SUPPLEMENT

TO

THE INTRODUCTION

TO THE

ATOMIC THEORY:

COMPREHENDING

A SKETCH

OF

CERTAIN OPINIONS AND DISCOVERIES

BEARING UPON

THE GENERAL PRINCIPLES

OF

CHEMICAL PHILOSOPHY,

Which have been brought into notice since the Publication of that Work.

BY

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PREFACE.

THE reasons that originally induced me to present to the world a sketch of those general principles of Chemical Philosophy, which were involved in the consideration of the Doctrine of Definite Proportions, are stated in the Preface to my Introduction to the Atomic Theory; and the same might now be alleged as an excuse for the publication of the present Supplement.

Though by no means an inattentive observer of the progress of chemical discovery, I have not, either on this, or on the former occasion, aimed at superseding the standard treatises already extant on those subjects, nor have I had the presumption to suppose, that I was able to stamp upon the doctrines which I supported or explained any sanction or authority, beyond what they already derived from the names of their propounders, or their own intrinsic probability.

But I am inclined to believe, that some advantage to the Science may accrue, from such an exposition of its leading principles, divested as much as possible of their technicalities, as is here offered, and that some, who would shrink from the labour of turning over a bulky volume in quest of information on the above points, might yet be glad to avail themselves of an Essay, in which these prominent points of general scientific interest are brought together within a small compass, and their bearings upon other departments of inquiry briefly pointed out.

But there are other reasons of a more local description, that have encouraged me to offer, more particularly to the Oxford public, the present sketch of the leading doctrines of Chemistry.

It seemed to me not improbable, that a demand might shortly exist for a text-book of such a description as the present, or at least that some additional interest might be excited in its contents, in consequence of discussions that may be expected to arise, with regard to the extent, to which an acquaintance with chemical principles ought to be held as an essential ingredient of a liberal education.

He must indeed be blind to the signs of the times, as well as to the current of academical feeling, who does not anticipate, that the period is approaching, at which the System pursued at this University will undergo some considerable modification.

There is indeed no predicting how long a time it may require to surmount the practical difficulties which serve to arrest the movement; but when I contemplate the natural and laudable anxiety which the Clergy at the present moment evince, to maintain that control over the education of the country which has hitherto been conceded to them, I cannot but feel convinced, that the demand existing amongst all classes for that description of knowledge, which involves some acquaintance with the truths of physical science, will sooner or later react upon the University, and impart a new character to the studies of those, whom she sends forth to answer the urgent call for national instruction.

Already this tendency of the public mind has begun to manifest itself here, by the measures for the encouragement of professorial Lectures which have been submitted to Convocation, and which are known to have been rejected by that body, only on the alleged ground of the insufficiency of the proposed scheme to effect the desired end.

Already too, the marked diminution, which has taken place in the attendance on all the public lectures here delivered, will have convinced the most sceptical, that a system of education framed upon the plan of our own, must, from its very tendency to render a spirit of emulation the moving principle of action in the mind of the student, extinguish in him sooner or later the desire for all other kinds of information, save for those which are found to conduce to the great end of academical distinction.

Neither, has any one of the many pamphlets on the subject which have been called forth by the recent discussions, pretended to vindicate the sufficiency of our present system, as it stands, to fulfil the conditions, now understood necessary, to constitute a liberal education, or to meet the exigences of the period in which we live.

Nevertheless, if I may judge from the nature of the schemes suggested in the above publications, I should infer, that the public mind amongst ourselves still requires to be enlightened, with respect to the true relative position of the several departments of science one towards another, and especially with respect to the claims, that may be advanced in behalf of the one to which the present Essay relates.

It is too much the custom, even amongst the advocates of modern science, to regard its several departments, as if they were placed on the same relative level—considering them all indeed as deserving the attention of men of education—but all as equally belonging to the superstructure, of which classical learning alone is to supply the foundation. Of the utility of the latter as constituting an essential part of primary education, I wish not to express a doubt; but I am at the same time of opinion, that the above-mentioned mode of considering the physical sciences has weakened the cause of those who advocate an extension of our system, and instead of tending to advance in public estimation any one of its departments, has lowered them all to the same standard, as that which the least important of their number is conceived to occupy.

It is quite true indeed, that there is no one branch of knowledge taught in this university, to which the attention of the student might not profitably be directed, or which, if cultivated in a proper spirit, would not tend to enlarge the range of his ideas, and to increase the sphere of his utility. But there is still, I humbly conceive, a distinction to be made in favour of those studies, which constitute as it were the grammar to every other kind of natural knowledge, and without some acquaintance with which, the student must be content to remain in the same state of ignorance, as to the causes of the commonest phenomena of the material world, which he would experience with respect to the moral, if destitute of the ordinary rudiments of scholarship.

In such a predicament that individual must feel himself, however high his attainments in other respects may be, who enters the world profoundly ignorant of the great physical and chemical laws of matter—that is, of the nature of those forces which operate on all bodies whatsoever, and of those distinctive properties, which characterize the substances most familiar to him, and most subservient to the common purposes of life.

Let it not be supposed however, that I mean to draw any invidious comparison between the importance of Chemistry, considered as a separate science, and that of other branches of scientific research. For it may be with reason demanded, what department of knowledge can be more interesting than that which unfolds to us the structure and functions of our own corporeal frame? What more calculated to awaken our liveliest curiosity than that which relates to the past revolutions of the globe we inhabit? What more in accordance with the peaceful occupations of a country clergyman, than botany, or other departments of Natural History?

Neither is it denied, that a thorough insight into Modern History, Political Economy, or the principles of Jurisprudence, will be of greater practical value to the future legislator, or to the country magistrate, than a profound acquaintance with the laws of the material universe.

But, as in the Scotch universities the principle is now repudiated, of adapting the nature of the education from the first with reference solely to the intended profession of the student; and hence as even the medical pupil is compelled to shew a certain acquaintance with what are there styled the Humanities; so in our own the converse ought to be equally recognized, and the great truth insisted on, that even the lawyer or the theologian will enter upon his respective duties under a disadvantage, if that narrowness of mind which is apt to be engendered by an exclusive addiction to one particular line of studies, has not been, at some period of his life or other, counteracted in him, by having had his attention directed to the acquisition of the rudiments at least of physical science.

I do not then assert, that mechanical or chemical philosophy hold, in themselves, a higher place than any of the above-mentioned studies, but I would merely suggest, that such a knowledge of either, as is requisite for duly comprehending the truths of other natural sciences—such a degree of elementary information respecting them, as is assumed in the very explanations offered of the leading phenomena[a] of the latter—ought to have a prior claim to the attention of the student, and be ranked rather as parts of the foundation of a liberal education, than as studies which may be advantageously engrafted upon it.

Nor need it be apprehended, that any one would be debarred by want of time, from prosecuting

[a] As for example, in Sir Ch. Bell's Animal Mechanics, in Mr. Lyell's Principles of Geology, and in the Treatises of Decandolle or others on Vegetable Physiology. Nay, how much of the force of the arguments adduced in such works as Paley's Natural Theology will be lost to the student without this preliminary knowledge!

those other departments of knowledge for which he may entertain a predilection. The intelligent Author of "Hints on the Formation of a Plan for the Revival of the Professorial System," has pointed out a method, by which, without necessarily prolonging in the least the prescribed period of academical study, a year might be set apart, after the present classical examination has been gone through, during which each person might prosecute some branch of learning more connected with his future profession or plans of life. And this is to be effected, by allowing a dispensation for the three last terms of undergraduateship, instead of one for the three first, as at present is done—a simple and rational change; for it seems more fitting to dispense with the pupil's residence, after he has become drilled in the habits of reading and thinking, which an academical education is supposed to impart, than to allow of his absence, before his character has been formed, and his tastes matured.

Upon the whole, therefore, I cannot, for the reasons already explained, altogether approve of that classification of the different branches of science under four distinct heads, which has been proposed by a Tutor of a College, in his otherwise judicious pamphlet, entitled, "Consideration of a Plan for combining the Professorial System with the System of Public Examinations," conceiving, that whilst every inducement should be held out to the student to acquire as extended a knowledge, as his time will admit, of some department either of literature or of science, according as his taste or views in life may suggest, it would be proper at the same time, to insist on a certain elementary knowledge of the fundamental laws of mechanics and of chemistry, if not from every graduate, at least from every one who leaves the University with the sanction of its highest honours. The same principle, in short, which in the sister University denies every kind of literary distinction to those who have not attained a certain amount of mathematical knowledge, ought surely to prevent our sending into the world, furnished with our highest credentials, persons, who, for aught we know, might leave us in the most profound ignorance of the nature of Gravitation, and of the constitution of the very Atmosphere which we breathe.

I would submit therefore to that portion of the academical body which is at present engaged on these questions, whether an examination on the leading truths of Physics and of Chemistry ought not to be gone through by every candidate for the degree of B. A.: the examination on Physics being limited to the general principles of "Natural Philosophy ;" that on Chemistry, to some of the points referred to in my Introduction to the Atomic Theory, and in the present Supplement, together with others of equally general import.

Should this be considered impracticable, I would then request them to consider, whether the same might not be made a condition to the higher degree of Master of Arts ; and thirdly, if neither the first nor the second proposition can be acceded to, whether such a test of initiation into the primary elements of these two, which together constitute the grammar of the physical sciences, ought not at least to be expected of the aspirants to those higher distinctions which the University has at her disposal.

Oxford, Feb. 11, 1840.

SUPPLEMENT

TO THE

INTRODUCTION TO THE ATOMIC THEORY.

WHEN Dalton, a few years ago, had succeeded in obtaining the assent of the scientific world to his beautiful and comprehensive theory of Atomic Proportions, it was imagined, and not without reason, that the science of Chemistry had attained a degree of precision, such as might place it on a level with those exact sciences, which had been longest known and most fully investigated.

It appeared possible to embrace within the compass of a very few simple propositions all the laws which regulate chemical combination ; and when, in the case of organic substances, the phenomena were such as could not be directly deduced from the principles of this theory, it was then thought reasonable to refer such anomalies to the operation of the living Principle, that mysterious Agent, which, by imparting new properties and new affinities to the inert mass, removed it, as it were, beyond the domain which came under the exclusive jurisdiction of chemical laws.

The principles with respect to the constitution of matter, which at that time appear to have formed the creed, expressed, or understood, of chemists in general, may perhaps be comprehended under the few following propositions.

1. Matter is composed of a number of particles incapable of further division (or of atoms), bound together by the force of cohesive attraction, and compound bodies are produced by the union of ultimate particles of different kinds of matter possessing an affinity one for the other.

2. There exists therefore a variety of elementary bodies, each of which is distinguished by the possession of certain fixed and unalienable properties, chemical as well as physical, so that the business of the analytical chemist is limited to the determination, of the nature of the several elements which enter into the composition of the substance he examines, and of the definite proportion they bear to each other.

3. The difference between one compound body and another can be referred only to two causes,—namely, either to their being formed of essentially different elements, or of the same elements combined in different proportions: so that all bodies possessing the same chemical composition must be regarded identical both as to *form* and *nature*—in physical as well as in chemical properties; whilst those which disagree, either in the nature, or in the proportion of their component parts, must be expected to differ likewise one from the other in both the above particulars.

4. Decomposition is caused by the approach of a foreign body, possessing a stronger affinity for one of the ingredients of a compound, than that which binds the latter mutually together, so that in every such case, the decomposing agent may be expected to enter into union with one or other of the elements of the combination which it destroys.

5. The water, which is found attached to many bodies, is essential to their crystallization, but does not materially affect their intrinsic properties; a salt perfectly divested of water being in no respect to be regarded as chemically different from one which contains it.

6. Organic bodies have their particles held together, partly by what is called the *living principle*, a principle,

distinct from chemical affinity, and superadded to it, so that the laws which operate upon inorganic matter are in many instances suspended by its influence.

Hence it is idle to expect, that any of the various chemical compounds which result from processes taking place in the living body, can be produced by artificial means, they being themselves resolved into their component elements, or into simpler forms of combination, so soon as the sustaining force, the principle of life, is abstracted.

I conceive, that the greater part at least of the above propositions, if propounded to a meeting of chemists not many years back, would have met with an almost unqualified assent, and doubtless a science, based upon these few postulates, did appear to have chalked out for itself a well defined boundary, within which every thing was clear and well established, whilst the less explored and more intricate field of inquiry which lay beyond, was looked upon as in a manner extraneous to it, and supposed to be influenced by distinct but unknown laws, which served to afford a convenient mode of accounting for every observed anomaly.

Accordingly the Atomic Theory, or the Law of Definite Proportions propounded by Dalton, which appeared at the time to embody, or at least to take for granted, the greater number of the principles above enumerated, was pronounced by Sir John Herschel himself, as being, after the laws of Mechanics, the most important, which the study of Nature had as yet disclosed.

Nor is it my intention in the following remarks to dispute in the least the justice of this encomium, or to retract one tittle from the humble but sincere tribute to the merit of that great man, which I myself offered a few years ago, in inscribing to him my Essay on the Atomic Theory, and in representing him, as the author of a system, with respect to the mode of combination between bodies, which stood foremost amongst the discoveries of the present age, for the universality of its applications, and the importance of its practical results.

It is indeed the circumstance which of all others most attaches the stamp of truth to the Daltonian theory, that it lends itself to all the new discoveries announced in Chemistry since its promulgation, so that each succeeding year has added something to the completeness of the evidence upon which it is based, as well as to the extent of the field which its jurisdiction embraces,—and this distinction it claims equally with the Newtonian system, to which in the scale of physical truths it may not improperly be compared.

Nevertheless it cannot be denied, that since the period of the reception of the Daltonian theory, many new views, involving some fundamental points of theory, have obtained currency amongst chemists, which, though perhaps nowise irreconcilable with that hypothesis, cannot be said to be comprehended under its principles, and which run entirely counter to many of those opinions with respect to the chemical properties belonging to matter in general, which are above stated as having obtained a tacit, if not a distinct recognition.

I conceive therefore, that an useful Supplement to my Essay on the Atomic Theory may be afforded, if I attempt to communicate a short account of those views with respect to the Constitution of Matter, which, if not actually promulgated, have at least grown into a more mature form, since the publication of that work.

But before I proceed, I may perhaps do well to advert to the increased use made of symbols amongst English chemists at the present time than at the period alluded to.

A brief sketch indeed of the method upon which Berzelius proceeded in forming the symbols which he has recommended to the adoption of chemists is given in pag. 50, et seq. of my former Essay, but the increased use now made of this plan of notation may render it proper on the present occasion to append the additional Remarks on the same subject, which, in my Address to the British Association in 1836,[a] I offered to the consideration of the meeting.

It appears then, that independently of the merely arbitrary symbols of Hassenfratz and Adet, which were recommended at the time when Chemistry first was moulded into its present form by Lavoisier, three Systems of Notation have been proposed, each one on high authority, but differing one from the other no less in principle than in the end proposed by their adoption.

The first was that suggested by the venerable founder of the atomic theory, Dr. Dalton, who aimed at expressing by his mode of notation, not merely the number of atoms of each ingredient which unite to form a given compound, but likewise the very mode of their union, the supposed collocation of the different particles respectively one to the other.

He proposed therefore a sort of pictorial representation of each compound which he specified, just as in the infancy of writing each substance was indicated, not by an arbitrary character, but by a sign bearing some remote resemblance to the object itself.

