

CHAPTER IV  
EXCHANGE CAPACITY

Base exchange capacities as determined by different methods:

The experimental details have been described in Chapter III.

(a) Base exchange capacities have been determined by the standard methods (161a), (73) by saturating the systems with 1(N) BaCl<sub>2</sub> and half saturated HCl and evaluating the acid liberated by potentiometric titration and also by indicator-method, using a suitable indicator, and Ba(OH)<sub>2</sub> and KOH as the respective bases. Determinations have also been carried out using the alkyl quaternary ammonium ion (CH<sub>3</sub>)<sub>4</sub><sup>n</sup>N<sup>+</sup> to saturate and subsequently titrating the material with tetra-methyl ammonium hydroxide. Tris-ethylene diamine cobalt (III) chloride was also used as a neutral salt to saturate the systems, and the liberated acids were titrated conductometrically using Ba(OH)<sub>2</sub> as the base. For bentonite, silica gel and aluminium hydroxide, the above experiments have also been repeated in 50% ethanol medium, to observe the effect of a solvent having lower dielectric constant on the exchange capacity. The titrants were all solutions in 50% ethanol.

Spectrophotometric methods were also utilized for the determination of b.e.c. Cationic dyes such as methylene blue, crystal violet and malachite green were adsorbed on the exchangers and adsorption isotherms were plotted from which the maximum exchange was determined. The results are presented in Table 4-1 .

The base exchange capacity was also determined potentiometrically, details of which may be found in Chapter VII, Section C. The b.e.c. data are presented in Table 4-3 .

It is observed that the exchange capacities of all the three exchangers in 50% ethanol are appreciably smaller than in pure water.

TABLE 4.1

Base exchange capacities of bentonite, silica gel and  $Al(OH)_3$  in m.e./100 g  
at 20°C.

Exchanger	Iron adsorption isotherm of 21	Half satd. KCl/KOH method	1(N)BaCl <sub>2</sub> / Ba(OH) <sub>2</sub> method	1(N) TMA-Cl TMA-OH method	1(N) Caen <sub>3</sub> Cl <sub>2</sub> / Ba(OH) <sub>2</sub>	Spectro- * photometric method
Bentonite	111	96	95	92	96	111 (MB)
		<u>72</u>	<u>76</u>	<u>74</u>	<u>72</u>	109 (CV)
						110 (MG)
Silica Gel	13.0	14.26	15.0	15.65	15.3	14.0 (MB) 15.1 (CV)
		10.60	11.0	10.69	10.71	13.9 (MG)
$Al(OH)_3$	6.31	6.13	5.92	6.52	6.05	6.60 (MB) 6.34 (CV)
		<u>4.12</u>	<u>3.91</u>	<u>4.22</u>	<u>4.14</u>	6.54 (MG)

\*(M.B) Methylene blue; (M.G) Malachite green;

(C.V) Crystal Violet.

values in 50% EtOH.

TABLE 4.2

Base exchange capacity values in m.e./100 g., determined polarographically for bentonite, silica gel and  $Al(OH)_3$ .

Exchanger	Saturating electrolyte	Supporting Electrolyte	Base Exchange capacity m.e./100 g
Bentonite	$HCl$	0.075 (N) $HCl$	112.6
	$HClO_4$	0.075 (N) $HClO_4$	108.9
	$HClO_4$	Without	108.0
	$HCl$	"	110.4
	$Coen_3Cl_3$	0.075 (N) $HCl$	103.4
Silica Gel	$HCl$	0.075 (N) $HCl$	13.20
	$HClO_4$	0.075 (N) $HClO_4$	15.60
	$Coen_3Cl_3$	0.075 (N) $HCl$	15.56
$Al(OH)_3$	$HCl$	0.075 (N) $HCl$	6.30
	$HClO_4$	0.075 (N) $HClO_4$	6.81
	$Coen_3Cl_3$	0.075 (N) $HCl$	6.96

TABLE 4.3

Data from the titration curves of  $Al(OH)_3$  with weak bases.

