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THE LIFE HISTORY OF A DOCTRINE.[1]

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THIS is the season of congratulation, and even if it were not, I should begin by congratulating my fellow members upon the present condition of our Society. We have every reason to be gratified. Statistics do not always convey a clear idea of the actual state of an organization, but they may be suggestive. The last annual meeting of the Society that was held in Washington occurred in 1897, just five years ago. At that time we had 1156 members. To-day the number has grown to 2176. The membership has nearly doubled. In 1897 the number of pages in the Journal of the Society for the first eleven months was 1315, while, for the corresponding period of this year, 2489 pages were published. To be sure, this included for 1902 the general index and the twenty-fifth anniversary volume. Omitting these, the figures are, for 1897, 1246, for 1902, 1956—an increase of 710 pages in five years. Any more rapid increase would almost be alarming.

One point suggests itself in this connection. Some of you may ask whether, under existing circumstances, it is desirable that there should be two journals in this country devoted to chemistry. Perhaps I am not the proper one to discuss this subject. There

[1] Presidential address delivered at the Washington meeting of the American Chemical Society, December 30, 1902.

seems to be an increasing demand for the American Chemical Journal as well as for the Journal of the Society. Having been in existence for nearly twenty-five years and being in robust health, the thought of giving up the ghost does not appear attractive to the former. It should, however, be clearly understood that there is no rivalry between the two journals, except such as may legitimately exist between friends, causing both perhaps to try to do their best. In these days of consolidation, the question may fairly be asked whether it would not perhaps be better to unite the two? It may be said that this subject has often been under friendly consideration, but the result has been unfavorable to consolidation. It must be confessed that the personal element enters into the discussion to some extent, and your speaker is the person involved. I feel more or less as though the American Chemical Journal were one of my children. Much of my activity has gone into the Journal for a quarter of a century. I have seen it develop from a feeble condition, through a dangerous second summer, through the usual list of children's diseases, until it was able to stand on its own feet and become self-supporting. While marriage is perhaps now in order, it is clear that this would involve a change of name and a loss of identity, and this I do not like to contemplate. So, my brethren of the Chemical Society, I ask you to bear with me for a few years longer. This independent journal will do our Society no harm. On the contrary, you may count on me to do all in my power to further the interests of the Society. One new reason why I do not want to give the journal up is that by force of circumstances I have, to some extent, recently been drawn away from my chemical bearings, and I do not wish as yet to occupy that position on the shelf that is, I suppose, awaiting me. My interest in chemistry is, I think, as great as it ever was, and I wish to do everything I can to keep up that interest. Through the journal I am necessarily kept more or less in touch with many of the active workers. While this is of no special importance to the workers, it is most helpful and refreshing to me, and, after a service of over thirty years in the ranks, I feel that I have a right to a pension. The only one I ask is the permission to continue as editor of my old journal without being subjected to the suspicion that I am an enemy of our Society and its constantly improving and now excellent Journal.

But this is all too personal, and I now pass to something impersonal. The general subject to which I ask your attention may be called "The Life History of a Doctrine". This title suggests a biological analogy. The life history of an animal includes a record of the events in the life of that animal from the earliest stages to the end—from birth to death. But there are events before birth. The life history is preceded by the embryonic history, and there are events after death—events biological, as shown in heredity; events chemical and physical as shown in decay and the reduction of the complex constituents of the animal to simple forms that can be assimilated by living things and thus enter again into the round of life. I do not refer here to spiritual events after death, for, in speaking of animals, I have not had man in mind, and it is customary, I believe, to deny to all animals, with this exception, the persistence of the spirit after death. In the analogy that I have in mind, however, the spiritual events are to be taken into account, for, as I think can be made clear, there is a life after death in the case of a good doctrine as in the case of a good man. The pursuit of this analogy is interesting (to me), but it will be more profitable to illustrate it by examples, of which there is no end. I wish especially to point out the bearing of the philosophy of the history of chemistry upon the present-day problems so far as this may be possible in the time at my disposal.

