particles, — in other words, any change which results in a modification of attracting force, — whether gravitative or the commonly called chemical attracting forces, results in an electrical potential; and conversely, that the passage of electricity through any medium produces a change of aggregation of the molecules and atoms. If we suppose that radiant energy is electro-magnetic, cannot we suppose that it is absorbed more readily by some bodies than by others, or, in other words, that its energy is transferred, so that with the proper sense we would perceive what might be called electrical color, or, in other words, have an evidence of transformations of radiant energy other than that which appeals to us as light and color? We have arrived at the point in our study of electricity where our instruments are too coarse to enable us to extend our investigations. Is not the physicist of the future to have instruments delicate enough to measure the heat equivalent of the red and the yellow and the blue violet rays of energy? instruments delicate enough to discover beats of light as we now discover those of sound? The photographer of to-day speaks in common language of handicapping molecules by mixing gums with his bromide of silver, in order that their rate of vibration may be affected by the long waves of energy. Shall we not have the means of obtaining the mechanical equivalent of such handicapped vibrations? We have advanced; but we have not answered the question which filled the mind of Franklin, and which fills men's minds to-day: What is electricity?

CHEMICAL AFFINITY.[1]

PROFESSOR LANGLEY first reviewed the history of chemical theory, and called attention to the final extinction of the term 'affinity' in the chemical literature of the present day.

Shortly after the opening years of the present century, three general methods were indicated for the study of the force of affinity. Instead of being successively taken up and abandoned, like all preceding speculations, they have remained steadily in use during the eighty years which have intervened, and to-day they are still the most promising means at our disposal. These three methods may be called the thermal, the electrical, and the method of time or speed. It will be convenient to consider each one separately.

The most important generalization to be drawn from thermo-chemical phenomena is, that the work of chemical combination, or the total energy involved in any reaction, is very largely influenced by the surrounding conditions of temperature, pressure, and volume; and the conclusion they force upon us in regard to the nature of affinity is most important, namely, that this force in accomplishing work is dependent, like all other forces, on the conditions exterior to the reacting system which limit the possible amount of change. Affinity is therefore at last definitely removed from the category of those mystical agents, so often imagined by our predecessors in a less critical age, which had no correlation with the general forces of nature.

Under the title 'dissociation,' St. Claire Deville gave to the chemical world, in 1857, a new and fruitful method of investigating the nature of compounds by determining the temperature at which bodies break up or are dissociated. The laws developed by Deville and his successors in this field show us, that, after the point is reached at which decomposition commences, the further breaking up is determined by the pressure of the evolved products of the reaction, so that the permanence of the body depends on the magnitude of two variables, pressure and temperature, either of which may be varied at will through a wide range.

The electrical method of dissecting chemical forces has been followed less actively than the thermal one. Besides the well-known experimental contributions of Davy, Becquerel, and Faraday, may be mentioned Joule's researches on the heat absorbed during electrolysis, and especially the work of C. R. Adler Wright, on the 'determination of affinity as electromotive force.' The general outcome of these researches is, that the products of electrolysis are so numerous, and so varied by the results of secondary actions, that it is very doubtful whether the electromotive force measured is that due solely to the union of those atoms which are indicated by the principal equation of the reaction.

The method of time or speed of chemical reactions has a history as old as that of its two associates; but the story is much less eventful, for very little work has been done in this field. The most notable work has been done by Gladstone and Tribe, by ascertaining the rate at which a metallic plate could precipitate another metal from a solution.

To these general methods for studying the problems of chemical dynamics, should be added the investigation of the action of mass, by Gladstone, in his well-known color work on the sulphocyanide of iron; of the chemical action of light, by the late J. W. Draper in this country, and Prof. H. E. Roscoe in England, as well as Becquerel in France, — pioneers who have since been followed by a host of students of scientific photography.

In the review just given, no attempt has been made to do more than glance at the important contributions to the theory and methods of measuring affinity. Many names have been passed by, and much work has been necessarily ignored.

