

Mr. Rider Haggard's splendid race are probably only the Ba-hima originally discovered by Speke in southwestern Uganda. At least, Sir Harry Johnston claims to have discovered in them the clue to many of the mysterious white race legends found in the Dark Continent. He was engaged in nothing more thrilling than a tour of inspection to Ankole when he came across them. They are of a very light complexion, and are the "aristocrats" of this region. Sir Harry Johnston says they are "obviously descended from a Gala, Somali, or other Hamitic stock," and adds that some of them are more like Egyptians than is the case with Galas and Somalis. Romance disappears before the tread of the explorer. The Dark Continent is dark no more.—Chambers's Journal.

#### THE DEVELOPMENT OF THE THEORY OF ELECTROLYTIC DISSOCIATION.\*

By PROF. SVANTE ARRHENIUS, Stockholm, Sweden.

At first sight nothing seems to be more evident than that everything has a beginning and an end, and that it is possible to divide everything. Nevertheless, the philosophers of antiquity, especially the Stoicist, concluded, on purely speculative grounds, that these opinions are not at all necessary. The wonderful development of science has reached the same conclusion as these philosophers, especially Empedocles and Democritus, who lived about 500 years B. C., and for whom the ancients had already a vivid admiration.

Empedocles professed that nothing is made of nothing, and that it is impossible to annihilate anything. All that happens in the world depends upon a change of form and upon the mixture or the separation of bodies. Fire, air, water, and earth are the four elements of which everything is composed. An everlasting circulation is characteristic of nature.

The doctrine of Democritus still more nearly coin-

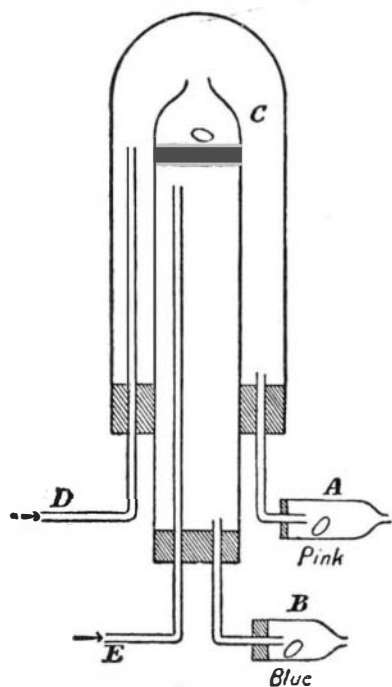


FIG. 1.

cided with our modern views. In his opinion bodies are built up of indefinitely small indivisible particles, which he called atoms. These are distinguished by their form and magnitude, and also give different products by their different modes of aggregation.

This atomic theory was revived by Gassendi about 1650, and then accepted by Boyle and Newton. The theory received a greatly increased importance by the discovery by Dalton of the law of multiple proportions. For instance, the different combinations of nitrogen with oxygen contain, for each unit weight of nitrogen, 0.57, 1.14, 1.72, 2.29 or 2.86 unit weights of oxygen.† Between these combinations there is no intermediate proportion. This peculiarity is characteristic of chemistry in contradistinction to physics, where the more simple continuous and gradual transition from one state to another prevails. This difference between the two sister sciences has often caused controversies in the domain of physical chemistry. The occurrence of discontinuous changes and of multiple proportions has frequently been assumed, when a closer investigation has found nothing of the sort.

The law of multiple proportions is the one fundamental conception upon which modern chemistry is built up. Another is the law of Avogadro, which asserts that equal volumes of different gases under like conditions of temperature and pressure contain the same number of molecules. This conception, dating from the beginning of the nineteenth century, was at first strongly combated, and it was its great value in explaining the new discoveries in the rapidly growing domain of organic chemistry which led to its general acceptance in the middle of the past century, after Cannizzaro had argued strongly in its favor.

There were, however, some difficulties to be removed before Avogadro's law could be accepted. For instance, it was found that the molecular volume of sal-ammoniac,  $\text{NH}_4\text{Cl}$ , in the gaseous state was greater than might be expected from its chemical composition. This led to the supposition that the molecules of sal-am-

moniac when in the gaseous state are partially decomposed into ammonia,  $\text{NH}_3$ , and hydrochloric acid,  $\text{HCl}$ . Indeed Von Pebal and Von Than succeeded in showing that this really happens. They used an apparatus that is shown in the annexed figure (Fig. 1). Two coaxial tubes are placed the one inside the other by means of a cork. The outer tube was closed at its upper end; the inner one was open and contained at *C* a diaphragm of asbestos and above that a piece of sal-ammoniac. The upper end was heated by an air-bath, so that the piece of sal-ammoniac was volatilized. After this a current

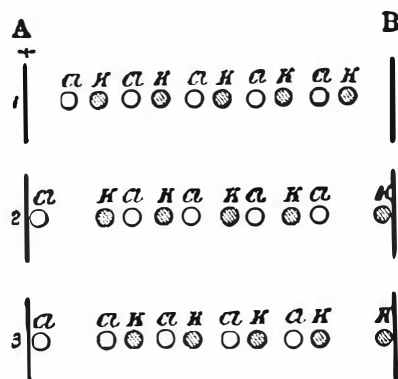


FIG. 2.