The doctrine of the transmutation of metals played a most important part in its day. · No one can trace it to its beginning. It is, however, clear, that it developed great strength and controlled the intellectual activities of the leading intellectual men of the world for several centuries. It led to the development of chemistry. The alchemists were the working chemists of their day. They taught the world the lesson that it is only by contact with the things of this world that we can gain knowledge of them. They laid the foundations of experimental science. The soul of alchemy was experiment. The fundamental doctrine of alchemy, transmutation, after a long and active life began to show signs of weakness; and in due time it took to its bed, and in spite of admirable medical care it died and was buried. No chemical doctrine has had anything like as long a life as this. To be sure, this could not have been possible, as the life history of the doctrine of transmutation covered a period longer than that which has elapsed since its death, though it is difficult to fix the time of its death with accuracy. It is dead now at all events, and we may ask the question: What came after death? The doctrine accumulated large wealth and left the world a large estate. I need not give you the inventory. Probably no one can do so. But we do know that we owe to the activities of those who were controlled by the doctrine of transmutation a long list of substances that are of fundamental importance, such as sulphuric acid, nitric acid, phosphorus, alcohol, ether, etc. This is the material side of our inheritance. How about the spiritual? I have said that experiment was the soul of alchemy. That will live forever. I should perhaps have said that experiment was one of the souls of alchemy, for I suppose it is not objectionable to assume that a doctrine may have more than one soul. The rule in regard to human beings seems to be perfectly simple, and it is generally accepted, but I once heard of a professor, who, speaking of some great disaster, said: "On this occasion three hundred souls perished—counting one soul to each body." Assuming that a doctrine may have more than one soul, I am inclined to think that a second soul of alchemy is to be found in the idea of the relationship between the elements—an idea that persists and keeps dangling before us the possibility of the transmutation, not only of base metals into gold or silver, but of all the elements one into the other from one end of the list to the other.

Let us take another doctrine—that of phlogiston. The embryology of this doctrine has not been clearly worked out, but its life history has been traced pretty carefully. We know how it died and, in the events that followed, it is not difficult to find evidence of its existence after death. It was through the influence of this doctrine that chemists came to recognize the common features of those phenomena that we now group together under the general name of oxidation. They were all ascribed to one cause, a subtle substance, phlogiston. The search for this substance became the great problem of chemistry. The possibility of finding it was a great incentive to work. What matters it that the doctrine of phlogiston became aged and died and was buried? It did good service—inestimable service. It kept its disciples at work and led them through this work nearer and nearer to the truth. In its life it passed through the period of infancy with all its attendant dangers, through the period of enthusiastic youth, through sturdy manhood, and it reached old age with its attendant signs of weakness and decay. It died at last, but only after a mighty struggle. The act of dying was prolonged. Since then generations of astute teachers of chemistry have pointed out to their perhaps even more astute scholars the errors of phlogisticians, and they have all smiled and wondered how these deluded men could ever have been deluded. Possibly they forget that those at whom they smile were the leaders of their times, and that these leaders were trying as earnestly as the chemists of our own day to learn the truth.

What is the spiritual part of the doctrine of phlogiston that lives after its death? Clearly it is the idea that all the phenomena of combustion, including calcination, have a common cause. That cause has, to be sure, been shown to be oxygen. The phlogisticians thought that the cause was phlogiston, a purely imaginary substance. Priestley and Scheele and Lavoisier showed that it is an invisible gas working quite differently from the way the phlogisticians supposed. The life of the doctrine of phlogiston left us richer in material possessions and in ideas. The discovery of oxygen which is no doubt the most important discovery ever made in the field of chemistry, tended to give a materialistic trend to the thoughts of chemists. Both the philosopher's stone and phlogiston were imaginary substances that were sought in vain. Although both have been described by enthusiastic, but inaccurate, and perhaps mendacious, workers and writers, neither of these subtle things could be found. It was, nevertheless, possible to *believe* in their existence and to indulge in the hope of their discovery. But now oxygen came on the scene. Indeed, it may be truly said that it took possession of the stage, and it has been playing the leading part in the field of chemistry ever since. Here is an invisible substance existing in the air and capable of bringing about the most astonishing changes in things. We can not realize the effect of this discovery upon the thoughts of chemists. I sometimes feel that I should like to have lived as a chemist in the latter part of the eighteenth century. What thrills the workers of that time must have felt when they heard of the discovery of oxygen and learned from Lavoisier what part it played in combustion! We sometimes plume ourselves upon the doings of our own times. Has there ever been a more active or more fruitful period in the history of chemistry than that wonderful period here referred to?

