

have recently been discovered between light and electricity which lead us to believe that the latter is most closely connected with the luminiferous ether."

"Clerk-Maxwell showed that the ratio of two electrical constants which are capable of being determined by laboratory experiments, and which are of such a nature that that ratio expresses a velocity, agrees with remarkable accuracy with the known velocity of light. This formed the starting-point of the electro-magnetic theory of light which is so closely associated with the name of Maxwell."

"According to this idea, light may be looked on as the propagation of an electro-magnetic disturbance, whatever the appropriate idea of such a thing may actually be. The theory has quite recently received remarkable confirmation by the investigations of Hertz, who has shown that what are incontestably electro-magnetic disturbances, and are investigated by purely electrical means, exhibit some of the fundamental phenomena of light, such, for example, as interference and polarisation. It appears that these electro-magnetic waves are strictly of a similar nature to the waves of light, though there is an enormous difference in the scale of wave-lengths, which in the case of light range about the $\frac{1}{1000000}$ th part of an inch, while the electro-magnetic waves which have been investigated by purely electrical methods range from a few inches to many yards."

"I have ventured to bring this interesting subject before you in the course of the address which I have just delivered. I have not attempted to lay before you the evidence on which scientific men rely for the truth of the conclusions which I have mentioned as well established. That would have required, not merely an evening address, but a whole course of lectures. Neither have I made any allusion to possible bearings of the scientific conclusions on questions relating to religious beliefs. Anything of that kind I leave to your own minds; my object has been simply to present to you very briefly the conclusions of science in that limited branch which I have selected, distinguishing as impartially as I could what is well established from what is debatable or even merely conjectural."

THE NATURE OF DEPOLARISERS.¹

WHEN an electric current is passed between plates of platinum through a solution of sulphuric acid, the hydrogen and oxygen are partly retained at the surfaces—and apparently also within the plates—and under these conditions are capable of interacting, as in the well-known Grove gas battery: so that in so far as the "gases" thus circumstanced are concerned the change may be expressed by a reversible equation. This reversal constitutes the well-known phenomenon termed polarisation by physicists.

Reversal owing to the retention of hydrogen in circuit is promoted to different extents by different metals—hence apparently the varying electromotive forces of single fluid cells containing different negative plates; and when the pressure is sufficient to retain the whole of the hydrogen at the plate, it becomes total—hence it is, for example, that zinc does not dissolve in sulphuric acid under great pressure.

Various substances known generally as depolarisers are used to prevent the accumulation of products of electrolysis and the consequent reversal of the action—such as copper sulphate in the case of the Daniell cell and "nitric acid" in the case of the Grove and Bunsen cells; but whereas the action of copper sulphate is easy to understand, that of "nitric acid" offers many difficulties. As the heat of dissolution of copper in dilute sulphuric acid is a negative value (about 12,000 units), the displacement of copper by hydrogen—*i.e.* the heat of dissolution of hydrogen in copper sulphate—is a positive value, so that not only does the presence of the copper sulphate prevent the accumulation of hydrogen, but in removing hydrogen it also serves to increase the electromotive force of the cell from about 37/46ths to about 50/46ths of a volt. The principle underlying this is extensible even to cases in which one part of the cumulative effect of the cycle of change is a negative value. Thus, although copper has a negative heat of dissolution, it will readily dissolve in dilute sulphuric acid if it be used in place of zinc in a Grove cell, the negative heat of dissolution of copper being more than compensated for by the positive heat of dissolution of hydrogen in "nitric acid"; and it is well known that copper dissolves in many weak acids in presence of oxygen. It is

easy to understand how oxygen acts in such cases, but the facts show that the effect produced by "nitric acid" is not so readily interpreted, and their consideration raises important questions of general application.

Russell has shown that when "nitric acid" is freed from nitrous compounds it does not dissolve silver, but that action sets in when a trace of nitric oxide is introduced, and continues with increasing rapidity as the quantity of the nitrous compound—a necessary product of the action—increases; Veley's later experiments have shown that the same is true of copper, without, however, affording any further explanation of the phenomena. Although it is not to be expected that such metals would dissolve in nitric acid even when coupled with a relatively electronegative conductor, as they have negative heats of dissolution, yet if the acid also acted as depolariser a cycle might be formed in which sufficient energy would be developed to condition change: it therefore follows that in such cases *nitric acid* does not act as the depolariser in accordance with the equation: $2Ag + 2NO_3H + ONO_2H = 2AgNO_3 + H_2O + NO_2H$, and that in point of fact the nitrous compound is the depolariser, although the nitric acid is the actual solvent of the metal, the hydrogen of the acid being virtually directed displaced by the metal with the assistance, however, of the current energy derived from its own oxidation by the nitrous compound.

But what interpretation is to be given of the behaviour of more active metals, such as zinc, magnesium, &c., which have positive heats of dissolution, and therefore are capable of dissolving in the pure dilute acid if coupled with a relatively negative conductor; does nitric acid in their case directly act as a depolariser? If it be capable of thus acting, such metals even when uncoupled should dissolve in the pure diluted acid. It is noteworthy that when such metals are dissolved in nitric acid hydrogen is sometimes evolved. It has been suggested that this hydrogen is derived from the interaction of the metal and water, but I cannot now regard this as a probable explanation; its production serves rather to suggest a deficiency of the depolarising agent, which cannot well occur if nitric acid be the depolariser. Indeed, if nitric acid be regarded as directly active, it is remarkable that in presence of the large excess of the acid which is always present any hydrogen should escape; and also that the reduction should extend so far as it often does, and not extend merely to the formation of nitrous acid. If, however, the acid be incapable of directly acting as a depolariser, and a nitrous compound be the initially active depolarising agent, it is no longer surprising that owing to the nitrous compound suffering further reduction it should be deficient in parts of the circuit, and that consequently hydrogen should escape. Why the reduction should extend so much further when metals having positive heats of dissolution are used, however, still requires elucidation.

In the case of sulphuric acid, whatever metal be dissolved in the *diluted* acid, no reduction takes place; and it is only when the concentrated and more or less heated acid is used that sulphurous oxide and other reduction products are obtained. It appears not improbable that reduction only takes place under conditions under which the presence of sulphuric *oxide* is possible, *i.e.* that depolarisation is effected by sulphuric *oxide* and never by sulphuric *acid*, although this latter may be regarded as the actual solvent of the metal. There is at present no evidence forthcoming to show that nitric acid can dissociate into the anhydride and water, and even if such a change took place in concentrated solutions, there is no reason to assume that it can also take place in dilute solutions, and that this is the explanation of the difference between nitric and sulphuric acids. It is well known, however, that nitric acid is resolved with extreme facility into nitrogen dioxide, water and oxygen, and that it is excessively sensitive to the action of nitric oxide—a trace of nitric oxide would therefore exercise a fermentative action and condition, the formation, it may be, of nitrous acid, or—as there is no evidence compelling us to suppose that the compound represented by the formula HNO_2 exists—it may be of nitrogen dioxide. In this latter case, solutions of nitric acid would resemble concentrated sulphuric acid in containing a reducible oxide, and it may be that their depolarising action is initially exerted through such an oxide alone.

To arrive at a clear conception of the function of acids in dissolving metals, and of the nature of depolarising agents, it would therefore appear to be necessary to take into account many circumstances to which hitherto but little attention has been paid.

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