point a small committee, nominated by the Royal Society, to assume responsibility for the organization of the central scientific exhibit, and a larger committee, acting on behalf of the research associations, to deal with the general organization of sectional scientific exhibits. With regard to the plea that was made in last year's report that a vigorous search for new knowledge and the more effective application of science to industrial processes offered a potent means of reestablishing our country and maintaining its population, it is recorded with satisfaction that in December, 1922, an act with a similar end in view was passed in France, creating a national office for scientific and industrial researches and invention in connection with the Ministry of Public Instruction. The report includes a summary of the work of the various research boards and committees of the Department of Scientific and Industrial Research. At the National Physical Laboratory, in addition to the researches which it necessarily undertakes in the discharge of its primary functions as the custodian of national standards, with a view to the improvement of measurements of all kinds, including those relating to standards of quality, much research work of a general character is carried out. It includes researches involving continuous observations over a very extended period of time, and researches requiring the use of exceptionally expensive equipment or other special facilities—for example, work at very high voltages or at very low temperatures. The Food Investigation Board dealt with varied problems affecting fruit, meat, fish and eggs; many of these have been noted in our columns. Among new investigations which are being carried on are the design of a commercial gas store for fruit, the growth and respiration of fungi under various conditions, the study of vegetables in transit from producer to market, the autolysis of meat and of fish, the bacteriology of fish and the freezing point of eggs in relation to the risk of overcooling. A report from the Oxygen Committee, shortly to be published, contains descriptions of the improvement of the known method of handling liquid oxygen and liquid air on a practical commercial scale; of these methods the committe has been principally concerned with the development of the double-walled vacuum vessel as a container. Among the other boards and committees carrying on different branches of research work are the Fuel Research Board, the Geological Survey Board, the Radio Research Board, the Physics, Chemistry, and Engineering Coordinating Research Boards, the Fabrics Coordinating Research Committee, the Adhesives Research Committee and the Lubrication Research Committee. During the academic year 1922–23 the committee made 403 grants to research workers and students in training; of these 252 were allowances to students to enable them to take advantage of the facilities offered by various universities and colleges or other research institutions, 38 were personal grants to research workers to undertake independent research or to act as scientific assistants to other investigators, and 14 were grants to scientific workers to enable them to employ laboratory assistants or to purchase equipment; the total expenditure on these grants was £50,000. The total expenditure of the committee during the financial year was £497,549, of which £264,493 came directly from the Exchequer, while £89,608 represents fees for tests and special investigations for outside bodies, and repayments from the service departments.

SPECIAL ARTICLES

GELS AND THEORY OF ADSORPTION*

THIS paper is not to give a summary of the theories that have appeared on adsorption. Time nor patience would permit such a presentation. On the contrary, the speaker, with due consideration for all theories thus far advanced, is going to present a point of view which is in harmony with the experimental facts which have been found out at the University of Maryland during the past three years.

Before beginning our work, I felt that the hypothesis, which said that the electrical charge on the colloid was due to the adsorbed ion, was the most general. You all know that this point of view arose from Hardy's work, but was first clearly presented by Bredig. Helmholtz's double layer theory was another way of accounting for the electrical charge. Furthermore, you are all familiar with Freundlich's assumption of adsorbed ions and Michael's idea of surface molecules being dissociated.

After reviewing the great amount of work on adsorption, it seemed to me that we did not need more theories on adsorption until more fundamental work was done, in order to prove the falsity or truth of the theories already in print.

Our work was started on silica gel and you all know that this gel is negative with respect to water. We assumed that this negative charge was due to the Helmholtz double layer and, according to Hardy's work, we had reason to believe that if the hydrogen ion concentration was decreased, the negative charge on the gel would increase, and similarly, if you increase the hydrogen ion concentration the gel would assume a less negative charge until it would assume a positive charge when the pH had fallen below 7. The Helmholtz theory also assumes that a charge of a particular sign can not exist without one of oppo-

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* Read before the Chemistry Section of the American Association for the Advancement of Science at the Boston Meeting on December 28, 1922.

site sign in its proximity; *i.e.,* when the silica gel becomes more and more negative by increasing the pH value of the solution, it should attract more and more positive ions into its proximity. With these points in mind, it seemed reasonable to suppose that a positive ion, such as would be furnished by some salt like potassium acid phosphate, would be more and more attracted into the neighborhood of the gel as the hydrogen ion became less; or, putting it in other words, that the adsorption of the potassium ion would increase with an increase in pH values. Results as shown in the following table seemed to bear out the supposition:

TABLE I

pH Value	mgm. K Ads. per gm. gel.	mgm. PO_4 Ads. per gm. gel.
9.501	9.63	—4.15
7.692	6.56	—4.15
6.086	1.74	—3.15
3.888	—0.68	—1.36

This would seem quite in tune with some of Dr. Loeb's work as far as the potassium ion is concerned, and the phosphate radical also has a tendency in the right direction, although at no time did it become positively adsorbed. Many salts of potassium and calcium were run, and there was no exception to the rule as far as the cation was concerned, but the anion presented some irregularities.

It next became of interest to find if the charge on the gel changed at a pH value of 7. Such determinations were easily run by an apparatus similar to that used by Briggs in his electroendosmosis work. Table II gives a sample of the results.

TABLE II

pH	Charge on Gel.	Time to flow 10 cm.	E.M.F.
6.526	neg.	16 min. 19 sec.	116
4.717	neg.	31 min. 54 sec.	120
3.567	neg.	32 min. 19 sec.	120
1.217	pos.	72 min. 3 sec.	119

According to Perrin's work, you would not expect this silica diaphragm to be negative in such a high hydrogen ion concentration unless it was due to a strong adsorption of some negative ion which was more strongly adsorbed than hydrogen. But the anions had been slightly, if any, adsorbed as shown in Table I.

In view of these facts it seemed necessary to make some other assumption as to the cause of the charge on the gel. The next most plausible theory seemed to be the ionization of surface molecules, but before applying this theory, a few words about the history of the ultramicron may be in order.

Work by Bütschli and others have led us to believe that the ultramicron in the hydrosol and hydrogel are identical. In the latter case the ultramicrons are closer together. It is further necessary for us to picture the ultramicrons in a hydrogel as being held together by a certain amount of cohesion and the interstices between these ultramicrons being filled with water.

Suppose that the molecules of silicic acid at the surface of the ultramicron suffered ionization. Then the ultramicron would become negative and might be represented thus:

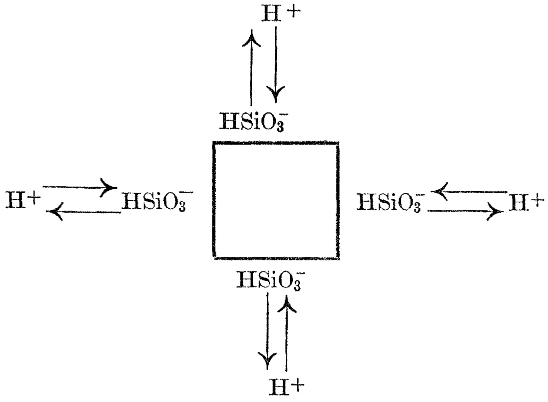

FIG. 1

The charge on the gel is now accounted for satisfactorily, and it is next to be seen if this theory will explain experimental facts.

On this theory the ultramicron should have a charge much in excess of a common ion, for, as illustrated in Figure 1, there would undoubtedly be many surface molecules ionizing. This is true to facts, for it has been shown that the charge on an ultramicron is many times that of a single ion.

Suppose an acid is added to these ultramicrons. This surface ionization will be decreased, and the gel will become less negative until it finally becomes positive, as shown in Table II. The equilibrium is expressed thus:

$$H^+ + H\text{-}SiO_3 \rightleftarrows H_2SiO_3 \rightleftarrows H^+SiO_2 + O\text{-}H$$

$$\xleftarrow[\text{pH} < 1.217]{} \qquad \xrightarrow[\text{pH} > 1.217]{}$$

Again, suppose that some alkali is added, such as sodium hydroxide, then the regular neutralization action should take place thus:

$$\square\, HSiO_3^{-} + \boxed{H^+ + OH^-} + Na^+ \longrightarrow$$
$$\square HSiO_3^{-} + Na^+ + H^+ + OH^-$$

i.e., sodium silicate is formed at the surface of the ultramicron. These surface molecules of silicate would be more highly ionized than the silicic acid and hence, the negative charge of the gel should increase. This is again true to experimental facts.