of hydrogen was led through both glass tubes *D* and *E*. Now ammonia diffuses more rapidly than hydrochloric acid; if, therefore, the vapor of sal-ammoniac is partially decomposed into ammonia and hydrochloric acid, we should expect that above the asbestos diaphragm there would be an excess of hydrochloric acid and beneath it an excess of ammonia. This Von Pebal showed to be the case. The hydrogen-current from *D* showed an acid reaction on a piece of litmus-paper in *A*, and that from *E* showed an alkaline reaction on a similar piece of litmus-paper placed in *B*. It was objected that the decomposition might possibly be caused by the asbestos of the diaphragm, or by the hydrogen. Von Than, therefore, made a diaphragm of sal-ammoniac, and substituted nitrogen for hydrogen, but the effect was the same.

These experiments were performed in the years 1862 and 1864. They were based on the doctrine of dissociation, which was at that time (1857) worked out by Ste. Claire-Deville, and developed by his pupils. From the most ancient times use was made of the fact that limestone at high temperatures gives off carbonic acid, and that quicklime remains. This and similar processes were studied by Ste. Claire-Deville. He found that the same law is valid for the pressure of carbonic acid over limestone and for the pressure of water vapor over liquid water at different temperatures. On these fundamental researches the theory of dissociation was based, a theory which has subsequently played an ever-increasing rôle in chemistry, and whereby a broad bridge was laid between physical and chemical doctrines.

At almost exactly the same time we find in the writings of Clausius on the conductivity of salt solutions the first traces of an idea that salts or other electrolytes may be partially dissociated in aqueous solutions. Buff had found that even the most minute electric force is sufficient to drive a current through a solution of a salt. Now after the scheme of Grotthuss, at that time generally accepted, the passage of the electric current through a solution is brought about in such manner that the conducting molecules, e. g., of potassium chloride ( $\text{KCl}$ ), are divided into their ions, which combine again with one another in the following manner: At first, as the current is closed, the electrode *A* becomes positive and the electrode *B* negative. All the conducting molecules  $\text{KCl}$  arrange themselves so that they

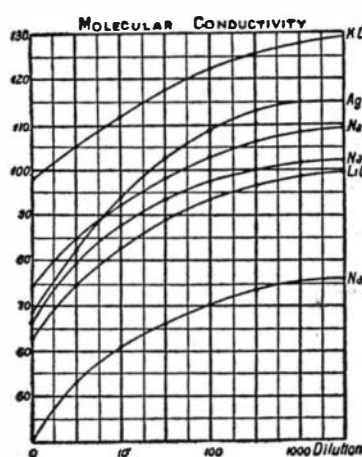


FIG. 4.

turn their positive ions (*K*) to the negative electrode *B*, and their negative ions (*Cl*) to the positive electrode *A*. After this, one chlorine ion is given up at *A* and one potassium ion at *B*, and the other ions recombine, so that the *K* of the first molecule takes the *Cl* of the second molecule, and so on (Fig. 2). Then the molecules turn round under the influence of the electric force, so that we get the scheme 3 and a new decomposition can take place. This represents the Grotthuss scheme, that supposes continuous decompositions and recombinations of the salt molecules.

As such exchanges of ions between the molecules take place even under the influence of the weakest electro-

motive forces, Clausius concluded that they must also take place if there is no electric force, i. e., no current at all. In favor of his hypothesis he pointed to the fact that Williamson, as far back as 1852, in his epoch-making theory of the formation of ethers, assumed an analogous exchange of the constituents of the molecules. At this exchange of ions it might sometimes, though extremely rarely, happen that an ion becomes free in the solution for a short time; at least such a conception would be in good agreement with the me-

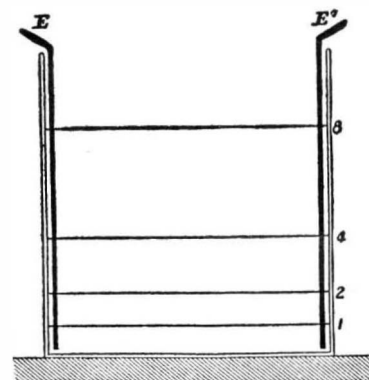


FIG. 3.

chanical theory of heat, as it was developed by Krönig, Maxwell, Clausius and others at that time.

