ADSORPTION OF MERCURIC CHLORIDE BY COLLOIDS—PART I

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Michaelis and Rona[1] (1920) distinguish between the adsorption of non-electrolytes and strong electrolytes by introducing the terms apolar and polar adsorption. According to them an apolar adsorption is the adsorption of non-electrolytes and weak electrolytes by different kinds of adsorbents and also that of strong electrolytes by charcoal, where both ions are taken up in equivalent amounts. On the other hand a polar adsorption is that adsorption where cations and anions of electrolytes are not taken up in equivalent amounts. M. A. Rakuzin and A. N. Nesmejamev[2] (1923) studied the behaviour of aqueous and alcoholic solutions of $HgCl_2$ and they found that kaolin and aluminium hydroxide do not adsorb $HgCl_2$ from aqueous solutions. In the present work the adsorption of $HgCl_2$ by colloids such as activated gels of ferric hydroxide, silica, aluminium hydroxide and a variety of activated carbon—acticarbon, has been studied in aqueous solution at different temperatures.

Experimental

The different gels of $Fe(OH)_3$, silica gel and $Al(OH)_3$ were prepared by the method given by Holmes in his *Laboratory Manual of Colloid Chemistry* and they were activated by dry air at 150° C. for four hours. The adsorption experiments were carried out in a thermostat by taking different molar concentrations of aqueous $HgCl_2$ and adding 1 gram of the adsorbent to each solution. The mercuric chloride taken was Merck's extra pure quality. The contents of the flasks were shaken constantly by a shaker kept in the thermostat. After 12 hours the solutions were filtered and Hg and Cl ions were estimated gravimetrically. Side by side blank experiments were also carried out.

The effect of the addition of a strong electrolyte on the adsorption of $HgCl_2$ was studied by adding sodium chloride (1 gram) to each solution. After adsorption by the colloids the amount of Hg ions was estimated gravimetrically.

1. *Biochem. Zeitschr*, 1920, **102**, 268.
2. *Münch. Med. Woch.*, 1923, **70**, 1409–10.

TABLE I

Adsorption of $HgCl_2$ by ferric hydroxide gel at 30° C.

	C_0	$Y_{30°}$	$dy_{30°}$
A	0·2 M	0·0652	0·0292
B	0·15 M	0·0516	0·0180
C	0·1 M	0·0327	0·0034
D	0·05 M	0·0223	0·0016
E	0·01 M	0·0066	— 0·0082

Where C_0 is the initial concentration in mols of $HgCl_2$, $Y_{30}°$ is the amount of Cl ion adsorbed in grams and $dy_{30}°$ the excess of Cl ion in grams adsorbed over corresponding Hg ion.

TABLE II

Adsorption of $HgCl_2$ by silica gel at 30° C.

	C_0	$Y_{30°}$	$dy_{30°}$
A	0·2 M	0·0832	0·0333
B	0·15 M	0·0476	0·0282
C	0·1 M	0·0288	0·0171
D	0·05 M	0·0170	0·0100
E	0·01 M	0·0029	— 0·0011

TABLE III

Adsorption of $HgCl_2$ by acticarbon at 30° C., 40° C. and 50° C.

	C_0	$Y_{30°}$	$Y_{40°}$	$Y_{50°}$	$dy_{30°}$	$dy_{40°}$	$dy_{50°}$
A	0·2 M	0·3222	0·3382	0·3372	0·0137	0·0259	0·0240
B	0·15 M	0·2916	0·2936	0·2945	0·0135	0·0146	0·0155
C	0·1 M	0·2525	0·2539	0·2541	0·0107	0·0124	0·0123
D	0·05 M	0·1851	0·1833	0·1825	0·0011	0·0006	0·0004
E	0·01 M	0·0586	0·0593	0·0583	—0·0002	—0·0004	—0·0004

TABLE IV

Adsorption of $HgCl_2$ in presence of NaCl by $Fe(OH)_3$ gel at 30° C.

	C_0	α	α'	X	X'
A	0·2 M	4·27× 10	6·3× 10	0·1002	0·0932
B	0·15 M	5·17× 10	,,	0·0951	0·0911
C	0·1 M	6·78× 10	,,	0·0831	0·0550
D	0·05 M	10·7 × 10	,,	0·0587	0·0370
E	0·01 M	31·5 × 10	,,	0·0419	0·0267

Where a and a' are respectively the degrees of dissociation before and after the addition of NaCl and X and X′ are the amounts adsorbed of the Hg ion before and after the addition of NaCl.

Discussion of the Results

Generally the adsorption of non-electrolytes and weak electrolytes is apolar, but in the case of $HgCl_2$, which is a very weak electrolyte, we find that although it is not very strongly adsorbed, its adsorption is polar. From the results obtained it can be seen that there is a preferential adsorption of Cl ions by these adsorbents and in moderately concentrated solutions the adsorption of $HgCl_2$ is found to be polar, *i.e.*, Hg and Cl ions are not adsorbed in equivalent amounts. However, as the concentration of $HgCl_2$ decreases, the adsorption tends to be apolar and between the concentrations of 0·01 M and 0·05 M, the adsorption is apolar. In the case of $Al(OH)_3$ there is no adsorption of $HgCl_2$ at all.

In the adsorption of solutions of electrolytes the electrical charge on the particles of adsorbents plays an important part. It is well known that the adsorbent tends to take up that ion which bears a contrary charge to itself. In the present case the charge on the particles was determined by the cataphoretic experiments and adsorbents used were of three types: (1) Acticarbon—neutral, (2) Silica gel—negatively charged and (3) ferric hydroxide—positively charged. In the adsorption of $HgCl_2$ by all these adsorbents there is a preferential adsorption of Cl ions the amount of which varies according to the charge on the particles and hence also the concentrations at which the adsorption tends to be apolar. In dilute condition the adsorption of $HgCl_2$ obeys Freundlich's isotherm $\frac{x}{m} = kc^{\frac{1}{n}}$, but the temperature has very slight effect on the adsorption, as can be seen in the case of acticarbon.

On the addition of NaCl which is a strong and highly dissociated electrolyte, to the $HgCl_2$ solution the Cl ion concentration is increased and therefore the dissociation of $HgCl_2$ is arrested to a great extent. Mercuric chloride undergoes extremely little ionization when dissolved. Now when NaCl is added to the $HgCl_2$ solution, it dissociates into Na^+ and Cl^- ions, the Hg ion in presence of excess Cl ions may form complex anions such as $HgCl_3$ ($HgCl_2 + Cl^- \rightarrow HgCl^-{}_3$) or $HgCl_4$ ($HgCl_2 + 2Cl^- \rightarrow HgCl^-{}_4$). From the results obtained, this theory of complex ion formation is supported because it can be seen that the adsorption of Hg ion is decreased to a certain extent and this must be due to the formation of complex ions of mercury which are less adsorbed than Hg ions. So the adsorption of $HgCl_2$ is decreased by the presence of NaCl and this is noteworthy since the poisoning effect of the mercuric chloride is lowered to a corresponding degree by this chloride.

The results of the adsorption of $HgCl_2$ in other solvents will be published later.

Summary

The adsorption of the $HgCl_2$ of different concentrations by colloids such as dry gels of ferric hydroxide, silica gel, aluminium hydroxide and acticarbon was investigated in order to study the nature of the adsorption of $HgCl_2$. It is found that at dilute concentrations of $HgCl_2$ the adsorption tends to be apolar, while at higher concentrations the adsorption is polar. The addition of a strong electrolyte such as sodium chloride retards the adsorption of $HgCl_2$ due to the formation of complex anions of mercury.