It was a great step forward to show that oxygen is one of the most powerful agents at work in the processes that are in progress on this earth. Not only combustion, but life in all its forms is in some way dependent upon it—animal life directly, plant life indirectly. Oxygen is the controlling factor in all the changes that are familiar to us. Some one, I do not know who, is responsible for that superficial and much quoted phrase "Without phosphorus no thought." The same statement could be made with equal truth in regard to other elements, such, for example, as nitrogen, carbon, hydrogen, sulphur, sodium, calcium, and, above all, oxygen. Indeed, we may almost say, without oxygen no chemical activity on this earth. This sudden appearance of oxygen and the recognition of its importance tended to put matter on a throne. "The study of material things will lead to the discovery of the hidden causes of other phenomena. See what the discovery of oxygen has done for us! Here is something tangible. Let us to work. There must be plenty of other things that operate as causes. If we can only bring these things to light, we shall be able to understand what is going on around us." So must the materialists have thought. There were, however, in those days, as there probably always have been, those who looked for the power behind the throne on which matter had been placed. To drop the figure and return to oxygen we may say that, while the discovery of this element gave the answers to many questions, it raised many new questions; and the attempts to answer these led again to regions of imagery.

One of the oldest tricks of the mind is the invoking of spirits in time of need. What causes all bodies to attract all others? We say gravitation, and somehow this spirit helps us. We feel as though we knew more about the phenomena of universal attraction when we have given a name to an imaginary and immaterial cause. So, too, when we inquire why oxygen causes the changes it is known to cause we can only conjure the spirits and give a new name. Oxygen unites with carbon; the carbon burns; a new thing is formed. It all becomes clear when we are told that it is chemical affinity that does it. Chemical affinity isn't an imaginary substance; it isn't something that we may see and handle. We haven't forgotten the philosopher's stone and phlogiston. Our imaginary cause is spiritual; it is not material. But this is a digression. It was intended to show how the mind reverts promptly to the subtle, however powerful the attraction of matter may be. We cannot, if we would, keep to things material.

Recalling, what perhaps even I have forgotten, that my theme is "The Life History of a Doctrine," I propose, now that I have tried to show what is meant by this phrase, to move on more rapidly, so that I may dwell somewhat more fully upon one particular doctrine that has been before the chemical world in one form or another for about a century.

The discovery of oxygen did not lead directly to the introduction of a new chemical doctrine. Its chief result, as far as doctrine is concerned, was the death of the doctrine of phlogiston.

The discovery emphasized the importance of taking into consideration the weights of the things worked with. It was by this means that Lavoisier achieved his brilliant success. That weight was rather lightly regarded in earlier days may be seen from the following quotation, which is taken from an essay by Dr. Jean Rey, published in 1630:

"My chief care hitherto has been to impress on the minds of all the persuasion that air is heavy, inasmuch as from it I propose to derive the increase in weight of tin and lead when they are calcined. But before showing how that comes to pass, I must make this observation—that the weight of a thing may be examined in two ways, *viz.*, by the aid of reason, or with the balance. It is reason which has led me to discover weight in all the elements, and it is reason which now leads me to give a flat denial to that erroneous maxim which has been current since the birth of philosophy—that the elements mutually undergoing change, one into the other, lose or gain weight, according as in changing they become rarefied or condensed. With the arms of reason I boldly enter the lists to combat this error, and to sustain that weight is so closely united to the primary matter of the elements that they can never be deprived of it. The weight with which each portion of matter was endued at the cradle, will be carried by it to the grave. In whatever place, in whatever form, to whatever volume it may be reduced, the same weight always persists. But not presuming that my statements are on a parity with those of Pythagoras, so that it suffices to have advanced them, I support them with a demonstration which, as I conceive, all men of sense will accept. Let there be taken a portion of earth which shall have in it the smallest possible weight, beyond which no weight can subsist: let this earth be converted into water by the means known and practiced by nature: it is evident that this water will have weight, since all water must have it, and this weight will either be greater than that of the earth, or less than it, or else equal to it. My opponents will not say that it is greater, for they profess the contrary, and I also am of their opinion: smaller it cannot be, since we took the smallest weight that can exist: there remains then only the case that the two are equal, which I undertook to prove. What is shown of this particle may be shown of two, three, or a very great number—in short, of all the element, which is composed of nothing else. The same proof may be extended to the conversion of water into air, of air into fire: and, conversely, of the last of these into the first."