Concentration of base	m.e./100 g base corresponding to first, second and third inflection points vis. (i), (ii) and (iii).		
	Hydrated Alumina (A)	$Al(OH)_3$ (B)	$Al(OH)_3$ (C)
Ethyl amine  $5.1 \times 10^{-3}$ (N)	(i) 1.17	(i) 3.16	(i) 3.16
	(ii) 2.49	(ii) 7.91	(ii) 7.91
	(iii) 5.41		
n-hexyl amine:  $3.5 \times 10^{-3}$ (N)	(i) 0.89		
	(ii) 1.79		
	(iii) 5.01		
$6.0 \times 10^{-3}$ (N)		(i) 2.44	(i) 2.44
		(ii) 7.61	(ii) 7.61
Trimethyl amine:  $3.5 \times 10^{-3}$ (N)	(i) 0.80		
	(ii) 1.60		
	(iii) 5.29		
Tetra-methyl am. hydroxide:  $4.1 \times 10^{-3}$ (N)	(i) 1.03		
	(ii) 2.10		
	(iii) 4.76		

This may be explained in the following way. The exchangers in H-form behave as weak acids. A decrease in the dielectric constant of the medium hinders the dissociation of the H ions bound with the exchanger matrix. On some exchangers, especially silica gel and  $Al(OH)_3$  (pp 4,5) some of the surface hydroxyls are known to be hydrogen bonded. A decrease in the dielectric constant of the medium certainly strengthens the hydrogen bonds, whereby total exchange of the surface H in the OH groups is not possible. Similar results were also obtained by Ganguli (73).

(b) Polarographic method:

Details of the experimental procedure have been described in Chapter III, pp 42-45. In essence, the method deals with the current-voltage curves of the electroactive ions which are incorporated in the colloids. The presence of exchangers in the polarographic medium makes the work unique, quite in contrast to the conventional methods where true solutions are used. Upon plotting the limiting current of the suspension against the concentration of the electro-active species in the suspension, a curve is obtained with a point of inflexion which is found to give the base exchange capacity. The curve is linear on either side of the point of inflexion, and is shown in Figs. 1-4. The b.e.c values determined for the three exchangers bentonite, silica gel and aluminium hydroxide are presented in Table 4.2. The electro-active species used to saturate the exchangers in the experiments are  $H^+$  and  $Co(NH_3)_3^{3+}$  ions. The adsorption and desorption of the latter on Pyrex glass and clay minerals have been studied by Chakravarti et al (44), (53), (50), while studies on the former appear in Chpts V and VI, of the present thesis.

The method is based upon the direct measurement of the limiting

TABLE 4.4

Diffusion currents and viscosity data of bentonite-TlCl system,  
in 0.075(M) LiCl.

Colloid concentration = 0.025 (g/100 ml)

Concentration of Tl in suspension (M) $\times 10^3$	$i_d$ in true solution ( $\mu$ amp)	$i_d$ in suspension ( $\mu$ amp)	Viscosity of suspension (milli poise)	$i_d/c$ $\times 10^{-4}$
1.83	0.119	0.113	9.23	0.59
3.77	0.158	0.138	9.41	0.42
5.66	0.262	0.241	9.50	0.42
7.55	0.335	0.318	9.59	0.42
9.45	0.445	0.395	9.62	0.42
12.51	0.593	0.521	9.71	0.42
14.93	0.705	0.618	9.76	0.41
18.57	0.890	0.773	10.50	0.41
22.62	1.064	0.926	9.77	0.41
24.57	1.150	1.034	9.76	0.42
26.43	1.249	1.133	9.63	0.43
23.61	1.344	1.260	9.66	0.43

TABLE 4.5

Diffusion currents and viscosity data of silica Gel-TiCl<sub>4</sub> system, in 0.075 (N) TiCl<sub>4</sub>.

Colloid concentration = 0.16% (g/100 ml)

Concentration of Ti in suspension (N) $\times 10^5$	$i_d$ in true solution ( $\mu$ amp)	$i_d$ in suspension ( $\mu$ amp)	Viscosity of suspension (milli poise)	$i_d/c \times 10^{-4}$
3.46	0.120	0.101	3.62	0.41
4.93	0.233	0.200	3.64	0.41
7.40	0.350	0.298	3.66	0.40
9.87	0.452	0.394	3.63	0.40
12.33	0.578	0.494	3.70	0.40
14.80	0.695	0.590	3.71	0.40
19.73	0.926	0.703	3.74	0.40
24.66	1.160	1.060	3.75	0.42
29.60	1.391	1.350	3.76	0.44
32.06	1.508	1.424	3.77	0.46
34.57	1.626	1.621	3.77	0.46
36.99	1.778	1.770	3.77	0.47

TABLE 4.6

Diffusion currents and viscosity data of  $\text{Al}(\text{OH})_3\text{-HCl}$  system  
in 0.075 (M)  $\text{LiCl}$ .