This therefore may be denominated the hieroglyphical mode of chemical notation; it was of great use in the infancy of the atomic theory, in familiarizing the minds of men of science to the mode in which combinations take place, and thus paved a more ready way to the reception of this important doctrine. Even now it may have its advantages, in conveying to the mind of a learner a clearer notion of the number and relation of the elements of a compound body one to the other; and in those which consist only of two or three elements, a symbolic representation after Dr. Dalton's plan might be nearly as concise as any other. But it would be difficult, consistently with brevity, to express in this manner any of those more complicated combinations that meet us in every stage of modern chemical inquiry, as for instance,

[a] Reports of the British Association, vol. V., page xxviii.

in the compounds of cyanogen, or in the proximate principles of organic life.

The second mode of notation is that in which the method adopted in Algebra is applied to meet the purposes of Chemistry. This method, whilst it is recommended by its greater perspicuity, and by being intelligible to all educated persons, has the advantage also of involving no hypothesis, and of being equally available by individuals, who have taken up the most opposite views of the collocation of the several atoms, or who dismiss the question as altogether foreign to their consideration. This therefore may be compared to the alphabetical mode of writing in use amongst civilized nations; the characters indeed may differ, the words formed by a combination of those characters may be very various, but the principles on which they are put together to express certain sounds and ideas are in all countries the same.

The third method of notation, which has been recommended by the authority of several great continental chemists, and especially of Berzelius, resembles rather a system of short-hand than one of ordinary writing, its express object being to abbreviate, so far as is consistent with perspicuity, the mode of notation last described. But although most chemists may find it convenient to employ some of these abbreviated forms of expression, it seems doubtful whether any particular amount of them can be recommended for general adoption, since the necessity for any abbreviation at all will vary, with the habits of the individual, the nature of his inquiries, and the objects for which his notes are designed.

A chemist, for example, the character of whose mind enables him quickly to perceive, and clearly to recollect minute distinctions, may find a much more abbreviated style of notation convenient, than would be at all advisable to others; one who is engaged in the analysis of organic compounds will be more sensible of the utility of such symbols, than another who is conversant chiefly with a less complicated class of combinations; and one who notes down the results of his experiments for the benefit of private reference, and not with any immediate view to others, may indulge in a more concise and complex system of notation, than would be convenient, where either of the latter objects were contemplated.

As the shortest road is proverbially not always the most expeditious, so in chemical notation more time may often be lost in correcting our own blunders and those of the compositor, where dots and commas of many sorts are introduced in the place of initial letters to express certain elements, than was gained by the more compendious method of expression employed.

For the purpose, therefore, of rendering more intelligible to beginners the mode in which various bodies are suppossd to combine, the Daltonian method of notation may still be of use, just as pictorial representation often comes in aid of verbal description to convey the idea of a complex object.

But where the design is to state in the clearest and least hypothetical terms the nature of a series of combinations, a mode of notation as closely as possible approaching to that adopted in Algebra seems preferable —remembering always, that as in Algebra we omit certain signs for the sake of greater brevity, the same may be allowable when we apply its principles to Chemistry, such abbreviations being of course most advisable in cases, where, by reason of the greater number of elements involved, the expression of them at whole length would occupy so much space, as to prevent the whole from being comprehended at a glance.

It may perhaps render the above remarks more intelligible to those who are not already conversant with the subject to which it relates, if I proceed to illustrate a little farther these three methods of notation, by placing some examples of each in opposition one to the other, on the two next pages of this work.[b]

[b] For a more complete list of Chemical Symbols see the Appendix to the Introduction to the Atomic Theory.

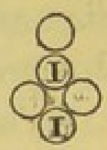
Examples of the Daltonian Method of Chemical Notation.

SYMBOLS OF

Hydrogen Oxygen Azote Sulphur Carbon

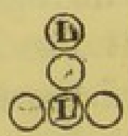
Metals

Protoxide of Iron. . . . 

Peroxide . . . . 

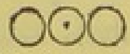
Protoxide of Lead .. 

Deutoxide . . . . 

Peroxide . . . . 

Sulphuret. . . . . 

Water . . . . 

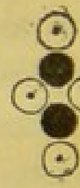
Deutoxide of Hydrogen 

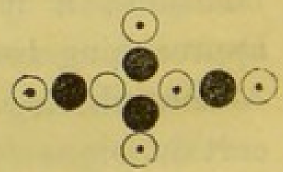
Carbonic Oxide . . . . 

Carbonic Acid . . . . . . 

Oxalic Acid . . . . 

Ammonia [c]. . . . . 

Alcohol . . . . 

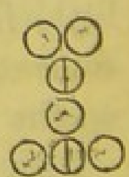
Ether. . . . . . 

Nitrous Gas . . . . . . 

Nitrous Oxide . . . . 

Hyponitrous Acid. . 

Nitrous Acid. . . . . . 

Nitric Acid . . . . . . 

[c] In this and in the following page Dalton's equivalents have been employed. Thus the atomic weight of nitrogen is only half that generally adopted.

Examples of the Algebraic Method of Notation, and of the abbreviated Form of it proposed by Berzelius.

SYMBOLS OF

Hydrogen	Oxygen	Azote	Sulphur	Carbon
H	O	N	S	C

Metals

Iron	Lead
Fe	Pl

	ALGEBRAIC METHOD.	BERZELIAN METHOD.
Protoxide of Iron	Fe. 1 + O. 1	$\dot{Fe}$
Peroxide of Iron	Fe. 1 + O. 2	$\ddot{Fe}$
Protoxide of Lead....	Pl. 1 + O. 1	$\dot{Pl}$
Deutoxide of Lead ..	Pl. 1 + O. 2	$\ddot{Pl}$
Peroxide of Lead	Pl. 2 + O. 3, or 1(Pl + O. 1) + 1(Pl. 1 + O. 2)	$\underline{\dddot{Pl}}$ or $\dot{Pl} + \ddot{Pl}$
Sulphuret of Lead....	Pl. 1 + S. 1	$\overset{,}{Pl}$
Water	O. 1 + H. 1	$\dot{H}$
Deutoxide of Hydrogen	O. 2 + H. 1	$\ddot{H}$
Ammonia	N. 2 + H. 3	$\underline{N}\,H^3$
Alcohol	H. 3 + O. 1 + C. 2, or 1(H. 2 + C. 2) + 1(H. 1 + O. 1)	$H^3O^1C^2$, or $2H^2C^2 + 2\dot{H}$
Ether..............	H. 5 + O. 1 + C. 4, or 2(H. 2 + C. 2) + 1(H. 1 + O. 1)	$H^5O^1C^4$, or $2H^2C^2 + 1\dot{H}$
Nitrous Gas	N. 1 + O. 1................	$\dot{N}$
Nitrous Oxide	N. 2 + O. 1................	$\underline{\dot{N}}$
Hyponitrous Acid....	N. 2 + O. 3................	$\underline{\dddot{N}}$
Nitrous Acid........	N. 1 + O. 2................	$\ddot{N}$
Nitric Acid	N. 2 + O. 5................	$\underline{\overset{\cdot\cdot\cdot\cdot\cdot}{N}}$
Carbonic Oxide......	C. 1 + O. 1................	$\dot{C}$
Carbonic Acid	C. 1 + O. 2................	$\ddot{C}$
Oxalic Acid	C. 2 + O. 3................	$\underline{\dddot{C}}$

Having explained how far the use of symbols has been rendered indispensable by the present advanced state of chemical knowledge, I proceed to the consideration of the general principles which I stated at the commencement as being received almost as self-evident axioms amongst Chemists.

And first with respect to the proposition which asserts, "that matter is composed of a number of particles incapable of further division (or of atoms), bound together by the force of cohesive attraction, and that compound bodies are produced by the union of the ultimate particles of different kinds of matter possessing an affinity one for the other."

The abstract proposition asserted in the above paragraph, which implies that nature has imposed a limit to the divisibility of matter, remains, I conceive, much on the same footing, as that upon which it rested at the time I wrote my Essay.

It may be recollected, that the arguments in favour of the existence of ultimate atoms therein stated, were founded upon the explanation which the hypothesis afforded of the different proportions in which bodies are found to unite, and that it had been supported by Dr. Wollaston on the further ground that, admitting the opposite hypothesis, there ought, strictly speaking, to be no positive limit to the extent of the atmosphere, but that each of the planets of our system would be surrounded by an aerial fluid, gradually decreasing indeed in density as it receded from the surface, but still indefinite in point of extent.

Now, inasmuch as neither the Sun, nor the largest of the planets, Jupiter, is surrounded by an atmosphere of such a density, as that which bodies of these dimensions would attract to themselves, were the whole of the space included within the limits of the solar system filled with air, Dr. Wollaston concluded, that the extent of our own atmosphere must be circumscribed, and therefore that the materials of which it consists must be incapable of infinite division.

Objections have been taken to this reasoning by a recent French writer, Mons. Dumas,[c] but on grounds which do not appear to me materially to affect its validity. It is contended, that the cold of the upper regions may be so intense as to reduce the gases composing our atmosphere to a state of solidity, or at least to render them liquid, in either of which cases a limit would be set to their further expansion, even though their particles admitted of indefinite division. But the author of this objection does not appear to have noticed, that his own distinguished countryman Mons. Fourier, in his celebrated Memoir on the Heat of the Globe, has assigned to the celestial spaces a temperature far too high, to allow of the consolidation, or liquefaction, of oxygen and nitrogen gases, bodies which have resisted the utmost intensity of cold that has ever yet been attained by artificial means, being proof even against that produced by the evaporation of frozen carbonic acid, and which creates in the bodies contiguous a temperature probably nearly 100 deg. lower, than that which is calculated as existing in those portions of space, that lie at the extreme limits of our atmosphere.[d]

The hypothesis of Mons. Dumas seems in fact a revival of the Ptolemaic doctrine of crystalline spheres, encircling our globe, and constituting a sort of substantial firmament around it; but its admission would be attended with difficulties from which the ancient theory was exempt, since the sun and other celestial luminaries, which in the latter were included within this boundary, would, according to the former view, lie beyond it.

The obstruction which this palpable barrier would create to the transmission of light and heat, I leave for opticians to speculate upon.

[c] Leçons sur la Philosophie Chimique, page 235.

[d] Fourier calculates, that the temperature diffused through space, by the aggregate effect of so many suns radiating heat, is not much inferior to that existing at the poles of our own planet.

I find however, that Mr. Whewell[c] objects on mathematical grounds to the inference, which Dr. Wollaston had deduced from the fact of the existence of a limit to the atmosphere of the planets belonging to our system, contending, that although the atmosphere did not consist of indivisible particles, still it would have a finite surface.

I shall not, therefore, any longer presume to build upon the above argument, but shall leave it for the present in the hands of geometricians—hoping, however, to indemnify myself for the want of its support, by appealing to considerations of another kind suggested to me by the writings of the author last alluded to in favour of the existence of atoms—considerations founded upon the analogy of created things in general, which Mr. Whewell has insisted upon in his Bridgewater Treatise.

"Vast," says he, "as are the parts and proportions of the Universe, we still appear to be able to perceive that it is finite; the subordination of magnitudes, and numbers, and classes appears to have its limits. Thus, for any thing we can discover, the sun is the largest body in the universe; at any rate bodies of the order of the sun are the largest of which we have any evidence. We know of no substance denser than platina, and it is improbable, that one denser, or at least much denser should ever be detected. The larger animals which exist in the sea, and on the earth, are almost certainly known to us. We may venture also to say, that the smallest animals which possess in their structure a clear analogy with larger ones have been already seen. Many of the animals which the microscope detects are as complete and complex in their organization as those of larger size; but beyond a certain point, they appear, as they become more minute, to be reduced to a homogeneity and simplicity of composition which almost excludes them from the domain of animal life.

"The smallest microscopical objects which can be sup-

[c] See Report of the Proceedings of the British Association in 1839, at Birmingham, from the Atheneum newspaper.

posed to be organic, are points, or gelatinous globules, or threads, in which no distinct organs, interior or exterior, can be discovered.[f] These, it is clear, cannot be considered as indicating an indefinite progression of animal life in a descending scale of minuteness. We can, mathematically speaking, conceive one of these animals as perfect and complicated in its structure as an elephant or an eagle, but we do not find it so in nature.

"It appears, on the contrary, in these objects, as if we were, at a certain point of magnitude, reaching the boundaries of the animal world.

"We need not here consider the hypotheses and opinions to which these ambiguous objects have given rise; but without any theory they tend to shew, that the subordination of organic life is finite on the side of the little as well as of the great."

Now whilst this argument from analogy may be adduced in favour of the existence of ultimate atoms, I cannot but conceive, that the ready explanation which the latter hypothesis affords of this limit to the progression of organic life in the descending scale, is in itself a still stronger corroboration of it.

If as Mr. Whewell observes, solids and fluids consist of particles of a definite, though exceeding smallness, which cannot further be divided or diminished, it is manifest, that we have in the smallness of these particles a limit to the possible size of the vessels and organs of animals. The fluids, which are secreted, and which circulate in the body of a mite, must needs consist of a vast number of particles, or they would not be fluids; and an animal might be so much smaller than a mite, that its tubes could not contain a sufficient collection of the atoms of matter to carry on its functions.

Nevertheless, although the abstract doctrine with re-

[f] This statement, however, is somewhat contradicted, or at least shewn to be less generally applicable, by the recent researches of Ehrenburg.

spect to the existence of ultimate atoms seems still to maintain that ascendancy over the opposite opinion, which it acquired from the period that Dalton first established the law of definite proportions, it must be admitted at the same time, that combinations amongst bodies may be more readily explained by imagining them to take place between certain definite groups of these atoms, than by assuming, as the father of the atomic theory preferred to do, that they resulted from the union of simple atoms of each ingredient.

Thus much at least appears clear, namely, that when a body by heat is resolved into the state of gas, so that its several parts exert a mutual repulsion, the parts so repelling each other are not single atoms, but groups of them.

Were not this the case, it must always happen, that when two gases unite and form a third, a condensation would take place to the amount of at least one half the original volume of the two separately.

For it is evident, that in order to combine, every atom of A must be brought into immediate contact with one or more atoms of B, and as the expansion of all elastic fluids by equal increments of heat is the same, the compound gas resulting from the union would occupy only half the space which its constituents had done before. But it so happens, that chlorine and hydrogen, when they unite to form muriatic acid gas, retain exactly their original bulk, so that it is clear that in their case at least the repulsive tendency, which causes them to exist in the state of an elastic fluid, must take place only between certain groups of particles, and that when they unite, each group of particles of chlorine, and each group of particles of hydrogen, must be divided into two, so that, notwithstanding their mutual combination, the number of groups between which repulsion operates will continue as before.

This supposition likewise enables us to account for the want of correspondence between the combining weights and the combining volumes of certain gases, though a definite proportion is in both cases equally maintained. Oxygen, for example, uniting with hydrogen, in the proportion, by weight, of eight to one, forms water, and as this is the more stable of the two known combinations of these two elements with one another, it seems probable, that an equal number of atoms of either ingredient concurs to form it, in which case the weight of an atom of oxygen, as compared to that of an atom of hydrogen, will be as eight to one. But if these be taken as the relative atomic weights of the two elements, twice the number of atoms of oxygen must be present in a given volume of oxygen gas, as in the corresponding one of hydrogen, because, to form water, exactly two volumes of oxygen unite with one volume of hydrogen.

