become fluid without heat being absorbed, and consequently cold produced: therefore the abstraction of that portion of free ca-

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[141] The windows in Russia are frequently covered with frost, and it is a common practice to clean them with salt. By rubbing the glass with a sponge dipped in common salt, the ice quickly dissolves, and the glass becomes immediately transparent.

loric from the materials which is necessary to produce fluidity[142], is sufficient to account for the formation of ice in a fluid that is immersed in it.

Towards the latter end of the seventeenth century, Mr. Boyle made experiments with various kinds of salts and other substances for reducing the temperature of water, and in the year 1683 published his "Experiments and Observations touching Cold;" a work of great labour and ingenuity[143]. By these

[142] Mr. Boyle so early as the year 1683 noticed that no salt mixed with snow would produce ice, "unless it helps the snow to dissolve faster than else it would." History of Cold, title i. § 13.

[143] He describes how real snow may be

researches he discovered that either common salt, alum, vitriol, sal ammoniac, lump-sugar, oil of vitriol, nitrous acid, caustic ammonia, or alcohol, when mixed with snow, had the power of freezing water, and thus laid the foundation for the modern discoveries on frigorific mixtures[144].

About this time the use of a mixture of snow[145] and common salt

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made artificially; he also speaks of a useful syphon which may be made with ice. Additional Experiments, pages 14 and 16.

[144] Experimental History of Cold, title i. pages 46—50.

[145] It is related, that the Duke of Tuscany distilled alcohol from wine, merely by putting snow upon the alembic, without the help of fire. Bartholinus de Nive.

had become very common in several countries in Europe[146]; but a long period intervened before any facts of importance were added to those which Mr. Boyle had published on this subject.

The art of making ice was for many years practised only as an amusement, and no one suspected that it would ever be applied to such important purposes[147], both of science

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[146] It was by a mixture of this sort that Fahrenheit, in the year 1710, fixed the zero of his thermometer; and he supposed this was the *extreme* point of cold.

[147] Some modern demonstrators in anatomy have availed themselves, as I have been told, of the use of frigorific mixtures in the dissection of the brain and the eyes of animals. To the great Boyle they are probably indebted for

and luxury. Like gunpowder, and many other valuable discoveries, it was at first considered to be of very trifling consequence [148].

In the beginning of the seventeenth century, however, drinking-cups made of ice [149], and iced fruits

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the idea; for in his History of Cold he says, "many years since, I made an experiment of freezing the eyes of oxen and other animals, whereby the fluid humours of that admirable organ may be so hardened, as to become tractable, even to unskilful dissectors. So I did with the brains of animals, which, though too soft to be easily dissected, may by congelation be made very manageable." Boyle's History of Cold. Postscript, page 253.

[148] Beckman, vol. iii. page 373.

[149] Very easy and simple directions for making ice-cups for drinking of wine in

were brought to table; and before its conclusion the French began to congeal all kinds of well-tasted juices, which were served up as refreshments at the tables of the great and wealthy[150].

In the year 1621 Barclay's Argenis, an interesting romance, was published at Paris[151], and its author places on the table of Juba, in the

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summer, will be found in Mr. Boyle's History of Cold, title xiv. page 137.

[150] Beckman, vol. iii. page 373.

[151] The Argenis has gone through many editions, and has been translated into most of the European languages. The first edition has an excellent portrait of the author, with this singular inscription by Hugo Grotius:

> "Gente Caledonius, Gallus natalibus, hic est
> Romam Romano qui docet ore loqui."

middle of summer, fresh apples for Arsidas, one half of which were incrusted with transparent ice. A bason of ice[152] filled with wine was also handed to him, and he was informed that to prepare all these things in summer was a new art[153].

A few years after the publication of the book just mentioned, a new

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[152] How this bason of ice was made, the author has informed us. "Two cups," says he, "made of copper were placed the one within the other, so as to leave a small space between them, which was filled with water: the cups were then put into a pail, amidst a mixture of snow and unpurified salt coarsely pounded, and the water, in three hours, was converted into a cup of solid ice, as well formed as if it had come from the hands of the pewterer."

[153] Barclay's Argenis, book v. chap. 5.

beverage was introduced, called *le-monade,* which soon came into high repute, and was recommended by physicians against putrid diseases. About the year 1660 an Italian from Florence, having learnt a process of freezing confectionary, which had been before employed only by jugglers, conceived the happy idea of converting such beverage entirely into ice. This found a ready sale, and was the occasion of so great an increase in the number of sellers of lemonade, that in the year 1676 the *lemonadiers* of Paris were formed into a company, and received a patent from the government[154].

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[154] Beckman, vol. iii. page 377.

In the beginning of the next century the principle of congealing water by the mixture of salt or nitre with ice and snow was so well known[155], that it was then become, in Paris and elsewhere, a common amusement for children, who had a trick of placing a jug containing a mixture of snow and saltpetre on a table over which water had been poured, and agitating the mixture with a stick till the jug became firmly frozen to the table[156].

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[155] The Duke de Chartres went often to a certain coffee-house in Paris to enjoy a glass of iced liquor. One day, in the year 1774, the landlord, we are told, to the great satisfaction and surprise of the Duke, presented him with his coat of arms formed of eatable ice.

[156] Beckman, vol. iii. page 373.

However, after the investigations of Boyle, no scientific experiments on the production of artificial cold seem to have been made till the subject attracted the attention of Dr. Blagden, Mr. Cavendish, Mr. Lowitz, and Mr. Richard Walker, who were at that time separately engaged in the same pursuit. The latter gentleman, however, was the first person who succeeded in producing ice in the middle of summer, merely by the solution of saline substances, without the aid either of ice or snow.

Having been thus successful, Mr. Walker pursued his experiments, and on the 20th of April 1787 actually succeeded in his attempt to freeze mercury. At the commencement of the experiment the temperature of the mercury was 45°; and as its freezing point is at 39° below zero, he obtained, without using a particle either of snow or ice, a reduction in temperature amounting to 84 degrees[157].

The apparatus[158] which Mr. Walker used in this experiment consisted

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157 This experiment, by which mercury was first seen in Great Britain in a state of solidity, was made at Oxford, Mr. Walker being at that time apothecary to the Radcliff Infirmary in that city.

158 A more simple and convenient apparatus for freezing mercury has been contrived by Dr. Henry. See his Elements of Chemistry, plate iv. fig. 42. Another, on a different construction, by Mr. Pepys, may be seen in the Phil. Mag. vol. iii. page 76.

of four pans, progressively diminishing in size, placed one within another, and these, when thus arranged, were all placed in a vessel still larger. Some of the materials for producing the reduction of temperature were put in each of these pans, and others in bottles in the spaces between them, so that those in the outermost pan received, before being put together, the cold produced by the frigorific mixture in the larger vessel; and those in each of the inner ones received, in like manner, the progressively accumulated cold of the next exterior pan [159].

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[159] See Walker on Artificial Cold, 8vo, Oxford, 1796.

The materials which Mr. Walker employed were strong nitrous acid, sulphate of soda, and nitrate of ammonia. Other substances have also been employed for the same purpose, viz. muriatic and sulphuric acids, pure potash, nitrate of potash, muriate of ammonia, sulphate of soda, phosphate of soda, and various other salts[160].

But the cheapest and most efficacious salt which has been employed for the reduction of temperature is

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[160] The expense of making frigorific mixtures is trifling, because, in many cases, the salts may be recovered by evaporating the water in which they were dissolved. Mr. Walker, who was in the habit of recovering the salt, remarks that no diminution was observed in its effect, after many repeated evaporations.

the muriate of lime, which was first used by Mr. Lowitz; and this when mixt with snow is extremely active in the production of cold[161]. Five parts of this salt well dried[162], and in the state of crystals, with three parts of snow, sank the thermometer, in Mr. Walker's experiment, from 32°

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[161] It should be remembered that every frigorific mixture has a certain point of temperature beyond which it can never act in the production of cold, and this is the point at which the mixture itself becomes frozen.

[162] Mr. Lowitz directs, not only that the muriate of lime should be perfectly well dried, but that it should be in that state in which it is crystallized with the largest possible quantity of the water of crystallization, which is effected by putting the solution to cool when of the specific gravity of 1.50 or 1.53.

to —53°, which was a reduction of 85 degrees [163].

The different materials for producing cold may be mixt in a variety of ways; but as several circumstances should be attended to, according to the nature of the articles employed [164], in order to afford a

[163] The greatest artificial cold which has yet been measured was —91°, which is 52° lower than the point at which mercury congeals, and 123° below the freezing point of water.

[164] Dr. Beddoes has remarked that sulphate of soda, while it retains its water of crystallization, produces, on the addition of sulphuric acid diluted with an equal weight of water, 46 degrees of cold; but when it has fallen into powder by being deprived of its water of crystallization, it produces heat rather than cold; and yet that sal ammoniac and nitre,

favourable result, I must refer the reader to Mr. Walker's publication itself for proper instructions[165].

Having offered these remarks on the modification of heat, and on the means of forming and preserving ice, a few observations on some of the means of guarding against and MODIFYING the effects of COLD, may not be unacceptable to the reader.

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when well dried in a crucible, produce a greater degree of cold than if they had not received this treatment. Beddoes on Artificial Cold, in the Phil. Trans. for 1787.

[165] Where salts of any kind are employed, it is of consequence to have them fresh crystallized, thoroughly dried, and then finely pulverized. The mixtures should be made rapidly, and in vessels as thin as can be procured.

