the most fundamental attribute of matter is motion, that a mass of matter is a mass of motion, that each substance consists essentially of a collection of molecular motions, and that the chief properties of bodies are consequences of such motions. Changes of volta-electromotive force are now generally recognized as being due to these motions, and as being disturbances of the universal ether which pervades all bodies and all space. Each degree of such force may also be regarded as a concrete result of an extensive series of molecular vibrations of extremely varied degrees of amplitude; this series being characteristic of the particular material combination producing it, analogous to the collection of vibrations producing a beam of light of a particular burning substance. The curves represent in addition the changes in amount of these motions; and by observing these changes in a single substance under a sufficient variety of conditions, a more or less complete graphic delineation of them as representing that particular substance might be obtained. When we are able to fully interpret the language or meaning of these curves, we shall learn a very great deal respecting the internal motions and changes of substances, and the conditions of conversion of potential into kinetic energy.

As each curve is a geometrical and quantitative representation of a series of such changes, a complete collection of such curves, yielded by all kinds of aqueous solutions, would constitute an extensive system of representations of the molecular motions of substances somewhat like that of the luminous spectra of bodies; and the magnitudes and harmonic relations of the degrees of electromotive force represented by the curves will form a very large basis of study for mathematicians, such as the spectra of bodies now afford. The entire subject appears to be nearly as large as that of spectrum analysis, and is not altogether unlike it.

The whole system of curves may be viewed as being in some respects analogous to the absorption spectra of liquids, and in a less degree to the spectra of gases. The relations between the different curves are probably more complex than those between the spectra of liquids, because the electrodes take part in the action; and still more complex than those between the spectra of gases, because of the influences of the solvent and of the electrodes, and because each dissolved substance is in the liquid state and under the influence of cohesion.

As the magnitudes and forms of the curves are manifestly related to the atomic and molecular weights of the dissolved substances, they are doubtless also related to the periodic series, and in this direction a study of them by mathematicians will lead to the acquisition of new knowledge. And as they reveal the kinetic changes which isomeric and other substances undergo when they pass from one state of chemical equilibrium to another in cases of chemical union, substitution, and decomposition, etc., they are evidently related very intimately to Newton's third law of motion.

With regard to the latter suggestion, in several researches (see "Relative Amounts of Voltaic Energy of Electrolytes," Roy. Soc. Proc., November, 1888, xlv., p. 266; "On Loss of Voltaic Energy of Electrolytes by Chemical Union," Proc. Birn. Philos. Soc., December 6, 1888, vi., p. 225; "Relative Amounts of Available Voltaic Energy of Aqueous Solutions," *ibid.*, vii., part 1; "Examples of Solution Compounds," *ibid.* and *Chemical News*, April, 1890), I have largely shown, by means of the "voltaic balance" method, that chemical union in definite proportions by weight of substances while in aqueous solution together is apparently universal; that elements unite with elements, with all kinds of acids, and with all classes of acid, neutral, and basic salts; that acids unite with acids, each with every other one, and each acid with every salt; and salts with each other in almost endless variety; and apparently that all kinds of dissolved chemical compounds, with but few if any exceptions, unite together more or less distinctly, in those definite proportions indiscriminately and without limit of kind, provided no separation of substance by precipitation or otherwise occurs. Also, by repeatedly doubling the molecular weight of a "solution compound" by successive additions to it of other dissolved substances of equal chemical value, each addition producing a new state of chemical equilibrium, in which chemical action and reaction are equal, I have by the same method shown that chemical union of substances while in aqueous solution together extends to large aggregates of molecules of the most varied kind and of considerable degrees of complexity (Proc. Birn. Phil. Soc., vi., p. 225). This universality of chemical union of substances while in solution together indicates the existence of an equally general cause of such union, and that cause must be a molecular one.

"The theory most consistent with these facts is a kinetic one, viz., that metals and electrolytes are throughout their masses in a state of molecular movement. That the molecules of these substances, being frictionless bodies in a frictionless medium, and their motion not being dissipated by conduction or otherwise, continue in motion until some cause arises to prevent them. That every different metal and electrolyte has a different class of motions, and that the molecular motion of each substance varies at a different rate by rise of temperature." This theory has been employed by me to explain certain thermo-electric phenomena in electrolytes (see Roy. Soc. Proc., 1888, xxvi., pp. 54-55). "In accordance with this theory chemical action is an effect of molecular motion, and is one of the modes by which that motion is converted into electric current." "These statements are also consistent with the view that the elementary substances lose a portion of their molecular activity when they unite to form acids or salts, and that electrolytes have usually a less degree of molecular motion than the elements of which they are composed" (*ibid.*)

A kinetic theory must agree with mechanical laws; we cannot create motion or energy, all motion arises from pre-existing motion, every efficient cause of material change is a kinetic one; the immediate source of all chemical change is the latent molecular motion of the combining or mutually acting substances. As neither were difference of substance nor union in definite proportions by weight is in itself an active influence, neither can it be the immediate kinetic cause of chemical change; but as both these circumstances invariably attend chemical union, and no such union occurs without them, we may conclude that they are necessary conditions of the union.