The history of the various modifications and additions which have been made to the primitive conception of the nature of affinity, when briefly summarized, appears to be this: Hippocrates held that union is caused by a kinship, either secret or apparent, between different substances. Boerhaave believed affinity to be a *force* which unites unlike substances. Bergman and Geoffroy taught that union is caused by a selective attraction; and therefore they called it 'elective affinity.' Wenzel and his success-

[1] Abstract of an address to the section of chemistry of the American association for the advancement of science, at Philadelphia, Sept. 4, by Prof. J. W. LANGLEY, of the University of Michigan, Ann Arbor, Mich., vice-president of the section.

ors showed that affinity is definite in action and amount: it has limits, or proceeds *per saltum*. Berthollet contended that affinity is not definite: he proves that it is often controlled by the nature and the masses of the reacting bodies. Dalton, Berzelius, Wollaston, and others held, on the contrary, this force to be definite, and to act *per saltum*: it is a power which emanates from the atom. Davy, Ampère, and Berzelius believed affinity to be a consequence of electrical action. Avogadro in one way, and Brodie in another, show us affinity exerted by molecules as well as atoms. It is a force which binds together, not only particles of the same substance, but also of heterogeneous substances. From the fact of the actual existence of radicles, and from the phenomena of substitution, was developed the notion of position, and that, therefore, affinity varied with the structure of the body as well as with its composition. The differences between the number of atoms which are equal to hydrogen in replacing power have led to the doctrine of valence, which, if it has any influence on theories of affinity, shows that this property of matter has two distinct concepts, — one, its power of attracting a number of atoms; the other, its power of doing work or evolving energy. These two attributes seem to be in no way related to each other. Mendelejeff and Lothan Meyer have shown, by the facts which are grouped under the title 'periodic law,' that the properties of elements seem to be repeating functions of the atomic weight. Hence affinity is connected in some way with that same property, which is also shown by the differential action of gravitation on the absolute chemical unit of matter. Finally, Williamson, Kekulé, and Michaelis have suggested that combination is brought about and maintained by incessant atomic interchange; hence, that affinity is fundamentally due to some form of vibration.

The idea which seemed so simple and natural a one to Hippocrates has grown successively more complex and less sharply defined; and we are compelled to admit that the years have not brought the theory of affinity to a state of active growth. Chemists have more and more turned their attention to details, to accumulating methods of analysis and synthesis, to questions of the constitution of salts, to discussions about graphic and structural formulae, and to hypotheses about the number and arrangement of atoms in a molecule; but they have not, until quite recently, made systematic attempts to measure the energies involved in reactions. Why? The answer can be found mainly in two reasons. First, the word 'affinity' is in bad odor. We see how enormously complicated the phenomena of chemical action have become, and we have lost all faith in hypotheses which can be evolved by the mere force of metaphysical introspection. Second, there is a more important reason, arising from what has hitherto been the traditional scope of our science. Chemistry alone of the physical sciences has offered no foothold to mathematics; and yet all her transformations are governed by the numbers which we call 'atomic weights.' What is it which causes chemistry, so preeminently the analytic science of material things, to be the only one which does not invite the aid of mathematics? It is because three fundamental conceptions underlie physics, while only two serve the needs of the chemist. If a term so much used just now by transcendental geometers may be borrowed, one would say that physics is a science of three dimensions, while chemistry is a science of two dimensions. In the first, nearly every transformation is followed by its equation of energy; and this involves the concepts space, mass, time: while, in the second, an ordinary chemical equation gives us the changes of matter in terms of space and mass only; that is to say, in units of atomic weight and atomic volume.

Think for a moment what physics would be to-day without those grand generalizations, Newton's theory of gravitation, Young's undulatory theory of light, the dynamic theory of heat, the kinetic theory of gases, the conservation of energy, and Ohm's law in electricity. Every one of these, except the last, is a dynamic hypothesis, and involves velocity — that is, time — as one of its essential parts. In comparison with the above, all ordinary chemical work may be termed the registration of successive static states of matter. The analyst pulls to pieces, the synthetic chemist builds up; each records his work as so many atoms transferred from one condition to another, and he is satisfied to exhibit the body produced quietly resting in the bottom of a beaker, motionless, static. The electrolytic cell tells us the stress of chemism for specified conditions as electromotive force; the splendid work done in thermo-chemistry enables us to know the whole energy involved when A unites with B, or when A B goes through any transformation however intricate, but it does not inform us of the dynamic equation which accompanies them, and which should account for the interval between the static states.

Whenever we look outside of chemistry, we find that the lines of the great theories along which progress is making are those of dynamic hypotheses. If we go to our biological brethren, we see them too moving with the current; the geologist studies upheavals, denudation, rate of subsidence, glacial action, and all kinds of changes, in reference to their velocity; the physiologist is actively registering the time element in vital phenomena, through the rate of nervous transmission, the rate of muscular contraction, the duration of optical and auditory impressions, etc.; even the sociologist is beginning to hint at velocities, as, indeed, we should expect in a student of revolutions; and we cannot ignore the fact that all the great living theories of the present contain the time element as an essential part. The speaker could but think the reason that chemistry has evolved no great dynamical theory, that the word 'affinity' has disappeared from our books, and that we go on accumulating facts in all directions but one, and fail to draw any large generalization which shall include them all, is just because we have made so little use of the fundamental concept, time. To expect to draw a theory of chemical phenomena from the study of electrical decompositions and of thermo-chemical data, or from even millions of the customary static chemical equations, would be like hoping to learn the nature of gravitation by laboriously weighing every moving object on the earth's surface, and recording the foot-pounds of energy given out when it fell. The simplest quantitative measure of gravity is, as every one knows, to determine it as the acceleration of a velocity: when we know the value of g, we are forever relieved, in the problem of falling bodies, from the necessity of weighing heterogeneous objects at the earth's surface, for they will all experience the same acceleration. May there not be something like this grand simplification to be discovered for chemical changes also?