Nature has made choice of several expedients for lessening the power of cold, and moderating the rigour of severe winters. The snow which generally covers the earth at this season, is one of these, and it is very efficacious in preserving the earth at one uniform temperature, however cold may be the surrounding atmosphere[166]. In like manner the at-

[166] Dr. Fletcher, Ambassador to the Court of Russia in the time of Queen Elizabeth, remarks thus: "This fresh and speedy growth of the spring there, seemeth to proceed from the benefit of the snow, which all the winter time being spread over the whole country, as a white robe, and keeping it warm from the rigour of the frost, in the spring time the sun draweth the herbs and plants forth in great plenty and variety in a very short time."

mosphere itself, being a bad conductor of heat, is a great preserver of the earth's temperature. Were it not for the atmosphere, the caloric inherent in the globe would soon pass off and be dissipated in unbounded space.

The temperature of the human body is uniformly preserved in the same manner. The air which is infolded with our garments prevents the animal heat from passing off, and hence it is that loose clothing is generally warmer than that which is fitted closer to the body.

There seems to be a living principle in vegetables, in the seeds of vegetables, and in fish, which enables these to resist the effects of cold, and of becoming frozen in temperatures lower than that at which water congeals. For, in rivers and other great bodies of water, when the water freezes, the rapidity of the process is moderated by the water itself giving out a large portion of caloric, during the act of freezing[167]. This circumstance is, in a variety of in-

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[167] Dr. Black has an experiment which decisively proves this to be a fact. "If," says he, "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 will gradually cool down to 22° without freezing. Things being in this situation, if the water be shaken, part of it instantly freezes, and the temperature of the whole rises to the freezing point, so that the water acquires 10° of caloric in an instant."

stances, of incalculable benefit to the world, besides shortening the duration of winter, and lessening its severity.

Man, in different parts of the world, has availed himself of some of these principles, and applied them artificially, either to better his situation with respect to climate, or to aid him in the common operations of life.

Thus, during the winter at Hudson's Bay, the surface of the lakes and rivers is covered with ice of such great thickness, that no water can be procured without cutting through the ice with axes and wedges, which is a very laborious and tedious operation. As soon, therefore, as the surface of the water which has been laid open has acquired a thin plate of ice, the labourer heaps over it a quantity of snow, which, by being a bad conductor of heat, prevents the caloric of the water from passing upwards according to its natural tendency. It is by this expedient that during the remainder of the winter the inhabitants have only to remove a little of the snow, when occasion may require it, and they have water immediately.

In some northern regions, where there are fortified places surrounded by moats, the inhabitants have staved casks of fish oil into the intrenchments, when they have been afraid of the approach of an enemy, that the oil, thus interposed between the surface of the water and the atmosphere, and being incongealable by cold, might protect the subjacent water from freezing, and keep the moats impassable [168].

The circumstance of an undisturbed body of atmospheric air defending whatever may be inclosed within it from the accession either of heat or cold, has, of late years, been taken advantage of in a variety of instances. Hence the origin of double doors and double windows, which infold sheets of air between them, and thus preserve the apartments at one uniform

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[168] Olaus Magnus in Historia Gentium Septentrionalium, lib. xi. cap. 20 & 21.

temperature. For, as atmospheric air is a bad conductor of heat, the doors and windows guarded in this way neither admit the heats of summer nor the cold of winter from without, while at the same time they prevent the escape of that genial warmth which it is so desirable to preserve in the apartments of the sick and the aged at all seasons.

In like manner certain culinary utensils are fitted up with double covers of block tin or copper, and in such utensils any fluid will boil sooner than it would in others, and will also be preserved at any particular temperature by the consumption of less fuel than would be required if they were covered only with single covers[169]. By similar contrivances the apparatus in some manufactories is sooner heated and easier preserved at one and the same temperament.

A modern philosopher[170] has

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[169] There are several very decisive experiments on the advantages of double covers, in Rumford's Essays, vol. ii. page 17 &c.

[170] "A cylinder canister," says he, "of planished tin, two inches in diameter, and of equal height, filled with boiling water, took 117′ to cool from 30° to 10°; but enclosed within a similar canister of four inches in diameter, it required 176′ to make the same descent. Another cylindrical canister of four inches, and which took 156 to cool from 20° to 10°, required 356′ when cased with a similar one of five inches." Leslie on Heat, 8vo, London 1804, page 3ъ0.

shown, by direct experiment, the effect of a sheet of air in keeping metallic or other pipes warm which are designed to convey heat; and at the same time has explained how, by a like expedient, liquids [171] might be preserved in a cool state in hot climates [172].

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[171] I have no doubt but that ice might be transported from place to place in the midst of summer, and preserved for any length of time, if the vessel containing it were, agreeably to Mr. Leslie's proposal, placed within the innermost of a number of tin canisters, which fit one within the other, especially if the outward one were clean and polished.

[172] On the same principle Mr. Buchanan has recommended the protecting water-pipes from freezing by enclosing them in tin-plate tubes, leaving a space of about an inch all round the

Metals are the best conductors of heat, and hence it is that the pipes which are employed to convey heated air or steam for warming apartments, should always be metallic; and when it is desirable that the heat should be given off rapidly, these pipes should be rough, or otherwise covered with a coat of paint[173].

On the contrary, whenever it is an object that such pipes should preserve the heat[174] as long as possible,

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leaden pipes. Buchanan on the Economy of Heat, 8vo, page 128.

[173] In some distilleries there is a considerable length of metallic pipes between the still-head and the worm-tub or refrigeratory: all such pipes should be painted black.

[74] For an account of the different power

as is always the case when metallic pipes are employed to convey heated air, hot water [175], or steam to a distance, the pipes should be highly polished, and always kept perfectly clean. For the same reason, our planished tin covers will preserve the warmth of our provisions exactly in proportion to the height of their

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which bodies with different surfaces have of preserving heat, see Leslie on Heat, p. 78 &c.

[175] In some of the print-works in Lancashire, boiling water is conveyed by copper pipes under ground from the steam-engine boiler to the different workshops, for the uses of the workmen; and in some cases the heat is so well preserved, that the water is delivered in the various apartments only two or three degrees below the boiling point.

polish and the degree of cleanliness with which they are kept[176].

With respect to the ECONOMY of FUEL, which naturally forms a branch of this essay, so much has been professedly written upon the subject by Count Rumford, that there seems nothing of importance left for others to add. I shall therefore presume to offer very little to his observations, except a few hints which arise out of

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[176] The builders of steam-engines thoroughly understand this principle. Hence the piston and cylinder in every modern engine are highly polished, and the superintendant is always enjoined to keep them perfectly bright and clean. A silver tea-pot on the same principle preserves the tea hotter than most others, and consequently extracts the vegetable principle more effectually.

my own practice, in the conduct of the manufactory in which I am personally engaged.

It is impossible, in an economical point of view, to give any general directions for the choice of coal, since this depends so much on the different localities and other circumstances[177]: a description, however, of the several varieties will be found in the Essay on Carbon. The fol-

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[177] In manufactories where large and expensive iron boilers are employed, sulphurous coals should be avoided, as the sulphur which rises during combustion is apt to occasion a rapid decay of that part of the boiler which is exposed to the action of the fire. It produces a sulphuret of iron, which wastes away as fast as it is formed.

lowing table of the comparative heat of different kinds of fuel was drawn up by Mons. Lavoisier. Equal quantities of heat were produced by the combustion of the following quantities of the combustibles annexed.

| | Pounds. | Measure. |
|---|---|---|
| Cokes . . | 403 | 17 |
| Pitcoal . | 600 | 10 |
| Charcoal . | 600 | 40 |
| Oak wood | 1089 | 33 |

In this experiment the cokes required $12\frac{1}{2}$ hours for their combustion, the coal 20 hours, the charcoal 5, the oak 4—4. An estimate has also been made of the relative quantities of heat produced from similar materials by Count Rumford, but I must refer the reader to his work for particulars[178].

M. Wiegleb has stated it as his opinion, that in the choice of wood fuel, the beech and hornbeam are to be preferred; next the oak, and other woods of great solidity. Next to these, the alder, aspen, birch, fir, ash, and the lime. The former excite a greater heat, and burn longer; the latter exhibit more flame, and leave but little residuum.

Charcoal is fitter for small chemical operations, as it is more easily managed: that which is made of the more solid woods is to be preferred.

Refuse tan, made up into cakes, is

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[178] Rumford's Essays, vol. ii. pages 75 &c., also pages 134—137.

also fit for firing, where a gentle and continued fire is advantageous.

In some places turf[179] is used with advantage. There is a great difference, however, in its internal quality; the heavy bituminous kind called *peat* is the best; but some care is required in drying it properly to prevent its entering into spontaneous combustion.

Mr. Mushet, of the Clyde iron works, gives the following calculation of the expense of getting peat

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[179] Formerly turf was much employed in some of our West Indian islands; but since hands have been scarce in consequence of the discontinuance of the slave trade, the planters cannot spare any of their men to cast turf, and are now obliged to take pitcoal from England,

in Scotland. A man, he says, will with ease cast 4,000 of an ordinary size in a day. For this quantity are required two carriers, and one person to pile it to dry. The peat when thoroughly dried will weigh nine pounds each; the product, therefore, will be 12,000 pounds, or upwards of five tons. The expense of this is as under:

| | s. | d. |
|---|---|---|
| Man's wages, 1 day, | 2 | 6 |
| Two women, at 1*s*. do. | 2 | 0 |
| Girl to pile it, | 0 | 6 |
| | 5 | 0 |

or 1*s*. per ton.

It has been found that four tons of dried peat will make something more than one ton of peat-char, which will produce a much stronger fire than coals or cokes [180].

Dr. Plot, after describing the method of cutting turf in Staffordshire, says, "the large ones in good weather will dry on one side in eight, on the other in four or five days at most. When dried, if they intend them for fuel in winter, they pile them up round in the manner of a hay-rick, ten or twelve feet high, and let them stand all summer; but if they are designed for manuring their land, they heap them up a good quantity together on the ground, and set fire to them, which they will take of themselves if they are dry [181]."