Colloid concentration = 0.175 (g/100 ml)

Concentration of $\text{Al}$ in suspension (M) $\times 10^5$	$i_d$ in true solution ( $\mu\text{amp}$ )	$i_d$ in suspension ( $\mu\text{amp}$ )	Viscosity of suspension (milli poise)	$i_d/c$ $\times 10^{-4}$
1.49	0.074	0.057	8.43	0.33
3.17	0.156	0.122	8.45	0.38
4.83	0.237	0.186	8.47	0.38
6.33	0.308	0.244	8.49	0.39
7.44	0.364	0.287	8.52	0.39
9.53	0.463	0.367	8.54	0.39
12.66	0.616	0.530	8.56	0.41
15.82	0.772	0.725	8.57	0.45
18.99	0.937	0.915	8.58	0.47



TABLE 4.7

Diffusion currents and viscosity data of bentonite- $\text{Coen}_3\text{Cl}_3$  system in 0.075 (M) LiCl.

Colloid concentration = 0.03% (g/100 ml)

Concentration of $\text{Coen}_3^3$ in suspension (M) $\times 10^5$	$i_d$ in true solution ( $\mu$ amp)	$i_d$ in suspension ( $\mu$ amp)	Viscosity of suspension (milli poise)	$i_d/c \times 10^{-3}$
2.50	...	0.006	9.26	...
3.75	0.084	0.007	9.41	0.77
11.75	0.113	0.071	9.50	0.60
14.75	0.139	0.072	9.59	0.43
17.50	0.167	0.077	9.62	0.44
25.50	0.225	0.081	9.71	0.34
29.25	0.260	0.082	9.76	0.21
35.25	0.333	0.171	10.50	0.53
33.0	0.365	0.247	9.77	0.65
41.25	0.399	0.341	9.76	0.82
43.75	0.422	0.412	9.69	0.94

TABLE 4.8

Diffusion currents and viscosity data of silica Gel-Coen<sub>3</sub>Cl<sub>3</sub> system in 0.075(N) HCl.

Colloid concentration of suspension = 0.16 % (g/100 ml)

Concentration of Coen <sub>3</sub> S in suspension (M) × 10 <sup>5</sup>	<i>i<sub>d</sub></i> in true solution (μ amp)	<i>i<sub>d</sub></i> in suspension (μ amp)	Viscosity of suspension (milli poise)	<i>i<sub>d</sub></i> /c × 10 <sup>-3</sup>
5.0	0.049	0.024	6.58	0.48
7.33	0.075	0.045	8.65	0.61
9.79	0.093	0.063	8.63	0.62
12.30	0.120	0.087	8.71	0.70
14.70	0.137	0.107	8.82	0.72
19.60	0.182	0.150	8.98	0.76
27.10	0.260	0.253	8.70	0.95
29.41	0.322	0.320	8.59	1.03

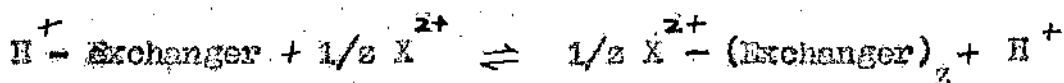
TABLE 4.9

Diffusion currents and viscosity data of  $\text{Al}(\text{OH})_3\text{-Coen}_3\text{Cl}_3$  system in 0.075(N) HCl.

Colloid concentration = 0.26% (g/100 ml)

Concentration of $\text{Coen}_3^3$ in suspension, (N) $\times 10^5$	$i_d$ in true solution ( $\mu$ amp)	$i_d$ in suspension ( $\mu$ amp)	Viscosity of suspension (milli poise)	$i_d/c \times 10^{-5}$
3.25	0.032	0.033	8.51	2.71
4.70	0.046	0.036	8.57	2.04
6.26	0.059	0.106	8.61	1.70
7.61	0.073	0.116	8.63	1.52
9.40	0.090	0.125	8.65	1.35
12.40	0.117	0.140	8.69	1.12
15.90	0.131	0.134	8.73	0.97
20.60	0.193	0.207	8.76	1.00
21.30	0.209	0.224	8.71	1.02
23.00	0.220	0.240	8.70	1.04

current of a suspension, where the wave is due to the reduction of the electro-active species added to the suspension. As the exchangers have the property of binding cations under suitable conditions, part of the added cations are incorporated into the solid matrix, due to ion-exchange as shown below:



(where  $X^{2+} = Tl^+$  or  $Coen_3^{3+}$ )

The ion-exchange characteristics of Tl on bentonite, silica gel and aluminium hydroxide have been described in details in Chpts. V and VI. The results of the polarographic work are discussed in the following paragraphs in terms of the limiting currents, the diffusion coefficients, role of the supporting electrolyte, viscosity of the suspension and double layer interactions.