Now these anomalies are easily reconciled by assuming, 1st, That all bodies, when converted into the state of gas, are resolved into certain groups of particles between which repulsion takes place, but that these by chemical means are often still further subdivided into smaller groups, which bear, however, always a certain numerical relation to the former.

Those who desire to prosecute this inquiry further, will do well to consult Dr. Prout's Bridgewater Treatise, in which the arguments in favour of the existence of molecular groups are clearly stated, and many curious deductions made from the principle assumed. They may also refer to the Leçons sur la Philosophie Chimique, by the French Chemist, Mons. Dumas, to which allusion has already been made, or to the Introduction to his Traité de Chimie appliquée aux Arts, the first volume of which appeared in 1828.

This philosopher has proposed to designate that description of molecular groups into which bodies are resolved by heat, physical atoms; and those simpler groups into which their affinities for other bodies often subdivide them, chemical atoms; and although persons disposed to be hypercritical may object to the application of the term in such a sense as the above, as they may also do to such a solecism in language, as the expression of a *compound atom*, which it has long been found convenient to employ, yet I conceive that either use of the word may be defended, if we only recollect, that the question now amongst the learned is no longer, whether in a mathematical sense matter is capable of indefinite division, but whether our knowledge of nature does not justify us in concluding, that its great Author has fixed a limit to its divisibility.

In this case, if we have good reason for believing, that the division can be carried to a *certain fixed* point by heat, and to a still further, but still a fixed and definite limit by chemical means, the former class of particles may perhaps, without involving an absurdity, be styled *physical* atoms, and the latter *chemical* ones.

But that even the latter are in reality made up of a number of particles, or in other words, that chemical agencies never resolve matter into its ultimate component parts, may be inferred from the curious and elaborate researches of Mons. Dulong and Petit on the specific Heat of Bodies.

These philosophers deduced from their experiments, that the latter is in the inverse ratio of their atomic weight, or in other words, that whatever the nature of a body might be, or whatever weight its atoms might possess, just the same amount of heat was required to raise each atom to a given temperature.

Now Mons. Dumas shews, that this conclusion is applicable, not to the chemical proportionals, or chemical atoms, as he chooses to denominate them, which enter into combination one with the other, but to their ultimate atoms merely, that these appear to have all (whatever their properties may be) the same specific heat, but that the chemical atoms consist of groups of these particles not corresponding in point of number.

The following, therefore, may perhaps serve as a brief abstract of the views at present entertained on this subject, views, which will be found on comparison to differ in certain respects from those, which I stated at the beginning of this essay to represent the received doctrine within a short period back.

And first, on the mathematical question which stands on the threshold of the subject, it cannot be expected that much new light should have been thrown, and we are still therefore equally at liberty to embrace the theoretical doctrine of the capacity for infinite division necessarily inherent in matter, or the more metaphysical and recondite hypothesis of Boscovich,[e] who deduces the primary qualities of all natural bodies from the existence of a number of ultimate points destitute of all properties, save that of mutual attraction and repulsion, operating at certain distances, and obedient to certain laws.[f]

[e] See my Atomic Theory, page 18.

[f] On this subject however I was favoured, soon after the publication of my Essay on the Atomic Theory, with a letter from the late Mr. Davies Gilbert, the following extract from which, whatever opinion may be formed of its intrinsic merits, will, I doubt not, be received with a feeling of interest, as emanating from one, whose decease the world of science and of letters has so much reason to deplore.

On the character and talents of that distinguished philosopher it is not my purpose here to dilate—justice will, I hope, be awarded both to the one and the other, by abler pens than mine. Nevertheless, as a member of that university, towards which from the first commencement of his academical career he ever evinced so warm an attachment, and which has so many motives for regarding his memory with gratitude and affection, I ought not to withhold, on the present occasion, my individual testimony, to the depth and extent of his acquirements—to the disinterested love of truth, which alone led him to amass such various stores of information—to his readiness in imparting them freely to others,—and to the simplicity of demeanour, and easy courtesy of manner, which rendered his society no less agreeable than instructive.

Much indeed as he may have advanced knowledge by those contributions to its various branches which bear his name, it must be allowed that he served its interests still more effectually, by the assistance he afforded to others in the prosecution of similar objects, and by the zeal and discernment he displayed in seeking out and enlisting in its cause talents, which, but for his exertions, might have continued in obscurity.

But the present stage of experimental knowledge, whilst it leaves us at liberty to speculate as before with respect to the inherent capacity of division, which may belong to the smallest conceivable portion of matter, as well as to the largest, affords at the same time grounds for the belief, that the Author of Nature has placed somewhere in the scale of minuteness a point, beyond

To him indeed, as the early patron of Davy, and his worthy successor in the chair of the Royal Society, the chemist may apply those lines, which his own modesty alone would have prevented him from claiming as his due:

——— quis magno melius succedat Achilli
Quam per quem magnus Daniis successit Achilles.

"Undoubtedly," says Mr. Gilbert, "we are utterly unacquainted with the *ὑπόστασις*, which sustains the qualities usually supposed to indicate matter, and we are as entirely unacquainted with that which sustains the qualities indicative of mind; but the striking inconsistencies involved in associating together the ideas of extension and of atoms have so embarrassed philosophers, that every expedient has been had recourse to for resolving the difficulties.

The most obvious mode, that of reducing the atoms to extremely small dimensions, utterly fails, for a particle extended to the millionth of an inch must be considered as capable of division as the earth itself.

At length Boscovich fell upon the expedient of denying the *ὑπόστασις* altogether.

Qualities are by him supposed to accumulate round points of space, attractions and repulsions succeeding each other.

If these principles be admitted, there can be no such thing as impenetrability. For as attraction and repulsion are merely potential, until they pass into energy through the medium of time, or as the effect produced by either is as the force drawn into the time through which it acts, it follows, that if the time be reduced without limit, by giving to the force an infinite velocity, one set of points would pass through another set, without producing the least sensible derangement.

As an illustration. A ball, shot from a gun, will pass through a board carrying the piece before it, but with such rapidity that the cohesive attraction of this piece to the rest of the board has not time to act.

Boscovich also conjectures, that the ultimate sphere of qualities may which no natural force can carry division. Now a body, of whatever dimensions we may assume it to be, which is held together by a force superior to any which can ever be brought to divide it, we denominate an *atom*.

The relative weight of these atoms may probably be indicated by the specific heats assigned to the several substances.

With these atoms however Chemistry, strictly speaking,

be one of attraction, extending into infinite space, and there constituting gravity.

There is however still another power inherent in matter, which in my opinion is quite as extraordinary as universal gravity itself.

I do not mean the quality of passiveness imputed by the ancients to matter, but rather the active power of maintaining itself in the condition whether of rest or motion in which it is placed, which we mean when we speak of the 'Power of Inertia,' a word as good as any other as a mere name, but etymologically quite incorrect.

In consequence of this quality, matter maintains to all eternity the state of motion in which it has been placed by the last power, acting through time, to which it had been subjected.

This power of maintenance is a quality in all respects distinct from that of attraction or of repulsion, and although, in the profound adoration of the Divinity, I can ascribe to Omnipotence anything not absolutely inconsistent with something else, yet nothing certainly short of infinite power could, as I think, be sufficient for adding inertia, or the quality of maintenance, to those abstract points of Boscovich.

If we use the word matter as synonymous with substance, or *ὑπόστασις*, then gravity and inertia will be *superadded* qualities, an upon this assumption will arise one of the most truly astonishing coincidences in nature, namely, that these two qualities always preserve the same invariable proportion one to the other, supposing gravity to act at a given distance, although we are unable to discover the slightest link of connexion between them.

If Venus, for example, moving in a circle, had either the velocity of her motion suddenly doubled, or the action of gravity reduced to a quarter, or her power of maintenance (her inertia) augmented fourfold, its orbit would change to a parabola.

We have not however anything practically to do with the ultimate particles or atoms of matter.

The great discovery of Dalton, one greater indeed than any made since Sir Isaac Newton discovered gravity and inertia, has proved that the proximate particles exist ἐν μετρῷ, καὶ ἀριθμῷ, καὶ σταθμῷ, and our faculties will not, I believe, enable us to go further."

has no concern, but it is with groups or assemblages of them, held together by a certain cohesive force which is proof against every other sort of attraction, that this Science is conversant.

These assemblages of atoms, (which perhaps should be distinguished by a separate name, but which Mons. Dumas denominates *chemical* atoms,) uniting with each other in various proportions, produce combinations according to the law of definite proportions, and are mutually displaced by the operation of chemical affinities.

Lastly, by converting a body into gas or vapour, we separate it into other groups of particles, consisting of one or more of those between which chemical union takes place.

The next proposition stated at the commencement of this Essay lays it down, that " there exists in Nature a variety of elementary bodies, each distinguished by the possession of certain fixed and unalienable properties, so that the business of the analytical chemist is limited to the determination of the nature of the several elements which compose the substances, and the definite proportion they bear to each other."

Now the first part of this statement, namely, that the chemical properties of each body, so long as it continued uncombined, were, like its physical ones, essential and constant, would, I conceive, have passed unquestioned previously to the electrical discoveries announced by Sir Humphry Davy.

That philosopher first threw a doubt upon this position, by shewing, that the chemical affinities of many substances may be heightened or diminished at pleasure, by rendering that electrical condition which belongs to them, when in contact with those bodies for which they possess an affinity, more or less intense, nay, that these properties apparently may be annulled during the period of their conveyance from one pole (as it was then called) of the battery to the other.

The former case indeed is illustrated in the common voltaic apparatus, where the zinc, which, if it be pure, or if it be amalgamated with mercury, remains unaffected by the acid, becomes acted upon by it, so soon as its electrical condition is rendered more intense, by being brought into connexion with a plate of copper plunged into the same menstruum.

The application of this principle to the protection of copper from the action of sea-water, is too well known to require to be dwelt upon on this occasion.

Of late, some very curious facts have been brought to light on this subject by Professor Schœnbein, of Basle, the substance of which has been confirmed by Sir John Herschel and others.

These, from their general tenor, might lead us at first sight to believe, that the affinity of iron for nitric acid, instead of being inherent in the metal under all circumstances, was superadded to it by certain extraneous influences, its existence being dependent upon the relations of the metal at the time to electricity, or on some other cause equally obscure.

Thus, if an iron rod be raised at one extremity only to a red heat, it will not be acted upon by nitric acid of the sp. gravity of 1.35.

2. This immunity from the action of the acid may even be imparted to a second rod, if brought into connexion with the first.

Thus if the heated wire be made to touch a second, and both be plunged into the same acid, neither one will be acted upon. The same immunity is obtained, if an iron wire plunged into nitric acid be simply made to touch a wire of platina.

3. The same wire, if made the positive electrode of the galvanic battery, is not acted upon by the acid, though it transmits the galvanic current, and consequently decomposes the water present; whilst on the other hand it is vehemently attacked by the same acid, when in connection with the negative electrode.

Hence the effect would seem to depend upon the electrical condition of the metal at the time being; but it is curious, that the same effect is produced, by simply immersing it for a few moments in acid, after which the action entirely ceases, and that it may sometimes be renewed by various mechanical methods, as by rubbing it with a copper wire, with glass, or in other ways.

From these and other experiments of the same kind that could have been quoted, the direct inference might seem to be, that the chemical properties of matter are adventitious and contingent; but in the present state of our knowledge it were hasty and unphilosophical to leap to such a conclusion, repugnant as it is to analogy, and based upon a comparatively scanty and ill understood series of experiments.

Nevertheless until we are able to reconcile with the opposite principle the different manner in which a body is often affected by the same reagent, according to the electrical condition that has been induced in it, we ought to hesitate in assuming as an established fact, that the chemical properties of matter are, like the physical ones with which it is endowed, invariable both as to kind and intensity.

Professor Graham, in his recently published Elements of Chemistry, has attempted, by following up views which Faraday put forth with respect to the theory of the Voltaic Pile, to bring under the same general law the phenomena of chemical and of inductive affinity.

In the statement given of his views, he has abandoned altogether the idea of electricity being concerned, remarking, that we have just as much right to attribute electrical attraction to chemical affinity, as chemical affinity to electrical attraction. Nevertheless, as it cannot be denied that an attraction, however produced[a], does take place between the masses of two bodies, at the very time when a chemical affinity is exerted between their particles;

[a] See for an explanation of this, Faraday's Researches on Electricity, especially " On Specific Induction."

and as it has been assumed, that the former species of attraction is due to a particular fluid called Electricity, it may render our views more intelligible, if we adopt the ordinary hypothesis, which regards electricity as the agent concerned in both series of effects.

Let us then suppose, that every particle of matter possesses a definite amount of electricity, which in a passive state is equally distributed over its surface, but which is liable to be displaced and determined to particular poles by the contact or near approach of certain foreign bodies. This destruction of the electrical equilibrium is called Polarity, and it is by virtue of it that ordinary chemical affinity arises.

But it may happen, that the disturbance of the balance of the two electricities is too slight in a particular instance, to render the resulting attraction between the particles of the body powerful enough of itself, to overpower the counteracting force of cohesion.

In such a case of course no chemical union will take place.

But if, at the same time that we disturb the equilibrium of the electric fluid in the particle alluded to, we also produce a similar polar condition in it, by bringing it into connexion with a body susceptible of an opposite electrical state to its own, as for example, when we bring together a piece of copper, and of amalgamated zinc immersed in an acid, which evinces no action upon the latter when alone, we may readily conceive, that the affinities of the metal for the solvent may be so far augmented, as to overcome the resistance which had before nullified its operation.

In this manner it may be possible to reduce to one and the same law, ordinary chemical attraction, and that augmented form of it which is produced by electrical induction; just as, to use Professor Graham's own illustration, attraction always exists between the magnet and steel, owing to the induced polarity caused in the latter when in proximity with the former, but this attractive force in the magnet is rendered more intense, by bringing its poles into contact with a bar of iron, as, in the common horse-shoe magnet, in which it is well known, that the poles are both rendered stronger, by being in juxtaposition with the opposite poles of the bar which connects them.

Thus, whilst modern discovery compels us to recognise a distinction between the physical properties of matter and their chemical ones, inasmuch as the former are always essential and inherent, the latter sometimes induced by extraneous agencies, there is at the same time nothing to contradict the belief, that the conditions, on which depends the capacity of being affected in this manner, are in themselves as permanent, and subject to laws as fixed and definite, as those which seem more directly to belong to their constitution and nature.

But if the chemical properties of matter are affected by changes in their electrical condition, it is not unreasonable to suppose, that a different arrangement of the particles of the same species of matter may alone be sufficient to bring about a change in its chemical constitution, by altering its relations to electricity.

Hence we are prepared on theoretical grounds for receiving the new doctrine which has so changed the face of chemical science, namely, that many substances which are known to be of a compound nature, are nevertheless in some sense to be regarded in the light of elements.

This is the case more especially in compounds belonging to the animal and vegetable kingdoms, so that it has of late become the business of the analytical chemist to determine, not as of old, the ultimate elements which organic matters contain, but the nature of the compound radicals which enter into their composition, and the proportions which these bear to each other.

Indeed the point in which chemistry has taken the greatest strides of late years, consists in the progress made towards ascertaining the proximate principles of which organic matters consist. A few years ago only one of them, cyanogen, had been noticed; but we have since been made acquainted with numerous others, which, though composed in general of the same elements, namely of oxygen, hydrogen, carbon, and nitrogen, are in themselves as remarkably contrasted in their properties, and give rise to as great a variety of combinations, as the elementary substances do, which form the basis of inorganic bodies.