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[180] Philosophical Magazine, vol. vii. page 44.

[181] Plot's Staffordshire, chap. iii. § 14.

A very economical kind of fuel is charred turf[182], but there is some nicety required in managing the process, which I believe nothing but practice can teach. M. Sage, who has published a paper on this subject in the Memoirs of the Academy of Sciences at Paris, entitled "An Inquiry into the comparative Intensity of the Heat produced by the Combustion of Charcoal and charred Turf," asserts that the heat produced from the latter is nearly in the proportion of three to one[183].

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182 Turf has a very disagreeable smell during its combustion, which is an objection to its use in open fire-places.

183 An abstract of this paper may be seen in the Repertory of Arts, vol. v. page 419.

M. Goettling has described how hydrogen gas may be collected from certain vegetables, and employed for the production of heat, in small chemical operations, instead of sperm oil or alcohol[184]; but all such combustible agents are too dear for common practice.

The management is, however, generally of greater consequence than the choice of fuel. The kind of fuel which is most suitable for any particular operation, is soon discovered, but how to employ it so as to produce the greatest quantum of heat by its means is not quite so obvious.

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[184] Almanack for Chemists, for the year 1785, page 185.

Count Rumford has stated that, in general, not less than seven-eighths of the heat generated, or which with proper management might be generated from the fuel actually consumed, is carried up into the atmosphere with the smoke, and totally lost. How important then is it that every proprietor of a manufactory should investigate the causes of this loss, and endeavour to remove them!

Where boilers are set in brick work over closed fire-places, the most common defect is that of having the fire-places too large[185]; the conse-

[185] This often arises from the obstinacy of an unskilful bricklayer. It is a great want of economy to employ inferior workmen to erect any kind of fire work. Whatever may be the

quence of which is that the bars cannot be entirely covered with fuel, and the cold air rushing from the ash-pit, between the uncovered bars, actually counteracts the effect of a great part of the burning fuel. In setting stills or boilers, it should be a general rule to have the fire-places no larger than is absolutely necessary for containing as much fuel as will be required to produce the intended purpose.

The fire-place should not only be small, but it should be constructed so that the whole of the bottom of the

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expense, I have always found the advantage of having furnaces well built in the first instance.

boiler be exposed to the action of the burning fuel [186], and that the whole of the flame and heated air do actually impinge upon the bottom before they reach the sides to pass from them to the chimney; for the heat which is applied at the bottom of a boiler, will be infinitely more effective than the same portion of heat when applied to its sides [187].

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[186] This is very effectually accomplished in some steam-engine boilers. These are of an oblong form, and they have a flue of from eighteen to thirty inches diameter running from end to end through the middle of them. The fire therefore first plays against the bottom of the boiler, and then passes through the midst of the water before it reaches the chimney. Might not this principle be applied in various other ways with advantage?

[187] It is on this account that some large stills

This is one reason why there is always so great a waste of fuel whenever pots or other vessels are heated over an open fire-place; for in this case, the heat only skims over the bottom, and passes off immediately into the surrounding atmosphere.

The doors of closed fire-places also are generally as improper as the fire-places themselves. They are usually made extremely thin, and the frames very light, which not only occasions them soon to wear out, but is the cause of their warping and twisting, and consequently they

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and other vessels of copper are made with the bottom to project inwards, presenting a concave, instead of a convex surface to the action of the fire.

never shut close afterwards. These doors are likewise made to fall into a rabbet, and are fitted up with latches, both of which are inconvenient, and indeed useless.

Having had many years experience in fitting up furnaces, I am decidedly of opinion that where cast-iron doors are employed, an opening of ten inches should have a door not less than three quarters of an inch thick; and larger fire-places should have thicker doors in proportion. These should be fitted up with strong wrought-iron hinges[188], such as will allow

[188] I have found it advantageous to have the straps of the hinges thick, and of such a length as to extend entirely across the door; for when these are well riveted to the door they

the doors to fall flat against the frames; and, instead of moveable latches, each door should have a large projecting knob firmly riveted into it.

The cast-iron frames ought to be as thick at least as the doors; they should be two or three inches broad, to enable them to stand steadily against the walls of the furnace[189]; and bars of wrought-iron, well fastened, should go, one from each corner, in a spreading direction, not less

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prevent the latter from warping, however intense may be the fire.

[189] In setting the frames, they should be fixed inclining a little towards the fire-place: this gives the doors a tendency to keep shut, and renders latches useless.

than eighteen inches or two feet into the solid mass of brick-work on which the boiler is to stand [190].

It is also of importance in every close fire-place, to have a door to the ash-pit; one that shuts easily and fits close to the frame on which it hangs; for without this it is impossible ever to regulate a fire so as to reap every advantage from its effects.

Having experienced the benefit of

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[190] There is a benefit arises from having these straps long and substantial which may not at first be apparent. They prevent the frame from receding from the brick-work, the consequence of which would be that air would pass into the fire-place between the frame and the masonry, and thus impair the draught of the furnace.

ash-pit doors, I have for several years been in the practice of having my fire-places fitted up with double doors and frames; that is, I have a strong iron frame cast, with two openings; to one a door is hung for the fire-place, and to the lower opening I adapt another for the ash-pit. The peculiar advantage of this is, that a double frame of this sort is more easily fixed, and can be attached more firmly to the brick-work than it would be possible to fix two frames, one immediately above the other.

These doors and frames are expensive at first, because they are weighty; but in the end they will be found to be more economical than any ready-made sale-doors that can be found [191].

Besides, since I have had these doors to the ash-pits I have dispensed with the registers in the chimneys [192]; for, I find that by a proper attention

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[191] One of these double frames, in which the fire-door is ten inches by eleven inches, and the ash-pit door eleven inches by sixteen inches, with the doors properly hung with strong wrought-iron hinges, costs me, at the first hand, about 40*s*.

[192] For some time I had registers in the chimneys, as well as doors to the ash-pits; but finding that both were more than servants would attend to, I have now discarded the former altogether, and perceive that every effect that can be desired may be produced by the ash-pit doors alone.

to the opening and shutting of the ash-pit door, I can admit any portion of atmospheric air into the fire-place, and thus have a complete command of the temperature and its application[193].

I have sometimes had moveable registers in the centre of the ash-pit doors; but these are too troublesome to be managed by ordinary servants; and a common plain ash-pit door, when properly hung, may be readily opened an inch, two inches or more, or

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[193] However deep the ash-pits may be, it is always advisable to have doors to them. Some scientific men in the metropolis have had doors of three feet in height to the ash-pits of their brewing coppers, and have found them very economical.

entirely shut, according to the choice of the laboratory-man employed.

In reverberatory furnaces for the decomposition of neutral salts and the manufacture of alkalies, ash-pit doors are of no use, as it is never necessary to check the fire suddenly [194], as

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[194] I cannot suffer this opportunity to pass without remarking that the proprietors of reverberatory furnaces should contrive to continue their processes night and day; or, if that be impracticable, they should rake up the fire and stop the passage to the chimney so as to prevent the furnace from cooling during the night. Furnaces thus worked will last six or seven times as long as those do which frequently stand idle. The contraction of the materials during the time of cooling, and the subsequent expansion, wear them out rapidly.

in other operations. On the contrary, I have found it advantageous to have the ash-pits as deep, and the chimneys as high[195], as possible, in order to occasion a strong and uninterrupted draught[196].

Where the heat is so intense as it is in these furnaces, doors and frames of the common make, or such as have

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[195] No chimney should be less than thirty feet high; and for large fire-places, or where more than one flue goes into a chimney, it ought to be much higher, and larger in proportion.

[196] In the Isle of Dogs, near London, there are chimneys for steam-engine boilers and for iron furnaces 100 feet high, which are found to be very advantageous. At Paddington waterworks the chimney is 120 feet from the plinth to the summit.

been just described, would be quite improper[197], and even wasteful, for they would be constantly red-hot: hence they would not only soon wear away, but being in this state of incandescence they would carry off a large portion of the heat, which ought to be employed in reducing the materials within the furnace.

Having experienced this, I had

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[197] For large reverberatory furnaces, steam-engine boilers, and other great concerns, I have sometimes seen very wide wrought-iron doors lined on the inside with a plate of cast-iron well riveted to the door. By forming these hollow, that is, if they were put together so as to inclose a thick sheet of atmospheric air, the door would become a non-conductor of heat, and would be very suitable for such apparatus.

recourse to a contrivance of hanging a thin sheet of wrought-iron before the fire-place, which proved to be a great amendment; and after this I had a door made with fire-bricks, the joints of which were secured with loam, and held in their places by four flat plates of iron screwed together at the corners. This massy door was moved upwards or let down before the fire-place by means of a weight which exactly balanced it, and was attached to a chain passing over a pulley.

This was an improvement upon the former; but both had their inconveniences, and these inconveniences led to the adoption of a small iron hopper fixed horizontally in the brick-work, properly let into the wall to defend it from the fire, and stopped by a thick piece of iron, cast exactly to fit it[198]. This I found to be a most complete way of stopping a fire-place[199], as no air can possibly get admittance but through the ash-pit, this being the only way by which it ought ever to pass.

There is, however, an inconvenience attending these square stop-

[198] See the plates, fig. 2 and fig. 3.

[199] I made use of this kind of hoppers for some particular kind of furnaces twenty years ago, and have never since seen any reason to alter my opinion of them. I was indebted to a work of Mr. Dossie, "The Elaboratory laid open," for the idea.

pers of iron, viz. If the wall of the fire-place be not very thick, and the hopper fixed at the very outside of the brick-work; whenever the fire becomes intense, the stopper is apt to expand by the heat, and get so firmly fixed within the hopper[200] as sometimes to be attended with much trouble.

