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On the first principles of chemistry

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- I. *On the First Principles of Chemistry.* By EDMUND J. MILLS, D.Sc., F.R.S., Young Professor of Technical Chemistry in the Andersonian College, Glasgow*.

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(1) **F**IRST principles are of all portions of a science the most difficult to grasp. The explanation of this fact lies in the law, first pointed out by Professor Ferrier (*Institutes*, p. 12), that what is first in the order of nature is last in the order of knowledge. To that subtle and accomplished philosopher (now, alas! no longer with us) the pure reason of mankind stands in eternal debt, and not least for the power and beauty of his exposition of this law of scientific progress. For, if it be progress to attain first principles, then "all science can advance only by going, in a manner, backwards, or rather by *coming round*;" and "the apotheosis and final triumph of

* Communicated by the Author.

human reason will be, when, having traversed the whole cycle of thought, she returns—enriched only with a deeper insight and a clearer consciousness—to be merged in the glorious innocence of her primitive and inspired *incunabula*.” The same thought, in its moral aspect, constitutes the lesson of the Prodigal Son*. The advancement of science, the excursions of the soul, are popularly represented as straight lines; on the contrary, they are returning curves. “The primitive articles of all thought, the seminal principles of all reason, the necessary constituents of all knowledge, the keys of all truth, lie at first buried under our very feet; but, as yet, we are not privileged to find them. We must first circumnavigate the globe; the whole world of speculation must be traversed by our weary feet. Hence every step forward carries us only further and further from the mark. Ere long the elements of truth—all that we are indistinctly looking for—lie in the far distant rear, while we vainly think that we behold them glimmering on the horizon in our front. We have left them behind us, though we knew it not—like decaying camp-fires, like deserted household gods.” “The intellectual, like the physical world, is *a round*; and at the moment when the wanderer imagines himself furthest from the house of humanity, he will find himself at home. He has revolved to the spot of his nativity. He is again surrounded by the old familiar things. But familiarity has been converted into insight; the toils of speculation have made him strong, and the results of speculation have made him wise” † (*ibid.* pp. 10, 11).

(2) The difficulty of the investigation, however, is capable of large increase from special conditions. Consider the case of chemistry. Detail has been added to detail, concrete result to concrete result, during an enormous interval of time; and the pure jewels of the science lie deep under a roadway, which has been hardened by the traffic and elevated by the rubbish of at least two thousand years. The ideal reformer who would disinter them must consecrate himself to the task, and live to universals; he must wrench himself from contemporary prejudices and associations, and, regarding each fact and theory in

* Trench (Notes on the Parables, 1870, pp. 387, 388) supposes, in accordance with the common interpretation, that the “younger son” is principally intended to illustrate the *sin* of desiring spiritual independence. The whole meaning turns upon the words *Εἰς ἑαυτὸν δὲ ἐλθὼν* (But when he came to himself), the attainment of ideal independence by way of experiment being the very point of the story.

† Compare also Mill on Utilitarianism, p. 2 (1863):—“The truths which are ultimately accepted as the first principles of a science are really the last results of metaphysical analysis, practised on the elementary notions with which the science is conversant.”

the light of this pursuit alone, deliberately put aside all judgments which are based upon dogma or authority. He must have an infinite capability of doubting. For his is no search for truth—of which all men chatter, but which none are admitted to possess; his is a reasoned labour; and the issue, of which he is careless, must in the main be wise. Such being the case, can we wonder that no clear statement of the first principles of chemistry has ever yet been made, and that even the very definition of the science is either unknown or obscure? Is it remarkable that, in the hundreds of chemical manuals that have been written, little or nothing is said of those secret springs that feed the literary stream, or of the dews that fertilize the less familiar province of experimental research?