"Chemists," says the French writer whom we have already so frequently quoted[b], "have ascertained the existence in all mineral substances of a certain number of bodies regarded by us in the light of elements; they have determined that these bodies combine together, and that their combinations are able afresh to unite, so as to give rise to three orders of substances, acid, alkaline, and neutral, which they have succeeded in throwing together into a certain number of natural groups, by which means they are enabled to take a more comprehensive and philosophical, as well as a more simple, view of their nature and relations.

One may easily understand, that with the 55 elements at present recognised, a series of combinations may be produced equal at least in point of number to those which are known to exist in the mineral kingdom; but the difficulty was to apply the same method to the case of organic chemistry.

There the number of distinct combinations recognised is not less great, nor is their character less diversified, and yet instead of 55 elements, we meet in the majority of known compounds with only three, or at most four.

The great problem therefore is to explain, in accordance with the laws of mineral chemistry, the existence of that great variety of substances, which we derive from the animal and vegetable kingdoms, in which we rarely discover any other constituents than carbon, hydrogen, and oxygen, with the occasional addition of azote.

Now Nature has accomplished this in a manner not less

[b] Dumas in the Annales de Chimie.

simple than unexpected, namely by forming out of the three or four simple bodies above enumerated, an assemblage of proximate principles, possessing the properties and relations that belong to the elements existing in the mineral kingdom. Thus organic chemistry may be said to possess its own peculiar constituents, some of which stand in the same place and relation to others as oxygen, chlorine, &c., and others in that of the metals and simple combustibles, and the fundamental distinction between inorganic and organic chemistry is, that in the former the radicals are, so far as is known, simple, in the latter they are compound. Perhaps indeed this distinction may be only apparent, and it may eventually turn out, that the radicals found in mineral substances are themselves compound, though they have hitherto resisted our powers of analysis."

With regard to this latter speculation, which borders upon the question of the transmutation of the metals, I may say something in another part of this Essay; but whether it be true or not that an analogy runs through all Creation in the particular alluded to, it is certain at least, that the same simple laws of combination pervade the whole, and that if the organic chemist only takes the requisite precautions to avoid resolving into their ultimate elements the proximate principles upon which he operates, the results of his analysis will shew, that they were combined precisely according to the same plan, as the elements of mineral bodies are known to be.

I will illustrate these general propositions by referring to the composition of alcohol, ether, and the several fluids, derived from, or in some measure related to them.

In the time of Lavoisier, when the task of analysis was limited to that of the determination of the ultimate elements of a body, and of the proportions they bore one to the other, nothing more was attempted, than to set down the amount per cent. of oxygen, hydrogen, and carbon present in the several bodies of this class which were then known. But it has since been discovered, that a very simple and beautiful relation subsists between alcohol and olefiant gas, and that the composition of the former is precisely the same, as that of one atom of the gas alluded to, and one of water, or according to another mode of expression, that the vapour of alcohol may be represented, as consisting of two volumes of olefiant gas, and two volumes of the vapour of water, condensed into one volume.

Now sulphuric ether, which is derived from alcohol by distilling it with sulphuric acid, has exactly the same constitution as that of two volumes of olefiant gas and one volume of aqueous vapour, so that it is, as if it had been formed, by abstracting from alcohol one half of the water present in it. Hence Dumas considered olefiant gas (a compound of two of carbon and two of hydrogen) as the base of these several bodies, standing in the same relation to water which an alkali does to an acid, and consequently readily entering into combination with it. Thus one atom of water with two atoms of olefiant gas forms sulphuric ether; whilst two atoms of each constitute alcohol.

Several other descriptions of ether are produced by the substitution of one atom of some acid for one of the atoms of water present in alcohol; thus chloric ether is produced by the substitution of one atom of chlorine, nitric, by that of one of hyponitrous acid, acetic by one of acetic acid, &c.

But though, for the purpose of illustration, I have adopted the views at one time entertained by Mons. Dumas with respect to alcohol and the other bodies allied to it, I must not forget to notice, that a different view of their constitution has been taken by the German chemist Liebig.

According to Dumas, in the series of compounds alluded to, water acts the part of an acid, olefiant gas of a base, and sulphuric ether is to be regarded in the light of a salt, composed of one atom of water and one of base; alcohol of two of water and one of base.

But Liebig contends, that it is more agreeable to analogy to regard ether as the oxide of an unknown base composed of $C^4\ H^5$, and alcohol, as a compound of this oxide with one atom of water.

Hence the composition of ether may be expressed by the symbol $C^4\ H^5 + O^1$, instead of $C^4\ H^4 + HO$; and that of alcohol may be represented as consisting of ether ($C^4\ H^5\ O^1$) + water (HO), instead of $C^4\ H^4 + H^2\ O^2$, as Dumas' hypothesis considers it.

In an elaborate article in the Annales de Chimie, Liebig has put forth at length all that can be said for and against this theory, refuting in the first place the arguments in favour of Dumas' supposition that ether contains water, and afterwards shewing that it is an oxide, being neutralised by acids, and forming with them a class of combinations analogous to the salts.

A remarkable discovery made in organic chemistry by the same philosopher in conjunction with Wöhler, has still further contributed to give a preponderance to these latter opinions.

This discovery was the relation subsisting between that highly poisonous substance, the essential oil of bitter almonds, and the inert body, benzoic acid.

The base of both these substances appears to be a compound radical, consisting of carbon, hydrogen, and oxygen, and this with an atom of hydrogen forms the oil of bitter almonds, but with one of oxygen benzoic acid. Hence by merely substituting an atom of oxygen for one of hydrogen, you convert the former organic compound into the latter, and accordingly the essential oil, if exposed for some time to air, spontaneously undergoes this change, and is metamorphosed, from one of the most virulent of poisons, into a mild innocuous acid, an ingredient in many animal as well as vegetable excretions.

Lowig has traced a similar class of compounds derived from the oil of the spiræa ulmaria.

The base of this is assumed to be composed of C^{12} H^5 O^4, and this with H^1 forms the oil extracted from the flowers of the plant; whilst the substitution of an atom of chlorine, one of iodine, one of bromine, or four of oxygen for the atom of hydrogen united with the supposed base, gives rise in each case to a totally distinct compound[c].

These and other similar facts appear of late to have given a preponderance to Liebig's views over those of Dumas, and it would appear from a recent memoir, that the latter chemist has himself in a great degree adopted the doctrines of his opponent to the abandonment of his own.

The existence of a compound radical, consisting of C^{14} H^5 O^2, which by its union with H^1 forms the oil of bitter almonds, and by the substitution of O^1 is converted into benzoic acid, is no longer hypothetical; and the view taken of its relation to these latter bodies is confirmed by the analogy which may be traced between it and the long known basis of prussic acid, cyanogen, C^2 N^1, and the compound of C^6 N^4, called mellon, lately detected by Liebig, which may be regarded as the root of a similar series of combinations.

A curious discovery of Dumas may also be adduced in corroboration of the theory which regards certain known compounds, as resulting from the union of hydrogen with radicals, consisting of two ingredients which have not themselves been isolated.

When oxalate of ammonia, a salt composed of C^2 O^3 (oxalic acid), $+ Az^1$ H^3 (ammonia), is exposed to heat, Dumas found that an atom of water (H^1 O^1) is disengaged; and that a white powder remains, consisting of C^2 $O^2 + Az^1$ H^2.

Now when hydrate of potass ($KO + HO$) is heated with this, the salt called oxalate of potass ($KO + C^2$ O^3) is formed, and ammonia (Az^1 H^3) is given off. In the former case, then, we must infer that the carbonic acid lost an

[c] Scientific Memoirs, vol. i. p. 151.

atom of oxygen, and the ammonia one of hydrogen; and that in the latter both bodies recovered from the water present with the potass what they had parted with previously.

It would seem to follow from these experiments, that there is a compound of $Az^1 H^2$ capable of existing in combination, though not yet exhibited in a separate form—which with 1 atom of hydrogen forms ammonia ($Az^1 H^3$). This hypothetical radical is called amidogen, and its combination with $C^2 O^2$ oxamide.

Another compound of azote and hydrogen, in the proportion of $Az^1 H^4$, is supposed to constitute that curious body, which amalgamates with mercury, in the experiment, in which ammonia, or its salts, are exposed to the decomposing action of the voltaic pile in contact with mercury[d].

The analysis of the mercurial amalgam by Berzelius indicates $Hg + H^4 N^1$ as its composition.

We have thus, it would appear, two compounds of nitrogen and hydrogen, both of which generate ammonia, the one by the absorption, the other by the disengagement of hydrogen.

Other bodies have since been discovered analogous in their composition to amidogen, and producing a similar class of compounds.

Thus Liebig and Wöhler have discovered a new compound called benzamide, consisting of the same ingredients as benzoate of ammonia, *minus* one atom of water, and from which ammonia may be disengaged by boiling it with a solution of caustic potass. A numerous class of similarly constituted bodies already promises to be discovered, to which the name of amides is applied; but for which I must refer to works expressly on organic Chemistry[e].

[d] This is however explained by Professor Daniell, (Introduction, p. 420,) on another principle, the same which will be alluded to in a subsequent part of this Essay under the head of adhesive attraction.

[e] See also in the Transactions of the Royal Irish Academy, vol. XVII. p. 423, a memoir by Professor Kane of Dublin, on the substance formerly called *mercurius precipitatus albus*, and now *hydrargyri am-*

Such are the facts that have led Liebig to represent the various products of the vegetable and animal kingdoms as probably made up of a certain number of compound radicals; consisting either of carbon and nitrogen, as cyanogen and mellon; or of carbon and hydrogen, as benzoin, spiroil, and many others; or of nitrogen and hydrogen, as amidogen; and up to this point analogy seems fairly to bear him out in his conclusions. But he has likewise endeavoured to give an extension to these same chemical views, in which we may have more difficulty in following him, though there are not wanting valid reasons, as well as weighty authorities on his side. This consists in the attempt to explain the composition of the acids found in inorganic substances on a similar principle to that which he has applied, as indeed had originally been suggested by Mons. Persoz of Strasburg, to the case of organic bodies.

Formerly we were in the habit of assuming that four or five combinations might take place between one elementary body and another; thus we considered that,

Sulphur with 1 atom of oxygen formed hyposulphurous acid.
——— 2 ——————— sulphurous acid.
——— 3 ——————— sulphuric acid.

But according to these chemists, the abovenamed combinations must be represented thus:

S. with 2 atoms of O. = sulphurous acid (a compound radical).
Sulphurous acid with 1 atom of O. = sulphuric acid.

And this additional atom of oxygen may be replaced by various elements; as by sulphur, forming the hyposulphurous acid (SO^2+O), by chlorine, forming the chlorosulphuric

monio-chloridum of the London pharmacopœia, which he regards as a compound of $Hg\ Cl + Hg\ H^2$, or a chloride of mercury united with an amide of mercury, and which he therefore calls mercuramide. To the same class he refers, in great part, the compounds formed by the absorption of ammoniacal gas, by chlorides of various bodies, as by chloride of phosphorus, chloride of tin, &c.

acid (SO^2+Cl), or by nitrous gas forming the nitrosulphuric acid (SO^2+NO^2).

In like manner the compounds of carbon with oxygen used to be represented as follows:

$C^1\ O^1$ carbonic oxide.
$C^1\ O^2$ carbonic acid.
$C^2\ O^3$ oxalic acid.

But Liebig proposes to represent carbonic oxide as a compound radical; one atom of which with one of oxygen forms carbonic acid; two atoms with one of oxygen, oxalic acid.

Nor is this the only change which he proposes to introduce in our mode of considering these acids.

According to the old notions it was necessary to suppose, that some of these acids derived their acidity from oxygen, others from hydrogen, others from chlorine, iodine, &c.

Thus sulphate and carbonate of soda, compounds of oxygen acids, were separated by an artificial line from chloride of sodium, common salt, which evidently belonged to the same class.

Now in order to remove this anomaly, it was originally suggested by Davy, that what we call the oxygen acids are in fact combinations of hydrogen with a compound base containing a certain number of atoms of oxygen.

Thus sulphuric acid is usually represented,

$$S + O^3 + HO.$$

Whereas it is possible to consider it,

$$SO^4 + H^1.$$

Hydrogen being the acidifying principle here, as it is in the case of muriatic acid.

This view, which at the period of its first promulgation by Sir H. Davy received but little general countenance amongst chemists, was afterwards more fully developed by Professor Graham of the university of London, who in his recently published Elements of Chemistry, p. 160, has presented us with a sketch of the leading arguments in its favour. More recently the distinguished German chemist Liebig has given to this hypothesis the weight of his name and authority, and the existence of analogous compounds amongst organic bodies has also tended strongly to recommend it.

Now the above view is supported by the fact, that the power of saturation which an acid possesses is dependent upon the amount of hydrogen present in it, and moreover that every known substance which exhibits acid properties contains hydrogen, either by itself, or in the form of water; for when destitute of this principle, as is the case with the anhydrous sulphuric, phosphoric acids, &c., it exerts no chemical reaction whatsoever.

But on the other hand we know nothing of the existence of those radicals which Professor Liebig assumes; we know of no combination of sulphur with four atoms of oxygen, forming a base which may unite with one or more atoms of hydrogen; so that in admitting it to exist, we may be accused of having fallen into the old error, which was committed by our predecessors, who imagined the hypothetical principle, phlogiston, and indeed are calling in the aid, not of one only, but of many such hypothetical principles to explain the phenomena.

Liebig's doctrine stands therefore at present on a very different footing with respect to probability, from that of Davy, who had demonstrated, that a *known* element *chlorine*, with a metal, or alkaline basis, would in fact form the compound, which had previously been regarded as produced by the union of muriatic acid with the metallic oxide.

Here there was nothing hypothetical, whereas Liebig's views on this subject rest at present chiefly upon assumptions.

But whatever becomes of that part of the theory of radicals which relates to the composition of inorganic substances, it at least must be allowed to represent in a very satisfactory manner the constitution of organic bodies, and to account for the otherwise anomalous proportions in which their ultimate principles are found combined.

Thus, let us take the case of a compound radical, the existence of which has been demonstrated, namely, cyanogen. Regarding this as the radical, and prussic acid and the other allied substances, as compounds of it with various elements, their composition may be stated as follows:

Cyanogen $C^2\ N^1$ (Symb. Cy.)
Cy^1+O^1 Cyanic acid.
Cy^2+O^2 Fulminic acid.
Cy^3+O^3 Cyanuric acid.
Cy^1+H^1 Hydrocyanic or prussic acid.
Cy^1+S^2 Sulphocyanogen.
Cy^1+Cl^1 Chloride of Cyanogen.
$Cy^3\ Fe^1$ Ferrocyanogen (Cfy).
Cfy^1+H^2 Hydroferrocyanic acid.

Let us contrast this with the old method of representing these compounds.

Cyanic acid $C^2\ N^1\ O^1$.
Fulminic acid $C^4\ N^2\ O^2$.
Cyanuric acid $C^6\ N^3\ O^3$.
Prussic acid $C^2\ N^1\ H^1$.
Sulphocyanogen $C^2\ N^1\ S^2$.
Chloride of cyanogen $C^2\ N^1\ Cl^1$.
Ferrocyanogen $C^6\ N^3\ Fe^1$.
Hydroferrocyanic acid $C^6\ N^3\ Fe^1\ H^2$.