In the meantime, Bouty, and particularly Kohlrausch, worked out the methods of determining the electric conductivity of salt solutions. In 1884 I published a memoir on this subject. I had found that if one dilutes a solution—e. g., of zinc sulphate—its conductivity per molecule, or what is called its molecular conductivity, increases not infinitely, but only to a certain limit. We may figure to ourselves an experiment performed in the following manner (Fig. 3): In a trough with parallel walls there are placed close to two opposite sides two plates of amalgamated zinc, *E* and *E'*. On the horizontal bottom of the vessel there is placed a layer of solution of zinc-sulphate that reaches the level 1. The conductivity may be  $k_1$ . After this has been measured we pour in so much water, that after stirring the solution the level reaches 2, which lies as much above 1 as this lies above the bottom. The conductivity is then found to be increased, and to have the value  $k_2$ . Increasing in the same manner the volume by addition of pure water until it is doubled, the level 4 is reached and the conductivity is found to be greater than in the previous case—say  $k_4$ . So we may proceed further and further; the conductivity increases, but at the end more slowly than at the beginning. We approach a final value  $k_\infty$ . This is best seen in the next diagrams, which represent the newer determinations of Kohlrausch (Figs. 4, 5).

I explained this experiment in the following manner: The conductivity depends upon the velocity with which the ions (*Zn* and  $\text{SO}_4$ ) of the molecules ( $\text{ZnSO}_4$ ) are carried through the liquid by the electric force, i. e., the potential difference between *E* and *E'*. If this potential difference remains constant, the velocity depends only on the friction that the ions in their passage through the liquid exert on the surrounding molecules. As these, at higher dilutions, are only water molecules, it might be expected that the conductivity would remain constant and independent of the dilution if it be supposed that all molecules,  $\text{ZnSO}_4$ , take part in the electric transport. As experiment now teaches us that the molecular conductivity increases with the dilution, even if this is very high (1,000 or more molecules of water to one molecule of  $\text{ZnSO}_4$ ), we are led to the hypothesis that not all, but only a part of, the  $\text{ZnSO}_4$  molecules take part in the transport of electricity.

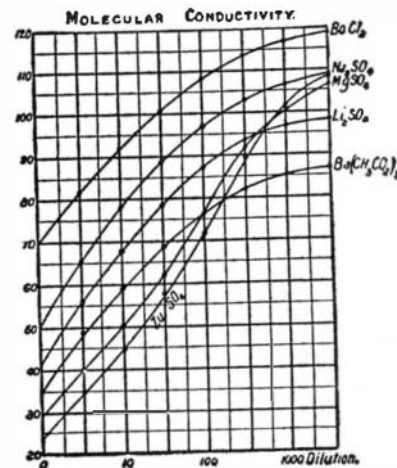


FIG. 5.

ty. This part increases with the dilution in the same proportion as the molecular conductivity  $k$ . The limiting value  $k_\infty$  is approached at infinite dilution, and corresponds to the limit that all molecules conduct electricity. The conducting part of the molecules I called the active part. It may evidently be calculated as the quotient  $k : k_\infty$ .

If now this new conception were only applicable to the explanation of the phenomena of electric conductivity, its value had not been so very great. But an inspection of the numbers of Kohlrausch and others for the conductivity of the acids and bases, compared with the measurements of Berthelot and Thomsen on their

\* Address before the Royal Institution of Great Britain, June 3, 1904.

† To explain this we suppose, in accordance with Dalton, that the molecules of the different combinations of nitrogen with oxygen contain two atoms of nitrogen and one, two, three, four or five atoms of oxygen.

relative strength with regard to their chemical effect, showed me that the best conducting acids and bases are also the strongest. I was thereby led to suppose that the electrically active molecules are also chemically active. On the other hand, the electrically inactive molecules are also chemically inactive. In this connection I would mention the remarkable experiments of Gore, which were easily explained by the new point of view. Concentrated hydrochloric acid, free from water, has no action on oxides or carbonates. Now this hydrochloric acid is almost incapable of conducting the electric current, whereas its aqueous solu-

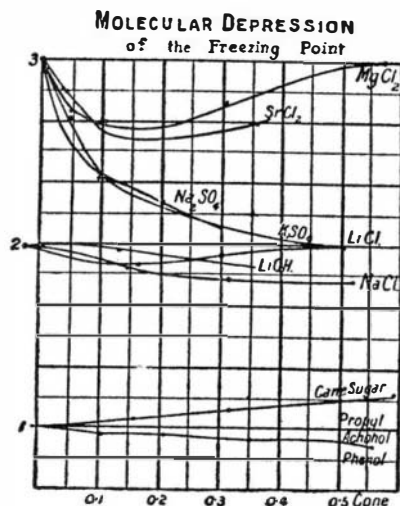


FIG. 6.

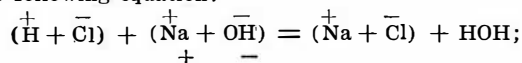
tions conduct very well. The pure hydrochloric acid contains, therefore, no (or extremely few) active molecules, and this agrees very well with the experiments of Gore. In the same way we explain the fact that concentrated sulphuric acid may be preserved in vessels of iron plates without destroying them, whereas this is impossible with the diluted acid.

An unexpected conclusion may be deduced from this idea. As all electrolytes in extreme dilution are completely active, then the weak acids must increase in strength with the dilution, and approach to the strength of the strongest acids. This was soon afterward shown by Ostwald to agree with experiments.