(3) Yet this investigation is much needed. I beg any dispassionate observer to survey the field of modern chemistry, and ask himself whether its condition has been satisfactory of late years. For my part, I came neutral to the task, with no tradition to support and with no interest but to inquire. Could I possibly justify the prevalent spirit in the science? Was the method of its theories reasonable? Did its leading doctrines harmonize with those of other sciences, and tend to ennoble man? And what was the cause that, even in popular opinion, it appeared unfruitful of discovery, and languishing rather than alive? The reader already knows the general tenor of the answers. Strength and light and vigour can only come from some fundamental reform, sufficient to alter the entire aspect in which chemistry is contemplated, and the entire method whereby chemical problems are solved. This reform can be reached, and only reached, by turning back to first principles.

(4) Where, then, are we to commence? The first principle of all science is motion. Every event of which we are conscious proves, on analysis, to be motion of some kind; and matter is not distinguishable from motion except as more or less determinate motion. Strictly speaking, "the motion of a thing" is a tautological expression, unless we mean by "a thing" another kind of motion, when the phrase becomes equivalent to "compounded motion." From the rigour of Hobbes's logic* there is no escape; indeed the almost unanimous voice of philosophy, from ancient to modern times, has asserted the universal prevalence of motion, the absence of all real rest. This grand idea has changed the character of human action wherever its mission has been accepted and its reality has been felt. Of late years it has, in some derived form, completely renovated and restored whole sciences. What is the life of

* *Humane Nature*, second edition, pp. 9-15.

modern geology or mathematics, but continuity; or of biology, but evolution? The greatest generalization of the practical consciousness is worthy to become our chief criterion and lay our fresh foundation.

(5) We have then to select those derived forms of the idea of motion which, lying nearest to it, are yet within the province of chemistry. One of these must necessarily be *action*, because the chief business of chemistry is a kind of work. Chemical substances are valued, not for what they are conceived as *being*, but as *doing*; and the first question we ask about a body is, What is its function? alcoholic, saline, ketonic, zincous, chlorous? in other words, How does it behave with this, that, or the other *reagent*? And it is made, bought, and sold for its *use*.

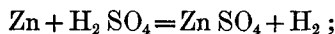
One objection that might be made here ought perhaps to be answered at once. It may be said that substances have a being in themselves—namely, a “constitution,” as it is technically termed—that their constitution consists in the arrangement of atoms, of which they are in reality made. Whether this is the case or not, shall be in due course examined. I content myself with remarking that constitution has been, and always is, considered of very small importance in comparison with action,—the two standing to each other in the relation of speculation and experiment. A moment’s consideration of particular cases will show this. Indigo, sugar, salt, and alcohol were extremely valuable before any thing whatever was asserted of their constitution—valuable then as now, for the *employments* to which they could be put, the producer prudently regarding their constitution with a wise indifference. Hence, then, we are on sure ground in adopting action as a first principle, whether we should have, or not have, to accept “being” or “constitution” at a later period.

(6) Chemical action, however, is not indeterminate. If it were so, all possible reactions might occur at one time, and all reactions would be possible. Isomerism could no longer arise. The two mononitrotoluols, for example, that are formed during the nitration of toluol could possibly be converted into each other, and would yield a confused or mean nitrotoluol; nay, rather, any nitric solution of toluol would be as definite a chemical substance as we now consider nitrotoluol itself. Thus the old theological guess, *Deus est actus purus*, cannot be transcribed for chemistry; in this science, action is determinate, conditioned, and a process.

The most important character of chemical action is *continuity*, which, as has been already stated, is an immediate derivative of the idea of motion. When two or more substances

are placed together in such conditions as to react chemically, various kinds of work are performed, and other substances are found to be present. Direct contact is not always necessary ; it may suffice that a shock or tremor traverse the intervening or diachemic medium, in order to produce the desired result. This is well seen in the experiments of Abel and others, where nitroglycerine, gunpowder, and the like have been fired without such contact, by the effect of distant explosions of particular quality.