The idea that a thing can be weighed by reason is, I suppose, an inheritance from the old philosophers who seem to have believed that all the problems of the universe could be solved by mental operations, or that any problem that could not be solved in that way was not worthy of their consideration. The first great generalization that was reached after the method of weighing was generally adopted by chemists was what we sometimes call the law of the indestructibility of matter, or, in more refined language, the law of the conservation of mass. Then followed the laws of definite and multiple proportions. Now a law of nature is quite a different thing from a doctrine. A law once discovered does not wither and die. It is eternal. Such a statement cannot be proved to be true. It calls for faith, but faith is called for at every turn in scientific matters as well as in spiritual. Without it progress would be impossible. As I am trying to deal with doctrines and not with laws, let me say that doctrines call for even a larger faith than laws. The very essence of a doctrine is faith in things unseen. The discovery of the laws of definite and multiple proportions led to the thought of atoms—not the evasive atoms of the Greeks, but atoms that could, in a way, be made the subject of experiment—the Daltonian atoms. This conception appeals to some minds very strongly. It is not necessary that we should know what the atoms look like, though this is highly desirable. The atom of chemistry can accomplish the purpose for which it was conceived by Dalton by simply standing for a unit of matter that can pass unchanged, so far as mass is concerned, through a series of chemical changes. That is all we need to think of under ordinary circumstances. Some refined thinkers have found mental objections to the atom and it has been the subject of innumerable attacks. It doesn't do some things that it appears to us it ought to do and we try to depose it from time to time. Particles that cannot be more than 0.001 of the size of an atom challenge the right of the latter to supremacy, and the novelty-seekers, the born iconoclasts, cry out, "Make way for the corpuscle; the atom has had its day." But, seriously, the corpuscle does not seem to threaten the atom of to-day or of the immediate future—say any time within the next million years. The atom may be composed of corpuscles. Indeed, I think chemists would rejoice to learn that this is the fact. On this point, let me quote J. J. Thomson, the father of the new corpuscle. Speaking of Lenard's observation that the penetrating power of the corpuscles depends only on their density, he says: "This is exactly what would happen if the atoms of the chemical elements were aggregations of a large number of equal particles of equal mass, the mass of an atom being proportional to the number of these particles contained in it, and the atom being a collection of such particles through the interstices between which the corpuscle might find its way." "Since the density depends only on the number of particles in unit volume and is independent of the nature of the resulting atoms, Lenard's result is a strong confirmation of the view that the atoms of the elementary substances are made up of simpler parts all of which are alike." I am as yet unable to form a judgment in regard to the value of the evidence thus presented, but my confidence in J. J. Thomson gives me faith in the thoughts suggested by him. As I understand it, the worst that can be done for chemistry by the corpuscle is to change the atom so slowly that it would take something like a million years to enable us to detect the change by the balance. Perhaps the atomic weights of the elements, or of some of them, are undergoing change. Whether in the course of geological ages the atoms are becoming simpler or more complex is a question that appears idle at first, and yet when we bear in mind the fact that the atoms of our day have already been subjected to a great variety of influences for ages past, and that the atoms that we know are comparatively complex, we may at least suspect that the tendency so far is towards complexity. But here we are face to face with a problem far beyond our powers—*the action of eons upon ions.*