It is evident, that the former mode of representing the composition of these bodies is far more clear, as well as more consistent with the analogy of the mineral kingdom.

We perceive then that the second proposition stated, cannot be adopted at present without considerable modifications; for neither on the one hand do those substances which we still hold to be elementary, manifest relations to others at all times the same in degree or intensity, nor on the other are those, which constitute the basis of organic substances, and which stand on the same footing with respect to the rest, which the elements of mineral bodies do to the salts and acids to which they give rise, necessarily themselves simple, or composed of one kind of matter. They resemble indeed rather the elements represented by Ovid, and other writers of antiquity, the bases of other bodies, but yet capable themselves of conversion from one shape into another.

I proceed now to consider the third proposition, stated at the commencement of my Essay, which asserts certain doctrines with regard to the compounds of these radicals, as the preceding one did respecting the radicals themselves.

It lays down in the first instance, that "the difference between one substance and another can be conceived to arise only from two causes, namely, from their being produced, either out of different elements, or out of the same elements combined in different proportions; whence it would seem to follow, that all bodies, possessing the same chemical composition, are identical both as to form and nature—as to their physical as well as to their chemical properties—whilst those which disagree either as to the nature or the proportion of their component parts, must be expected to differ one from the other in both the above particulars."

Now I have already given a sketch, in my Essay on the Atomic Theory, of certain doctrines then winning their way amongst the scientific public, which ran counter to both the conclusions that seemed to flow from the principles above laid down. It has been found, for example, that the same ingredients united together in precisely the same proportions, will often give rise to several compounds, as distinct in their nature as those whose component parts themselves vary. Such bodies are now distinguished by the term "*isomeric*," denoting that they consist of equal parts or proportions of the same elements.

In some cases, the distinction between them appears to arise from the different degrees of condensation which the ingredients have undergone.

Thus we have at least four compounds of carbon and hydrogen in equal atomic proportions.

The first of these is olefiant gas, in which two volumes of the vapour of carbon and two of hydrogen are condensed into one volume.

The second is etherine, a liquid obtained by Faraday from oil gas that had been condensed to render it portable, in which four volumes of each ingredient are condensed into one.

The third is cetene, an oily liquid described by Dumas, in which sixteen volumes of each are condensed into one. And to this Dumas adds an hypothetical substance called methylene, in which he calculates that one volume only of each is condensed into the same compass.

In these cases then the difference of properties may be explained by the different degrees of proximity into which the particles are respectively brought, but the cause which determines them to prefer the one condition rather than the others, seems involved in mystery.

Dr. Prout[f] has ingeniously suggested, that if we suppose combination to take place, not between the ultimate atoms of matter, but between certain groups of atoms; if we assume also, that groups of various amounts, though always mutually related one to the other in point of number, have a tendency to combine with the atoms, or groups of atoms, of certain other substances; and if we imagine, that the chemical properties of the mass are modified by the number of ultimate atoms clustered together in the same group, the different properties of isomeric bodies may admit of a plausible explanation.

Thus the self-repulsive molecule of water on entering into combination, is often found to be divided into two or three (perhaps more) parts. Now as the division of an ultimate atom would imply a contradiction, we must conclude, that the molecules of oxygen and of hydrogen are much more compounded than as commonly repre-

[f] See his Bridgewater Treatise.

sented, and must each of them contain at least three component or sub-molecules. Hence the self-repulsive molecule of water will consist of at least nine component sub-molecules, (viz. three of oxygen and six of hydrogen,) which we may suppose to be associated—in the first place the hydrogen with the oxygen *chemically*—and afterwards the three sub-molecules of water with one another *cohesively*, so as constitute one spheroidal molecule, in a manner, that with a little ingenuity it would perhaps not be difficult to represent mechanically. Now it is very possible, that the chemical properties of a sub-molecule of water, or of any other substance, may differ from that of the molecule itself; or to express it in other language, that a group of 100 atoms, for example, should possess properties somewhat different from one consisting of 50, or of 25, and hence that the bodies compounded of the former may vary from those formed out of groups in which either of the latter proportions prevail.

But there are other isomeric bodies to which this explanation, imperfect as it is, cannot be extended; as for instance, where two or more bodies identical in point of composition exist in the same condition, either as solids, liquids, or gases.

In some of these cases[g] we may refer the difference to their being derived from two different isomeric bodies. Thus if A contains methylene and water as its constituents, and B, olefiant gas and water, the analysis may present the same ultimate elements in the same proportions in both, and yet the chemical nature of the two may differ.

Thus alcohol may be regarded as a compound of 1 atom of olefiant gas $C^4 H^4$, and 2 atoms of water $H^2 O^2$, its ultimate analysis therefore yielding $C^4 H^6 O^2$; whilst the liquid called pyroxylous spirit consists of 1 atom of methylene $C^2 H^2$, and 1 atom of water $H^1 O^1$, or together $C^2 H^3 O^1$.

[g] See Dumas, Leçons sur la philosophie chimique, 8me Leçon.

Hence the proportions of the ultimate elements appear to be the same, and in a gaseous state both substances are of equal density.

In this case therefore the difference must be explained by the presence of olefiant gas in the first, and of methylene in the second.

In another class, the difference between two isomeric bodies may be traced to a difference in the processes from which they have originated.

Thus formic ether and acetate of methylene contain both the same proportions of carbon, hydrogen, and oxygen, and their density in the gaseous as well as in the liquid condition is conceived to be identical.

Nevertheless their chemical properties would seem to differ, for formic ether is resolved by the alkalies into formic acid and alcohol, acetate of methylene into acetic acid and pyroxylous spirit.

Now this difference in chemical constitution may be referred to the circumstance, that formic ether is produced by the action of formic acid upon alcohol; and acetate of methylene by that of acetic acid upon pyroxylous spirit.

Hence in the former compound the elements are arranged as follows:

I atom of formic acid $C^2 H^1 O^3$
I atom of sulphuric ether $C^4 H^5 O^1$
Making together $C^6 H^6 O^4$.

And in the latter compound thus:

I atom of acetic acid $C^4 H^3 O^3$
I atom of water $H^1 O^1$
I atom of methylene $C^2 H^2$
In all $C^6 H^6 O^4$.

There is yet another class of isomeric bodies to which none of the above explanations apply, such for example as the tartaric and paratartaric acids, together with several other organic compounds.

No doubt can exist, that in these as well as in the other cases mentioned, a different arrangement of the particles which compose the mass has taken place in one of the resulting bodies than in the other; and this accounts for the fact of their assuming different crystalline forms, and having different relations to light, electricity, and other physical agents, and also for their combining proportions not corresponding. But why the same ingredients should affect one rather than the other arrangement, is a question still veiled in obscurity.

For some of these cases of isomerism however, Dr. Prout has supplied us with an ingenious and plausible explanation, assuming the presence in them of a minute portion of some foreign matter, which modifies the properties of the staple ingredients in such a manner, as to impart new characters to the entire mass [h].

The change produced in the properties of iron by an infinitesimal portion of carbon, or in that of steel by a slight admixture of silver, platina, and other metals, and the different relations to electricity imparted to mercury by being alloyed with less than a millionth part of potassium, are facts which lend support to this hypothesis, though it must be confessed that its adoption only removes the difficulty one step further back; and that the presence of the supposed foreign matter is in the greater number of cases unproved.

Nor is the assumption of different properties by bodies which in their constitution appear to agree, the only point on which recent discoveries clash with the established principles of the chemistry of a former age.

We have also to inquire, how it happens, that the same substance will sometimes assume two or more crystalline forms, without any alteration of its qualities supervening.

Bodies which thus present themselves under two different forms are termed *dimorphous;* and the number of these already known is so great, that it may perhaps

[h] See Introduction to the Atomic Theory, page 79.

be doubted, whether there be any body in nature, which constantly occurs in the same physical condition under all circumstances.

A familiar instance of dimorphism is exhibited in the case of carbonate of lime, which, without any change in its chemical properties or its composition, is found, sometimes in the form of calcareous spar, sometimes in that of arragonite.

Now two questions here present themselves. 1st, If this difference in crystallization results, as no doubt it must, from a different arrangement of the particles composing the mass, why has not the latter induced an alteration in the chemical properties of the body, as it appears to do in the class of isomeric substances?

2dly, In what manner can we account for a body, precisely identical in nature and composition, assuming one form at one time, and a distinct one at another?

The former of these questions is perhaps the most easy of solution.

We may imagine every compound body to be made up of a congeries of integrant particles, every one of which must contain at least one atom, or if you please one group of atoms, of either constituent.

Thus every particle of carbonate of lime contains at least, one atom of carbonic acid, and one atom of lime.

Now it is easy to perceive, that a different arrangement of the integrant particles, unaccompanied by any change in the relative proportions of the atoms of which each of them is composed, may bring about a different description of crystal, so that in one instance we may have arragonite, in another calcareous spar, resulting from the same materials.

This then is what happens in a case of dimorphism; and we may readily understand, that such a variation in the arrangement of the integrant particles need not necessarily involve a change in the chemical properties of the mass.

Let us next assume, that the ultimate atoms of which each of the constituents of this dimorphous body is composed, as in the case before us, the ultimate atoms of carbonic acid and of lime, undergo a change of arrangement. In this case we should have an *isomeric* body produced, the chemical properties being altered, no less than the physical ones of density and crystallization.

The ancients, who were often happy in their mode of elucidating their ideas, compared the production of different bodies from the same elements, to the formation of different words by the interchange of the same letters. Thus Lucretius:

> Jamne vides igitur, paullo quod diximus ante,
> Permagni referre, eadem primordia sæpe
> Cum quibus, et quali positura contingantur,
> Et quos inter se dent motus, adcipientque,
> Atque eadem, paullo inter se mutata, creare
> Ignes e lignis ? quo pacto verba quoque ipsa
> Inter se paullo mutatis sunt elementis,
> Quum ligna atque igneis distincta voce notemus.

Now to follow up this same analogy a little further, we may compare isomeric bodies to words composed of the same letters differently arranged, and dimorphous ones to words consisting of the same syllables transposed, each syllable bearing the same relation to the word it contributes to form, which each integrant particle of a compound does to the substance produced by its union with others.

But how are we to explain the second difficulty, namely why the same body should sometimes affect one crystalline form, and sometimes another?

On this subject we are, it must be confessed, still much in the dark; but some little light has been thrown upon the question by the researches of Mitscherlich, who has shewn, that heat in many cases tends to modify the crystallization of a body, by causing it to expand unequally in different directions, enlarging the acute angles, and thus imparting to it a tendency towards the cube.

Hence it is very possible, that the same substance, if made to crystallize at a high temperature, may assume a different form from that which belongs to it at a lower one; and this is actually found the case with carbonate of lime, which, when deposited from a solution in the cold, assumes the rhomboidal form of calcareous spar, but when from water of a higher temperature, becomes arragonite[i].

But if it be true, that a mere variation in the arrangement of the same particles is alone sufficient to produce an entirely different material, we are naturally led to speculate as to the possibility, that the substances which, inasmuch as they have hitherto resisted our powers of decomposition, we regard as simple, may themselves be isomeric bodies, or be produced by a different arrangement of the same elementary matters.

Several of this class of bodies are known to be dimorphous, that is, to be capable of assuming two different crystalline forms, yet from this difference of structure no alteration of chemical properties results.

But supposing them to be compounds, and supposing the elements of which they consist to undergo the same kind of transposition, which takes place in the case of many binary compounds, and it is then easy to understand, that many of the metals, simple combustibles, and supporters of combustion, may be formed out of the same elements differently arranged.

Cyanogen, a body known to be compound, has the same chemical relation to hydrogen and the other simple combustibles, which oxygen and chlorine possess: there is therefore nothing contrary to analogy in supposing, that other bodies which stand in the same relation may likewise be compounds.

Cyanogen exists under two different forms, and so like-

[i] See an excellent Review of the present state of our knowledge in regard to dimorphous bodies, by professor Johnston of Durham, in the 7th report of the British Association for the advancement of science, in which the causes of dimorphism are more profoundly discussed than seemed consistent with the scope of the present Essay.

wise do sulphur and carbon. One of the forms in which cyanogen exists, is as a gas, the other as a solid. There is therefore as great a difference in physical properties produced in cyanogen, as exists between any two of the bodies regarded as elementary, between iodine and bromine, for instance, or between oxygen and sulphur. If such a change in physical properties can result from *dimorphism*, why may not an equal difference in their chemical properties be occasioned by that transposition of their ultimate component parts which takes place in *isomeric* bodies, if only we suppose them to be compound? and if that class of bodies, which stands in the same relation to them in the vegetable and animal kingdoms, be of a compound nature, is there not at the least a probability, that the same may turn out to be the case with the radicals of mineral bodies also[k]?

Thus have the beautiful discoveries of Mitscherlich and others brought us back to the very speculations which engrossed the alchemists of old; so that it has happened in this case, as in that of the atomic theory itself, that modern science has incidentally lent support to views, that had been originally brought forwards on grounds altogether different, and by a class of persons, whose habits and principles of reasoning were as opposite as possible from their own.

I now proceed to consider the fourth proposition, which I set out with announcing as the understood creed of men of science a short period back, and which may be stated as follows:

" Decomposition is caused by the approach of a foreign substance, possessing a stronger affinity for one of the ingredients of a compound than that which binds them

[k] Mons. Dumas, to whose remarks I have been so much indebted in this part of my Essay, has suggested, as a confirmation of this hypothesis, that several of the undecompounded bodies have equivalents, which are either the same, or some multiple one of the other. See Leçons, p. 319.

mutually together, so that in every such case, the decomposing body may be expected to enter into union with one or other of the elements of the compound which it destroys."

Now this position, which would have then seemed an almost obvious consequence of the received views with respect to chemical combination, cannot in the present state of our knowledge be received without considerable limitation.

It has been found, that there are substances, capable of causing decompositions, and of bringing about new unions between certain elementary and compound bodies, merely by virtue of their *presence*, and without themselves combining with either constituent.

The numerous cases in which this is assumed to take place have led to the invention of a particular term, *catalysis*, (dissolution,) to indicate the property in question, thus marking the distinction between what takes place here, and in a process of *analysis*, where a new substance being presented to an existing combination, annuls it, by uniting itself with one of the constituents.

The first case of the kind was presented to us by Döbereiner of Jena, in the property which he shewed to belong to spongy platina, of bringing about an union between hydrogen and oxygen gases, at a temperature at which under other circumstances they remain together without combining.

This remarkable discovery has been followed by other similar ones, in which the same substance is the agent employed.

Thus alcohol, when once kindled, will continue, after the flame has been extinguished, to unite with oxygen rapidly enough to cause, if in contact with spongy platinum, a certain degree of heat, being converted in consequence into acetic acid; and in like manner pyroxylous spirit, when left in contact with spongy platinum under a covered jar, is converted into formic acid. Various other substances appear to act catalytically upon that curious compound called oxygenized water, its oxygen being disengaged, and its reconversion into common water being effected, by the alkalies, the metals, or the metallic oxides, when brought into contact with them, although in cases where the substance introduced does not combine with the oxygen liberated.

In like manner the nitrosulphuric acid of Pelouze is decomposed, by spongy platinum, by oxide of silver, by metallic silver, by powdered charcoal, and by other substances, which are not acted upon by any of the constituents of the compound which they decompose.