Continuity is, moreover, observed in the relation of the masses of the acting substances. According to the evidence we possess (and some of it is of the highest order of accuracy), *no matter what may be the masses of the substances reacting, the entire mass of each takes part in the process.* If we immerse an ounce of zinc in water, and add to it a quantity of hydric sulphate, the whole of this reagent acts, whether it weigh an ounce, a pound, or a hundredweight ; and it is known by experiment that if water, zinc, and hydric sulphate be placed in contact, the rate, amount, and quality of the action all depend on a cosmic law—the masses of the acting system—and vary as these vary*. Of this rich and indefinitely great variety of process, the Daltonian symbols show us but a poor and single point,—



all the hydric sulphate that is not required to make zinc sulphate, though undeniably sharing chemically in the process, is omitted from the expression ; and it may be added that the equation itself, one of the most frequently written in books and memoirs, has never yet been realized in the history of chemistry. May I suggest to those students who are seeking subjects for investigation, how much more profitably their time would be employed in examining the commonest definite equations, than in such enterprises as trying to find out by experiment what is the position of the third bromine atom in tribromobenzol ?

(7) The mind of Berthollet was clearly impressed with the necessity of reconciling the laws of chemistry with those of astronomy. As he contemplated the evening sky and watched the marshalling of its glorious host, no thought of atoms rose (as in Dalton) with those distant clusters ; but the conviction that the earth's laws are not discrete from those of heaven, and that the principle of celestial attraction must be identical with, or animate, the chemical process. The law of chemical mass,

* For the demonstration in the case of gases, see Bunsen's 'Gasometry,' p. 254 (English edition).

though thus foreseen by Berthollet, was not placed by him on a complete experimental basis; and the idea that both he and Bergman perhaps possessed, that each substance has a mass of its own, has probably been investigated but by a single chemist. Later researches have, however, placed the law in a clearer light. Gladstone, for example, in 1855*, showed that, in a certain group of reactions, "There is nowhere any sudden increase. . . . If the partition of the bases and acids in the mixture really take place at first in atomic proportions, it is evident that, being at full liberty to act and react, the salts arrange themselves according to their respective mass, without reference to their respective atomic weights"†.

It is, however, more especially to Harcourt & Esson and Guldberg & Waage that we are indebted for the investigation of this subject. Thus, for example, the former chemists examined the deportment of mixtures of potassic permanganate, hydric oxalate, hydric sulphate, and manganous sulphate in presence of a quantity of water which may be regarded as constant, the effect particularly traced being the oxidation of the oxalate by the permanganate present. The authors invariably regard the entire weight of a reagent present as active; and they prove that the amount of oxidation that takes place is directly proportional to the total amount of permanganate remaining in solution at a given time. In a second inquiry into the reduction of hydric or a similar peroxide by hydric iodide in an aqueous solution of varied content, they show‡ that "whether the solution contains in each cubic centim. 746 millionths of a gramme of hydric sulphate, or 150 times that quantity, 604 millionths of a gramme of potassic iodide or 9 times that quantity, or whether hydric chloride or hydrosodic carbonate be substituted for hydric sulphate, whether the temperature be 0° or 50° C., and whether the portion of change require for its accomplishment intervals of one or two minutes, or intervals of half an hour or an hour, this reaction still conforms to the law that the amount of change is at each moment proportional to the total amount of changing substance." The processes above referred to, as well as others confirmatory of them, are represented by Esson as continuous lines; and where then the case is not too complicated to treat, the law of action is figured graphically as a hyperbola or, ordinarily, a logarithmic curve.

* A reduction of all the most important of Gladstone's numerical results has been given by myself in this Journal [IV.], October 1874, where they are shown to agree with the formulæ of certain logarithmic curves, the use of which was first introduced into chemistry by Esson.

† Phil. Trans. 1855, p. 189.

‡ Phil. Trans. 1866, pp. 127, 128.