Even if we assume the corpuscle, our conception is still materialistic, and we have to face the question, What is matter? That is a deep question—one of the deepest that can be asked. It is not difficult to show that all definitions of matter that have been given are totally inadequate; to show that matter is a product of the imagination; that we know matter only in so far as it affects our senses, and our senses are affected only by the different forms of energy. By logic we can easily, with Ostwald, reach the conclusion that "matter and energy are not to be thought of as distinct, as, for example, body and soul." We cannot help agreeing with him further when he says: "If we attempt to think of matter as separate from the various forms of energy nothing is left. Matter is, in fact, nothing but a group of different energies in space." But what is energy? This question would have been promptly referred to the physicists by the older chemists, but the chemists of to-day are physical chemists or chemical physicists, and they grapple with such questions without reserve. Perhaps the nearest approach to an answer is that of Herz, who, according to Ostwald, "expressly declines to see anything in the electromagnetic theory of light but a system of six differential equations." By means of mathematics, relations may be expressed and the story of nature told in a way that is clear to one who understands the language, and perhaps the time will come when men will have a complete record of the various forms of activity of nature, and they may then see that our mechanical and materialistic conceptions of natural phenomena are like the rude drawings of a child as compared with the paintings of Raphael. We have glimpses of such a scientific millenium in a few nooks and corners of physics. When that time shall come the physicists and chemists will in a way be superfluous. Everything will take the form of mathematics. By mental operations alone it will then be possible to solve such problems as may remain to be solved. It will then no longer be necessary to work with things—or rather with those manifestations of energy which in by-gone ages (say the twentieth century) had been crudely interpreted as indicating the existence of matter. A few models of molecules, of atoms, of corpuscles, and, I fear I must add, of ions, may then be preserved in the archaeological institutes for the contemplation of mathematical philosophers.

What I have just said has not been intended as a criticism of any tendency. I have had that vision as others have. So, too, I have had visions of a heavenly kingdom to come, and I am thankful that this has been vouchsafed to me. But that heavenly kingdom is far away and so is that scientific millenium. Meanwhile there is work to be done here on earth and with earthly things. If we were all angels, a good many problems that now worry us would be solved—never to be solved again. So, too, in that scientific millenium such work as scientific men now do will not be called for. I sometimes think that the man with the distinctly mathematical mind must necessarily be unhappy if he applies himself to the study of natural phenomena. The points of contact between his language and the facts established are relatively so few that he must have sensations like those of a man with large wealth in a desert island. I once knew a young mathematician, even then distinguished, who had made something of a study of physics. He needed to add to his income and an opportunity offered itself to him to coach some students of physics. He tried this and had to give it up. One evening I found him in great distress. He told me that he had been trying to explain the law of falling bodies to his scholars and had failed to make any impression on them. He confessed that he himself had no conception of the significance of the law except as it appeared to him in a mathematical expression. He could not think of a falling body as such. The mathematical expression $\frac{dx}{dt} = gt +$ constant, however, made all clear. He tried to convey his own thoughts to his students and he was greeted with open-mouthed wonder. So, too, I knew a physicist who approached his problems in much the same way. He would not let his class of beginners work with a lever and deduce the law from the results of their own experiments, which to me appeared an instructive exercise, "for" he said "the lever is a mathematical instrument and it is not necessary to experiment with it in order to determine the laws of its action."

On the other hand, I have been told that Lord Kelvin says he cannot form a clear conception of any natural phenomenon without the aid of a model. I remember years ago, when he was lecturing at the Johns Hopkins University, that he showed his hearers a beautiful model of light waves, and I am sure they had the power to convey light to a number of brains that would have been in darkness if any other method had been adopted. Whether we will or not, we have the non-mathematical mind to deal with, and this brings me back to chemistry and that special doctrine of chemistry that has to deal with atoms.