Reflecting on this obstacle, it occurred to me that a hopper might be so fixed as to be stopped with small coal instead of the usual door, and that in this way the difficulty might

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[200] I have occasionally employed these kind of hoppers for closed fire-places of the very smallest size, and have been much satisfied with them. In such cases the heat not being so intense, this inconvenience does not happen.

be avoided. I therefore made such an alteration in the construction of the last reverberatory furnace which I had occasion to erect, as enabled me entirely to discard the use of any metallic door or stopper whatever.

In this furnace the hopper which I employed was five inches square in the clear, and this was fixed upon a broad plate of iron built in the brick-work, and projecting eight inches beyond the face of the wall. The design of this was merely to be a support for the small coal which was to fill the hopper, and be piled against it, as a succedaneum for the iron stopper above mentioned.

The small of pit-coal, being a non-conductor of heat, proved to be a mode of stopping the entrance of a furnace as perfect as probably will ever be devised: for, if a furnace draw well, the coal which fills the hopper will not become ignited at all, except that part of it which is nearest the burning fuel; and when the hopper is properly stopped, one cannot discover how any of the heat of the furnace can possibly escape so as to be wasted.

When it becomes necessary to replenish the fire, all that the workman has to do, is to loosen the coal within the hopper, to push the whole of it into the fire-place with a shovel which should be made on purpose to fit it[201], then to throw in as much

[201] I have omitted to mention that the

fresh fuel as he judges to be sufficient, and again to stop up with small coal as before.

It should be recollected, however, that whatever perfection there may be in the mode of stopping the entrance into a furnace, this will be no cure for a large fire-place; for if a fire-place be larger than it ought to be, or so constructed that the hopper does not command every part of it, a continual current of cold atmospheric air will rush in between those bars which are not covered with fuel, and carry much of that heat into the

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hopper should be fixed several inches above the level of the fire-bars, that whatever fuel is put through may fall into the fire-place without any difficulty.

channel of the chimney which ought to be spent within the furnace.

This is the chief circumstance which renders a hopper fire-place so much better than those with a door and frame; for where there is a hopper there can be no occasion for any door and frame; and the *four* sides of the furnace may be brought up sloping alike with masonry. Such a furnace will hold much more fuel than one that has only *three* sides of brick-work; and consequently the area for the bars may be much diminished [202].

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[202] One of the most important alterations of late years in the building of inclosed fire-places, is that of reducing their length to one half of the former dimensions, and adding

Besides, if the four sides of any furnace be sloped very considerably, so as that its upper diameter be twice the diameter at the bars, there will never be any danger of such a furnace having a false draught through the bars; because whatever fuel is thrown in through the hopper, will fall on all sides towards the middle of the furnace, and form a uniform covering to the grating.

I have found it convenient to have the hopper on one side of a furnace and the ash-pit on another, or at the

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something in lieu of the length to the width. The advantages which arise from this alteration will easily be perceived. It was no uncommon thing formerly to build the fire-place of a furnace four feet long.

end of the furnace: by this arrangement the assistant can supply his fire without being annoyed by the heat of the ash-pit.

Such furnaces as are designed for producing a great heat should be furnished with loose bars of a considerable size[203], resting upon two or three strong bearing-bars[204]; for all

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[203] It has lately been found advantageous to have fire-bars much narrower than formerly. By this alteration a fire burns more regularly, being more equally supplied with atmospheric air than it could be in fire-places with bars three inches wide. Half that substance is sufficient for any fire-place.

[204] Respecting the width between the bars, the space which I have found to be the best, is half an inch, and this is sufficient for a fire-place of any dimensions. By casting the bars

grates, or sets of bars cast together, and united in one frame, will warp and twist, and are with great difficulty cleared of the scoriæ or clinkers. Joggle-bars, as they are called, or such as fall into distinct and separate notches, are also very inconvenient. It is more profitable for the proprietor of a manufactory to have a pattern in wood made to his own mind, and to have all the bars cast by it. The form of the bars which I have found most useful, may be seen in the plates, fig. 5.

If such bars be fixed upon strong and plain bearers, they will have

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with a shoulder at each end, exactly a quarter of an inch thick, as shown at fig. 4. it gives the proper opening.

room to expand by the heat without bending, may easily be moved to the right or the left, to loosen the scoriæ, and may readily be drawn out of the fire-place at pleasure.

In building a large furnace I have found it convenient, when I have employed a hopper, to leave an opening of two or three inches immediately above the fire-bars, as long as the whole breadth of the fire-place; and such an opening may be easily made by inserting a strong bar to support the brick-work over it. Through this opening the workman can occasionally introduce a poker for stirring the fire and loosening the scoriæ, and through the same opening he can draw the bars, or replace them, as he may have occasion.

When a fire-place is built after this manner, it will be profitable to have a deep ash-pit: then, if the workman wishes to cool the furnace expeditiously, he may draw out the bars through the orifice above mentioned, and the whole contents of the fire-place will fall at once into the ash-pit.

At some very large steam-engines I have seen a fixed door and frame at the opposite end of the furnace to that at which they feed the fire, for the purpose of drawing out the clinkers of the coals, without incommoding the man who attends the fire; but I know from experience that the construction just described will in the end prove to be the most convenient. The aperture, as it rises only three inches above the surface of the bars, will not injure the draught of the fire-place, because the bed of fuel which covers the bars will be always thick enough to stop up that opening completely. See plates, fig. 6.

I have already urged the importance of employing an ingenious and experienced bricklayer, for it will always be prudent and economical to have every furnace well done at the first; for they not only answer their respective purposes better, but they consume less fuel, and will frequently last three or four times longer than those which are built by an ordinary workman.

To effect this in the best manner, it is obvious that the materials should be of the best kind, selected from different sorts for the respective parts of the work, and calculated for that particular furnace which the proprietor wishes to erect.

There are, however, a few necessary instructions from which I have derived so much advantage in my own manufactory, that I should be inexcusable were I to neglect to mention them.

It is a common opinion, that if good fire-bricks be used in the interior of the fire-place and in the flues, any thing will do for the exterior, or for the solid part of the fabric. This is not strictly true, for I have found it adviseable to have even the external parts composed of the best building bricks that I could procure; for close joints and compact work[205] can only be made with such materials; and whenever a furnace is taken down to repair a fire-place, these bricks may be used again and again; whereas common place-bricks can never be taken down whole, and consequently are useless for a second erection.

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[205] If the workman does not lay close joints, and make the whole fabric very compact, he can never be certain that the air will not find a passage into the fire-place through other channels besides the ash-pit.

Wherever an intense fire is required, bricks made with the best Stourbridge fire-clay should be used; the joints should be rubbed very close, and that part of the work should be laid with good fire-lute[206].

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[206] The fire-lute which I have employed for many years, never having been able to discover a better, is made thus: Good clay two parts, sharp washed sand eight parts, horse-dung one part. These materials are to be intimately mixed, then beaten up with a little water, and afterwards the whole is to be thoroughly tempered like mortar, by treading it for a considerable time with the feet. Mr. Watt's fire-lute is a good one, but it is more expensive. Take, says he, porcelain clay from Cornwall, (not pipe clay) pound it, and mix it to the consistence of thick paint, with a solution of borax, in the proportion of two ounces of borax to a pint of hot water.

It is not, I believe, generally known, but there are some brick-makers at Stourbridge, proprietors of the clay pits there, who will make bricks of any form or of any dimensions that may be desired. Some friends of mine have had an entire fire-place made with that sort of clay[207], agreeably to patterns sent for the purpose; and it was so contrived, that though the bricks differed in form and size, every piece had its appro-

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207 The Stourbridge clay is of a very peculiar kind; it lies at a great depth in the earth, under the bed of coal, and is known to the workmen by the name of *clunch*. It is a gray clay, of a sandy nature, and better adapted for making large crucibles and fire-brick than perhaps any in Europe.

priate place, and fitted the adjoining one with the greatest nicety.

For some particular purposes it might be worth while to go to this expense; for when the several parts are put together with a thin mixture of Stourbridge clay, sharp sand, and water, the first fire that is lighted within the furnace, will burn the whole into one entire and compact mass.

In putting up the large stills used in the distillation of nitrous and muriatic acids, I have been accustomed to have an abundance of old iron hoops laid within the solid brick work, some on every course; with the view of holding it together and preventing a strong fire from crack-ing it, or forcing it outwards;—but I am now of opinion that these are not of much use, excepting in chimneys and in the walls which form the flues, and where the brick-work is necessarily very thin; for even where a great number of hoops have been laid in the work has sometimes cracked, and produced a false draught in the fire-place.

A better expedient, and one which I have lately adopted with great success, is that of laying four flat iron bars in the brick-work of each still, one on each side of the fabrick, and at the height where the fire has most force. I have these bars three-eighths of an inch thick, and two inches broad, and of a length sufficient to extend the whole length or breadth of the mass of brick-work in which they are to be imbedded.

These bars are made by the smith to fit the places where they are to lie, and are bent at each end so as to clip the masonry and prevent its moving: but before they are bent there is a slit of about two inches made in the end of each, which enables the smith to divide so much of the bar and to turn one up and the other down, by which contrivance it binds two courses of brick-work instead of one. See the plates, fig. 7.

The irons being thus prepared, and the work brought up to the proper height to receive them, the bricklayer places one on one side of the furnace and another on its opposite side, and then raises another course of brick-work all round the whole area. Two of the irons being thus built in, the two others are laid in the same manner on the other two sides of the building, and built in as before. By this arrangement the whole is secured in a very complete manner, and I see no reason to expect that any thing will give way till either the stills or the fire-places are entirely worn out.

These expedients are all designed for the purpose of making the work durable, and preventing a current of atmospheric air setting in towards the fire-place in any direction otherwise than through the ash-pit: but for the economy of fuel, it is of equal importance that the bricklayer should be careful in the construction of the chimney, on which the goodness of every furnace so much depends.