Hydruret of sulphur is likewise decomposed by the action of alkalies, whilst it is rendered more stable by acids.

The decomposition of ammonia, by passing it through heated metallic tubes, seems to be a case of the same kind; for this gas may be made to traverse porcelain tubes at an equal temperature without undergoing any change.

The above cases of catalytic action are taken from the inorganic kingdom; but they occur much more commonly in the processes of organic chemistry. Of the vegetable principles upon which catalytic action is distinctly exhibited, one of the best instances perhaps is starch, which undergoes the changes into sugar [b], gum, and the substance called by the French chemists *dextrine*, under the operation of substances, which do not enter into union either with it, or with the ultimate principles of which it consists.

Payen in France, who has recently written a very elaborate Memoir on Starch, in the Annales des Sciences Naturelles, represents it as composed of a number of concentric layers, surrounding a common axis, so as to form a globular or elliptical mass. These layers being of unequal density, have been shewn by Mons. Biot to polarize light in a particular direction, and hence this new instrument of

[b] Sugar, according to Berzelius, (Ann. de Chimie, vol. lxvii.) is composed of 2 $C^3 H^8 + 5 O$, and is therefore an organic oxide, uniting with bases such as lime, alkalies, and oxide of lead. It is isomeric with starch, gum arabic, lactic acid, inuline, pectic acid, and other bodies.

analysis has been introduced into chemical researches, as a means of distinguishing it from other allied substances.

The whole mass of the Starch in its natural condition is insoluble in cold water, but long continued boiling causes a change in its characters, rendering it gradually soluble in water of ordinary temperature. When this is brought about, it acquires the property of polarizing light to the right, and on account of this peculiarity has acquired the name of *Dextrine.*

Now it seems to be ascertained, that the change from insoluble Starch into soluble Dextrine, which is brought about artificially by boiling, takes place also in nature spontaneously. But it would appear, that it occurs in those parts of the plant only, in which it is requisite, that the amylaceous matter stored up for the purposes of its internal economy should be rendered soluble in water, so as to be dissolved by the aqueous fluid of the sap, and carried up by the vessels or channels of circulation to those parts where a supply of it is wanted.

Now it is the opinion of Payen, suggested by the experiments of Pelouze and others, that in both these cases the change is brought about, through the instrumentality of a minute portion of a substance present along with it in the seeds of barley, oats, and probably of most other plants, *so soon as they begin to germinate*, and which, from its property of separating starch from other ingredients, as well as of altering its properties, is called *Diastase.* Diastase may be obtained by macerating malt in cold water, and then submitting it to a strong pressure. The liquid expressed contains the Diastase, in union with other matters, from which it may, however, be separated by adding Alcohol, which precipitates it in the form of a white flocculent mass.

Diastase seems to be expressly intended by nature to render starch soluble, and thereby capable of being taken up by the sap, and it is interesting to find, that it exists in the Potatoe, only just at the point of insertion of the Tuber, that is, just at the point where the young shoot would be sent out.

And it is a beautiful arrangement of nature, that this magazine of nourishment should, so long as it is not wanted, be insoluble in water, so as to remain unchanged and unacted upon, whilst a provision is made for rendering it soluble, and thereby fitted to circulate through the plant, by preparing, just at the points where it is required, a minute quantity of a foreign matter, which, without affecting its properties by entering into combination with it, serves, nevertheless, to bring about in it this essential change in its power of dissolving in the sap.

When the change into Dextrine and Sugar has taken place, the substance, at the same time that it acquires the property of dissolving in cold water, loses that of acquiring a blue tinge with Iodine.

Diastase then seems to act catalytically upon Starch, producing a change in the arrangement of its particles, and, consequently, a new substance, without combining itself with the ingredients.

Another case of catalytic action is presented by the conversion of starch into sugar through the agency of sulphuric acid.

If starch be boiled in water with about $\frac{1}{100}$th part of sulphuric acid, in about 24 hours the liquor acquires a sweet taste, and the starch disappears.

But that this is not owing to any chemical union between the sulphuric acid and starch, is evident from the circumstance, that the same amount of acid exists in the solution, after the production of the sugar, as before it.

Berzelius conceives, that the process of fermentation itself, during which Sugar is converted into Alcohol and Carbonic acid, furnishes a case of an analogous description.

It seems to be fully ascertained, that a small quantity of a substance called gluten, present in yeast, is essential to the process, for pure sugar and water will not ferment by themselves. But the gluten, so far from combining with the ingredients, is said even to be increased during the process, so that it would seem to act upon the saccharine matter *catalytically*.

I ought, however, to notice, that a different explanation of the process of fermentation has been offered by a French Savant, Mons. Cagniard de la Tour, in a late communication to the Institute. He contends, that gluten is a living principle, which consists of a number of little globular bodies capable of reproduction, and that so long as these retain their vitality, they continue to act upon any solution containing sugar, and by some effect of their growth, cause the disengagement of carbonic acid, and the formation of alcohol. He has examined the ferment of beer (yeast) under the microscope, and found it to consist of these little globules, and, watching it during the continuance of the fermentative process, he perceived new globules appear, attached to, or emanating from, those originally observed.

Hence he contends, that the organic matter, of which yeast consists, is capable of growth or reproduction, and considers the above inference to be confirmed by the fact, that this material, so far from being consumed by the process of fermentation, which it produces, exists, on the contrary, in larger quantity at its close than at its commencement.

But Liebig, in his treatise on organic Chemistry, has with reason objected to this hypothesis. He admits, indeed, that infusoria may obtain a suitable nidus in bodies undergoing fermentation; but he contends, that, like the mites in cheese, their entrance may be prevented by the exclusion of the air which conveys their ova; whilst the globular form of the particles, which has been taken for an evidence of organic structure, is nothing more than that naturally belonging to substances like gluten and albumen, whose particles have never yet been observed to assume a regular geometrical arrangement.

Neither would it be practicable, if we adopted this solution in the particular case before us, to extend the same to the many other examples of catalytic action which the organic kingdom presents.

Thus the conversion of Alcohol into Ether, which takes place by distilling it mixed with a certain proportion of sulphuric acid, is supposed to be a phenomenon of a similar kind, and to be produced by the catalytic action of the acid.

It has indeed been explained, as arising from the strong affinity which subsists between sulphuric acid and water; and as alcohol was represented as a compound of ether and water, it was supposed that the ether was produced owing to the abstraction of water from the alcohol by the acid; but it is objected, that potass, chloride of sodium, quick-lime, and other substances which possess an equal affinity for this liquid, fail in converting alcohol into ether, and Mitscherlich has shewn, that if alcohol be poured upon sulphuric acid at a temperature higher than that of boiling water, a proportion of water and of ether, exactly equivalent to the alcohol employed, will distil over.

Hence it would appear, that the action of sulphuric acid upon alcohol is *catalytic.*

This new principle furnishes us with a clue to the formation of those many products, which result from the selfsame fluid in the living Animal and Vegetable.

It is in this way we can understand, how from the sap alone, sugar should be produced in one part of the Plant, camphor in another, an essential oil in a third, caoutchouc, or milky juices, in a fourth.

It is probably in the same way, that muscle, nerve, sinew, mucus, and all the other secretions of the Animal, are elaborated out of one common material, the Blood.

The manner in which the presence of a third substance brings about this new arrangement of the particles of an existing compound, must be still admitted as obscure; yet, perhaps, some light may be thrown upon it, if we apply to its elucidation the new principles of electrical induction, which Faraday has introduced to explain the action of the ordinary voltaic pile.

It is admitted, in the first place, that the elements of an organic compound are in a state of unstable equilibrium, in some cases indeed with the divellent and quiescent attractions so nearly balanced, that nothing but the inertia of the atoms tends to maintain the existing combination. Any cause, then, which should enhance in the slightest degree the force of affinity subsisting between the atoms not already combined, must bring about a new arrangement of the entire mass.

Now the introduction of the minutest portion of a foreign body, such as a ferment, which is itself undergoing chemical action, may operate in this manner. No chemical action can take place, without rendering the substances between which it operates, *pro tempore* positive and negative, or, to adopt the explanation of Faraday, causing a polarity amongst their particles. This polarity must induce an opposite condition in the particle nearest to it; the latter affect consecutively the next in order, and so on throughout the entire mass. But the accumulation of attractive energy about a particular pole of a particle, must, of course, alter its relation to that next it, and thus the induced chemical affinities will be propagated throughout the whole mass, until a totally new arrangement of the constituent elements may ensue.

This property of stirring up dormant chemical affinities is not confined indeed to ferments, or other foreign matters which may be introduced into organic compounds, it is seen likewise to prevail in various instances in which inorganic matter alone is concerned, and should therefore be referred to a cause which admits of being extended to both.

Thus platina alone is unable to decompose nitric acid, whilst an alloy of platina and silver is readily dissolved in it.

Thus azote by itself does not burn in oxygen gas, but when mixed with hydrogen, the latter communicates to it the property of combustion in atmospheric air, or in oxygen gas.

Thus water acidulated with sulphuric acid is not decomposed by copper, and but slowly under the same circumstances by nickel; but an alloy of these two metals with zinc, called German Silver, is speedily dissolved.

The fourth proposition stated will also, in another sense, be found to embrace only a portion of the truths which modern Chemistry has revealed to us, since it overlooks the very remarkable influence which cohesive attraction exerts upon chemical combinations.

This is remarkably exemplified in the solubility of recently precipitated silica in water, as compared to its entire insolubility when in a state of aggregation; and the knowledge of this fact affords us the only clue we possess to the presence of this earth, in the juices of plants, and in other positions, from which its own nature would seem to exclude it.

But there is another mode in which the attraction between like bodies appears to operate, bearing, as it would seem, somewhat of the same relation to the cohesive attraction which binds together their particles, which the attraction between masses of matter of dissimilar natures, when in opposite electrical conditions, bears to the elective attraction which exists between the ultimate atoms of each. This has frequently been applied by Geologists and others, to explain certain phenomena that have presented themselves to their observation, but has not, so far as I am aware, received the attention it deserves from Chemists[c].

It is well known, that if an intimate mixture of finely comminuted clay and sand is left together, as in the common operations of pottery, the silica will, after a certain time, be found collected in clusters.

Dr. Faraday has shewn, that the same principle causes camphor, if suffered to evaporate in a glass vessel, to arrange itself round certain nuclei on the surface, instead of being equally disseminated throughout.

The same principle has been called in to explain the

[c] It is noticed in Graham's Chemistry, p. 180.

nodules or concretions of one kind of stone, as of flint, so frequently found to occur in rocks of another description. The adhesion of smooth plates of glass or of metal, when brought into close contact, and the property of water to adhere to solid substances, which gives rise to the phenomenon of capillary attraction, and to the hygrometric power belonging to certain earths, may be accounted for in the same manner, as may also the capacity, which most porous substances possess, of absorbing, and even condensing within their pores, the gases with which they happen to be surrounded.

A remarkable instance of this was afforded me when I visited Vesuvius in 1834, in the gradual disengagement of large volumes of muriatic acid, steam, and sal ammoniac, from cavities in the still incandescent lava, that had been emitted from the mountain several months before[d].

These volatile products could not by possibility be generated within the crevices of the lava from which I found them to be exhaled—they must have been entangled within its pores at the time it issued from the volcano; and when we consider the high temperature that at that time belonged to the liquid mass, it would seem that some other force besides that of the superincumbent pressure, must have contributed to their confinement.

The curious manner in which gases appear in some cases to adhere to metallic surfaces, without actually combining with them, seems another fact in illustration of the same principle[e]. It is from this that Dr. Faraday deduces the power which certain solid bodies, such as Platina, pos-

[d] See my Memoir on Vesuvius in the Philosophical Transactions for 1834.

[e] Nobili explains, on the same principle, those beautiful appearances which are presented by certain metallic plates, upon which, if immersed in acetate of lead whilst forming the positive electrode of the battery, the negative electrode being brought immediately above it, rings "caused by films of oxygen of different thicknesses, and, consequently, of different colours," make their appearance; but recent experiments have shewn, that the rings are in reality composed of peroxide of lead.

sess, of condensing on their surfaces gases, and thus determining a combination between them; it is thus that Daniell explains the ammoniacal amalgam formed by voltaic action, of which mention has already been made, referring to the analogous case of the absorption of oxygen at a white heat by silver, which can only be supposed to exert an adhesive attraction for the gas, as it disengages it again on cooling; and, if I recollect rightly, it is in this manner that Schœnbein is at present disposed to account for the insensibility of iron to the action of nitric acid, under certain conditions.

I conceive, that the circumstances, by which this singular kind of attraction is regulated, deserve a more full investigation, and that it is highly proper to distinguish it by a separate name from the cohesive attraction subsisting between the particles of matter. Perhaps the term *adhesive attraction*, which has been already proposed for it, would be sufficiently characteristic.

It has been questioned, indeed, (see Persoz, Chemie Moleculaire, p. 875.) whether this species of attraction is essentially different from that which we denominate cohesive, and it may very safely be conceded, that the primary cause of both will most probably turn out to be the same.

But so also may cohesive attraction itself, according to the ingenious generalization of Mossotti[f], be included under the same law as that of gravitation, and the chemical affinities of bodies be regarded as the consequences of their physical properties, as Persoz has attempted to demonstrate.

None of these hypotheses, however, even if they were more fully established, and more completely developed than they can claim to be, ought to prevent us from ranging under distinct heads, and treating as separate branches of science, these several phenomena, regarding the attraction which operates between masses of matter distinct from that which takes place between their particles, as electrical attraction is from chemical affinity, or as the repulsive energy exerted by heat upon masses of

[f] See Scientific Memoirs, vol. i. page 448.

matter, is from the same force which imparts an elastic condition to their particles.

The fifth proposition, noticed in the commencement, which states, "that the water attached to many bodies, though essential to their crystallization, does not in other respects affect their properties," has been considerably modified by recent researches, particularly by those of Professor Graham, which have shewn, that water contributes, not merely, as was supposed, to the particular geometrical form which a mineral has a tendency to assume, but likewise to the chemical relations it possesses towards other substances.

Professor Graham establishes in the first place, that acids, such as the phosphoric, combine with water in certain definite proportions, just as they do with bases, that one atom of water at least is in most cases necessary to their existence, but that they disengage this atom when they unite to an equivalent quantity of any other base. Thus water acts as an acid with bases, as in the case of the hydrate of potass, lime, &c., and as a base in the instance of acids, as the liquid sulphuric and nitric acids testify.

We may, therefore, distinguish several states in which water exists as the constituent of a compound.

1st, as water of crystallization, viz. as essential to the crystalline form which the substance assumes.

2dly, as an acid, combined with alkalies, earths, &c.

3dly, as a base, being essential to the existence of the acid with which it is combined.

To this Professor Graham has since added a fourth condition in which it may occur, forming what, in his last Memoir (1837), he has called *constitutional water*. In this case, we have a certain proportion of water united to a given salt, but capable of being driven off from it by another, in consequence of the stronger attraction which the latter exerts.

Thus the sulphates of magnesia, of zinc, &c., contain, besides their water of crystallization, a proportion of constitutional water, which may be replaced by sulphate of potass; so that, instead of

$$\dot{Zn}\,\dddot{S}+\dot{H} \text{ we obtain } \dot{Zn}\,\dddot{S}+\dot{K}\,\dddot{S}$$

$\dot{K}\,\dddot{S}$ being substituted for $\dot{H}$.