The doctrine of atoms is still alive though it came into being about a hundred years ago. It has been proved to be illogical as the ether that fills all space has been shown to be incapable of existence. Properties must be ascribed to the atom that it cannot possess and the same is true of the ether. What are we to do? Throw over the atom and the ether? Although both have been convicted of being illogical. I do not think it would be logical to give them up, for they are helpful in spite of their shortcomings, and in some way they suggest great truths. They are symbolic. It would be as illogical to give them up as it is, in my opinion, to deny the existence of a power in the universe infinitely greater than any of the manifestations familiar to us; infinitely greater than man; a power "that passeth all understanding." The atom helps us; the ether helps the physicist. We cannot give them up without losing our hold on many phenomena. For a century the phenomena of chemistry have been interpreted in terms of atoms. Take away that conception and, though it would be possible to deal with these phenomena, I cannot believe that they would appear as clear as they now do. In an address before the chemical section of the British Association for the Advancement of Science last summer Professor Edward Divers took as his theme "The Atomic Theory without Hypothesis." Let me quote a few passages from his address. He says: "The atomic theory of chemistry stands unsurpassed for the way in which it has fulfilled the purpose of every great theory, that of giving intellectual mastery of the phenomena of which it treats. But in the form in which it was enunciated, and still is universally expressed and accepted, it has the defect of resting upon a metaphysical basis, namely, upon the ancient hypothesis that bodies are not continuous in texture, but consist of discrete, ultra-minute particles whose properties, if known, would account for those of the bodies themselves. Hence it has happened that, despite the light it throws upon the relations of chemical phenomena and the simple means it affords of expressing those relations, this theory has always been regarded with misgiving, and failed to achieve that explicit recognition which its abounding merit calls for. Indeed, the desire has been expressed to see the time when something on a more solid foundation shall have taken its place." Professor Divers thinks that in dealing with chemical phenomena we can avoid thinking of discrete particles of matter. The law of constant proportions is, to be sure, entirely comprehensible as a law without the aid of the atomic theory, and so is the law of multiple proportions, but can we possibly, as yet, coordinate them without this aid? I do not think I can, and this doesn't worry me. The kind of atom that my mind's eye sees seems to help me, but that eye has not troubled itself with other attributes of the atom than that one which is needed. It will be remembered that in Dalton's time it was proposed to substitute for the atom the equivalent and some even wanted to use the conception of combining numbers. This last conception appeals to the systematic mind at first, but one cannot go very far with it without tacitly accepting the atomic theory. On this point Professor Divers says: "Refusing to commit themselves to belief in the hypothesis, chemists have thought from the first to escape the adoption of the atomic theory by putting Dalton's discovery into something like these words: Numbers, called proportional or combining numbers, can be assigned to the chemical elements—one to each—which will express all the ratios of the weights or masses in which substances interact and combine together. Perhaps," says Professor Divers, "the atomic theory is successfully set aside by expressing what is an actuality as an unaccounted-for possibility. But then those who use any such mode of expressing the facts without reference to the theory, never fail also to adopt the doctrine of equivalents, and thus, by this double act implicitly give in their adherence to the theory."

While the atomic theory can be used without using atoms, this must involve a great effort for the average mind. Why should we make the effort? If we can get a broader and deeper and clearer view of chemical phenomena by making the effort, by all means let us make it. Can we? That is the whole question. Apparently, not enough chemists have made the effort to furnish us with the necessary data upon which to base a conclusion. I should like to ask a dozen chemists to give me each his idea of the atom. The results would be interesting. Some years ago I sat next the late Bishop Brooks at a dinner party, and I had an extremely interesting conversation with him. I remember many things he said and, as having some bearing on the question I am now dealing with, I quote this remark: "I am sure", he said, "that every individual has a different conception of God. If we could get at these conceptions we should probably be greatly surprised to find how markedly they differ from one another." Each individual injects his own personality into his conceptions, and the conceptions change according to circumstances.

At first, weight, or, more accurately, mass, was the only attribute of the atom that needed to be taken into consideration, except, of course, that power of combining with other atoms which is its fundamental attribute. Soon after the atom came to be a part of the chemist's equipment, two important attempts were made to add electrical charges to the atoms. Davy and Berzelius took different views of the way in which the electrical charges led to chemical acts, but they both agreed that chemical acts are essentially electrical. Every atom had, not only weight but an electric charge which did not add to its weight, but helped to explain its activity. The atom bore this charge for many years. It was thought that it gave it up and returned to its original simple form when the dualistic conception of the constitution of compounds gave way to the unitary conception. When it was found that chlorine, an electro-negative element, could take the place of the electro-positive hydrogen without creating any marked disturbance, chemists thought it best to turn their backs on the electro-chemical theory. In fact, the old electro-chemical theories in their original forms were untenable, but this is quite a different thing from saying that electrical charges have nothing to do with chemical action. It appears to-day that these electrical charges are the controlling factors in chemical phenomena, but of that farther on.