In determining the form, the size, and the height of a chimney, an experienced workman will have no difficulty; but it appears to me that a proper attention is not always paid to the thickness of the walls, or to the materials of which they are built.

No outer wall of a chimney should be less than nine inches thick, but they would be better if they were fourteen or eighteen inches in thickness; and such materials should always be chosen as are the worst conductors of heat[208], provided they are sufficiently compact, and have no crevices for the admission of atmospheric air[209].

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[208] Some improvement might be made in the construction of our large boilers and evaporating pans, as to their power of conducting heat. What could possibly be worse contrived for preserving the heat than the large iron pans of the soap-boiler, which generally stand three or four feet out of the ground without any casing whatever? Our soap-makers formerly boiled in wood. The French manufacturer boils in brick. Chaptal's Chemistry applied to the Arts, 8vo. London 1807, vol. i. page 153.

[209] It is not only requisite that a chimney should admit no atmospheric air through its sides, but it is also desirable that the sides of the chimney should not cool the smoke and heated air within it; for, the higher the tem-

Some chimneys are placed at the back of a furnace, others over the door[210]: some boilers are set immediately over the centre of the fire-place, others at a considerable distance from it: in some cases the still or the boiler is suspended over the furnace so that the bottom is entirely exposed to the action of the fire, while in other instances the still is supported by brick-work, and only

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perature can be kept in the interior, the better will be the draught.

210 Whatever may be the situation of a chimney, it is always best to have it stand independent of the boiler, still, or furnace to which it belongs. It is best to build the chimney first, and when that is finished, then to erect the apparatus round it, as may be most convenient.

partially exposed to the fire: one is heated only by the flame and hot air which impinge against the bottom; others have split draughts and worm flues of different kinds; and each of these modes may be applied with advantage to some particular purposes. But, as a skilful workman will never be at a loss to decide these points, I hasten to offer a few remarks on the management of the fuel, previous to the consideration of the necessity of an attention to temperature in our manufacturing processes; which although the last is certainly not the least important branch of this interesting subject.

If a chimney throws out a large quantity of smoke, it is impossible there can be a proper economy of the fuel; for the smoke is occasioned by particles of the coal which ought to have been detained in the fire-place, and there consumed in the production of heat[211].

This loss is chiefly occasioned by too much coal being cast into the fire-place at once, which prevents any of it from being properly ignited; whereas, if a small portion were always thrown in at a time, and this suffered to become thoroughly inflamed, or half burnt out, before more be added, the combustion would then

[211] What Dr. Black has said on this subject is worth the perusal of manufacturers; it may be seen in his Lectures, 4to, vol. i. pages 312—316.

proceed regularly, more heat would be produced, and not half the coals would be used which are now consumed[212]. This is a point of considerable importance in every manufactory where many coals are burnt; but it is very difficult to induce ordinary servants to attend to it; because, when the fire-door is opened, there is less trouble in putting on two or three shovels full of coal at once, than in furnishing half a shovel full at a time, and that very frequently.

The effect of heaping an unnecessary quantity of coals upon a grate

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[212] I have found it advisable not to disturb the fire burning in a closed fire-place, more than necessary. Coals should be put so as they may lie light upon the grate.

in a closed fire-place is very mischievous and detrimental. The great mass, instead of entering properly into combustion, only moulders away, or is carried in the state of smoke through the channel of the chimney into the atmosphere; and the heat which is produced by the coals, instead of rising up to the boiler, and doing its proper office there, is forced through the bars into the ash-pit, and entirely lost.

A workman who would attend to these particulars would save to his employer what would be equal to his own wages, in fuel; the work would be better done, and the effect produced with more certainty. Besides, when the fuel is burnt to such a point as to have become a kind of charcoal, and no more smoke is given off, instead of heaping fresh coals upon such fuel, the ash-pit door should for a time be shut, to prevent the access of cold air; and the fuel, in this high state of incandescence, should be left undisturbed, in order that it may have its proper influence on the matter submitted to its action. Practice alone can teach how long a fire should remain in this state: but it is of consequence to manage it thus; for whenever, after this treatment, a proper quantity of fresh fuel is added, this fresh fuel will sooner get into full combustion, and the whole of it will be effective.

I pass over many other important

particulars respecting the management and economy of fuel in closed fire-places, because they have already been well considered and explained in excellent detail by Count Rumford, whose Essays may be studied with advantage by all those who are desirous of investigating this important subject[213].

Much might be done in the way of economy, by the employment of the waste heat which is now lost in the generality of manufactories, and which the proprietors, by a little reflection, might contrive to put to a good account.

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[213] Rumford's Essays, vol. ii. Essay 6th ; and vol. iii. Essays 10th, 11th, and 14th.

In large buildings where it is necessary to have iron pillars to support the floors, how easy would it be to have these pillars cast hollow[214], and to convey heated air, or waste steam from an engine-boiler into them, and thus warm extensive premises at no expense! A gentleman in the neighbourhood of Manchester has erected a cotton-mill, several stories high, on this principle. The floors consist of a number of small brick arches, the abutments of which

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[214] There is a perfection peculiar to cast-iron pillars, that they may be made ornamental at little or no expense; and hollow pillars for supporting a roof or floor, will cost much less than those which are cast solid, and still be of sufficient strength.

are supported by hollow pillars, and these pillars are heated with steam or kept cool as he sees occasion. By this construction he also saves insurance, as there is nothing combustible employed throughout the building.

I have often noticed the vast loss of heat arising from the exposed state of most of the steam-engine boilers. There would surely be an advantage in building a wall round them, and covering them from the action of the weather. Thus there would be a hot room attached to every steam-boiler, which might be applied to many useful purposes.

In like manner, to those manufacturers who have occasion for large quantities of coke, if they have coal in their neighbourhood that will coke, how advantageous would it be to put up a proper oven or two for the purpose, and apply the spare heat for burning lime, heating stoves, &c.! The heat that is usually lost is very considerable, and it is so intense that it might be made sufficient for almost any purpose.

In most cases of distillation, the liquid which comes over is run through a refrigerating metallic worm immersed in a vast quantity of water. The design of this is to convert the gaseous product into a fluid nearly as cold as the surrounding atmosphere, and which without this would be mostly lost in steam. Why might not the worm in many cases be fixed within a vessel surrounded by the wort or other liquid which is intended to be distilled, and which by this means could be heated to a certain point in readiness for the still, and at no additional expense ?

In some of the West India islands this principle is already acted upon. A worm is made to pass through the sugar-wash, and this heats it ready for the still, and thus enables the planter to draw more rum in a given time. It has been thought, however, that the principle might be applied with more effect, if the heated air and smoke from the fire-place were made to pass through the wash : and several sets of apparatus of this kind are, as I understand, now in preparation in London for some houses in Jamaica. A drawing of one of these I have procured, and have had it engraved to accompany these Essays[215].

A great saving of fuel is effected by the introduction of the dome and back copper. This vessel, which is used by some brewers for boiling their wort, is constructed like a common copper, except in the cover, which is made like a very broad-brimmed hat, turned up very high all round the edge.

When the wort within the copper boils, the attendant turns a cock and fills this broad gutter in the cover, and which contains many gallons,

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[215] See the plates, fig. 8.

with cold liquor. The consequence of this is, that the cover being filled with *cold* liquor, it condenses the steam as soon as it is formed, and becomes itself heated to 170° or 180°. When the liquor acquires this heat it is let off into the copper below, and the cover is refilled with cold liquor.

For safety, the crown of this cover is furnished with a weighted valve, from whence the steam may escape whenever the fire is greater than it ought to be. By having the wort thus covered all the time it is boiling, the fine aroma or peculiar and grateful flavour of the hop is entirely preserved; whereas in a common open copper it passes off with the steam.

The saving of coals is also considerable.

These desultory observations on the economy of fuel having been extended much further than I at first designed, I must be more concise than I otherwise would in describing those cases which I have selected as instances of the value and the necessity of paying the utmost attention to *temperature* in the conduct of manufacturing processes, and with these I shall conclude this Essay.

There is no complaint so common among workmen, as that of processes sometimes failing which have usually succeeded, and this without any apparent cause. On such cases I have frequently been consulted, and scarcely recollect an instance where I had not reason to suspect that it arose chiefly from a want of attention to the temperature at which the process was conducted.

The physician in his curative operations knows how necessary it is to attend to the temperature of the chambers of the sick, and to the bodily temperament of his patient: the distiller of ardent spirits knows how important it is to regulate the temperature of the refrigeratory, and that, if it rise above a certain degree, a portion of the distilled spirit will be dissipated in the atmosphere and lost: the glass-maker is aware that the goodness of his glass entirely depends on the care with which he reduces the temperature in the process of annealing[216]: the gardener must also acknowledge how absurd it would be to expect success in his crops without attending to the heat of his beds, his walls, or his vinery: and why should the manufacturer imagine that there can be any chemical operation in which the degree of temperature is of little moment?

Formerly the brewer had no guide to determine when the water was cool

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[216] The operation of annealing glass is often conducted very improperly, and to this negligence the fragile nature of much of the glass in common use may be ascribed.

"The slightest wound engrav'd on glass unneal'd
Runs in white lines along the lucid field,
Crack follows crack, to laws elastic just,
And the frail fabric shivers into dust."

enough for mashing the malt, but the being able to see the reflection of his face in that fluid; and the fermentation of the wort was conducted by guess only, which occasioned frequent failures and disappointments. He has, however, in the thermometer, now found an unerring guide.