#### Limiting currents:

The general features of the C-V curves are in keeping with the characteristics of the electro-active species present in the suspension. Characteristic maxima appear which are efficiently suppressed by Triton-K-100. The limiting currents for the Tl systems appear to be diffusion controlled when supporting electrolyte is used. The  $i_d/c$  values appear to be constant (Cf. Tables 4.4 - 4.6). For suspensions of  $Coen_3^{3+}$  - systems, however, the  $i_d/c$  values are not constant, indicating that diffusion does not control the limiting current. The  $i_d/c$  values for bentonite and aluminium hydroxide systems (Cf. Tables 4.7-4.9) decrease upto the equivalence point, while for silica gel it increases. In the bentonite system, there is considerable aggregation upon adding  $Coen_3^{3+}$  and the supporting electrolyte. This is clearly visible to

the eye. Thus the current obtained is mainly due to the free  $\text{Coen}_3^{3+}$  in solution phase. In the case of aluminium hydroxide, the first wave is probably an adsorption wave, as the current in the suspension is higher than the current in true solution corresponding to same concentration of electro-active ions and  $E_{1/2}$  is shifted in the +ve direction. In the TI systems limiting current of suspensions are, found to be appreciably smaller than that corresponding to a true solution of similar concentration of the same electro-active species. This depression of the limiting current ( $\Delta i_d$ ) may be explained in terms of (a) increased viscosity of the system due to presence of the macromolecular particles, and also electro-viscous effect, (b) the decrease of the diffusion coefficients of the electro-active species in the suspension when interaction of electro-active ion with substrate occurs, and (c) the interaction of the double layer associated with the mercury drop and that associated with the charged colloid particles.

It should be pointed out here that the limiting current of the centrifugate of the suspensions is found to be smaller than that of the suspension (Cf. Table 4.10 ). This implies that in the suspension the limiting current observed is due to the reduction of not only the free  $\text{K}^{2+}$  ions in solution phase, but also due to the reduction of the ions which are adsorbed on the exchanger surface. The macro-particles are also apparently diffusion controlled. A finer distinction between free and adsorbed reducible ions, in regard to their mode of approach to the cathode is not possible on the basis of our data. However, for the macro-particles the limiting current might be partly convection controlled, as the limiting current is very sensitive to the speed of stirring of the suspension. Corresponding to high speeds, the limiting current is not at all reproducible. It increases greatly with greater

TABLE 4.10

Limiting currents (after residual corrections) for bentonite- $\text{TiClO}_4$  suspension and its centrifugate containing different amounts of  $\text{TiClO}_4$ .

Supporting electrolyte — 0.075 M  $\text{LiClO}_4$

Concentration of Ti in suspension m. e. $\times 10^3$	Limiting current of suspension ( $\mu$ amp)	Limiting current of centrifugate ( $\mu$ amp)
1.836	0.052	0.035
5.47	0.086	0.059
8.205	0.139	0.122
9.82	0.170	0.147
13.675	0.203	0.198
15.945	0.249	0.225
18.69	0.293	0.254
21.405	0.410	0.340
24.14	0.435	0.354
25.96	0.466	0.401
28.695	0.527	0.491
34.43	0.624	0.543

speed of stirring.

The departure of viscometric properties of dilute suspensions from ideal conditions, as predicted by Einstein has been discussed in considerable detail by Marshall (162). No attempt is made to summarise these here. However, it should be pointed out that the contributions of Weigner, Mitra, Mukherjee and Chakravarti (162), (15), (43) were found to be helpful in the context of the present investigation. In the present case,  $Tl^+$  and  $Coen_3^{3+}$  ions respectively replace the  $H^+$  on the exchanger surface. Both of them have a different hydration status than the  $H^+$ . Moreover, since  $LiCl$  is used as a supporting electrolyte there is always present an excess of  $Li$  ions in the system. The position of  $Li$  ion is very low in the normal lyotropic series viz.,  $Li^+ < Na^+ < K^+ < Rb^+ < Cs^+$ , but as it is present in a concentration appreciably greater than that of  $Tl^+$  or  $Coen_3^{3+}$ , some amount of the electro-active ions are desorbed by the  $Li$  ions. Moreover, where  $Tl^+$  or  $Coen_3^{3+}$  concentrations are very low, the  $Li$  ions will also exchange with the  $H$  of the  $H-X$ -exchanger system. The  $Li$  ion is known to be a highly hydrated one, and therefore its contribution towards the viscometric properties must be appreciable (15).