Similar results were arrived at by Guldberg & Waage*. They found that the force which produces the formation of A' and B' increases proportionally to the coefficient of affinity (k) for the reaction $A + B \rightleftharpoons A' + B'$, and is proportional to the product of the active masses (p, q) of the two substances A and B: they equate the force to kpq , and, on this basis, find themselves able to represent the results of a long and detailed experimental investigation into the measurement of chemical attraction. They have also shown that the results of the researches of Berthelot, Scheerer and Debus are capable of representation on their principles. But their examination of Debus's research on the fractional precipitation of mixed baric and calcic chlorides by sodic carbonate deserves especial notice, because the numbers obtained by that chemist had long been supposed to support the ordinary view that chemical action is characterized by discontinuity. No real break, however, occurs. Of his three investigations, they take that† in which, according to its author, the experimental data are least open to objection. Here the only variable is calcic chloride (p), and the precipitate is baric carbonate (x) (here represented as sulphate); and the weight of the latter is given in terms of the former by the equation

$$x = \frac{0.389 - 0.035p}{1 - 0.080p},$$

an expression in which no discontinuity is involved. It is, indeed, remarked by Debus himself, that what he regarded as sudden changes are very similar to the gradually increased distention and ultimate fracture of a string stretched by a weight.

Bunsen's well-known experiments on the explosion of mixtures of certain gases also need consideration here, for the reason just referred to. The following Table‡ is a specimen of the results obtained:—

Comp. mixture.			Consumed by detonation.		Ratio $\frac{\text{CO}}{\text{H}}$.
CO	H	O	CO	H	
72.57	18.29	9.14	12.18	6.10	2 : 1
59.93	26.71	13.36	13.06	13.66	1 : 1
36.70	42.17	21.13	10.79	31.47	1 : 3
40.12	47.15	12.73	4.97	20.49	1 : 4

Now, suppose that, instead of causing the above four mixtures to explode, Bunsen had been able to contrive some means

* *Études sur les Affinités Chimiques*, Christiania, 1867.

† *Ann. Chem. Pharm.* vol. lxxxviii. p. 238.

‡ Watts's 'Dictionary of Chemistry,' vol. i. p. 860.

allowing of their gradual reaction (such, for example, as is used in a gas-battery), and had examined the composition of the gas from time to time. Then doubtless it would have been found that the peculiar relation he observed is reached continuously, and is merely a maximum value of one of the functions in the equation to the reaction; and this would have been noticed in each of the four cases. Thus each abrupt relation would appear as but one of a long unbroken series. The experiments, however, were not so designed as to show this, or give any chance of showing this; on the contrary, they were explosions—broken, abrupt, discontinuous—of set purpose. To deduce discontinuity where we have expressly introduced it, is to beg the entire question. But even so, the evidence of a break is fallacious. We might as reasonably infer, from the striking of a clock at regular intervals, that it had not been previously going, though in fact the entire phenomenon is ultimately based on the gradual uncoiling of a spring. In like manner all the “definite and multiple proportions” of chemistry depend upon, and are evidence of, some action exerted continuously.

The process of exhausting the chemical energy of a substance, as represented mathematically in logarithmic equations, requires an indefinitely great period of time for its accomplishment. Hence we can understand how chemical action is possible. *It can begin because it never has ended.* During any period we choose to assign, every substance retains a minute but real reserve of unexhausted energy, sufficient to meet or to induce some further attack. For it is as experimentally certain that the generated substances take part in a reaction as it is that the generators share therein. When, therefore, a body is enclosed in some vessel and set aside, it must not be regarded as inactive; it may quiver, but will not expire. Thus has the old adage, *corpora non agunt nisi sint soluta*, been deposed by modern research; and “*affinitates quiescentes*” have regained more than their ancient importance.

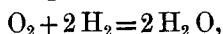
It appears, then, that chemical action is a process at once definite and continuous. Those positions in its course which Dalton termed “definite proportions” are fitly conceived as maxima or minima on curved lines.