In the preparation of vinegar, the manufacturer depends chiefly upon the sun for the additional temperature which he requires for completing his process. In large establishments, therefore, a great space of land is allotted for the exposure of the casks to the influence of that luminary. There are, however, some proprietors of vinegar-yards who have found by experiment that the vinegar sooner acquires its maximum of acidity by being kept in a more regular temperature than can be obtained by the sun's rays, since hot days are frequently succeeded by very cold nights. Such manufacturers, having erected stoves and prepared rooms for the reception of the vinegar, keep it at that exact temperament which they have proved to be best adapted to the process, and find they can finish the work in less than two thirds of the time usually required for perfecting the business[217]. How easy then would it be for every manufacturer to make this experiment for himself, to ascertain by a few trials what is the proper

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[217] See Essay I. in this volume, page 75—79.

temperature for conducting the process to the greatest advantage, and in the least time!

What an accession to the stock of knowledge might be expected, if Government would give every possible encouragement, by medals, honorary rewards, and prizes, to those who made the most important discoveries in the line of their several professions! In China, the emperor[218] is every year informed what farmer is the most distinguished in the im-

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[218] "A sovereign ought never to be the subject of regret for giving pensions to those, who having the necessary talents, consecrate themselves to studies useful to their country." M. Carrard's Prize Essay, on the Spirit of Legislation, 8vo, London 1772, page 220.

provement of his lands, and he makes him a mandarin of the eighth order[219].

Few processes require a more strict attention to temperature than the crystallization of salts. Some require a hot, others a cold situation; and I am not acquainted with any one species that does not give finer crystals when set to shoot at its own peculiar degree of temperature, in preference to all others.

The solution of a salt is also as much governed by temperature as its crystallization: and it is on a knowledge of this principle that the separation of one species of salt from another generally depends. The re-

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[219] Montesquieu's Spirit of Laws, book xiv, chap. 8.

fining of saltpetre may be mentioned as a familiar instance. In this operation the crude nitre, or rough petre as it is called, is dissolved in hot water, nearly to the point of saturation. Part of the water is then evaporated by boiling; and as the liquor becomes concentrated, the muriate of soda, which is nearly as insoluble in hot as it is in cold water, separates itself from the nitre, and gradually precipitates. This is successively removed as it falls, and the boiling is continued till the operator is satisfied that all the muriate has fallen: the hot liquor, which contains the purified nitre in a state of solution, is then drawn off into the coolers to crystallize.

In the manufacture of earthen-ware and porcelain a great variety of temperatures are required, according to the nature of the goods and the progress which has been made in their preparation. Large glasshouse-pots, according to the present management, require two years for drying, previously to their being submitted to the heat of the potter's oven. Earthen-ware which takes frost during its drying, will inevitably prove very brittle.

In the tanning of hides it has always been known that the process went on much better in summer than in winter. How natural then is it to have recourse to artificial temperature! Mr. Brewin, an ingenious tanner in the Borough of Southwark, is the only person that I know of who has profited by this palpable improvement in the manufacture; and he will doubtless be amply repaid the expenses which have been incurred in erecting stoves and building flues, to convey extra heat to the pits in which the hides are steeped; for the quality of his leather is much improved, and the process is now shortened by several months.

Had this excellent man resided in France under the administration of the great Colbert, who annually set apart forty thousand crowns[220] for the encouragement of ingenious ma-

[220] Prize Essays on the Spirit of Legislation, 8vo, London 1772, page 341.

nufacturers, he would doubtless have received a public remuneration[221].

The working cutler, when he has iron and steel to forge of good qualities, knows that his sole dependence for the excellence of the tools he fabricates, is upon the degree of temperature at which the work is conducted in its different stages. He knows that a sword must be tempered at a heat very different from a penknife, an adze different from a saw, and a watchspring different from a lancet; but the pyrometer has not

[221] In Persia, where the lands require to be watered artificially, if any one has the art of conducting water to a place where it never was before, he has the enjoyment of the advantage of it for five generations.

yet been employed by these manufacturers, and to this circumstance the difficulty and uncertainty of procuring a good edge tool may be attributed [222].

Neither has the thermometer been made use of by the tallow-chandler, although it is evident that he ought never to make any candles without employing that instrument: indeed, chipping of candles is owing entirely to the neglect of this circumstance, not to say that there is reason to believe that the tallow is often injured,

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[222] This subject will be further treated of, and some hints for the improvement of the present methods of tempering will be given in the Essay on Edge-tools, which shall constitute a part of these volumes.

in the first instance, by melting it at an improper heat.

The seed-crushers and makers of certain vegetable oils often suffer considerably in consequence of their processes being conducted at an improper temperature. One instance may be taken from the operation of drawing linseed oil. The workman knows that unless the seed be in some measure heated, the oil will not flow; he therefore roasts it over a charcoal fire, and loses ten or fifteen per cent. in weight by that operation. If there be the least want of care, the loss will be much more considerable[223]. By

[223] This subject will be resumed in the Essay on the Application of Steam.

ascertaining what is the real necessary temperature, and by a proper arrangement, this process might be managed with as much certainty as any other.

The dealer in Greenland whale oil might also increase the profits of his trade very much by preparing his oil for sale when the weather is suitable for the operation. This kind of oil is always purified by passing it through large flannel bags, which retain the impurities, and suffer the finer parts to percolate through them. When the oil has undergone this treatment, it is called *bagged* oil, and is then deemed fit for sale. At a low temperature, a considerable quantity even of this latter kind would concrete, and might be separated by similar means; whereas in a warm atmosphere this dissolves, and, being less inflammable, very much injures the oil for burning.

By proper attention to this circumstance, all the oil which is designed for burning might be very much improved, and the portion thus separated from it, would be worth more to the soap manufacturer for making yellow soap, than similar oil which had not undergone this process. I conceive that an oil-merchant would do well always to bag different oils in different seasons; though many experiments might be necessary before it could be ascertained what was the exact temperature at which the respective kinds would most copiously deposit this feculence.

Madder is an article of great consumption throughout Europe. It is chiefly cultivated in Holland, where it euriches the farmer, and is a considerable source of profit to the Dutch merchants. Plantations of madder have also been made in this country, and the thing has been attempted in France: but it failed, as I understand, in both countries, from the circumstance of the growers not knowing the proper temperature at which the stoves ought to be kept for drying it.

This might surely be ascertained by common means; and if the inconvenience of making experiments during the time of harvest be an insurmountable objection, how easy would it be for an enterprising agriculturist to procure a person from Holland to give him the necessary instruction !

When the French minister was informed that the workers in silk were in the habit of importing organized silk from Piedmont, to serve as a chain[224] for their stuffs, because they were ignorant of the method of drawing the silk from the cocoons, he did not hesitate about the proper remedy, but invited the celebrated Vaucanson into France, who not only gave them the information they wanted on that particular point, but invented a

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[224] The French knew before how to prepare their own silk for the woof, but were unable to make it good enough for the chain.

machine for platting the stuffs of gold and silver, and giving them the brilliancy of those of the Levant. Thus, by the aid of an ingenious foreigner, the nation acquired a new and very considerable branch of commerce[225].

In dyeing woollen cloths with indigo, the blue is more intense, and the colour more permanent, when the vat is used cold. Of these facts no dyer is ignorant; and yet it is a common practice to employ heat, because this makes the indigo go much further, and the colour strike quicker. I would suggest whether it is not likely that there may be one certain

[225] Carrard's Memoir, presented to the Literary Society of Berne, page 328.

temperature at which the indigo would be completely exhausted, and yet the permanency of the dye not impaired.

In the china-blue-dipping, one of the processes of calico-printing[226], the temperature of the lime vat is of the utmost importance. When the lime is slacked for this purpose, and the vat is prepared with it, there can be no certainty that it will properly fix the printed indigo in the fibres of the cloth, unless it be left at rest till it become as cold as the surrounding atmosphere. To conduct this process with certainty, a thermometer is

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[226] For an explanation of this process, see the Essay on Calico-printing.

indispensable; for the indigo is either fixed or spoiled at the first immersion.

Printed calicoes sometimes sustain an injury by not being stoved at a proper temperature. The common heat of the stoves is about 90°. If they are suffered to rise much above that standard, there is great danger of the acids injuring the fabric of the cloth, and rendering it tender. On the contrary, some of the colours would spread or enlarge, and perhaps run the one into the other, if the temperature of the stove were allowed to fall, and the calicoes to become cold before they were cleansed of the superfluous mordants.

About Rochdale in Lancashire,

and in some parts of Yorkshire, the clothiers dye yellows and oranges with the common heath or ling, taken from the moors and uninclosed common fields. They mow it when in full flower, about the time of hay harvest. It is spread out to dry as they do hay, and then laid up in ricks or barns in the same manner.

This vegetable produces, by means of a tin mordant, a more beautiful yellow on woollen cloths, than either weld, quercitron, bark, or fustic; the colour being not only brighter, but much more intense than what can be procured from either of those dyes. This colour is, notwithstanding, of very little real value, for it will not bear the action of the sun and air like that produced from weld, nor even so well as fustic.

The manufacturers, therefore, invariably dry the goods which are dyed with heath, under cover and in the shade. A very large quantity of coarse cloths, called *bockings*, are dyed with this cheap vegetable substance for the American market; and as it has been used in this way only seven or eight years, the Americans, I fancy, have not yet learnt to distinguish the goods which are dyed with heath from those which are dyed with fustic. I relate these circumstances merely for the purpose of suggesting whether there may not be some particular temperature at which the heath may be used so as to give a permanent dye.

A very excellent yellow may also be given by the quercitron bark; but if a printer of calicoes be desirous of getting the very finest colour, it can only be procured by making the decoction of the bark, at a very low temperature[227]. If, for instance, the colour be extracted from the wood by a heat of about 86°, the goods may be dyed with this decoc-

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[227] The most permanent yellow dye we know of is procured from the *weld*. I have often made experiments on extracting the colour from this plant, but I never observed that the beauty of the dye was in the least impaired by boiling.

tion at 200° or 205°; but if the colour be extracted at a higher temperature than 86° or 90°, the liquor will inevitably acquire more or less of a brown colour. A high temperature separates the tan [228] as well as the colouring matter, and much deteriorates this very useful and beautiful dye.