The diffusion coefficients ( $D$ ) of the electro-active species in the suspension have been calculated from Ilkovic equation using the observed diffusion currents and measured values of 'm' and 't' where 'm' is mass of mercury which flows per second and 't' is the drop time in seconds. The results are shown in Fig. 5 as a function of the concentration of the electro-active ion in the suspension. The  $D$  values obtained are the overall resultant values for  $Tl$  ions in the solution phase and the  $Tl$ -exchanger complex in suspension. The calculated  $D$  values are found to be appreciably smaller than those for the

corresponding ion under identical conditions in true solution. A greater deviation of the observed values from the values in true solution indicates greater interaction of the electro-active ions with the exchanger matrix. Movement of the macro-particles with the electro-active ion on // it, to the electrode surface is obviously a relatively difficult process as compared to the free electro-active ion in true solution. As it // appears from the Fig. 5<sup>5</sup> the values of diffusion coefficients are almost steady upto an electrolyte concentration corresponding to the exchange capacity, and thereafter increase sharply. This also corresponds to a sharp increase in the limiting current. Tables 4-4-4-9 show the viscosity data as a function of the concentration of the electro-active ion in suspension. The viscosity gradually increases with increasing concentration of electro-active ion, but corresponding to a concentration equivalent to the b.e.c. the viscosity becomes steady // for  $P1^{+}$  and decreases for  $Coen_3^{5+}$  systems. It may be mentioned here that the not change in the viscosity of the systems are however small. The above data may be understood if we remember the inherent relationship of diffusion with viscosity (136).

#### Role of supporting electrolytes

Polarograms of suspension containing electro-active ions, when recorded without using any supporting electrolyte, show high limiting currents. This is due to the occurrence of migration currents. The plot of limiting current vs. concentration of electrolyte added shows linearity with a point of inflexion; the concentration of the added electro- // lyte at this point corresponds to the b.e.c. of the exchanger Fig. (1-4). // It is apparent from Figs. 1-4 that the features of the curves are better in absence of the supporting electrolyte rather than when



it is present. LiCl and LiClO<sub>4</sub> are the two supporting electrolytes used in the present investigation. The concentration of the Li ions in the suspension are kept 20 to 30 times greater than that of the electro-active ion in the system. In spite of the greater hydration and resulting poor affinity for the exchanger, the higher concentration of Li<sup>+</sup> enables it to exchange a part of the electro-active ions from the exchanger. In this way more electro-active ions X<sup>Z+</sup> are set free in the solution phase, thus increasing the diffusion current and decreasing the  $i_{dc}$ . This causes the inflexion point to be less sharp.

causes

The amount of electro-active ion desorbed by the supporting electrolyte has been determined by centrifugation of the suspension and polarographic estimation of the amount in the solution phase. It is found that for all the three exchangers (where X = Tl) about 50-75% of the ions initially held by the exchanger is desorbed. For Coen<sup>3+</sup> systems desorption is less than 20%.

The effect of supporting electrolyte on the systems has been studied in details by the determination of several characteristic parameters such as the diffusion coefficient (D), the diffusion current constant (I), the limiting currents, half wave potentials (E<sub>1/2</sub>) etc., corresponding to various concentrations of supporting electrolyte and electro-active ion in the suspension. Table 4.11 shows such values for the bentonite- TlClO<sub>4</sub> system where LiClO<sub>4</sub> is the supporting electrolyte. It is seen that when no supporting electrolyte is used, the limiting current is appreciably high due to the presence of migration currents. With increase in the concentration of the supporting electrolyte the limiting currents gradually increase, as more and more of the Tl ions come into the solution phase, due to desorption by Li<sup>+</sup>. It is

TABLE 4.11

Polarographic data on bentonite- $\text{TiClO}_4$  system.

