Agitation of the immersed metals is well known to influence the current. Shaking one of the metals reversed occasionally the direction of the current; palladium was the metal which most frequently manifested this effect. The agitation of that metal rendered it either more negative or less positive in a considerable degree, especially in solutions of potassic chloride and cyanide. In those of the bromide, antimony was the metal, the current from which was most affected by shaking. The effect of shaking was less in the iodide solutions than in those of the bromide.

*Note.*—Some years ago I made a note as follows: "If water is nearly saturated with a suitable salt at 15°C., and the upper part is then kept hotter and the lower part colder than that temperature for a long time, will the upper part become stronger and the lower weaker?" Recently, since this research was completed, the following statements have been published: (see "Nature," vol. xxii, p. 356, August 12, 1880, also vol. xxiii, p. 207, December 30, 1880) "Influence of Temperature on the Distribution of Salts in their Solutions," by M. Soret. "The concentration of the heated part diminishes, that of the cold increases. The difference grows with the original concentration, and nearly in proportion. In the series of the alkaline chlorides the difference is greater (for the same concentration) the higher the molecular weight of the salt. The phenomenon seems to have no relation to solubility of the salt." If these statements are correct (as is very likely) they affect to a slight extent all the results of the present research (and of other researches) on the thermo-electric behaviour of solutions, because they show that the chemical composition of the aqueous solution is slightly altered by the rise of temperature. If also the strength of the thermo-electric currents of liquids depends upon the degree of amplitude of vibration of the molecules of the salt, &c., in solution, it will probably vary, in the case of solutions of alkaline chlorides, with the degree of concentration of the solutions, and the molecular weights of the salts, like the phenomena in M. Soret's experiments.

## VII. "Influence of Voltaic Currents on the Diffusion of Liquids."

By G. Gore, LL.D., F.R.S. Received December 1, 1880.

(Abstract.)

The subject of this paper is an investigation of the effects produced by electric currents whilst passing through the surfaces of mutual contact of two electrolytes lying upon each other. (See "Proc. Roy. Soc.," vol. 30, p. 322.)

By an examination of about forty pairs of electrolytes of the most varied kinds, including solutions of various mineral acids, acid salts,

neutral and alkaline ones, &c., also of different degrees of dilution, the influence upon the effects of the kind and strength of the liquids, the strength of the current, and of various other circumstances, was determined. Two different apparatuses were employed in these experiments, viz., a single and a double meniscus one; the former was the most easily managed, and yielded the phenomena in their simplest form.

It was found that the phenomena are very complex, and consist of a mixture of physical and chemical effects. That they are chiefly due to electrolytic changes, to differences of specific gravity, to ordinary liquid diffusion, to electrolytic transfer and diffusion of liquids, and to heat of conduction-resistance. That also the mutual contact surfaces of the liquids act to some extent as electrodes and osmotic diaphragms. That by the electrolytic action, various phenomena, such as layers of liquid of different specific gravities, &c., lines, strata of colour, alteration of form of the surfaces of the meniscuses, liquid currents, &c., were produced. That by the heat evolved, expansion and streaming upwards and downwards of the liquids, evolution of gas and steam, and boiling of the liquids at their contact surfaces took place. Nearly all the phenomena and their conditions have been examined and discussed, but some of them, however, have not been fully explained.

The movements of the meniscus and apparent transfer of the bulk of the liquid were examined in a special apparatus in several ways, and a conclusion was drawn from these and the previous experiments, viz., that by the causes already named an apparent, and, also to a small extent, real bodily movement of the liquid did occur.

Some experiments were also made with two superimposed electrolytes in capillary tubes for the purpose of comparing the effects produced on passing an electric current through them, with those which occur in a capillary electroscope. The conclusion arrived at was, that the two classes of movement were considerably different, and that the movements obtained with the two electrolytes were more allied to those observed by Armstrong ("Phil. Mag.," xxiii, 1843, pp. 194–202), Quincke ("Pogg. Ann.," vol. cvii, 1859), Jürgensen and Wiedemann, on passing electric currents through non-conducting liquids in capillary tubes.

By means of numerous and varied experiments with apparatuses similar to that used by Porrett (Thomson's "Annals of Philosophy," vol. viii, 1816, pp. 74–76) in electric osmose experiments, the influence of electric diffusion of liquids upon the results was examined. From the results of these it was inferred that the apparent movement of the mass of the liquids was considerably different from that of electric osmose; in the osmose experiments it was found that the amount of liquid transferred was nearly always greater when the current passed from a weak to a strong solution of the same salt or acid than when it

passed in the reverse direction. This circumstance partly explains some of the phenomena observed in the double meniscus apparatus.