(8) In this place we may consider the question, What are the substances that act? As has been stated in (4), matter is directed motion; and, after considerable reflection, I feel strongly convinced that the definition is both sound and adequate. Hence we conceive that matter cannot be made up of discrete parts, whether we term these atoms, monads, particles, radicals, or centres of force. This inference, which is ulti-

mately based on Hobbes's analysis of sensation, and therefore upon experience, appears to me unimpeachable; nor has any one yet been able to discover, either by accident or the most ingenious design, a single atom or ultimate point of any kind. Parts do not exist until we make them, and then they are new wholes. If, for example, I cut a piece of paper into two parts, it cannot be correct to say that those parts existed in the paper before; and they are now no longer parts, but two new whole pieces of paper. We may proceed a step further. Water is usually said to consist of hydrogen and oxygen. How can it do so when they are gaseous bodies, and it a liquid, at the ordinary temperature? The answer is, Because you can obtain hydrogen and oxygen from it. We might as reasonably affirm that a chrysalis is a butterfly. Having added to water an enormous amount of energy, the result has been two gases; resume the energy, and water is reproduced.

$$\text{Water} + \text{energy} = \text{hydrogen} + \text{oxygen}.$$

The common statement omits "energy" and is therefore an erroneous equation; for it leaves the student open to infer, as many young students do, that water is decomposable without any exertion whatever. The phenomena are, in fact, quite consistent with hydrogen, oxygen, and water being either of them compound or simple. Thus, instead of writing



we might with equal exactness represent the experiments by the equation

$$\begin{array}{ccc} (p+x) & + & (p-x) = 2p, \\ 32 & + & 4 \quad 36 \end{array}$$

which exhibits water as a simple body, just intermediate between hydrogen and oxygen. I examined this same question some years ago, when investigating a kindred topic—the ideas relating to chemical substance. In a memoir upon this subject, I pointed out that the principle of classification, as applied to chemical substance, at once shows that we have been gradually conceiving it as *homogeneous*, and chemical substance is analytically defined as *homogeneous substance*. "Each element is, as has been stated, homogeneous; that is, the whole list of elementic discriminants fails to show that it consists of more than one thing, or that it can be made by putting two or more things together. Each amine is homogeneous; because the varied application of aminic discriminants, such as potassic hydrate, hydric chloride, platonic chloride, reveals one thing only"*.

* Phil. Mag. [IV.] vol. xl. p. 261.

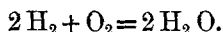
I cannot dismiss the question of chemical substances without referring for a moment to those that are isomeric. The general phenomena of isomerism are conceived to point irresistibly to an atomic theory of some kind. As I have discussed this topic elsewhere *, and shown that all the *experimental* evidence on this subject leads up to continuity, I will not again refer to it, but merely adduce the following simple illustration of my view. Imagine a number of insulated Leyden jars, alike in weight, volume, and every other particular of construction. Let each of these be charged with a different amount of electricity; and let the electricity be positive in some jars, in others negative. Now let the same piece of charged gold-leaf be caused to approach the knob of each jar in succession, its initial state being restored before each approach: in no two cases will the attraction (or repulsion) be the same in amount. This is exactly the position of the phenomenon of isomerism. All we know of it is that certain bodies, having equal (gaseous) volumes for equal weights, behave differently when a standard energy is applied to them. To measure, both in quality and quantity, the energy associated with each isomeric substance, is to give a complete account of the phenomenon of isomerism. Into this account the atomic element does not enter.

Thus, then, whether we consider the act of mechanical division or of chemical decomposition, or the fundamental idea educible from the classification of chemical substances, or what is the most real meaning of our sensations, the answer is practically a single one. The substances that take part in chemical actions have no parts or radicals; they are *homogeneous*, consisting of directed motion.

Energy is only known to us as diffuse (non-isolable) motion; matter, as concrete (isolable) motion. Whether the one kind can be transformed into the other, and what, in case such a change can be effected, is the nature of the intermediate substances, are questions which I can only raise, and not solve. Until periodic verifications are made of the quantities in which standard elements combine, we have not even approached the threshold of an experimental answer. No one, for example, can assert that argentic chloride has the same composition now that it had 100 years ago. So uncertain is the axiom that no matter can ever be lost.

(9) Some consequences of this result must now be traced.