Supporting electrolyte-  $\text{LiClO}_4$  of different concentrations.

Concentration of $\text{LiClO}_4$ (M) $\times 10^3$	$E_{1/2}$ Volts	Diffusion current ( $\mu$ amp)	$m^{2/3} t^{1/6}$	Diffusion Coefficient (D) $\times 10^6$ $\text{cm}^2/\text{Sec}$	Diffusion current constant (I)
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Concentration of  $\text{Ti}^+$  in suspension =  $0.71 \times 10^{-5}$  n.e.

0	-0.62				
3.65	-0.52	0.22	2.94	3.46	1.13
7.31	-0.49	0.28	3.08	4.33	1.35
10.9	-0.49	0.32	3.07	7.43	1.71
17.4	-0.49	0.33	3.09	9.43	1.87
20.0	-0.49	0.43	3.19	11.49	2.06
31.0	-0.49	0.45	3.17	12.83	2.15
64.0	-0.485	0.46	3.20	13.91	2.27
75.0	-0.485	0.47	3.30	11.02	2.12

Concentration of  $\text{Ti}^+$  in suspension =  $1.41 \times 10^{-5}$  ml.eq.

0	-0.65				
3.65	-0.515	0.62	3.14	5.90	1.43
7.31	-0.505	0.55	3.23	6.06	1.49
13.20	-0.500	0.64	3.94	9.36	1.66

(Contd)

Concentration of $\text{LiClO}_4$ (M) $\times 10^3$	$E_1$ Volts	Diffusion current ( $\mu\text{ amp}$ )	$i^2/3t^{1/2}$	Diffusion Coefficient (D) $\times 10^6$ $\text{cm}^2/\text{sec}$	Diffusion current constant (I)
27.4	-0.49	1.58	3.03	10.36	1.86
40.0	-0.49	1.75	3.18	11.49	2.06
51.0	-0.49	1.84	3.14	15.10	2.20
75.0	-0.49	1.79	3.25	11.89	2.04

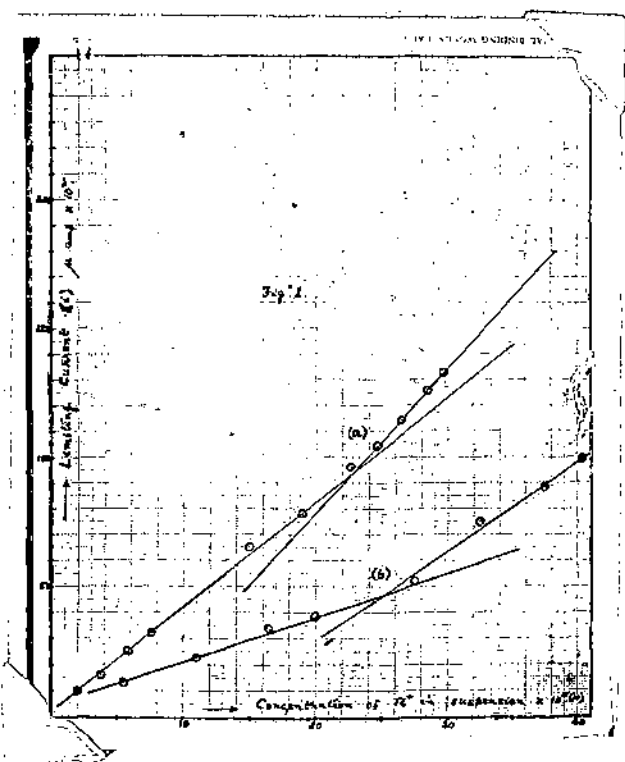
Concentration of  $\text{Pb}^{2+}$  in suspension =  $3.303 \times 10^{-3}$  ml. eq.

0	-0.6	...	...	...	...
5.65	-0.50	1.80	3.32	7.62	1.88
7.31	-0.50	1.88	3.14	8.76	1.80
18.2	-0.495	1.81	3.12	8.76	1.80
27.4	-0.495	1.84	3.15	8.89	1.81
40.0	-0.495	2.15	3.25	11.69	2.03
51.0	-0.495	2.09	3.27	11.92	2.04
64.0	-0.49	2.22	3.30	11.83	2.09

desirable for the present investigation to have a minimum concentration of the supporting electrolyte in order that the desorption may be small. Though a concentration of 0.075(M) has been used in the present series of experiments, Table 4. // shows that a concentration of 0.05(M) of the supporting electrolyte is adequate for the purpose.