This constitutional water is expelled with more difficulty than the water of crystallization.

Bisulphate of potass, is a sulphate of potass united to a sulphate of water, and is formed as follows:

Sulphuric acid Sp. Gr. 1.78 consists of $\dot{H}\,\dddot{S}+\dot{H}$ or

Acid 1, basic water 1, + constitutional water 1.

and the latter is replaced by Sulphate of Potass, hence we have $\dot{H}\,\dddot{S}+\dot{K}\,\dddot{S}$.

Sulphate of magnesia is $\dot{Mg}\,\dddot{S}+\dot{H}$, or sulphate of Magnesia, with 1 atom of constitutional water, omitting the water of crystallization.

Oxalic acid contains 1 atom of basic water, and 2 atoms of constitutional water, hence its formula is $\dot{H}\,\underline{\dddot{C}}+H^2$. In the oxalic salts of the magnesian family the constitutional water is retained, the basic disengaged. Thus oxalate of magnesia is $\dot{Mg}\,\underline{\dddot{C}}+H^2$, the basic water being replaced by magnesia; oxalate of potass $\dot{K}\,\underline{\dddot{C}}+\dot{H}$, binoxalate $\dot{K}\,\underline{\dddot{C}}+\dot{H}\,\underline{\dddot{C}}+\dot{H}^2$.

Thus nitric acid is $\dot{H}\,\overset{\cdot\cdot}{\dddot{N}}+H^3$, whilst in nitrate of copper the $\dot{H}$ (basic water) is replaced by $\dot{Cu}$.

Certain French Chemists[c] even contend, that solutions of salts in water are true atomic combinations.

Professor Graham has also pointed out a curious law, with regard to the acids of phosphorus and of arsenic, which probably will be found to extend to others, I mean, that the acid possesses an affinity for just so many atoms of a base, as the number of atoms of water with which it is already combined.

Thus common phosphoric acid having 3 atoms of water, unites with 3 atoms of base; pyrophosphoric having 2 of water, combines with 2 of base; metaphosphoric having 1 of water, with 1 of base.

[c] See Persoz, Annales de Chimie, vol. 63.

This disposition it may be difficult to account for according to the known laws of Chemistry, but Liebig[f] mentions other instances of a similar kind.

Thus Cyanuric acid consists of		$Cy^3\ O^3 + 3$ Aq.
Fulminic	————————	$Cy^2\ O^2 + 2$ Aq.
Cyanic	————————	$C^1\ O^1 + 1$ Aq.
Citric	————————	$C^{12}\ H^{10}\ O^{11} + 3$ Aq.
Pyrocitric	————————	$C^{10}\ H^8\ O^6 + 2$ Aq.
2nd pyrocitric	————————	$C^5\ H^4\ O^6 + 1$ Aq.

The same chemist explains these facts very ingeniously, on the following principle.

Phosphoric acid owes its acid properties to the presence of a certain proportion of water; thus dry tartaric acid has no tendency to combine with bases; accordingly, when 1 atom of water is abstracted from phosphoric acid, $P^3 + Aq^3$, it is resolved into $P^2 + Aq^2$, plus P^1, which latter, being anhydrous, is inactive. When 2 atoms are abstracted, its power of saturation is, for the same reason, diminished to 1, $P^1\ Aq^1$ being active; P^2 inactive.

Hence metaphosphoric and pyrophosphoric only differ, from each other, and from common phosphoric acid, in containing 1 or 2 atoms of inactive or anhydrous phosphoric acid.

The important part which, in these cases, water seems to play, in imparting to the compound, into which it enters as an ingredient, its most active properties, and the impossibility of pointing out a single acid, destitute at once of water, and of its constituent hydrogen, are the circumstances that principally lend a foundation to the bold theory noticed in a former part of this Essay, which supposes all the acids to consist of a compound radical united with hydrogen as an acidifying principle.

The arguments in favour of this view are stated with much clearness by Professor Graham[g], but I will pass over

[f] Annales de Chimie, 1838.

[g] Elements of Chemistry, p. 389, et seq.

their consideration, as the several theories suggested on these points are admitted by the best authorities to be so nearly balanced, that new discoveries may at any moment give the preponderance to one over the other.

The sixth proposition, which affirms, "that organic bodies have their particles held together, partly by what is called the living principle, so that the laws which operate upon inorganic matter, are in many instances suspended by its influence," seems, to say the least, questionable, and the corollary grounded upon it, "as to the impossibility of producing, by artificial means, any of those compounds which result from the principles of life," is contradicted by fact.

We know already of at least two, if not of more, distinct substances proceeding ordinarily from living processes, which can be formed at pleasure by art. Such, for instance, is formic acid, which is excreted by ants, but may also be procured very readily by chemical means. Such, too, is urea, which Wöhler has succeeded in producing by the action of ammonia upon cyanogen, or by decomposing cyanate of silver with muriate of ammonia, and cyanate of lead by ammonia. The crystals formed are identical with those of urea, whilst the composition is the same as that of the salt called cyanate of ammonia, the properties of which are very different. These two, therefore, are isomeric bodies, and one of them, though it derives its existence from the ordinary processes of life, is capable of being produced without the intervention of the living principle at all.

There is little doubt, that the progress of research will bring to our knowledge many similar cases, and that it will eventually appear, that all the other secretions or excretions of animals and vegetables are only so far dependent upon life, inasmuch as, in consequence of the favourable temperature which it sustains, the constant circulation of the fluids it occasions, and their exposure to external agents in vessels of different shapes and dimensions, a mechanical separation of the ingredients of the blood is effected in some instances, and a chemical change produced in its constitution by catalytic action in others.

No one, indeed, who recollects how quickly the component elements of most organic structures ordinarily resolve themselves into simpler forms of combination, when life becomes extinct, can pretend to question the sustaining influence of that principle; but there seems good reason for believing, that the latter operates indirectly, through the instrumentality of the nervous system, rather than directly, by imparting to the elements of the living structure new affinities, or suspending old ones.

If, indeed, the latter were the true solution, there would seem to be no good reason, why the decomposition of the animal structure should not necessarily and immediately ensue upon the abstraction of the principle of vitality, whereas it is well known, that these changes only take place, when favoured by a suitable temperature, and promoted by the agency of external causes.

The laws indeed which regulate the decomposition of organic matters, bear a sufficiently close resemblance to those that prevail amongst mineral bodies.

The more complicated their structure may be, the more readily are they found to be resolvable into their component parts; for the greater the number of proximate principles which an organic substance may contain, the more the chances are multiplied, that something will interfere to disturb the balance of the sustaining affinities.

Now this disturbance may be occasioned either by the action of certain extraneous bodies, such as the air, or by the presence within itself of some species of ferment. In the former case the decomposition is effected in consequence of the oxygen of the air seizing upon the most combustible element, according to the general law of chemical action, and therefore uniting exclusively with the hydrogen, with which it forms water. This disengagement of hydrogen, however, sets at liberty a portion of carbon, which, with the oxygen of the organic body, constitutes carbonic acid gas.

There will therefore remain a solid, consisting of the residue of the carbon and oxygen, with a smaller proportion of hydrogen than before.

It is in this manner that ulmine is formed by the putrefaction of wood[f].

In the second case, where air is not necessarily present, the decomposition is caused by a ferment, which invariably contains a portion of nitrogen. This therefore is a case of catalytic action, such as has been before adverted to, and is regarded by Liebig as bringing about a species of slow combustion, called by him *eremacausis*, which is excited between the oxygen, the carbon, and the hydrogen, by the presence of a ferment.

The putrefaction then of vegetable and animal matters appears to be produced, not by any sudden cessation of those affinities which had previously bound their respective elements together, but by the predominance over them of other natural forces, which we may without much difficulty conceive to have been controlled under the circumstances in which the living body is placed; nor does there seem any sufficient reason for calling in the intervention of an occult principle to explain that, to the solution of which, by known causes, every fresh advance in chemical knowledge seems to bring us into closer approximation.

The experiments of Dr. Wilson Philip, which establish, on the one hand, that digestion is dependent on the influence of the nerves that supply the stomach, and on the other, that when this influence is cut off, the passage of the galvanic fluid may, to a certain extent, supply its place, will, I conceive, rather tend to favour the view

[f] Woody matter, or lignin, consists of

$C^{36}\ O^{24}\ H^{48}$

H^{24}, forming water, with the oxygen presented to it.

$C^{36}\ O^{24}\ H^{24}$ remain.

Of which $C^{6} + O^{12}$, form carbonic acid.

Leaving $C^{30}\ O^{12}\ H^{24}$, which constitutes ulmine.

See a Memoir by Liebig in the Ann. de Chimie, June, 1839.

here taken, than to discountenance it, at least in the opinion of those, who are unwilling on such slender grounds to adopt the formidable conclusion, which infers the identity of the nervous with the electric fluid[g].

For, admitting these agents to be distinct in their nature one from the other, we can best explain this correspondence in the character of their respective effects upon digestion, by supposing them both to act as *specific stimuli* upon the parts concerned in the process; by virtue of which, it may probably happen, that the requisite agitation of the materials operated upon will be promoted, and such secretions from the organs themselves elicited, as are calculated to induce those changes, which bring about the gradual conversion of the aliment into chyme and blood.

Some, indeed, like the late Mr. Abernethy[h], whose lectures I formerly attended with so much delight, seem to flatter themselves that they are making head against materialism, by assigning to the direct agency of a vital fluid the processes of the animal economy; but whilst no one can more highly appreciate the acuteness, the tact, the originality of conception, which that distinguished surgeon brought to bear upon subjects relating to his own profession, I have not, I must own, an equal respect for his metaphysics; and I have always felt, that those who, in imitation of him, would assign to that immortal principle of our nature, which manifests itself in the operations of thought and intellect, any concern in the functions of the perishable body, more direct and immediate than that which it may exert through the medium of the nervous system, so far from establishing on a surer foundation the doctrine of the soul's immortality, are, in fact, degrading that *divinæ particula auræ* to a level with electricity, chemical affinity, and other influences, which affect equally inanimate as well as animate matter.

[g] See some appropriate remarks on this question in Dr. Prout's Bridgewater Treatise, chapter on Digestion.

[h] See his Enquiry on the Probability, &c., of Mr. Hunter's Theory of Life, 1814.

Those who wish to investigate this subject more fully, may consult the Remarks on the Theory of Secretion in Dr. Bostock's excellent System of Physiology, in the concluding remarks of which I fully concur, namely, that when we suppose, that any real explanation is afforded of the phenomena, by ascribing them to the operation of the vital principle, or to any vital affinities, which is merely a less simple mode of expressing the fact, we are indulging in one of those delusive attempts to substitute words for ideas, which have so much tended to retard the progress of physiological science.

To conclude then, we perceive, that whilst the progress of discovery has introduced nothing which cannot be reconciled with the Theory of Atomic Proportions, it has, nevertheless, made us acquainted with several laws of matter, which could not have been anticipated at the time that doctrine was first propounded.

The cause, or causes, which produce different properties in substances of like constitution, or analogous ones in those of different composition, and the mode in which a body, by its presence, causes a new arrangement in the elements of an existing compound, or a dissolution of the union between them to take place, without combining itself with either, are questions of great intricacy and of high interest, which within the few last years have, for the first time, come under discussion.

The discoveries of Graham open to us a new chapter, as it were, in the history of chemical combinations, by pointing out the definite compounds which take place between water, acids, bases, and salts, whilst the theoretical views of Liebig would lead us to reverse the old doctrine of Lavoisier, and to represent acids as necessarily containing hydrogen instead of oxygen, as a part of their composition.

Lastly, instead of indolently referring to the operation of a vital fluid the various principles which present themselves in the animal and vegetable kingdoms, we are emboldened to consider their phenomena, as attributable to the same laws as those which operate on unorganized matter, and thus to look forward to a wide field of investigation, which our predecessors left unexplored and untrodden, as belonging altogether to another province of Philosophy.

THE END.

POSTSCRIPT.

I WAS formerly indebted to an intelligent friend, for pointing out to me an error in the Introduction to the Atomic Theory, which I am glad to have this opportunity of correcting.

" It is correctly stated (p. 58.) that the volume or bulk of an atom of hydrogen is twice that of an atom of oxygen, since the term volume represents magnitude in three dimensions. But in p. 65. the linear distances or diameters, not the volumes of atoms, are made the objects of comparison; and these, as has been pointed out by Dr. Dalton (New System, vol. I. part II. p. 226.), are proportional to the cube roots of the spaces containing equal numbers of atoms.

Thus the diameter of the atom of oxygen : diameter of the atom of hydrogen : : $\sqrt[3]{1} : \sqrt[3]{2}$, or 0.794 : 1.

If the particles of hydrogen were mutually kept apart to a distance twice as great as those of oxygen, they would occupy at the same temperature, not double, (as stated in the text,) but eight times (2^3) the space."

INTRODUCTION.

The brevity of twenty minutes allowed for a paper to enter on important scientific subjects for public health, will permit of further extension: that can be said in an introduction, in few remarks, on the exclusion, and as to what may be considered superstition in the medical sciences.

A question arises, whether men's (bad) habits, in the case of public health, are to be encouraged?—invitation being circulated in the medical press to create discussion and acceptation of incontrovertible and beneficial views in medical sciences, for the public health.

The belief, reliance, and talk of things that do not exist and cannot be seen or experienced, as Lavoisier's views of heat and of nutrition by the union of carbon and oxygen, are obviously superstition. No one has seen the heat produced, and no one has experienced the nutrition from bodies, as clay, flint, glass, or charcoal, that largely contain these elements. The chemical phenomenon after a candle has been burnt in oxygen or in atmospheric air, is no proof, having no collateral evidence and no practical illustrations of heat and nutrition; therefore the theory, the basis of present medical sciences, is entirely superstition—like the homœopathic practitioner who prescribes for a patient, and the shopman who supplies the globules to the patient, neither party knows the existence of the medicine in the globules; no chemical analysis can prove it, the globules being prepared by a third irresponsible party, apart from the prescriber and seller, who cannot vouch for the fulfilment of the prescription. Homœopathy is, therefore, practically superstition. Imagination of effects is all that can be adduced, the diet being the most probable cause of cure, and neglect of proper medicines being often the cause of death.

Mesmerism being only dealt out in the general to the rich, is sufficient for its expulsion, besides its inapplicability in all cases of disease to which human beings are heir. Its tenets may be right, as regards electric action on the blood in order to increase the temperature, but this electric action, or heat, is to be obtained in marked degree in all cases by the use of tea or coffee, and nitrogenous medicines, which are available and practical by every denomination of practitioners.

Hydropathy is also limited to the wealthy and aged, and not employed for the infant; those who have indulged at the table, or have been exposed to the vicissitudes of climate or weather, are the votaries to the craft. Self-denial seems the chief means to be observed; the use of cold water stays the stomach and quiets the nervous system. The water establishments are supported by persons who have not self-denial at their own command, therefore the system is best carried out by another in the shape of a medical adviser, with all the attendant dangers and chances of cure.

The subjects of cataract, hernia, stricture, cholera, the deaf and dumb, and the element nitrogen, are particularly pointed out as objects of grievous errors which scientific men are bound to surmount. Although this paper is not considerd suitable for the association, yet other scientific societies are now invited to criticise and refute the views. There are too many great and important truths set forth to allow of silence.

