

## The Electric Charge of Colloids.<sup>1</sup>

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SINCE Hardy's publication in 1900, the electric charge of the particles has been the central problem of colloid chemistry. I propose to develop this point of view for both suspensoids and emulsoids, and indeed in the same manner for both types.

In 1907, Freundlich propounded his theory, according to which the origin of the electric double layer was to be sought in a preferential adsorption of one of the ions of the liquid. This theory was applicable to colloid particles with regard to the external phase, and to capillary electric phenomena with regard to the moving liquid. It gave a satisfactory explanation of many facts concerning the coagulation of suspensoids and of the investigations of Perrin and Elissaffoff on electro-osmosis, of Kruyt on streaming potentials, and of Powis on cataphoresis. Several problems of colloid chemistry could be elucidated by these investigations, *e.g.* the irregular series of flocculation, peptisation, etc. Nevertheless this theory, according to which the double layer is built up only by ions coming from the external liquid, so that the material of the solid wall does not take any part in the process, could not explain all the facts. Especially the investigations on the alkaline sol of SnO<sub>2</sub>, carried out by pupils of Zsigmondy, make it obvious that in this case the inner side of the double layer is built up by stannate and not by hydroxyl ions.

The special conditions of the atoms at the periphery of a crystalline particle can account for the formation of a double layer, as Fajans has pointed out. For example, when a negative sol of AgBr is made from solutions of AgNO<sub>3</sub> and KBr, with a slight excess of the latter, the Ag-atoms in the crystal lattice are each surrounded by six Br-atoms, whereas an Ag-atom at the crystal boundary is connected to five only; thus it will attract a Br-ion from the surrounding liquid towards the vacant place. This ion, however, is accompanied by a K-ion, which will place itself near the attracted Br-ion. Thus the double layer is formed by the special selective attraction of the solid phase. This train of thought, when slightly modified, holds too for a disperse amorphous phase. According to Langmuir and Harkins, the molecules at a phase interface are oriented with their electrically polar parts towards the water; therefore the conditions are similar to those at the surface of a crystal lattice.

Has the electric charge in the case of lyophilic colloids, like the proteins, the same capillary electric character as in that of the suspensoids? If not (and most physiologists consider it so), colloid chemistry is on the wrong track. The behaviour of proteins is often explained as if they gave real solutions, electrolytically dissociated as amphoteric electrolytes, following Ostwald's law of dilution. Kruyt and De Jong have made investigations on

the sol of agar, the behaviour of which cannot possibly be interpreted in that way, the agar being a carbohydrate though giving a typical lyophilic colloid. They pointed out that there is a considerable decrease of viscosity when small amounts of electrolytes are added, the effect being a function only of the valency of the cation, just as is the case with suspensoids and capillary electric phenomena. This effect is the electro-viscous effect, already predicted years ago by Hardy, and thoroughly discussed in the late von Smoluchowski's last paper.

As the electric charge of the agar particles has, without any doubt, just the same character as that of, say, a gold sol, why should a gelatine sol have a charge of quite another origin? Investigations in collaboration with different pupils (unpublished until now for the most part) have convinced me that with gelatin, glycogen, casein, starch, gum arabic, and even with rubber in benzene, the capillary electric phenomena play the principal rôle and can account for the behaviour, which is often interpreted as if we were not dealing with colloids, but with electrolytes in real solution. The influence, especially, of neutral salts can now be understood much better.

The only difference between suspensoids and emulsoids lies in the fact that the latter are hydrated to a large extent, viscosity showing this fact clearly. Water bound by hydration acts as a stabilising factor, just as the electric charge does. The latter can be removed by electrolytes, as mentioned before, and the hydration by adding alcohol or acetone. When hydration only is removed, there remains a suspensoid with all the typical properties of such. Salting out a protein is a combination of the removal of charge (according to the valency) and of hydration (according to the lyotropic strength). Special experiments with agar have made this obvious.

Dr. Bungenberg de Jong has pointed out that the action of tanning agents, like tannin, is a mere dehydration, causing just the same effects as alcohol, though by a very different mechanism.

As a general conclusion, I wish to emphasise the view that the electric charge of all colloids has the same origin, namely, a capillary electric one. The electric charge of suspensoids is their only stabilising factor, the emulsoids having a second in their hydration. With both, the way in which the double layer is built up is not always independent of the material from which the particle is made: with a gold sol, as well as with an agar sol, the double layer behaves in perfect accord with the adsorption theory of Freundlich. With the sol of stannic oxide, as well as with a protein sol, the ions of the molecules situated in the periphery of the particles play an important rôle in the constitution of the double layer.

The advantage of the train of thought developed here lies in the principle of unity according to which colloid-chemistry can be treated.

## Plant Ecology.

IN "Die Vegetationsverhältnisse der Grimselgegend im Gebiet der zukünftigen Stauseen" (Bern, Wyss Erben, fr. 8), Dr. Eduard Frey records the character of the vegetation of an area which will soon be submerged in connexion with a water-power scheme in the upper Aare. The area is of special interest in affording a unique opportunity for studying the colonisation of naked siliceous rock and

broken soil exposed by the prolonged retreat of the glaciers. Dr. Frey describes in detail the physical characters of the district and the statics of the different plant associations, and also traces the succession of plant life from the original colonisation of unoccupied rock and debris by lichens and mosses to the ultimate condition in which vascular plants are mainly concerned. He remarks on the crowding