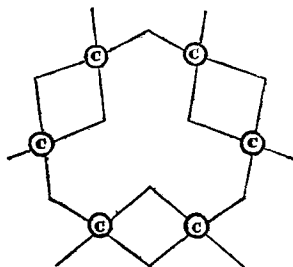
(a) The vices and virtues of the common chemical equations are typically depicted in the well-known expression



* Laboratory, 1867, p. 54.

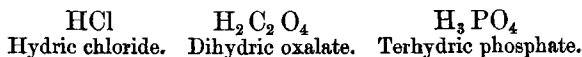
But this equation is a *suppressio veri*, by omitting “+ energy” from its right-hand side ; and a *suggestio falsi*, by proposing to consider any bulk of water as made up of at least three parts. We must therefore abandon the common chemical equations.

(β) On the ordinary supposition, bodies are supposed not only to have parts, but to have such parts disposed in a certain way ; this is their *constitution*. The constitution of benzol, $C_6 H_6$, is, for example *,



But it has been shown that quantity does not consist of parts at all, however arranged. The theory of “constitution” is therefore shattered by the same stroke that smote its parent the “equation.”

(γ) According to the Berzelian nomenclature (revived in recent times, and by far the most scientific that has yet been devised for chemistry), formulæ are represented by dual names which correspond to the specific and generic names of biology. Thus we have



similar to *Pinus sylvestris*, *Geranium robertianum*, &c. These names, therefore, suggest what the formulæ suggest ; and, with the formulæ, they must retire. The less grammatical names, such as sodium chloride, calcium nitrate, are clearly involved in a similar fortune.

Here I may perhaps be encountered by the question, What is to be the instrument of discovery and reasoning if the atomic theory be discarded ? This inquiry is sometimes so confidently made, that it seems to be deemed unamenable to a reply. But the answer is obvious, and it is furnished by history. Chemistry existed before Dalton. The discoverers of the cause of the increase of weight of metals by burning, of the chemical

* Kekulé, *Lehrbuch*, vol. ii. p. 496.

nature of respiration, of the composition of water, of the first accurate quantitative methods in analysis, were none of them atomic theorists. Can we say that, aided by the atomic theory, we have equalled or surpassed those great achievements? And if the atomic theory is indeed the legitimate parent of the interminable horde of derivatives, isomers, polymers, and the like, which swarm across the science, why has it done nothing, or so little, to train and educate them? Or dare we venture to surmise that there must be something inherent in the very nature of that theory which accounts for this pauper progeny—which explains why so many substances are made and then set adrift in literature unmeasured, unclothed, and requiring to be investigated all over again. The object of chemistry has become an art of breeding. May it not be possible that many minds, habituated to the ease and fancies of atomic speculation, have lost the rigour and hardness required for the exactest research? The examination of natural phenomena is best effected with the minimum of assumption of any kind; and instead of demanding a theory, it would be better to ask how we could dispense with one. It is juster and wiser to adhere to facts than attempt to transcend them.

(10) Chemistry is extremely deficient in symbolic expressions for its facts, and, except in Brodie's partly published calculus, has none to which mathematically deductive processes can to any extent be applied. Provided that any equation does not violate the law of even numbers, and will add correctly, we may write out any grouping of symbols we please, and the prospect *may* hold; but we cannot say that it *must* hold. Contrast the enormous resources which are at the disposal of the mathematician when he wishes to represent the position of a point, and the light and fulness of his representation, with the pitiful poverty of "modern chemistry" (as it is triumphantly termed), whose equations only tell you in substance that two and two make four. Assuredly it is time that chemical investigators approached in earnest the subject of a new symbolic system, and sought for data to lay it upon a broad foundation. At present such important processes as continuous etherification and continuous saponification are utterly unable to be suitably expressed. Some suggestions towards the desired result may be stated as follows.

(α) From what has been several times repeated in this memoir, it will be apparent that *every symbol, whether of chemical substance or of chemical operation, must represent a whole.*

Mathematical methods involve no discontinuity, and may therefore be applied to such symbols. Thus instead of writing $2\text{H}_2 + \text{O}_2 = 2\text{H}_2\text{O}$, some equation of the form $2x + y = z$ would

be legitimate. Here no assertion is made that water is a compound body.