By adopting the above theory, "that electrolytes are

throughout their masses in a state of molecular movement; that the molecules of these substances, being frictionless bodies in a frictionless medium, and their motion not being dissipated by conduction or otherwise, they continue incessantly in movement until some cause arises to prevent them," and associating it with Newton's third law of motion, viz., that "the actions of bodies upon one another are always equal and in opposite directions," we are driven to the inference that what we term "chemical affinity," or the immediate active cause of chemical union, is latent or potential molecular motion and the mutual impact and momentum of the molecules of the uniting substances. When two dissolved substances are brought by admixture of their solutions into mutual contact, a portion of the molecular motion of the one substance is neutralized by an equal amount of opposite motion of the other, and the two portions are converted into free heat, electric current, or other form of energy, and the molecules thus brought into nearer proximity retain their new positions and distances. This agrees with the usual evolution of heat, loss of voltaic energy, depression of electromotive force, and frequent increase of density, which occur during chemical union. According to this view, every dissolved chemical compound is an instance of balanced molecular motion, and it is the neutralized portions of motion which escape as heat and electric current. How far there is any originality in these ideas I leave to other persons to decide.

Many of the facts evolved by the several researches I have referred to point toward the conclusion that measurements of volta-electromotive force and voltaic energy are essentially measurements of "chemical affinity" between the dissolved substance and the positive metal. An analogous idea has already been suggested by other investigators. E. F. Herroun, adopting a view of Helmholtz's, has inferred that "the electromotive force of a voltaic cell is a measure of the actual transformation of free energy," and concluded that it "furnishes a more accurate measurement of the free energy, and therefore of true chemical affinity, than data derived from calorimetric observations" (Phil. Mag., 1888, xxvii., pp. 230, 233). The amounts of voltaic energy lost by two substances during their act of chemical union clearly indicate to a large extent the quantities of opposite molecular motion neutralized by their union. For instance, a much larger amount of such motion is neutralized by the union of sodium with chlorine to form sodic chloride than by that of hydrogen with chlorine to form hydrochloric acid; and no doubt, by investigating the losses of electromotive force and voltaic energy attending the chemical union of substances in aqueous solution, we may learn a very great deal respecting the quantitative relations of "chemical affinity" between metals and electrolytes; but a great obstacle to making accurate measurements of such "affinity" by this method is the unmeasured portion of energy lost by "local action." It may be further remarked that, disregarding "local action," the chemical union and neutralization of opposite molecular motions only occurs while the circuit is closed; and that at the instant of closing the circuit, potential energy is converted into kinetic energy, and a multitude of electro-magnetic waves of very varied lengths are generated and radiated into space; the conversion of energy, therefore, in this kind of case depends upon closing of the circuit.

The results obtained by varying the strength or the temperature of the liquid at each metal separately support the conclusion that, in an ordinary voltaic cell, nearly the whole of the energy is due to action at the zinc, and but little to that at the platinum, and that the latter acts nearly wholly by obviating the greater counter electromotive force which would occur by using a more corrodible metal, and by diminishing the resistance which a less conducting substance would offer. The mere absence of an obstacle to a change cannot be an active cause of that change; and any substance which takes an essential part in any physical or chemical action, and (like the platinum plate) remains exactly the same in every respect after the action as it was immediately previous to it, cannot have been a real cause of that action, or of any loss or gain of energy attending it. The presence of the negative metal is only a static permitting condition. It enables, without any expenditure of energy on its own part, the opposite potential molecular motions of the positive metal and the liquid to neutralize each other and to be converted into voltaic current.

The method described in this paper is not merely a technical one of detecting substances, nor is it specially fitted for such a purpose; but it is an extensive new department of chemical and molecular research, and a general system of representation by means of geometrical curves, not only of individual substances, but of some of the fundamental changes of the molecular motion of substances which are inseparably related to their chief chemical properties; and it will in this way supply mathematicians with a new and extensive series of facts, representing, in terms of electromotive force, the degrees of volta-chemical action of metals and electrolytes upon each other. One of the chief uses of it as a method of research will be to examine the molecular structure and chemical composition of dissolved substances, to detect differences and changes in them caused by heat, light, chemical union, substitution, or decomposition, etc.; and to detect and measure molecular and chemical differences in isomeric liquids. It may be used to detect and measure the changes gradually produced by light and heat in chlorine water and bromine water, the influence of light upon nitric acid, the degrees of retarding effect of colored glass screens, etc., upon various chemical changes caused by light, the gradual oxidation of a solution of sulphurous anhydride by exposure to air, the spontaneous decomposition of aqua regia, the rate of decomposition of a solution of potassium iodide by chlorine water, the speed of displacement of one acid by another, etc., etc. The examples given and researches suggested are sufficient to indicate the very great extent of the subject.