ON THE SCIENCES OF MEDICINE AND SURGERY.

The sciences of medicine and surgery are known to us through the knowledge of physiology, which is acquired through the assistance of analogy, anatomy, and chemistry.

Physiology treats of intimate knowledge of things, whereby we adapt their uses.

Analogy treats of like things, as tea and coffee are allied to the blood.

Anatomy treats of divisional parts of things.

Chemistry treats of constituents of things.

Tradition speaks of received notions without the knowledge of the above branches of science.

We have false and true traditions.

What constitutes the knowledge of the medical sciences?

The ground work of these sciences must be in the knowledge of the uses of the materials of the globe. These materials are found beneficial as far as physiology, analogy, anatomy, and chemistry have revealed to us their fitting purposes. Without the knowledge of these branches of the sciences our practice would be quackery.

The materials most common to our use are the atmosphere, tea, coffee, cocoa, Irish moss, &c., as food—ammonia, quinine, morphia, strychnine, &c., as medicines, or nitrogenous vegetables, or compounds.

By the aid of chemistry, these materials have been found to be composed of the same elements as our blood, viz.—carbon, oxygen, hydrogen, and nitrogen, in various quantities.

By the aid of analogy, the human blood is supplied with renovating properties from these nitrogenous substances.

By the aid of anatomy, curative processes are expedited.

By the aid of physiology, suitable food and medicine are selected in health and disease.

False traditions in medical sciences cannot be tolerated, as follows:

1. Lavoisier's notions of heat and nutrition
2. Galen's notions of the flow of the blood.
3. Dr. S. Johnson's notions of the state of the deaf and dumb being hopeless.
4. Of the incurability of cholera.
5. Of the deficiency of cow pox to mitigate, or prevent, small pox.

Chemistry having ascertained the existence of elements in the materials, it next becomes the part of the physiologist to appropriate the uses of these elements as far as experience would direct him; if their uses have been misapplied or neglected, surely great fault must arise in the practice of the sciences.

The discovery, in 1772, of the element nitrogen in our atmosphere, and its uses not being yet appropriated, will appear a great blot on medical science.

The misapplication of the uses of the elements carbon and oxygen, in producing heat and nutrition, are also great blots on medical science. Because such a man as Lavoisier, about 70 years ago, is supposed to have given such adaptations, are we bound by respect to antiquity to perpetuate such great blunders? Certainly not.

Galen's teaching that the arterial system was part of the respiratory system—consequently air must be in the arteries—was dogmatical, bigotry, and false. He always found blood in the arteries; and no one has found heat or nutrition to be effected by the union of carbon or oxygen. These theories, or traditions, were, and are, dogmatical, bigoted, and false.

The facts of carbonic acid gas causing the fall of quicksilver in the thermometer, and causing the heated body in fever and in warm weather to be cooled, are too palpable to be lost sight of, or to be highly esteemed for contrary or imaginary effects.

The facts of nitrogenous vegetables and medicines being employed to renovate the fatigued body and mind, and to restore health, are too palpable to be cast aside and to be thought nothing of. Our daily foods being found analogous to the human blood, are too palpable to be cast aside. "The blood is the life." The blood is the means of healing and curing all diseases and injuries; the blood must, therefore, be preserved in a normal state.

We are in the age of thinking and acting without being bound down by a state, colleges, or bigotry, or superstition, or traditions, in matters of facts and of science. We adduce examples in physiology, in analogy, in chemistry, and in anatomy.

In Physiology. In physiology of tea, coffee, blood, brain, and bile; that tea and coffee are foods of ordinary use, with much importance being attached to them, because they supply the blood with ingredients that are allied to the blood, brain, and bile.

In Analogy. In analogy, that similitude exists between food, medicine, and blood; that the aqueous humour dissolves the lens in the adult as well as in the infant; and that the cure of cholera is effected by the uses of nitrogenous food and medicine. (See hereafter.)

In Chemistry. In chemistry, the discovery of alkaloids in tea, coffee, bark, opium, &c., and of similar ingredients in the brain, bile, and blood, and also of ammonia escaping largely from cholera patients. (See Liebig's *Animal Chemistry.*)

In Anatomy. In anatomy, that the transparent cornea, aqueous humour, capsule of the lens, and the lens, can be perforated frequently with a needle, without pain and without danger; the parts being less vascular than other external parts of the body.

Cataract.

Hernia. That hernia consists of soft parts of different degrees of organization. The external parts are the skin, cellular tissue, and fat, and are little organized. The internal parts are the lining membrane (peritoneum) of the abdomen and of the bowels, and the bowels themselves. These are much organized.

Arteries are contingencies to hernia.

The omentum, if any, is distinct from the gut; is less organized and less dangerous.

Stricture.

That stricture in urethra is caused by inflammation of soft parts adjacent and external to the urethra; viz., ligaments, muscular or membranous portions, which suspend and move the parts. The urethra is not generally found diseased, or obstructed after death; but a thickening, externally, is invariably found before and after death. The seat of stricture is on the muscular or membranous parts. Sir C. Bell supports this view. (See his *Anatomy*, vol. iii., page 410.)

Physiology and Anatomy. 1. Cataract.

Physiology and anatomy teach us, that a safe operation for cataract, by solution of the lens through the anterior chamber, can be performed without recourse to a difficult and hazardous operation, or operations which are now performed.

Physiology and Anatomy. 2. Hernia.

Physiology and anatomy teach us, that safe reduction of hernia, by the application of cold water and the taxis, can be performed without recourse to the difficult and hazardous operations with the knife, which are now performed.

Physiology and Anatomy. 3. Stricture.

Physiology and anatomy teach us, that a safe cure of stricture in urethra, by means of topical applications and internal medicines, can be performed without recourse to the catheter and the knife. Mr. Syme supports this view in his writings.

Physiology and Analogy. 4. Cholera.

Physiology and analogy teach us, that cholera has been successfully cured by giving nitrogenous medicines and food, which supply the loss or waste of ammonia that has been largely eliminated in this dire disease, where no organic disease exists.

Physiology and Anatomy. 5. Deaf and Dumb.

Physiology and anatomy teach us, that the deaf and dumb can be cured where disease exists. This disease has been palpably spoken of by men of distinction—Messrs. Pilcher and Levison—before Medical Societies.

Physiology, Analogy, and Experience. 6. Nitrogen.

Physiology, analogy, and experience teach us, that the element nitrogen is the source of heat in the animal economy and source of nutrition in the animal and vegetable kingdoms. Dr. Carpenter and Professor Voelcker, in their writings, support these views. Let it be asked, Has anyone refuted them? They are constantly practised by men ignorantly.

Other important and minor ailments, to which human beings are heirs, can be illustrated; but these might suffice for the present.

New Views.

We now adduce examples of new views of practice of medicine and surgery, with comment on present views, without going into the ordinary minute explanation, as in books displayed, as follow:

On cholera, deaf and dumb, cataract, hernia, and stricture in urethra.

Cholera. Cholera, its eccentricities in all climates, in all ages, sexes, and conditions of life, and situations of locality, completely baffle human understanding and skill to divine how to check or prevent so dire a disease; unless in its cure by the use of the rejected and despised element nitrogen, which is ignominiously called "an excrement." If it can be supposed to be prohibited from atttacking London, or any other populous city, by a host of engineers, the same steps should be also adopted in climates that are quite different from our own. It appears to be a scourge that is diffused at unaccountable times, and in all seasons, throughout the chief extent of civilised land. Its existence without a marked cause after death is also a mystery to us, unless we can appreciate successful practices of fifty years, according to three printed prescriptions (herewith enclosed), containing nitrogenous medicines, without mercury.

Very analogous success is adduced in the solution of the lens by the aqueous humour. How this takes place we know not. Chemists have not divined the cause of dissipating the opacity of carbonate of lime in the lens, or of rendering the hardened lens soluble. These are physiological points in medicine and surgery not to be controverted, or elucidated by anatomy or chemistry.

Deaf and Dumb. Deafness is easily detected at four months old; so that if deafness and dumbness should come on after, the cause must be attributed to disease of the organs from infantile diseases, which require to be treated before the disease gets into a chronic or incurable state, which would preclude all chance of success.

The idea of all cases of deaf and dumb emanating from intermarriage of first or second cousins is preposterous, when disease has been palpably pointed out and cured, as before stated, when hearing and speech have resulted.

Cataract. Cataract is an opacity of the capsule of the lens and of the lens itself, arising in the general without any known cause. There are four kinds; viz., milky, soft, hard, and membranous.

Mr. J. C. Saunders' plan of solution in the infant is found to be successful in the adult, in every case connected with the lens and the capsule.

Hernia. Hernia is a displacement of bowels of different parts from their natural position, having different names, according to their locality. A stricture is formed at the neck, where the bowels emerge from their situation. This stricture is marked around the bowel; the mark of a ring is always seen on the bowel; this ring is caused by pressure of another isolated body,—*i.e.*, the adjoining cellular tissue,—which has mechanical effect on the bowel, like the ring on a finger, whereby congestion of the bowel is produced, and gangrene is the result of congestion. It is not inflammation of the bowel: there is no adhesion of the ring to the bowels or finger, except from continued inflammation in chronic cases of hernia. The congestion of blood is relieved by cold water or ice; thereby pain and distension of vessels are lessened, when reduction by the taxis is easily effected.

Where hernia happens, the patient is generally far away from a hospital and convenience of a hot-water bath. The first surgeon at hand should be instructed to employ the most active and immediate means—viz., cold water in a bladder externally, and, by enema, internally, which constrict the blood vessels; thereby congestion is removed, and the hernia will be often reduced by its own efforts, or by slight use of the taxis. The congestion of a finger caused by a ring would not be removed by a warm bath. The surgeon would not cut off the finger, or the ring; neither should he cut the bowels, nor the stricture.

Disadvantages of present plans: Ignorance of the first surgeon at hand, therefore delays, and, frequently, a long tedious journey for the poor; or no convenience for hot water bath, or not sufficient hot-water, or parboiling the patient, besides the danger, after the knife of exposing the delicate bowels to manipulation and to cold air, which causes numberless deaths, even under the direction of the most skilful surgeons.

Stricture. Stricture in urethra causes retention of urine, by the closing of the urethra at two or three different parts of the canal. There are several kinds, arising from various causes.

Inflammation, and its consequences, are the chief for our consideration. If inflammation of the mucous membrane causes stricture, the whole length of the canal would be liable to stricture. Such is not the case; therefore we look for the cause of stricture exterior to the mucous membrane, as in goitre. The external swellings to the passage must naturally cause pressure, or stricture.

The enlargement, or inflammation, is subdued by local applications and internal medicines, as in goitre, so that the passage is relieved when the urine passes freely without a catheter, the cause of stricture being entirely removed.

Whilst we know the anatomy and physiology of cataract, hernia, and stricture in uretha, we need not, as it were—

Open the works of a watch to wind it up;
Neither kill the goose for the sake of the egg;
Nor cut open the bellows for the sake of curiosity;—

the present operations for hernia* and stricture being often performed when, by delays and age, there is little or no chance of success.

Instruction to the living may be set forth; but this idea will soon vanish if due attention is paid to the physiological views laid down. Futhermore, it is contended that a prized student of anatomy and of chemistry might be thoroughly ignorant of the physiological points herein set forth; therefore physiology is a new branch of educational knowledge, fitting for the benefit of public health.

BY WILLIAM PARKER, M.R.C.S., L.A.C.

3rd October, 1857; 27, *Daniel Street, Bath.*

	Cases operated on.	Deaths.	Successful.
* See *Medical Times and Gazette*, 31st Jan., 1857 ...	25	14	11
" " 10th Oct., 1857 ...	30	20	10
	55	34	21

FROM THE "NORTH DEVON JOURNAL," DECEMBER 1ST.

To the Editor of the "North Devon Journal."

SIR,—I observed in the *Times* of September 27th, a letter from Mr. W. Herapath, of Bristol, the celebrated analytical chemist, on the "Austrian Specific for Cholera." He gave his analysis of one fluid ounce, as follows:

Sulphuric acid (density 1.845)	19.07 grs.
Nitric acid (density 1.500)	11.31
Gum and sugar	23.62
Water	407.50
	461.50

It appears this remedy was allowed to be used by the Austrian authorities (in 1831—32) on the persons of some of the criminals, and that the result was a recovery in every instance.

On turning over an old memorandum-book a few days since, I found the following recipe, which was copied from some public print in 1832, when cholera first made its appearance in this country, and I was struck with the similarity to the Austrian specific:

"CHOLERA MORBUS.—From a letter of Mr. Thomas Hope, Surgeon, Hospital Ship, Canada, River Medway, May, 1831, wherein he asserts the following recipe to be almost a specific in Cholera Morbus, in a 30 years' practice, and gives the following proof:—'I was Surgeon of the *Dolphin* in the year 1825, between the 17th and 26th of July in that year. I had 264 cases of cholera from which (with the exception of 16 being under treatment for three days, four patients demanded attention for four days, and three for five days) every patient was restored within the space of 53 hours. One who had been previously ill demanded longer attention. The remedy I gave was of—Nit*rous* acid, one drachm (not nit*ric*, that has foiled me); peppermint water or camphor mixture, one ounce; tincture of opium, 40 drops: mix. A fourth part to be taken every three or four hours in a cup full of thin gruel. The belly should be covered with a succession of hot cloths dry; bottles of hot water to the feet, if they can be obtained; constant and small sippings of finely-strained gruel, or sago, or tapioca; *no* spirits—*no* wine—*no* fermented liquors till quite restored.—THOMAS HOPE, Surgeon.'"

I am, Sir, your obedient servant,

GILBERT KNILL COTTON.

Barnstaple, November 30th, 1853.

N.B.—I do not venture to give an opinion myself on an universal remedy for any specific disease, but have merely compared the two statements of 1831 and 1853.

To the Right Hon. Sir Benjamin Hall, Bart., President of the General Board of Health.

27, Daniel Street, Bath; 6th Sept., 1854.

SIR,—I have the honour to acknowledge the receipt of a letter, dated 5th instant, from your Secretary, in reply to my application of the 4th instant. I herewith forward, as requested, the prescription and plan used by me for the cure of Cholera:—Saturated Solution of Muriate of Ammonia, 1 oz.; Saturated Solution of Alum, 1 oz.; Dillwater, 1 oz.; Strong Infusion of Coffee, 1 oz.; Camphor Mixture, 4 ozs.; mix: a teaspoonful to be taken every ten minutes. A teaspoonful of strong Infusion of Coffee to be taken at intervals, which will allay thirst. Beef-tea made as follows:—Lean beef cut into thin slices, pound of; table salt, tablespoonful of; black pepper, ground, tablespoonful of; grits, two tablespoonsful of; boiling water, quart of; the whole to be put into an earthenware jug and kept near the fire and covered; in half an hour a tablespoonful to be taken, when the stools have subsided for an hour or two, and repeated every half hour until the stomach can relish solid food. Abstinence from wine, spirits, beer, sago, and gruel.

Lotion for the sick room, to be kept in a saucer:—Solution of Chloride of Lime, 1 oz.; Common Vinegar, 1 oz.; Camphor Mixture, 6 ozs.: mix.

Further particulars of treatment, &c., comprised in my short and plain Treatise on Cholera, I left in the hands of Mr. Tom Taylor on the 16th ult., with other papers, for your consideration. I have the honour to be, Sir, your obedient servant,

WILLIAM PARKER.

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