(β) The use of such symbols will depend upon the object in view. One instance of their application has been given in (7), where the effect of one variable (calcic chloride) on another variable (baric sulphate) is thereby expressed. The logarithmic and hyperbolic curves of Esson, in which are shown the relations of changing substance to change produced, also make use of such symbols. These are representations of the chemical process.

But we require to use symbols for other purposes. Supposing that, in Debus's investigation, baric iodide had been used instead of baric chloride, what weight of the former would have done the same work as the latter? The answer to this question gives us the real or *dynamic equivalent* of baric iodide in terms of baric chloride. In other words, if i stand for baric iodide and c for baric chloride, it is a solution of the equation

$$i = fc.$$

It was after such numbers that Bergman sought in vain; but he was the first who clearly saw their immense importance. In memory of him we may term them Bergmannics. For the few that are known I refer to the Proceedings of the Royal Society, vol. xviii. p. 348, and this Journal (IV.), vol. xlv. p. 506*. Thus, if N stand for thallous, argentic, or plumbic nitrate reduced to the unit (NO_3), and P stand for potassic nitrate, the bergmannic is

$$N = \frac{8}{5} P;$$

if S stand for sodic nitrate,

$$S = 1 P.$$

Diffusion bergmannics were obtained by Graham (Phil. Trans. 1850, p. 46), who proved that they are not by nature atomic, but either equal weights or multiples of equal weights. Such questions are of the highest importance. The manufacturer, for example, who is required by alteration of prices or other economical reasons to substitute one substance for another, ought to have such numbers ready to hand. Should the agriculturist desire to use potassic instead of sodic nitrate on a grass crop, he ought to know what weight of grass will be produced by one as compared with the other. The physician should know what weights of quinine, cinchonine, and strychnine, &c. do the unit of work. All this, and more, is not only attainable but near.

* See also Chłiżyński, *Ann. Chem. Pharm. Suppl.* vol. iv. p. 226.

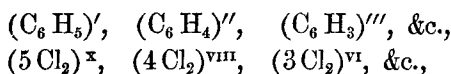
14 Dr. E. J. Mills on the First Principles of Chemistry.

Having harvested such dynamic units, and classified them upon a common scale, we should certainly see a new calculus and a new nomenclature. Instead of Daltonian atomic weights, we should have the realities which I have termed bergmannics; and chemical substances, instead of being named dually, on the current system, would be called by their bergmannic symbol. Chemistry is now in the same position as we should be, if, with the sovereign, the shilling, the penny, &c. in circulation, we were unable to express the value of one in terms of the others. For the common "equivalents" are not, so far as we know, equivalents at all. They are defined, for instance, as the weights of Li, Na, Ag, &c. that will displace H in the expression HCl. We might as well say that the value of the loads in a railway truck are always equivalent, whether the load consists of air, of hay, or bullion. It is sufficiently obvious that the real equivalent of a body is that which performs the unit of work, however that unit may come to be defined*.

The law of decrease of chemical energy throws considerable light upon this question of equivalence. Let, for example, the "successive steps" in the chlorination of benzol be one and the same kind of operation throughout; let $+B$ represent that chemical property of benzol (it is enough to assume *one*) which is reduced by chlorination, and $-C$ that chemical property of chlorine which accumulates on the benzol by chlorination; also let β be a factor less than 1, γ a factor greater than 1. The law in question leads, at its simplest, to the equation

$$y = B\beta^x - C\gamma^x,$$

y being the sum of the aforesaid properties after a stage x of chlorination. Thus the residues $B\beta^x$ and $C\gamma^x$ form geometric series, the actual "valencies" of which decrease therefore by a common factor, not alter by a uniform difference. In other words, the arithmetical series of valencies,



is inconsistent with the law. This result affects the entire doctrine of substitution. It also justifies Erlenmeyer's remark, that there cannot really be any such thing as a polybasic acid.