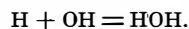
The Norwegian natural philosophers, Guldberg and Waage, had developed a theory according to which the strength of different acids might be measured as well by their power of displacing another acid in solutions as by their faculty to increase the velocity of chemical reactions. Therefore, we may conclude that the velocity of reaction, induced by an acid, would be proportional to the quantity of active molecules in it. I had only a few experiments by Berthelot to demonstrate this proposition, but in 1884 Ostwald published a great number of observations that showed this conclusion to be true.

The most far-reaching conclusion of the conception of active molecules was the explanation of the heat of neutralization. As this is much more easily understood by means of the theory of electrolytic dissociation, I anticipate this for a moment. According to this theory strong acids and bases, as well as salts, are at great dilution (nearly) completely dissociated in their

ions, e. g.,  $\text{HCl}$  in  $\text{H}^+ + \text{Cl}^-$ ,  $\text{NaOH}$  in  $\text{Na}^+ + \text{OH}^-$  and  $\text{NaCl}$  in  $\text{Na}^+ + \text{Cl}^-$ . But water is (nearly) not dissociated at all. Therefore the reaction of neutralization at mixing a strong acid, e. g.,  $\text{HCl}$  with a strong base, e. g.,  $\text{NaOH}$ , both in great dilution, may be represented by the following equation:



or,



The whole reaction is equivalent to the formation of water out of both its ions,  $\text{H}^+$  and  $\text{OH}^-$ , and evidently in-

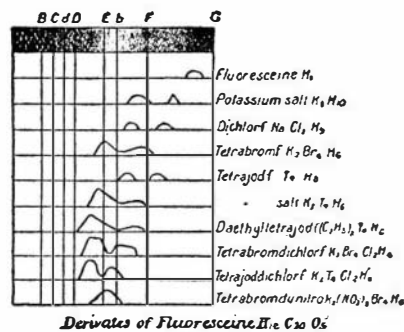


FIG. 7.

dependent of the nature of the strong acid and of the strong base. The heat of any reaction of this kind must, therefore, always be the same for equivalent quantities of any strong acids and bases. In reality it is found to be 13,600 cal. in all cases. This thermal equality was the most prominent feature that thermochemistry had discovered.

It was now asked in what respect the active state of the electrolytes differs from the inactive one. On this question I gave an answer in 1887. At that time Van't Hoff had formulated his wide-reaching law that the molecules in a state of great dilution obey the laws that are valid for the gaseous state, if we only replace

the gas-pressure by the osmotic pressure in liquids. As Van't Hoff showed, the osmotic pressure of a dissolved body could much more easily be determined by help of a measurement of the freezing point of the solution than directly. Now both the direct measurements made by De Vries, as also the freezing points of electrolytic solutions, showed a much higher osmotic pressure than might be expected from the chemical formula. As, for instance, the solution of 1 gramme-molecule of ethylic alcohol— $\text{C}_2\text{H}_5\text{OH}$ —46 grammes—in one liter gives the freezing-point  $-1.85$  deg. C., calculated by Van't Hoff the solution of 1 gramme-molecule of sodium chloride— $\text{NaCl}$ —58.5 grammes—in one liter gives the freezing-point  $-3.26 = -1.75 \times 1.85$  deg. C. This peculiarity may be explained in the same manner as the "abnormal" density of gaseous sal-ammoniac, viz., by assuming a partial dissociation—to 75 per cent—of the molecules of sodium chloride. For then the solution contains 0.25 gramme-molecule of  $\text{NaCl}$ , 0.75 gramme-molecule of  $\text{Cl}$  and 0.75 gramme-molecule of  $\text{Na}$ ; in all, 1.75 gramme-molecules. Now we have seen before how we may calculate the number of active molecules in the same solution of sodium chloride, and we find by Kohlrausch's measurements precisely the number 0.75. From this I was led to suppose that the active molecules of the salts are divided into their ions. These are wholly free and behave just as other molecules in the solutions. In the same manner I calculated the degree of dissociation of all the electrolytes that were determined at that time—they were about eighty—and I found in general a very good agreement between the two methods of calculation. In a few instances the agreement was not so good; I therefore made new determinations for these bodies and some others. The new determinations were all in good conformity with the theoretical prevision.

The next figure (Fig. 6) shows the freezing-points of some solution of salts, and of non-conductors. As abscissa is used the molecular concentration of the bodies, as ordinates the molecular depression of the freezing-point, divided by 1.85, that should be expected if no dissociation took place. As the figure shows, all the curves for the non-conductors—in this case cane-sugar, propyl-alcohol and phenol—converge toward unity with diminishing concentration. At higher concentrations there occur deviations from the simple law.

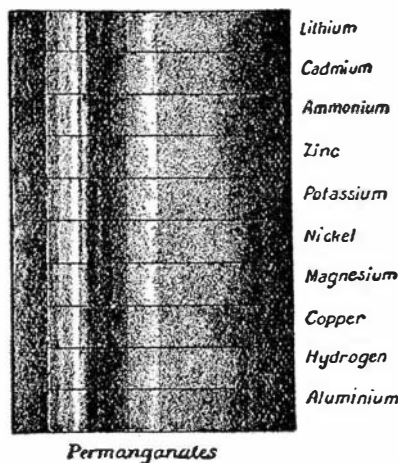


FIG. 8.