The next change that took place in the conception of the atom was that which followed the discovery of Frankland that there is a limit to the number of atoms that can combine with any other given atom. This was followed up by Kekulé and the doctrine of valence was the result. Atoms differ from one another in respect to the number of other atoms with which they can combine. It would be interesting to follow the life history of this doctrine of valence. It has had a most eventful career. It has been chastened by experience, and now it appears to us freed, to a great extent, from the faults of youth. It is far from dead. Indeed it is probably at the beginning of its career. The phenomena of valence must be reckoned with and the study of these phenomena carries us back to the atoms and leads us to seek in them the causes of the differences in the composition of the compounds which are formed by their union.

It has unquestionably been shown that the original form of the doctrine of valence is not tenable. Elements cannot be classified rigidly under a few heads as univalent, bivalent, trivalent, quadrivalent, etc., nor can we hold the other view that all the elements have either an even number or an odd number of valences or bonds, though there appears to be some truth in this latter view. The artiads and perissads of our youth may return to us, but before they are received it will be necessary for us to ask them a few questions, and for them to answer them satisfactorily. In fact, we have learned that the phenomena of valence need to be studied carefully before we can discover the laws that govern them. The views that prevail to-day are but the foreshadowing of a broader conception of valence. This subject is very much to the front at present. The speculations of Werner with reference to complex inorganic compounds have awakened wide interest and have set many to thinking. One cannot ignore the mass of evidence put forward by Werner that tends to show that in many compounds it is necessary to assume the existence of a core or inner sphere consisting of a group of atoms in combination, this core holding in combination a definite number of atoms or groups. Whether that which holds together the atoms that make up the core is what in simpler compounds manifests itself as valence remains to be seen. At all events, if the views of Werner should prove to be correct, we shall have two kinds of valence to deal with—that of the inner sphere and that of the outer sphere, or that of the core and that of the shell. In a recent article Werner extends his views and introduces the conception of secondary valences. Thus he holds that in ammonia the three valences that enable the nitrogen atom to hold the three hydrogen atoms in the molecule of ammonia are different from that which enables ammonia to combine with a molecule of hydrochloric acid. The former he calls the "primary valences" (Hauptvalenzen), the latter a "secondary valence" (Nebenvalenz). He does not think that the two differ fundamentally. So Thiele in his study of the phenomena of saturation among organic compounds is obliged to assume the existence of "partial valences (Partialvalenzen), and the facts described by him are singularly in accord with the assumption. This applies up to the present only to the compounds of carbon. Thiele's "partial valences" are, however, not to be confounded with the secondary valences of Werner or the other earlier "residual valences" of Armstrong. A discussion of this subject might be made interesting and profitable, but I cannot go into it here. So many curious valence phenomena have been observed of late that one cannot help feeling that we are about to have a revelation that will make the old as well as the new phenomena appear clear. Carbon is bivalent and quadrivalent. That has always been clear, though Nef has made it clearer than it used to be. But now comes trivalent carbon that Gomberg has shown us, and we may be prepared for almost anything. And oxygen that has been regarded as a very model of bivalency these many years is getting restless, and is beginning to show that it too can do the unexpected. It seems clear that it can act as a quadrivalent element, but, according to Walden, it has even higher powers.