The quercitron bark is also employed in dyeing *woollen* cloths, and for this purpose the dye may be extracted at a temperature somewhat higher than it is ever adviseable to

[228] I have found that a small portion of muriate of tin will precipitate the tanning principle from vegetable decoctions; but I have not yet made such experiments as will warrant my giving particular directions.

use it for calicoes: but if these woollen goods be afterwards *hot* pressed, which is a customary process in finishing them for the market, the colour will be changed to a brown; whereas, by submitting the same kind of goods to the action of a *cold* press, the colour is never impaired. Here the variation in the treatment produces such difference in the effects, that the most unscientific workmen are absolutely compelled to attend to temperature.

It has been discovered that the solvent power of water in some cases is very much increased by giving it a temperature above that of 212°. For instance, if it be heated in closed vessels to 220°, it is much more efficacious in bleaching cotton goods than water at a boiling heat. This, however, can only be accomplished by pressure. I mention the circumstance in this place, because I conceive the principle to be important, and that it might be applied with advantage to many other useful purposes. It is true, that this additional temperature can never be imparted to water without employing artificial pressure, as I have remarked; but we know so little of what changes might be effected in the properties of bodies by treating them with caloric under the pressure of several atmospheres, that nothing surely can be more deserving of a diligent and patient investigation.

It is well known how difficult it is to fuse chalk or marble, because, when these substances acquire a certain temperature, the carbonic acid escapes, and they become lime. Sir James Hall, nevertheless, effected the fusion of chalk at a very moderate temperature, by employing a sufficient pressure to prevent the separation of its carbonic acid and water, and in this way he converted the chalk into perfect marble[229].

Some very unexpected results have also been produced by the different methods of cooling certain mineral

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[229] The detail of these very interesting experiments will be found in the sixth volume of the Edinburgh Philosophical Transactions.

substances[230] which had been reduced to a state of fusion. About seven hundred weight of the *Rowley rag*[231], a species of basalt, was fused in a common reverberatory furnace, by the late and ever-to-be-lamented

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[230] An account of Sir James Hall's experiments on the cooling of basalt, may be seen in the fifth volume of the Transactions of the Royal Society of Edinburgh.

[231] This stone is found in the neighbourhood of Rowley in Staffordshire: the village stands upon it. It is of a dark gray colour, and, according to Dr. Withering, it consists of 48 silex, 32 of alumine, and 20 oxide of iron. It is so hard, that Birmingham and some other towns in the neighbourhood are paved with it. It is sometimes employed to mix with the materials for making the common black bottle-glass.

Mr. Gregory Watt, who carefully noticed the changes which it underwent during its different stages of cooling, and communicated the result of his observations to the Royal Society.

This basaltic mineral melted easily; and when a portion of it was taken out in a state of fusion, and cooled quickly, it produced a very hard, opaque, black glass[232]. When the fire had been continued for six hours, the chimney was closed, and the

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[232] I believe any of the common bottle-glass may be reduced to a stony substance, by first melting it, and then cooling it very slowly; and that it may afterwards be restored to its shining, vitreous appearance, by remelting it, and then abstracting the caloric with rapidity.

whole surface of the liquid mass was covered with heated sand; after which eight days elapsed before the whole substance was sufficiently cool to admit of examination.

On removing the indurated mass from the furnace, it exhibited very different appearances, according to the varied action of the heat; and that which had cooled the slowest, was of a dull dark gray colour, very similar in appearance to the original rag-stone. In one case a rough granulated substance is produced, and in the other a shining and smooth glass[233]; and though the difference

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[233] I have examined some of the specimens, and the difference in their appearance is as

is so striking, it is occasioned entirely by the variation in the length of the time allowed to this matter for its reduction of temperature[234].

It has been ascertained that steel contains more carbon than wrought iron, though less than cast iron. From the knowledge of this fact an ingenious manufacturer at Chester-

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great as could well be conceived. They were presented to me by a relation of Mr. Watt, soon after the experiment was performed.

[234] From these experiments Mr. Watt has endeavoured, in a very philosophical way, to account for the regular figure of the natural basaltic columns, and even for their regular articulations. His reasoning is extremely ingenious and satisfactory; but the reader must be referred to the memoir itself, which may be seen in the Phil. Trans. for 1804.

field has invented a new mode of making cutlery, and certain other implements in cast iron, and afterwards converting them to a substance resembling either wrought iron or steel. This he effects by burying the respective articles of cast iron in a mass of native oxide of iron previously pulverized, and submitting the whole to a long continued heat.

In this operation the oxygen of the oxide combines with the superfluous carbon of the cast iron, and, forming carbonic acid or carbonic oxide, escapes, and leaves the metallic articles in the state of wrought iron or steel, as the operator desires.

This process, which in general answers very well, sometimes will entirely fail, and disappoint the artist. This I should ascribe to its having been conducted at an improper temperature. For if too little heat be given, the native oxide does not impart its oxygen; and if the heat be too intense, or continued beyond the proper time, too much of the carbon will be abstracted, and the articles of cutlery which were designed to have the properties of steel, will be reduced to the state of soft wrought iron. A good manageable pyrometer would enable the operator to escape these disappointments.

In the decomposition of the sulphuric salts for the production of alkalies, a business which I formerly carried on to a considerable extent, I was often perplexed by a similar difficulty. Whenever I could superintend the process myself, I could judge tolerably well of the progress of the operation from the appearances which the materials exhibited within the furnaces; but in my absence, and during the night, the whole very often went entirely wrong, and the alkaline product was of very little value. For, if a sufficient heat had not been duly maintained, the sulphates were not decomposed; if the decomposition had taken place, and the fire was then suffered to go down, the sulphates would in a great measure be regenerated; and if, during the latter part of the operation, the heat became too intense, then the nascent alkali was elevated, and passed away through the chimney, and was dissipated in the atmosphere. Had I then been in possession of a good pyrometer, all these evils might have been avoided.

I know of nothing that better deserves a premium than the invention of a cheap pyrometer, calculated for general use, and applicable to the highest temperatures. That invented by Mr. Wedgwood was an instrument of this kind, but unfortunately the method by which he prepared the small cylinders of argillaceous earth is entirely lost[235].

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[235] Mr. Guyton has proposed platina as a material of which a useful pyrometer might be

The want of a good pyrometer is severely felt by the manufacturers of Birmingham. Cases daily occur of losses sustained in consequence of their not knowing how to ascertain the precise degree of heat in high temperatures. A single instance will be sufficient to explain my meaning.

It has been customary to fit up the best fowling-pieces with touch-holes of gold, because those of iron or steel are soon eroded and worn away by the sulphur of the gun-

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constructed, as it is not fusible at the heat of our furnaces, and would not be eroded by any of the gaseous products evolved by the most intense fires. See Nicholson's Journal, vol. vi. page 89.

powder, which unites with this metal and converts it to a brittle sulphuret.

Nothing can be easier than to mould these gold touch-holes properly, and also to fix them firmly within the gun-barrel; but there is an after-process to be performed, which is attended with considerable difficulty. One of the last operations in finishing a gun-barrel is that of hardening the breech, which can only be done by submitting it to a high degree of heat; and if ever the precise degree that is necessary for the process be exceeded, it is ten to one but the gold melts, and the manufacturer has to replace it with another touch-hole[236].

[236] When this occurs, the workman has the

The temperature at which gold melts is well known; the gunsmith, therefore, has only to ascertain what degree of heat is necessary for hardening the breech; and then, by employing a pyrometer, the accident above mentioned could never happen.

In heating madder for dyeing what

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trouble of again softening the temper of the barrel before he can fix another touch-hole to it, and consequently the same expense and risque of hardening it must be incurred, besides the loss of time. Owing to these inconveniences the gun-smiths have nearly discarded the use of gold, and now make the touch-holes for the best pieces of platina, although they cost nearly double the price. I have been informed that Mr. Manton, a very eminent gun-smith of Dover-street, was the first person who employed platina for this purpose.

are called army-reds, the intelligent dyer well knows that he ought to increase the temperature of the liquor very gradually, and therefore he never attends the operation without carrying a thermometer with him. The scientific gardener has one degree of heat for his cucumber frames, another for the vines, a third for his pinery, and others again for the different exotics, as his experience has prescribed[237]. The sugar-refiner has a stove at one temperature for the bastard sugar, at another for the loaves, and at a third for the candy. The maker of varnish, the general

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[237] Some further Remarks on this subject will be found in the Essay on the Application of Steam.

manufacturing chemist, the hatter, the calendrer, the colour-maker, and a variety of other artists[238], are all dependent on the circumstance of their seizing some one particular temperature, for the success of their respective operations, and often without being conscious of their obligation. I trust, however, that enough has now been offered to induce every manufacturer, who may peruse these loose hints, to apply them to his own

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[238] Even in the manufacture of cheese and the churning of butter recourse must generally be had to an increased temperature; neither will the dough properly ferment, which is designed for making bread, unless it be exposed to a temperature generally higher than that of the atmosphere in this latitude.

business, and to consider, whether some of his peculiar processes might not be very materially improved by a variation of the temperature at which they have usually been conducted. This is the chief object I had in view in composing this Essay; and as all the principal observations are founded upon experience and the best information I could procure, I entertain some confidence that it will be acceptable, and prove highly useful, particularly to the British manufacturer.

The superior knowledge of our manufacturers has been the great source of our excellence as a commercial nation; but there is a danger, amid the growing intelligence of the age, of our losing this proud preeminence, unless some spirited individuals, in every class of society, aim at informing the public mind, and exciting that emulation among our respective artists, which is sure to stimulate their exertions and lead them on to perfection.