A MERCURY STILL FOR THE RAPID DISTILLATION OF MERCURY IN A VACUUM.

By FREDERICK J. SMITH, M.A., Millard Lecturer in Mechanics and Physics, Trinity College, Oxford.

WHEN mercury is distilled in a vacuum, in the usual apparatus, a large portion of it when vaporized, on reaching the internal domed surface of the bulb in

which the operation is conducted, forms itself into minute spheres, which grow heavy and run down the inside of the bulb; and only a small quantity of the metal finds its way into the central tube, from which it is caught for use.

The advantage of the new form of vacuum mercury still, of which I venture to give an account, is that all the mercury which condenses in the head of the bulb is prevented by its shape from returning to the mercury from which it has been separated by heat. This is not the case in the mercury still of Weinhold, or Clark, or in those stills in which only the mercury which collects in the eduction tube is caught, as in the beautiful new form of apparatus devised by Messrs. Dunstan & Dymond, for the purification of small quantities of mercury (*supra*, p. 367). In the former of these instruments, some portion of the mercury vapor condenses on the surface of the bulb and then falls back to the mass of mercury from which it has just been separated. The mercury still which is described in the following lines has been constructed with a view to obtain a more rapid yield of pure mercury than stills of this class have hitherto been capable of producing. The yield of mercury from the new form of still is about four times as great as that from one of the old pattern, the consumption of gas in each case being the same. The construction and method of using the still are as follows: BK is a bulb and tube about 34 inches long, supported on a stand not shown; the bulb has a ring-shaped channel, CC, round its upper end; into this channel a piece of "Sprenzel" tube, D, is fused. This is furnished with two taps of glass, E and F; E is in connection with a water jet pump, F is terminated with a piece of bent tube. A is a cistern for holding the mercury which is to be distilled. H is a ring of gas jets.

The method of using the still is as follows: The tap, E, is opened, F is closed; a water pump then exhausts the whole system, and the mercury to be acted on rises from the cistern, A. The cistern being large and shallow, only a slight change takes place in the height of

the mercury in the bulb, when the level of the mercury in the cistern changes. While the pump is exhausting, the ring of gas jets is lit, and in about ten minutes, in the case of the still in our laboratory, the mercury fills the tube, D, any metal which comes over being caught in the bulb, G. The tap, E, is then closed and F opened; the still then continues to work by virtue of the vacuum formed by its own mercury. It has been found necessary to place a gas regulator on the pipe which supplies the jets, as the change of pressure in the gas mains is considerable. An automatic arrangement, depending for its action upon the height of the mercury in the cistern, shuts off the gas when the surface of the mercury falls below a certain point. In using stills of this class the mercury before distillation should be carefully freed from moisture, as a minute quantity of water will often cause a fracture in the heated tube or bulb.—*Philosophical Magazine*.

THE PHOSPHORESCENCE PRODUCED UPON THE FIRST CONTACT OF OZONE WITH CERTAIN FLUIDS.

By ERNST FAHRIG.

SOME years since, in experimenting with some new liquid preparations of ozone, I accidentally observed a phenomenon which immediately attracted my attention, and led me to make many more experiments upon the subject. But these further tests, instead of clearing up the matter by affording a definite explanation of the peculiar action produced, only mystified me the more; for they merely served to upset the various theories and explanations which have from time to time suggested themselves, not only to me, but to scientific friends to whom I have mentioned the matter; and in my own view, they render no less untenable a theory which has been publicly advanced by some others who have independently discovered and worked in the same field, and to which I shall presently refer. Thus perplexed, I have resolved, with the editor's kind permission, to publish an account of these experiments in this journal, in the hope that some among its wide circle of readers may be able to throw some fresh light upon the question.

My first observation of the phenomena was in the following manner: I was in a dark room, and having in my hand a sealed bottle about three-quarters full of a preparation of ozone (in this instance a solution of ozone in water containing a small percentage of other substances, which I have found in the course of my experience are necessary to retain the ozone in solution), I with no particular purpose in view gave the bottle a vigorous shaking up; instantly I