The influence of molecular structure of the liquid was discussed, and it was observed generally that the greater the degree of physical and chemical differences between the two liquids, the more conspicuous were all the effects.

The influence of viscosity, specific gravity, adhesion, and ordinary diffusion, &c., of the liquids was also considered, and conclusions respecting them drawn, by the aid of the results of the experiments. It was concluded that they all affected the phenomena; that the phenomena of lines and apparent movement of the liquids were not wholly capillary; that although ordinary diffusion affected the results, its usual effects were modified by the current, which aided diffusion at the negative meniscus and neutralised it at the other.

Heat having been found to operate only as a disturbing element, the influence of rise of temperature was not specially investigated. The effects of heat resulting from conduction-resistance, and from chemical and electro-chemical action at the meniscuses were, however, observed; in some cases streams of liquid, evolution of gas and steam, and even the phenomena of boiling, were seen in the contracted portion in the midst of the mass of the liquids.

The electrical conditions were essentially important. The electric current produced both physical and chemical effects, consisting of electrolysis, dissociation of water from salt, and simple mechanical movement and diffusion of liquid by electric convection. As these phenomena appeared to be immediate effects of the current, either the current acted under conditions which were not uniform, and produced effects which required different degrees of electro-motive force to produce them, or the current consisted of several portions of electricity of different degrees of electro-motive force. The former supposition harmonised with the fact that the ingredients of chemical compounds were held together more strongly than those of mere mechanical mixtures. The physical portion of the effects were considered to result from electric convection due to electric charge and conduction-resistance at the surfaces of contact of the liquids, and in capillary tubes also at the surface of the glass. The unequal transfer of acids and bases, and the liberation of ions at the contact surfaces of the liquids, further influenced and complicated the effects. It was predicted as probable, that as the amount of electric osmose was greater from a weak solution of a salt or acid to a strong one than the reverse, conduction-resistances to currents of opposite direction passing through such an arrangement would be similarly unequal. Evidence was also adduced for the conclusion that every inequality of structure or composition of the liquid in the path of the current must act to some extent as an electrode. As no visible lines or movements of

liquid were produced without electrolysis, and electrolysis would reasonably account for several of the phenomena, it was concluded that electrolysis was not merely a concomitant circumstance, but also acted as a cause. The converse phenomena of the subject of this paper have been made the subject of a separate research, entitled "The Production of Electric Currents by Diffusion and Osmose of Liquids." No effect of magnetism upon the lines or movements of the liquids was sought for.

Chemical action was found to be only a coincident and not a fundamental part of the phenomena; it constantly took place by electrolysis and by contact of liberated ions, and occasionally by contact of the original liquids. The lines and strata of liquid at the meniscuses were produced with almost every possible chemical combination of electrolytes; and references are given to experiments which prove this; they were also the more difficult to produce the less the differences of chemical composition of the two liquids.

## VIII. "Experiments on Electric Osmose." By G. GORE, LL.D., F.R.S. Received December 7, 1880.

The following experiments were made for the purpose of elucidating a question in a research on "The Influence of Voltaic Currents on the Diffusion of Liquids" (*ante*, p. 250), and are published separately, in order to facilitate reference to them by other investigators.

As, also, the discovery of an exceptional instance is often of considerable importance, an additional number and variety of solutions were purposely examined with that further object until such a one was found. I anticipated that the proportion of exceptional instances would be "about one or two per cent."

The experiments were similar to that made by Porrett ("Annals of Philosophy," vol. 8, p. 74). The vessel employed was about 7·0 centims. high and 3·0 centims. diameter, of thick glass, divided vertically into two equal parts, its edges being covered with vulcanised india-rubber, with a diaphragm of biscuit ware about 1·5 millim. thick placed between them; the whole being held together between two upright bars of wood by means of a clamp-screw, so that the diaphragm might be readily removed, and replaced by a clean one. The electrodes were of sheet platinum, about 18 millims. wide; and the electric current (except in the cases otherwise mentioned) was from 12 Grove's cells of one pint capacity, and in single series. The liquid was usually about 2 centims. high in the vessel, and at the same level on each side of the partition previous to passing the current in each experiment. The diaphragm was frequently changed.

The following table exhibits the compositions of the liquids tried,