The period is not far distant when I trust a British minister would incur a very serious responsibility were he to neglect to reward any individual who had been the means of improving the manufactures of the country. PERICLES, the great Athenian statesman, who valued himself on the circumstance that during the whole of his administration he had not occasioned the death of a single citizen, established new games and prizes with the sole view of exciting a noble emulation among the Athenians; and while he held the reins of government the arts were carried to the highest point of excellence and perfection. The Romans, on the contrary, restricted commerce and the arts;—they would not allow a senator to have a vessel at sea that could contain more than forty muids[239].

The great COLBERT, whom I have before mentioned, directed, that the different French artists should expose their works every year to the eyes of the public, and that the public should

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[239] The nobles of Venice, even in the present times, are not allowed to exercise commerce.

adjudge a crown of honour to him who should most excel in the beauty and execution of his work. He animated and recompensed all who distinguished themselves, and his zeal for the great and the useful, was followed by the most brilliant success.

A subsequent administration patronised the great REAUMUR, who was indefatigable in his experiments to discover the composition of the Chinese porcelain[240], and who also carried off from the Germans the art of refining tin, and of converting iron into steel.

It would be difficult indeed to say

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[240] Some account of the exertions of this admirable experimentalist will be given in the Essay on Earthen-ware and Porcelain.

what a people might not do by proper encouragement. In China, two of her finest and most fertile provinces (Kiang-nan and Iche-kiang) were gained from the sea by the industry of her inhabitants.

The merchants and manufacturers of England are proverbial for their enterprise and assiduity; and, if not crippled by excessive imposts, which paralyse the exertions of any people, nothing can prevent their having a full share of the commerce of the universe. That minister, therefore, must surely be ignorant or infatuated, and extremely culpable, who, when relieved from the perplexities of war, does not pride himself in aiding the genius, strengthening the hands, assisting the efforts, and increasing the means of such a laborious, industrious, and ingenious set of men as those who now so effectually support the character of the British nation.

Plate I.

Fig. 1.

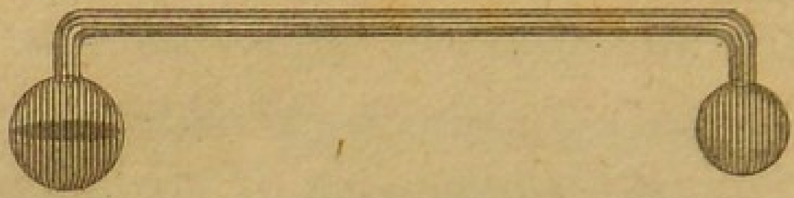


Fig. 2.

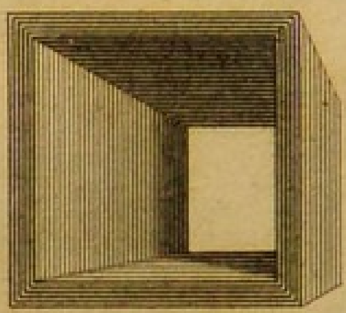


Fig. 3.

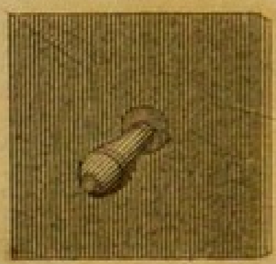
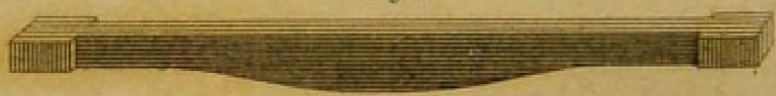


Fig. 4.

Fig. 5.



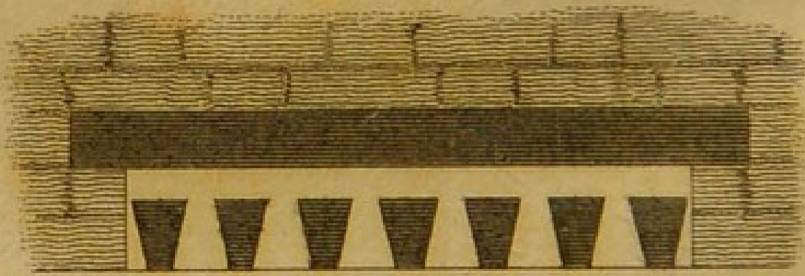
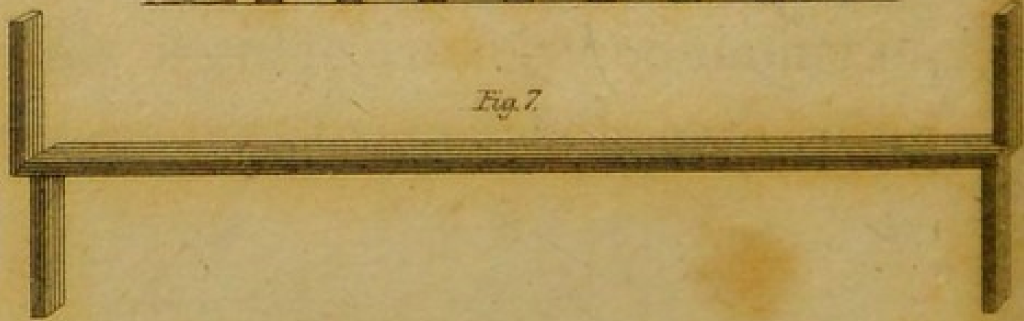


Fig. 6.

Fig. 7.



S. Parkes. del.

Jas. Davis. sculp.

*The following ought to have formed part of the* Essay on Temperature, *as one of the means of producing ice artificially. It should have been introduced at page 271, and was omitted only through inadvertence.*

A method of freezing at a distance, by Dr. Wollaston. From Philosophical Transactions for 1813, Part I.

"It is well known that the temperature of liquids is cooled by evaporation, but in close vessels evaporation is limited by the great bulk into which the vapour expands. Dr. Wollaston in this paper describes an ingenious contrivance of his, to which he has given the name of CRYOPHORUS, by means of which water may be frozen in close vessels by its evaporation, with great facility.

"The instrument which he employs is a glass tube, as shown Plate I. fig. 1. Its internal diameter is about one-eighth of an inch, each extremity is blown into a ball, and the tube is bent at right angles about half an inch from each ball. One of the balls is filled not quite half full of water. This liquid is boiled for some time to expel the air, and the capillary tube at the extremity of the other ball is then sealed hermetically. If the empty ball of this instrument be plunged into a mixture of snow and salt, the vapour within it is condensed so fast, that the water in the other ball freezes."—Dr. Thomson's Annals of Philosophy, vol. ii. p. 230.

*Omitted at page 318.*

In erecting furnaces which are intended to sustain a great heat, the composition of the mortar is of the utmost importance. When I was in the habit of using stone-lime, such as is produced in several of the midland counties of England, I found the following proportions made the hardest and the best mortar.

Lime fresh burnt, and measured while in lumps, one bushel; sharp river sand, well washed, four bushels. The whole to be intimately mixed and thoroughly tempered.

For the internal parts, which are

not exposed to the air, a still larger proportion of sand might, I found, be used with advantage.

The best proportions for common chalk-lime are, I believe, lime one bushel, and sharp sand two bushels; though that which is thoroughly and uniformly burnt will take three bushels of sand to one of lime.

It has long been a general complaint that the common chalk-lime contains a considerable proportion of unburnt stone, or carbonate of lime, which is a great loss, and renders it difficult to ascertain the exact measure of sand that ought to be used with it.

In consequence of this, some lime-kilns have been erected at Bow and elsewhere in the neighbourhood of London, with chimneys which rise thirty feet above the body of the kiln; and these occasion so powerful a draught that the complaint just mentioned is entirely obviated.

The Earl of Stanhope has also erected lime-kilns on a new principle for burning lime in such a manner that it may be delivered to the consumer in a perfect state.

In the Journal de Physique for the year 1775, page 311, is a plan and description of a kiln for burning lime after it has been once slacked and reduced to powder. The design of this is, that it may be used in mortar quite hot. It is recommended to be employed in the following proportions, and it is said that such mortar will become extremely hard.

| | Parts. |
|---|---|
| Fine sand . . . . . . | 3 |
| Well burnt brick, ground | 3 |
| Slacked lime . . . . . . | 2 |
| Lime slacked in the air, and afterward recalcined . . | 2 |
| | 10 |

The stone consistence which mortar acquires is owing partly to the gradual absoption of carbonic acid, and partly to the chemical combination of a portion of the water which is employed in making it. Hence, if lime reduced to powder and then recalcined, or burnt lime reduced to powder without being slacked, be added to mortar, the mortar when dry will acquire much greater hardness than it otherwise would.

For the different works at Woolwich and elsewhere, belonging to Government, all the lime which is consumed in making mortar is ground dry to a very fine powder, and used in that state without being slacked. It is taken from the kiln quite hot, and ground nearly in a state of incandescence. This prevents that absorption of carbonic acid gas which would otherwise take place; and in making mortar with such lime, a much larger proportion of sand may be employed than can possibly be used even with the best lime if prepared after the old manner; and it has often been demonstrated that, provided the mortar have sufficient tenacity, it will form a harder cement in proportion to the quantity of sand employed.

Having undertaken to give some directions for the erection of furnaces, I thought it behooved me to offer these few hints respecting the preparation of the mortar, on the goodness of which the perfection of every furnace so much depends.

The mortar of the ancients contained more sand than is generally used at present, and the extreme solidity of all the ancient buildings has often been noticed. Pliny[241] and

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[241] Lib. xxxvi. c. 23.

Vitruvius[242] have informed us what were the proportions of lime and sand used in their time, and that it was customary to burn the lime close to the spot where the buildings were erected, that the workmen might have it immediately from the kiln.

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[242] Architectura, lib. ii. c. 5.

END OF THE FIRST VOLUME.

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