Whatever may come of all this, it is clear that we must enlarge our conception of the atom. It not only has the power to combine with other atoms, but under given conditions it has a definite number of such powers. If we attempt to represent these powers to our minds we can only use the grossest methods. The union of two univalent atoms does not necessitate the conception of direction. But when two univalent atoms unite with one bivalent atom we can hardly avoid thinking of two points of contact on the bivalent atom and of two directions in which it exerts its powers of combination. This conception of direction is, further, forced upon us by a study of the phenomena of stereochemistry, especially in the field of the chemistry of the compounds of carbon. But, if the carbon atom exerts its powers of combination in definite directions that can be determined by observation, it is, to say the least, highly probable that all other elements act in the same general way, and indeed many facts have been discovered within the last few years that have given a clue to the stereochemistry of nitrogen, of sulphur, of silicon and other elements. Indeed, in the studies of Werner, already referred to, stereochemical phenomena are illustrated in many ways by compounds of platinum, palladium and other metals that enter into the complex inorganic bases.

Our imaginary atom then has mass. It has the power to combine with other atoms under the proper conditions. This power is either a unit as in the univalent elements, or it is divisible by 2, 3, 4, 5, 6, 7 or 8 in the case of other elements. Further, one and the same element may exhibit different powers under different conditions, but the laws governing these variations are not known. Finally, the powers of combination of a polyvalent atom are exerted in definite directions that can to some extent be determined. These directions are evidently subject to variation, and some effect upon a compound caused by displacement has apparently been shown in the case of some carbon compounds; at least Von Baeyer's strain theory is based upon this assumption.

The latest turn that has been given to the conception of the atom brings in again the electric charge. It appears that the cotemporaries of Berzelius were too easily frightened, and Berzelius was nearer right than they supposed. Every book on the history of chemistry has an obituary on the electrochemical theory of Berzelius. But now it appears that the electrical charges assumed by him must be assumed by us. These have come more and more to the front of late, and chemical union is being regarded more and more as due to the interaction of these charges. According to the modern conception, an atom may or may not be carrying a charge of electricity. When carrying its charge it is called an ion, and it is then ready for action. When the elementary ion gives up its charge, either by entering into combination with another ion, or other ions, or by being set free, it becomes an atom. But more than this. The electrical charge of an ion is either a unit charge or a multiple of this. The bivalent ion has two charges, the trivalent ion has three, etc. The experimental basis for these ideas is found in the electrolytic phenomena that are included in the scope of Faraday's law. Faraday found that a definite quantity of electricity causes a definite amount of decomposition in a conductor of the second class; and, further, he found that when the same current is passed through solutions of the salts of different metals in series, the masses of the different metals that separate are proportional to the combining weights or the equivalents of these metals. To make clear the full significance of these facts would require more time than is at my disposal. Suffice it to say, that in terms of our present theory it takes twice as much electricity to set a bivalent atom free as to set a univalent atom free; three times as much for a trivalent atom, etc. How to conceive of one, two, three, or four charges of electricity on an ion I leave to the physicists to explain, though it must be said that they are not in the least called upon to explain.

The atom has thus been followed in its career down to to-day. The changes in our conceptions have been traced sufficiently for our purpose. It is at present a bundle of attributes and with these attributes it is a convenient nucleus for thought. Nothing has been said of the dynamics of the atom, by which I do not, of course, mean chemical dynamics in general. So far as the atom is concerned our knowledge of its motions may perhaps fairly be summed up by saying that it seems probable that it moves in some mysterious way, and perhaps the phenomena of chemistry are all due to this motion. But that carries us into the region of speculation pure and simple, and in this region the scientific worker feels uncomfortable. The atmosphere is too rarefied for him.

If you now ask what is the soul of the doctrine of atoms? I can only answer that this soul is still in the course of development. The doctrine has some immortal attributes, but what will live after its death is too early for any one to say.

"Prove all things. Hold fast that which is good."

[Contribution from the Havemeyer Laboratories of Columbia University, No. 74.]

ON THE COMPOSITION OF COWS' MILK.

By H. C. Sherman.

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In general the percentage of fat in cows' milk varies much more than that of the other constituents. It is probably safe to say that a variation of 3 per cent. in fat is as common as a variation of 1 per cent. in the total amount of other solids. Milk is apt to be regarded, therefore, as consisting of a serum of quite uniform composition in which is suspended a variable amount of fat. It is, however, a matter of some importance both from the physiological standpoint and as an aid in judging suspected