CCXVI. A NOTE ON MOVEMENTS AND PRECIPITATIONS OF AN AMPHOTERIC COLLOID DUE TO AN ELECTRIC FIELD AND SLIGHT ELECTROLYSIS.

A MODIFIED HARDY'S EXPERIMENT SUITABLE FOR DEMONSTRATION PURPOSES.

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WHILE observing microscopically the cataphoretic movement of a gelatin-protected silver colloid it was found:

- (1) That the particles in the centre of the field migrated towards the anode.
- (2) That a wave of particles emerged from each electrode.
- (3) That these waves ultimately met near the centre of the field, where they precipitated.

Hardy [1899] described similar effects using, however, U-tubes and boiled egg-white solution. Our experiment presents the same phenomena, but is so simply performed as to be suitable for class work.

It is conducted in large cells, the walls of which are formed by two glass plates (selected flat lantern slides do well for this purpose). The individual particles, of course, cannot be observed by this method, but the essential facts relative to the electrical phenomena known to occur in amphoteric colloids can be observed or deduced.

The nature of the silver colloid.

The silver colloid we employed was prepared by Bredig's method in a menstruum of 0.5 % gelatin (Coignet's best) in water. No salts were added separately. A slight amount of electrolysis occurs in the experiment. After 10-20 minutes' sparking with about 5 amp. passing at 230 v. D.C., the fluid acquires a dark brown colour, due to the colloidal dispersion of the silver. The colloid so obtained should be centrifuged to remove the larger particles, after which it may be preserved for months if it be protected from the influence of light. On examination under the high power microscope, using dark ground

illumination and a red light, innumerable minute particles are seen. The particles are, of course, in active Brownian movement and are mostly smaller than $0.2\text{ }\mu$ in diameter. As before mentioned, these particles migrate towards the anode in an electric field, showing that they are negatively charged. The reaction of the colloid is slightly alkaline.

During the preparation of the colloid, in the manner described, each particle of silver is considered to acquire an envelope of gelatin. This envelope apparently imparts properties to the colloid which are essentially those of gelatin. From this point of view the phenomena of the experiment will be discussed. The silver nucleus acts in the macroscopic experiment as a visible indicator of the location of the particles.

EXPERIMENTAL.

The two lantern slides must be chemically clean. For this purpose they are treated with chromic acid, water and alcohol, the alcohol being removed by burning rather than wiping. The glass plates are kept 0.03 mm. apart by the insertion of platinum foil electrodes at the opposite sides of the cell. The cell is completely filled with the colloidal solution, care being taken to exclude all air bubbles. Excessive colloid is wiped away from the edges of the cell before sealing it with melted paraffin. The paraffin is applied by means of a hot glass or metal rod. The finished cell will have a light yellowish-brown colour. The electrodes are then connected to a source of electricity, with the results shown in the photographs (Plate VII, Figs. 1 to 5). These were taken at the times indicated without interrupting the experiment, panchromatic plates being used. The cell was placed on a glass platform and illuminated from below, the camera being placed overhead in the inverted position.

The points to be noted are the following.

(1) A wave of particles first appears emerging from the negative electrode soon after the current is applied. This indicates that the particles of the colloid have a negative charge. The photographs demonstrate that the wave which comes from the negative electrode is smooth and shows no signs of precipitation.

(2) After a short but perceptible lag a much denser wave is seen to emerge from the positive electrode. The lag in the appearance of the positive wave is due to the attraction exerted by the positive electrode on the negatively charged particles of the colloid. No repulsion of these particles by the positive electrode can occur until their charge has changed its sign. This is effected by the electrolytic production of acid at the positive electrode. As soon as this change of sign has occurred the particles tend to be repelled from the electrode and from each other. In the process of changing the sign of the charge, precipitation of the particles occurs and this precipitation accounts for the greater density of the positive wave. Moreover, this wave shows an

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5.

Figs. 1-5. Photographs of macroscopic experiment in progressive stages.

Fig. 1. Taken 3 minutes after application of 20 volts D.C.

Fig. 2. Taken after 10 minutes from beginning of experiment.

Fig. 3. Taken after 50 minutes from beginning of experiment.

Fig. 4. Taken after 150 minutes from beginning of experiment.

Fig. 5. Taken after 18 hours from beginning of experiment.

(The times stated are approximate.)

irregular convoluted formation, well illustrated by the photographs. The zone of precipitation in the positive wave is situated, in the early part of the experiment, near the positive electrode, but recedes from this electrode as the experiment proceeds. The approaching negative particles attracted by the anode are discharged, precipitated, reversed in sign and redispersed by the advancing acid wave. The positively charged particles behind the wave are strongly repelled by the positive electrode and tend to sweep before them the uncharged particles in the isoelectric state in the anode wave. Behind the dense anode wave proper we see, in the photograph, evidence of a smooth zone of dispersed particles, behind which is a clear acid zone. If the experiment be performed sufficiently slowly, the convolutions will not appear in the anode wave. On strongly increasing the potential across the cell, however, the positive wave immediately develops an undulating character. We believe that the precipitation of the particles is necessary before these undulations can occur. The change of sign of the particles apparently does not take place absolutely simultaneously, so that some of them are more repelled from the positive electrode than others. In this way, possibly, the convolutions may arise.

(3) In front of the positive wave there is a clear zone which is not present in advance of the negative wave.

(4) Ultimately the two waves meet and precipitate practically together near the centre of the cell. In this position a neutral zone is formed by the neutralisation of the acid and alkali of the respective waves. In this zone, naturally, the precipitation of the protein particles occurs. This is well shown in the photographs, where the positive and negative waves are united in a zone of common precipitation.

(5) If the current be stopped while the waves are advancing, they show a marked tendency to diffuse back again in the opposite directions to the directions in which they are travelling, showing that the charges of the electrodes are necessary for the movements of the waves. If the current be stopped after the common precipitation has occurred near the centre of the cell, then the precipitated waves remain unaltered for a considerable time.

(6) Slight evolution of gas, due to electrolysis, is seen to occur at each electrode.

A further experiment was carried out, in which strips of neutral litmus paper were placed in a cell of the macroscopic type. The paper should not contain an excess of alkali. This experiment showed that the acid and alkali waves preceded the visible positive and negative waves respectively for a small distance and showed the close relationship between these waves and the changes of reaction. It likewise showed that the zone of common precipitation occurred where the acid and alkali waves met. As the colloid waves recede from their respective electrodes, their velocities diminish. If the colloid be made slightly more alkaline by the addition of free alkali, the positive wave

has an increased lag in emerging and the zone of common precipitation is shifted towards the anode. On the other hand, if the colloid be slightly acidified, the positive wave emerges first and the appearances are reversed, the zone of common precipitation being now moved towards the cathode.

SUMMARY.

Photographs of a modified Hardy experiment are described, which demonstrate simply some of the electrical properties of amphoteric colloids. The experiment should be helpful for class demonstration purposes.

REFERENCE.

Hardy (1899). *J. Physiol.* 24, 288.