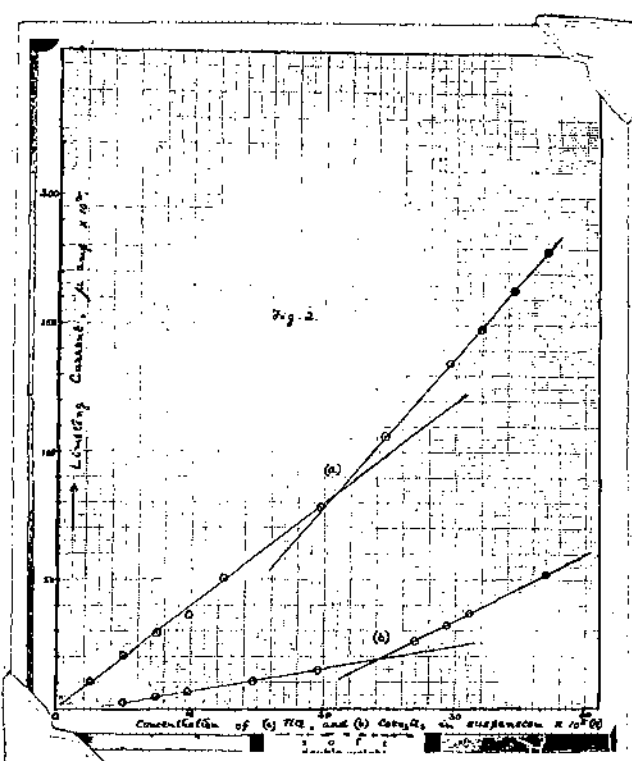
The values of the diffusion coefficients and the diffusion current constants (I) (Cf. Table 4. // ) show that with increase in the concentration of the supporting electrolyte these values increase rapidly upto a supporting electrolyte concentration of 0.05(M) and progressively tend to attain a limiting value. The limiting current also behaves similarly. Compared to the corresponding values of  $Tl$  in true solution under identical conditions of experiment the  $D$  and  $I$  values are much smaller. This diminution of the values is partly due to the increased viscosity of the system due to presence of the colloidal particles, and partly due to the slow diffusion of the macro-particle associated with the  $Tl$  ion. Absolute values of the diffusion coefficient cannot be determined unless a supporting electrolyte is found which will not desorb the electro-active species from the solid matrix. However, indications are strong for the reduction of  $Tl^+$  from the solid-matrix, at the d.m.e.

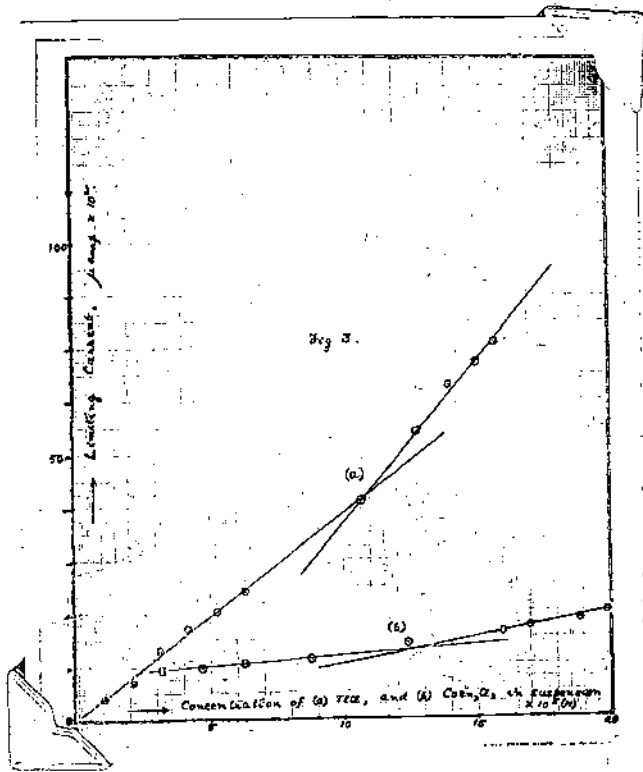
The polarographic method described above, may be yet far off from attaining the status of a "standard method" of determining exchange capacities. Certain problems in connection with the experiment must be solved and certain observations must be clearly understood by further work in the line, before a fuller understanding and interpretation of the results may be achieved.