The study of the speed of reaction has but just begun. It is a line of work surrounded with unusual difficulties, but it contains a rich store of promise. All other means for measuring the energies of chemism seem to have been tried except this: is it not, therefore, an encouraging fact, that to the chemists of the nineteenth century is left for exploration the great fruitful field of the true dynamics of the atom, the discovery of a time rate for the attractions due to affinity?

THE MISSION OF SCIENCE.[1]

AFTER thanking the section for the honor conferred upon him by electing him their chairman, and referring to the success of the meeting of the British association at Montreal, Professor Thurston announced as the subject of his address, 'The mission of science.' He spoke of his address, as vice-president at St. Louis in 1878, on the philosophic method of the advancement of science, in which he had called attention to the need of specialists, amply supplied with the proper means, to do the work of observing, collecting, and co-ordinating the results of observation. As an all-important factor in this the modern system of scientific investigation, he had spoken of the men who have given, and who are still generously and liberally giving, material assistance by their splendid contributions to the scientific departments of our colleges and of our technical schools.

It may well be asked, What is the use, and what is the object, of systematically gathering knowledge, and of constructing a great, an elaborate system, having the promotion of science as its sole end and aim? What is THE MISSION OF SCIENCE? The great fact that material prosperity is the fruit of science, and that other great truth, that, as mankind is given opportunity for meditation and for culture, the higher attributes of human character are given development, are the best indications of the nature of the real mission of science, and of the correctness of the conclusion that the use and the aim of scientific inquiry are to be sought in the region beyond and above the material world to which those studies are confined.

It being granted that the mission of science is the amelioration of man's condition, it becomes of importance to consider the way in which our knowledge is increased. While the scientific method of advancement of science is evidently that which will yield the greatest returns, it is not the fact that we are indebted to such philosophic methods for the production of the modern sciences. The inventor of gunpowder lived before Lavoisier; the mariner's compass pointed the seaman to the pole before magnetism took form as a science; the steam-engine was invented and set at work, substantially in all essential details as we know it to-day, before a science of thermo-dynamics was dreamed of.

But all this is of the past. Science has attained a development, a stature, and a power, that give her the ability to assume her place in the great scheme of civilization. Hereafter she will direct and will lead. The blind, scheming ways of the older inventor will give place to the exact determination, by scientific methods, of the most direct and most efficient way of reaching a defined end, — methods now daily practised by the engineer in designing his machinery.

It is only in modern times, and since the old spirit of contempt for art, and of reverence for the non-utilitarian element in science, has become nearly extinguished, and since our systems of education have begun to include the study of physical science, that we have had what is properly called a division of 'applied science.' In the days of classical learning, science was only valued as it developed a system of purely intellectual gymnastics. Archimedes was the most perfect prototype, in those days, of the modern physicist and mechanician, of the scientific man and engineer; yet he, and all his contemporaries, esteemed his discovery of the relation between the volumes of the cylinder and the sphere more highly than that of the method of determining the specific gravity of a solid, or the composition of an alloy, and deemed the quadrature of the parabola a greater achievement than the theory of the lever which might 'move the world.' His enumeration of the sands of the seashore was looked upon as a nobler accomplishment than the invention of the catapult, or of the pump, which, twenty-one centuries after his death, still bears his name.

No system of applied science could exist among people who had no conception of the true mission of science; and it was not until many centuries had passed, that mankind reached such a position, in their slow progress toward a real civilization, that it became possible to effect that union of science and the arts which is the distinguishing characteristic of the age in which we live.

In illustration of the gradual evolution and growth of correct theory, and of this slow development of rational views, of the methods of scientific deduction, and of the invariably tardy progress from a beginning distinguished by defective knowledge and inaccurate logic, in the presence of what are later seen to be

[1] Abstract of an address to the section of mechanical science of the American association for the advancement of science at Philadelphia, Sept. 4, by Prof. R. H. THURSTON of Stevens institute, Hoboken, N.J., vice-president of the section.