The sodium ions in equilibrium with the silicate ions on the surface of the ultramicron would have a tendency to diffuse through the solution, but they can not go without taking the ultramicron in their train. This should happen when the ultramicron does not have too great mass, and in such a case we have what is known as peptization, but if the mass of the ultramicron is too great, the sodium ions are not able to pull it along and consequently the sodium ion is held in the vicinity of the ultramicron and we have what might be termed adsorption. Experimental facts bore out these assumptions, for when the silica gel was treated with a solution of sodium hydroxide until the alkalinity of the solution had entirely disappeared and the analysis run, it was found that part of the sodium was found in the solution with its attending ultramicrons, while the balance was in the proximity of the ultramicrons which had too great mass to migrate. The surface of the unmigratable ultramicrons is so great that the result was a fairly high so-called adsorption.

In the light of this, it was reasonable to suppose that the adsorption of potassium, as shown in Table I, might be due to a replacement of the sodium, but if this were the case, the total adsorption of the sodium and potassium should be equal to the adsorption of the sodium, and what part of this adsorption was potassium would depend on the ratio of the solubilities of sodium and potassium silicates. Furthermore, if some salt like silver nitrate were used which had a more insoluble silicate than the potassium more of the sodium should be replaced but the total adsorption should be the same. A few results are given in Table III to show the general run of experiments.

TABLE III

Adsorption of Metals by the Hydrogels of Silicon

Solutions Used		Equivalents of Na Ads. per gm. Gel.	Equivalents of M.[1] Ads. per gm. Gel.	Total Equivalents of Metal Ads. per gm. of Gel. ....
C = 0.02N	C = 0.02N			
NaOH	$NaNO_3$	45×10^{-5}		45×10^{-5}
NaOH	KNO_3	14×10^{-5}	31×10^{-5}	45×10^{-5}
NaOH	$AgNO_3$	12×10^{-5}	33×10^{-5}	45×10^{-5}

Using similar notation to that already used, the reactions might be represented thus:

$$\square HSiO_3Na + KNO_3 \rightleftarrows \square HSiO_3K + NaNO_3 \quad (1)$$

$$\square HSiO_3Na + AgNO_3 \rightleftarrows \square HSiO_3Ag + NaNO_3 \quad (2)$$

According to the results given in Table III, equation (2) would be carried nearer completion than equation (1) before equilibrium was established, but the total metal adsorbed in any case is the same.

These are a few points to show the trend of our results and conclusions in regard to silica gel. We are now investigating alumina and ferric oxide gels in order to find what theories will best apply to these cases, but the work has not yet reached such a state that we wish to draw definite conclusions, but our present work seems to indicate that there are four different types of adsorption from solution; namely, (1) chemical adsorption, which follows the mass law, (2) exchange adsorption, where one ion is adsorbed at the expense of replacing an equivalent amount of a second ion, (3) partition ratio adsorption, where the adsorption obeys Henry's law, and (4) electronic adsorption, where the adsorbed material seems to be held by a secondary valence. There is also what might be called a fifth type which is a combination of two or more of these types. We feel quite sure that we have a combination adsorption in the case of both ferric oxide and alumina gels, but we shall wait until a later date to report more detail on this.

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NORTH CAROLINA ACADEMY OF SCIENCE

The twenty-second annual meeting of the North Carolina Academy of Science was held at the North Carolina College for Women at Greensboro, May 4 and 5, 1923.

The secretary reported a total membership of 203, an increase of 40 members over the preceding year, and also that some 60 members were now members of the American Association for the Advancement of Science, an increase of 50 per cent. over the previous year.

The following officers were elected for the ensuing year: *President,* C. M. Heck, Department of Physics, State College; *vice-president,* J. P. Givler, Department of Biology, North Carolina College for Women; *secretary-treasurer,* Bert Cunningham, Department of Biology, Trinity College; *executive committee*—A. Henderson, Department of Mathematics, University of North Carolina; H. B. Arbuckle, Chemistry Department, Davidson College; J. W. Nowell, Chemistry Department, Wake Forest College.

The North Carolina Physics Teachers Association, meeting with the Academy, elected officers as follows: *President,* W. T. Wright, North Carolina College for Women; *vice-president,* A. A. Dixon, State College; *secretary-treasurer,* A. L. Hook, Elon College.

The North Carolina Section of the American Chemical Society, meeting at the same time and place, elected the following officers: *President,* J. O. Halverson, Department of Agriculture; *vice-president,* F. C.

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[1] Metal other than sodium.