Bentonite - LiCl (a) and  
 bentonite - LiClO<sub>4</sub> (b) in 0.075%  
 LiCl and 0.075% LiClO<sub>4</sub> respectively.

silica gel - LiCl (a)  
 and silica gel - Coen<sub>2</sub>Cl<sub>2</sub>  
 (b) in 0.075% LiCl.

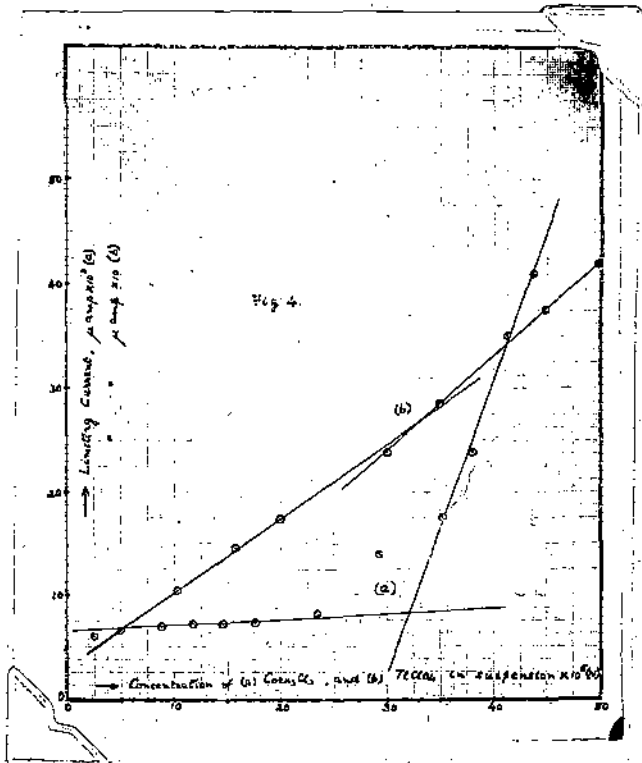


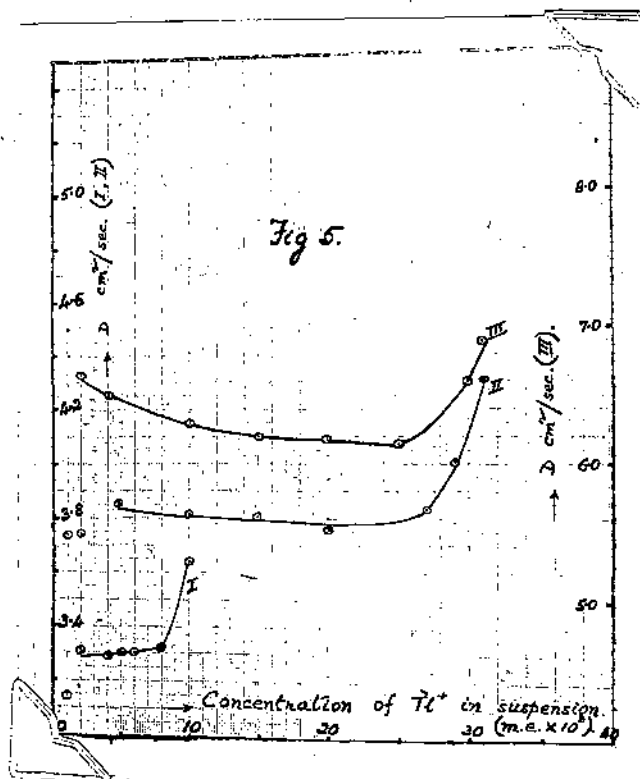


Aluminium hydroxide -  $\text{TlCl}$   
 (a) and aluminium hydroxide  
 -  $\text{Coen}_3\text{Cl}_3$  in 0.075 (M)  $\text{LiCl}$ .

(a) Bentonite -  $\text{Coen}_3\text{Cl}_3$  in  
 0.075 (M)  $\text{LiCl}$ .

(b) Bentonite -  $\text{TlClO}_4$  without  
 supporting electrolyte.





Diffusion coefficients of exchanger-TlCl in suspension. supporting electrolyte - 0.075 (M) LiCl.

I  $\rightarrow$  Aluminium hydroxide - TlCl.

II  $\rightarrow$  Silica gel - TlCl.

III  $\rightarrow$  Bentonite - TlCl.