(11) The following summary will serve to exhibit in a clear light the difference between the chemical principles I advocate

* One instance of such a definition might be,—*The equivalent of a substance is that weight of it which, in a tube of unit capacity, liberates the unit weight of iodine in the unit of time.*

(the *Theses*) and those which are more or less ostensibly current (the *Antitheses*).

Theses.

- i. The first principle of science is motion.
- ii. The first principle of chemistry is action.
- iii. Such action is determinate, continuous, and takes place between wholes; it cannot be regarded as finite.
- iv. Acting substance is homogeneous, and consists of directed motion.
- v. Symbols of substances should be homogeneous, and represent wholes; equations of action must be continuous.
- vi. α . The equivalent ("bergmannic") of a substance is that weight of it which performs the unit of work.
 β . If there be "valencies," their series must advance by a common factor.

Antitheses.

- i. The first principle of science is matter.
- ii. The first principle of chemistry is neutrality, indifference, or saturation.
- iii. Chemical action is indeterminate or partially determinate; it occurs in successive stages, between very small and indivisible parts; and it is completed almost instantly.
- iv. Acting substance consists of moving or stationary atoms.
- v. The symbols of most substances should represent composition; the equations of action are identical with those which show the mere final distribution of weight.
- vi. α . The equivalent of a substance is that weight of it which takes the place of a unit weight of hydrogen.
 β . There are "valencies," and their series proceed by a common difference.

(12) What, then, is to be the practical result of this discussion? Some interest may perhaps attach to the mere exhibition of a chemical system so different from that which now prevails, and sundered therefrom by so broad an interval; but the result would then hang lifeless, with no more purpose than a picture on a wall. Neither has it been my object so to convince the reader as to awaken in him some sudden enthusiasm for a new, or rather for the old, cause. I call upon him to consider for himself which system, the atomic or dynamic, he deliberately prefers; to ask himself which of these, either in its largest generalizations or minutest details, best corresponds to his reasoned views of nature; and, finally, to decide (for it is worth deciding) to which he could assign those elements of rectitude, of justice, and of well-being which, as a member of a social order, he values most. For, in the long run, no part

of ourself is dissociated from another part ; and the principles which underlie chemical work this hour, become in the next the springs of moral action. Here, then, is neither mist nor vagueness ; these tests are decisive and at hand. All real philosophy is human ; its foundations lie deep in the granite of every day experience ; and the superstructure is lucid as the noon. In that keen light I place the issue.

II. *On the Microscopic Characters of some Peculiar Forms of Coke.* By E. TULLEY NEWTON, Assistant Naturalist H. M. Geological Survey*.

[Plate I.]

IN the extensive collection of fuel substances formed by Dr. Percy, F.R.S., there are certain specimens of Coke presenting very peculiar forms. The Doctor kindly placed these specimens in my hands that I might have the opportunity of examining them microscopically, and also suggested the desirability of publishing a short account of my observations.

The specimens are of two kinds, both obtained from a coke-oven, and are so unlike each other that there can be no doubt that they have been formed in an entirely different manner. One of them has a silvery metallic lustre, and is usually attached to some object, either as a flat expansion, or in masses of feather-like branches (Plate I. figs. 1 & 2), having much the appearance of minute stalactites. The surface, which is sometimes smooth, mostly appears to consist of a number of minute globules or bubbles closely packed together. When any considerable thickness is formed it becomes very hard and dense. Specimens of this kind of coke may be seen in the Museum of Practical Geology, Jermyn Street ; and perhaps the most remarkable example is that in which some plaited cane and straw, and also some clay tobacco-pipes, are coated over with the most beautiful feathery stalactitic masses of this peculiar coke.

The bubble-like appearance of some specimens might lead one to suppose that they were formed by the bubbling of the semifluid hydrocarbons, in a manner similar to that which may be often seen when ordinary coal is burnt in a grate ; but the fact that objects, such as the tobacco-pipes just mentioned, become coated with this coke, shows conclusively that this cannot be the case. And, again, the bubbling process

* Communicated by the Author.