As examples of binary electrolytes are chosen  $\text{LiOH}$ ,  $\text{NaCl}$  and  $\text{LiCl}$ —their curves all converge toward the number 2. As ternary electrolytes are chosen  $\text{K}_2\text{SO}_4$ ,  $\text{Na}_2\text{SO}_4$ ,  $\text{MgCl}_2$  and  $\text{SrCl}_2$ , they are decomposed into three ions, and their curves therefore all converge toward the number 3.

As I had taken a step that seemed most adventurous to chemists, there remained to investigate its chemical and physical consequences. The most general and wide-reaching of these is that the properties of a highly attenuated solution of an electrolyte ought to be additive, that is, composed of the properties of the different ions into which the electrolyte is decomposed. This was already known to be the case in many instances, and Valson had to this end tabulated his "modules" by the addition of the one value for the negative to the other for the positive ion, we may calculate the properties of any electrolyte composed of the tabulated ions. In this way we may treat the specific weight (Valson), the molecular friction (law of Kohlrausch), the internal friction (Arrhenius), the capillarity (Valson), the compressibility (Röntgen and Schneider), the refractive index (Gladstone), the natural rotation of polarization (law of Oudemans), the magnetic rotation of polarization (Perkin and Jahn), the magnetization (Wiedemann), and all other properties of the electrolytes hitherto sufficiently studied.

The most important of these additive properties are those of which we make use in chemical analysis. As is well known, it is generally true that chlorides give a white precipitate with silver salts. It was said formerly that silver salts are reagents for chlorine. Now we say that silver ions are reagents for chlorine ions. This expression is better than the old one, for neither all silver salts, e. g., potassium silver cyanide and many other compounds of silver, nor all chlorine compounds, e. g., potassium chlorate and many organic chlorides, give this characteristic reaction. The experiment succeeds only with such silver and chlorine compounds as are in a measurable degree decomposed into silver and chlorine ions. Ostwald has treated this question comprehensively, and in this way he has given a rational exposition of the general phenomena of analytical chemistry. To this fact belong, also, the

poisonous effect of some salts; this effect may be considered as a special physiologically chemical reaction of the chemical compounds. On this point there are many valuable researches by Krönig and Paul, Clarke and others.

A property that is of physical character, but is much used by the analytical chemist, is the color of the solutions. It has been subjected to a rigorous research by Ostwald. At first we will trace how a compound, e. g., fluoresceine,  $\text{H}_{12}\text{C}_{20}\text{O}_5$ , behaves if one replaces its hydrogen atoms by other atoms, e. g., metals, iodine, bromine, or atomic groups ( $\text{NO}_2$ ). The curves in the next figure (Fig. 7) indicate absorption-bands in the spectra of the corresponding compounds. A replacement of  $\text{K}_2$  for  $\text{H}_2$  in the fluoresceine itself alters the absorption-spectrum in a most sensible manner. This depends upon the property that the fluoresceine is dissociated to a slight extent, which is in striking contrast to the permanganic acid which will be discussed immediately. Instead of a single absorption-band in the blue in the first case, we find two absorption-bands in the blue-green and the green part of the spectrum for the second. A similar observation may be made for the tetraiodine-fluoresceine and its potassium salt. In general the figure shows that the spectrum is changed in a very conspicuous manner at the smallest chemical change of the molecule.

It might therefore be expected, after the old manner of view, that the replacement of hydrogen by a metal in permanganic acid, or of one acid rest by another in the salts of para-rosaniline, would wholly change the character of the spectra. This is not the case, as Ostwald has shown. The spectra are wholly unchanged, as Figs. 8 and 9 show. The spectra are all produced by the same substance, viz., the permanganate-ion, in the one, the para-rosaniline-ion, in the other case. Only in the case of the para-rosaniline salts we observe that the absorption is sensibly weaker in some cases than in others. The weakening depends upon the hydrolysis of the salts of the weak acids, e. g., acetic and benzoic acids. This reasearch of Ostwald shows in a most convincing manner the correctness of the views of the theory of electrolytic dissociation.

It has been objected to this theory that, according to it, it might be possible by diffusion to separate both ions, e. g., chlorine and sodium from another in a so-

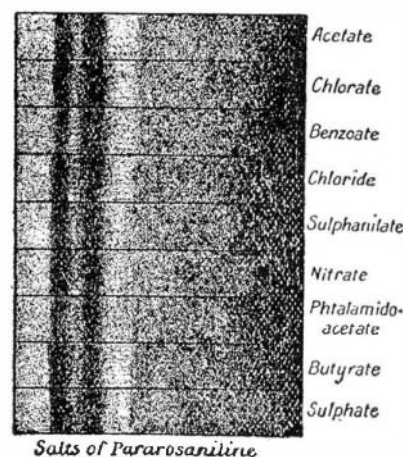


FIG. 9.

lution of sodium chloride. In reality chlorine diffuses about 1.4 times more rapidly than sodium. But the ions carry their electric charges with them. Therefore if we place a solution of sodium chloride in a vessel and pour a layer of pure water over it, it is true that in the first moments a little excess of chlorine enters the water. By this the water is charged negatively, and the solution under it positively, so that the sodium ions are driven out from the solution with a greater force than the chlorine ions. As soon as that force is 1.4 times greater than this, the chlorine ions travel just as slowly as the sodium ions. It is not difficult to calculate that this case happens as soon as the chlorine ion is contained in the water in an excess of about the billionth part of a milligramme over the equivalent quantity of sodium. This extremely minute quantity we should in vain try to detect by chemical means. By electrical means it succeeds pretty well, as Nernst has demonstrated experimentally for his concentration elements. Therefore, the said objection is valid against the hypothesis of a common dissociation of the salts, but not against a dissociation into ions, that are charged with electricity, as Faraday's law demands. Probably this objection has hindered an earlier acceptance of a dissociated state of the electrolytes, to which, for instance, Valson and Bartoli inclined.

The gaseous laws that are valid for dilute solutions have made the calculation of the degree of dissociation possible in a great number of cases. The first application of that nature was made by Ostwald, who showed that the dissociation equilibrium between the ions and the non-dissociated part of a weak acid obeys very nearly the gaseous laws. The same was afterward demonstrated to be true for weak bases by Bredig. The strongly dissociated electrolytes, chiefly salts, exhibit even in dilute solutions (over 0.05 normal) anomalies, that are not yet wholly explained. Prof. Jahn, of Berlin, is at work upon this most interesting question.

The equilibrium between a greater number of electrolytes has been investigated by myself, and found to be in good agreement with the theoretical previsions. This section includes the questions on the weakening of an acid by addition of its salts, and on the so-called



avidity of the different acids, that is, the proportion in which two acids divide a base at partial neutralization. Calculation gives very nearly the numbers observed experimentally by Thomsen and Ostwald. For heterogeneous equilibria between electrolytes the theory is worked out by Van't Hoff and Nernst, who have in this way elucidated the common method to precipitate salts used in analytical chemistry.

By help of the gaseous laws it is also possible to determine the heat evolved at the dissociation of a weak acid or base, and in this way I was able to calculate the heat of neutralization of acids and bases in a general manner. In an analogous way, Fanjung calculated the changes of volume at dissociation of a weak acid or base and at the neutralization of these bodies. All these calculations gave values very nearly agreeing with the observed ones.

An important rôle is played by the water, which may be regarded as a weak acid or base. By its electrolytical dissociation it causes the hydrolysis of salts of weak acids and bases. By observation of the hydrolysis, it was possible to calculate the electrolytic dissociation of water, and this quantity was soon after determined by electrical measurements by Kohlrausch and Heydeweller in perfect agreement with the previous calculations. For physiological chemistry this question is of the greatest importance, as is confirmed by the experimental results of Sjögqvist and others. Also for the explanation of volcanic phenomena, the concurrence between water and silicic acid at different temperatures has found an application.

The catalytic phenomena in which acids and bases are the chief agents have been investigated by many observers, and it has been found that the catalytic action depends on the quantity of free hydrogen or hydroxyl ions that are present in the solution. To this review, that makes no pretension to be complete, may also be added the wide-reaching researches of Van't Hoff, Ostwald, and especially Nernst, on the electromotive forces produced by the ions. By these investigations we have now acquired an explanation of the old problem of the manner in which electromotive forces in hydro-electric combinations are excited.

I have now traced the manner in which the idea of electrolytic dissociation grew out of our old conception of atoms and molecules. Sometimes we hear the objection that this idea may not be true, but only a good working hypothesis. This objection, however, is in reality no objection at all, for we can never be certain that we have found the ultimate truth. The conception of molecules and atoms is sometimes refuted on philosophical grounds, but till he has got a better and more convenient representation of chemical phenomena, the chemist will, no doubt, continue to use the atomic theory without scruple. Exactly the same is the case for the electrolytic dissociation theory.

This theory has shown us that in the chemical world the most important rôle is played by atoms or complexes of atoms, that are charged with electricity. The common tendency of scientific investigation seems to give an even more preponderating position to electricity, the mightiest agent of nature. This development is now proceeding very rapidly. Already we see not only how the theory of electrons of J. J. Thomson, in which matter is reduced to a very insignificant part, is developing, but also how efforts are made with good success to explain matter as only a manifestation of electrodynamic forces (Kaufmann-Abraham).

To these modern developments the work of British men of science has contributed in the most effective manner. The bold previsions of Sir William Crookes seem to be rapidly acquiring a concrete form, to the great benefit of scientific evolution.—Popular Science Monthly.

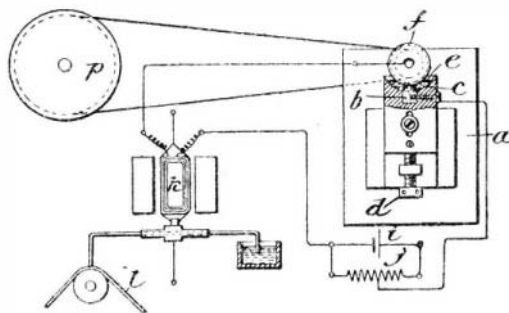
#### OIL-FILM RECEIVER FOR SPACE TELEGRAPHY.

COHERERS for space-telegraph receivers have hitherto depended on the imperfect contact due to the natural film of oxide or other material which exists on most metals and which acts as the intervening layer, preventing full conduction between a pair of metal pieces brought into light contact in some random or unmetrical manner. Sometimes a contact between a spring pressing lightly on a point has been utilized. More usually, however, the accidental light and imperfect contact between the particles of a mass of metal filings has been employed. In each case the electrical disturbance due to the impact of ethereal waves has resulted in "coherence" and increased conductivity in the coherer, and "decoherence" has been occasioned by agitation or tapping. All coherers depending upon imperfect or light contact between bodies are subject to variation of sensitiveness and require frequent adjustment or renewal.

Dr. Oliver J. Lodge, of Birmingham, Alexander Muirhead, of Shortlands, and Edward E. Robinson, of Birmingham, England, in a recent United States patent propose to dispense with the use of imperfect contacts in the construction of detectors or receivers and to use a thin film of some insulating material to separate the conducting masses which compose the detector or receiver and to obtain in a definite manner the light pressure desirable when the maximum sensitiveness is required. To this end they employ as the insulating film a thin layer of paraffin oil or similar insulating substance interposed between two metallic or conducting surfaces and frequently renewed, and for the pressure they depend on the hydrostatic pressure of a column of liquid, preferably employing mercury or other conducting fluid as one of the two conductors, the other one being solid and plunged to a given depth in the mercury.

To apply the film of oil, a layer of oil is placed upon the mercury, so that when the solid metal, preferably in the form of a platinum or iron point or a metallic wheel, is immersed to a small depth into the mercury it carries down with it a superficial film of oil. When the platinum or iron point or wheel is immersed into the mercury the depth of immersion must be slight, so that there may be as little capacity as possible between the two conductors, the insulating film employed acting as a perfect insulator or dielectric between the two. The smaller the capacity of the detector or receiver the more sensitive it will be to the ethereal waves. Although it is feasible to receive signals without actual immersion of the point or wheel into the mercury, yet the insulating film in such instance would necessarily be considerably thicker, requiring more battery power to break it down, which is correspondingly undesirable. For this reason it is preferable to obtain a thinner film by immersion, making use of the hydrostatic pressure of the mercury for that purpose and permitting the use of a much lower voltage.

It has been found that so long as a feeble voltage is applied (say three-tenths of a volt or less) the film is strong enough permanently to resist the passage of a current, but that whenever the electro-motive force rises to, say, one volt or more, as it does at once, for an instant, if a spark has occurred in the neighborhood or if electric waves have been received from a distant station, then the film is broken down, easy conduction is caused, and a signal is recorded. To restore the continuity of the film again, motion is sufficient, and one of the simplest plans is to withdraw the metal point from the mercury into the supernatant layer of oil and immediately plunge it back again into the mercury. This withdrawal and reimmersion is very easily accomplished automatically, either by mechanical or electrical means or by the action of the current which the broken-down film itself transmits or otherwise, the reimmersion of the point following instantly on the cessation of the current by the restoration of the film. Obviously this motion may be effected in any appropriate manner, whether by rotation or translation or vibration. For instance, the immersed conductor might be the rim of a rotating wheel, or it might be supported on a vibrating body, such as the prong of a tuning fork, or it might be simply depressed into the mercury and withdrawn therefrom



OIL-FILM RECEIVER FOR SPACE TELEGRAPHY.

by attachment to the siphon-recorder coil or other moving part affected electromagnetically by the signaling current. The passage of a comparatively strong momentary current across the broken-down film is no detriment, since the film, being liquid, can be completely and certainly renewed. The metal used should be clean, free from any film of its own and not liable to amalgamate with mercury. One of these methods is illustrated herewith, showing the receiver attached to a moving wheel.

The conducting part, *f*, is shown in the form of a disk or wheel slightly immersed in the mercury, *b*. The constant rotation of the wheel, effected by such means as a clockwork train, represented diagrammatically at *p*, brings about the restoration of the continuity of the oil film between the wheel and the mercury after the breaking-down action of ethereal waves received from a distance. The amount of pressure of the mercury upon the disk or wheel is regulated by means of the screw, *d*, fixed beneath the trough, *c*, which contains the mercury, so as to raise or lower it, and so regulate the immersion. The film or layer of paraffine oil acting as an insulator is shown at *e*.—Western Electrician.

#### THE GREATEST ELECTRIC SHOCK ON RECORD.

THIS shock was received, on August 23, 1903, by an Italian named Archimedi Lazzari, from Mantova, Italy. He is a strongly-built man, 36 years of age, and by profession a mechanical blacksmith, in which capacity he worked during the whole of the construction work for the Canadian-American hydraulic plant at Parnahyba, State of Sao Paulo, Brazil.

This company supplies electricity for tramways, light, and power in the city of Sao Paulo, which is 33 kilometers away from the generating station at Parnahyba. The station contains four 1,000-kilowatt, 252-ampere, 2,300-volt, 60-cycle alternators, of the New York General Electric Company's make. The voltage is raised by means of transformers up to 24,000 volts.

A little before the date mentioned, the management decided to change all the iron framework behind the high-tension board to wooden work. It was also found advisable, as additional panels had just been erected, to change over the position of some of the old panels

in order to symmetrize the board, thus permitting the high-tension buses to be divided into halves, by means of switches, to facilitate cleaning.

Everything being in readiness at 12 o'clock midnight, on Sunday, August 23, the work was commenced, this being the hour of lightest load. Archimedi was working in his professional capacity. At about 5:10 A. M., the ironwork had been removed and the wooden framing placed in position. The buses had also been divided into halves preparatory to being connected to their respective switches. There are two separate sets of bus-bars, one above the other, either of which can carry the entire load, so that as the work proceeded the current was changed alternately from one set to the other, thus avoiding the necessity of working on live wires. Every precaution had been taken against accidents, and, in fact, it was over-zeal to be cautious which caused the mishap. The buses being divided, and the work being carried on upon the dead section, one of the operators, Thomas W. Bevan, Jr., son of the powerhouse superintendent, went over to work near the live half. Archimedi, wishing to warn him of his danger, took hold of Bevan junior's wrist, and leaned forward to speak with him; at the same time he had his foot against an anchor bolt of the iron framework which had just been taken down. This bolt was cemented on to the floor of the gallery (the high-tension board being on a gallery), the latter being made of steel rails with brickwork arching between the rails. Archimedi leaned over too far and came too near one of the 24,000-volt bare copper wires, which was one of the secondary leads off the main transformers to the high-tension board. Immediately the current jumped onto his shoulder, passing through his body and out at his feet onto the anchor bolt. Both Archimedi and Bevan, Jr., remained transfixed, while Mr. Bevan, Sr., thinking it was his son who was on the wire, leaped into the air (in order to disconnect himself from the ground) and plunged against his son. The shock pulled both men off the wire, and Archimedi loosened Bevan's wrist, only to fall near the wire again, in almost identically the same position as before, only this time the whole current was passing through his own body, not as before, when a portion must have been shunted through Bevan, Jr. Mr. Bevan, Sr., who was thrown violently on the floor, tried to kick Archimedi's foot from under him, only to find that every time he (Mr. Bevan, Sr.) touched the stricken man's foot, his own legs were shot back with terrific force. Archimedi remained thus until the power was taken off. He must have been fully half a minute under the action of the current. He claims to have been conscious all the time, and says that he felt nothing. In fact, he was able to describe exactly what occurred, and says he felt the power taken off the first time, and then come on again, as he fell the second time near the wire. On the power being taken off he immediately became unconscious, and his mouth had to be opened with the end of a file, and a piece of wood put between his teeth to keep them apart, while his arms and legs were being worked so as to produce artificial respiration. In a little over ten minutes Archimedi was able to walk about on a man's arm. He felt sick and had fearful burns on his shoulder and his foot, but after about six weeks' absence he came back to work and has not missed a day since. Both the Bevan's suffered nothing greater than little burns over the body, wherever the current came in contact.

All the men present are willing to vouch as to the place in which Archimedi suffered the shock, namely, on the high-tension gallery, and there are no wires there except bare copper wires, all under a pressure of 24,000 volts.

The writer, who was present (and who at once rushed to the switchboard under the gallery and pulled out the main exciter switches), observed a heavy arc between Archimedi's foot and the anchor bolt, and Bevan, Jr., saw a similar arc formed between his shoulder and the wire. There was apparently, therefore, no actual contact with the wires, and owing to the high resistance of the arcs, the current was greatly reduced in volume. This probably explains the reason why the men were not killed instantly.—W. de F. B. Davids in London Electrician.

#### A CONTEMPLATED MAGNETIC SURVEY OF THE NORTH PACIFIC OCEAN BY THE CARNEGIE INSTITUTION.

A PROJECT for a magnetic survey of the North Pacific Ocean by the Department of International Research in Terrestrial Magnetism has been favorably acted upon by the executive committee of the Carnegie Institution of Washington, and authorization has been given to begin the work this year. An initial allotment of \$20,000 has been made to cover the expenses for the current year.

As is well known, the state of our knowledge of the distribution of the magnetic forces over the greater portion of the earth—the oceanic areas—owing to the paucity of precise data, is exceedingly unsatisfactory. This fact is especially true for that great body of water, the Pacific Ocean, rapidly developing in great commercial importance.

Capt. Creak, for many years superintendent of the Compass Department of the British Admiralty, now retired, says: "The North Pacific Ocean is, with the exception of the voyage of the 'Challenger,' nearly a blank as regards magnetic observations, and I therefore think the magnetic survey proposed will be of great value."

Hence, except for data from occasional expeditions and such as were acquired in wooden vessels a long time ago, the present magnetic charts used by the nav-