

CHAPTER - III

III Phenol - Epichlorohydrin - Tetraethylenepentamine  
Type Chelating Amphoteric Ion Exchange Resins

EXPERIMENTAL

III (a) Synthesis of Chelating Amphoteric ion-  
exchange resins:

Chelating amphoteric ion exchange resins are synthesised from epichlorohydrin, various phenolic derivatives and tetraethylenepentamine by the method described in I - (a).

III (b) Moisture content of resins:

Moisture content of these resins ( $H^+$  form and  $OH^-$  form) was determined as described in I - (b).

The values of % moisture content of these resins ( $H^+$  form and  $OH^-$  form) are presented in Table - TP - 37.

III - (c) Density of resins:

(i) True density ( $d_{res}$ ), (ii) Apparent density ( $d_{col}$ ) and (iii) void volume fraction of these resins ( $H^+$  form and  $OH^-$  form) were determined as described in I - (c) (i); (ii) and (iii).

The values of  $d_{res}$  and  $d_{col}$  of these resins ( $H^+$  form and  $OH^-$  form) are presented in Table - TP-38.

The values of void volume fraction of these resins ( $H^+$  form and  $OH^-$  form) are presented in Table - TP - 39.

III - (d) (i) Total ion exchange capacity and  
(ii) Concentration of ionogenic groups:

Total ion exchange capacity ( $H^+$  form and  $OH^-$  form) was determined as described in I - (d) (i).

Concentration of ionogenic groups and volume capacity of these resins ( $H^+$  form and  $OH^-$  form) were determined as described in I - (d) (ii).

The values of total ion exchange capacity, concentration of ionogenic groups and volume capacity of these resins as cation exchanger as well as anion exchanger are presented in Table - TP - 40 and Table - TP - 41 respectively.

III - (e) Metal (Cu) exchange capacity:

Metal (Cu) exchange capacity of these resins ( $H^+$  form) was determined by following the procedure described in I - (e) and the values are presented in Table - TP - 40.

III - (f) Rate of exchange:

Rate of exchange of these resins ( $H^+$  form and  $OH^-$  form) were determined as described in I - (f).

The values of the capacities of these resins were plotted against time and shown in Figs. 19 to 24 and presented in Table - TP - 42.

III - (g) pH-titration studies and apparent  $pK_a$  and  $pK_b$  values:

pH titration studies and apparent  $pK_a$  and  $pK_b$  values of these resins were determined as described in I - (g).

The values of the capacities of the resin were plotted against the pH of the solution and shown in Fig. 25 to 27.

The apparent  $pK_a$  and  $pK_b$  values for these resins are presented in Table - TP - 43.

III - (h) Thermal Stability:

Thermal stability of these resins as cation exchanger in free acid form and in salt form such as sodium form was determined as described in I - (h). The results are presented in Table - TP - 44.

Thermal stability of these resins as anion exchanger in free base form and in salt form such as chloride form was determined as described in I - (h). The results are presented in Table - TP - 45.

III - (i) Effect of the temperature of equilibration on the capacity of the resin:

The study of the effect of varying equilibration temperature of the capacity of the resins ( $H^+$  form and  $OH^-$  form) was carried out according to the method described in I - (i). The results are presented in Table - TP - 46.

III - (j) Oxidation resistance test:

Oxidation resistance test of these resins in free acid free base form was carried out as

described in I - (j). The results are presented in Table - TP - 47 and Table - TP - 48 respectively.

III - (k) Swelling behaviour:

Swelling behaviour of these resins ( $H^+$  form and  $OH^-$  form) in various solvents was studied as described in I - (k).

The results are presented in Table - TP - 49 and Table - TP - 50 respectively.

III - (l) Sorption behaviour of some metal bivalent cations on cationic form ( $NH_4^+$  form) of the amphoteric resins from ammonium acetate - dimethylformamide media:

A sorption study was carried out following the procedure as described in I - (l) and the results of  $K_d$  values are presented in Table - TP - 51.

III - (m) Column Chromatography:

Before the chromatographic separations, the resin bed was prepared by making a slurry of the resin in  $NH_4OAc$  (0.25 M) - DMF [40%, v/v] <sup>and</sup> transferred to the graduated column. The resin bed thus prepared was pretreated with 0.25 M  $NH_4OAc$  solution.

Phenol - Epichlorohydrin - Tetraethylenepentamine  
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RESULTS AND DISCUSSION.

General:

We have synthesized chelating amphoteric ion exchangers from the various phenolic derivatives, epichlorohydrin and tetraethylenepentamine. The phenolic derivatives employed for synthesising the resins possess the following structural characteristics.

- (1) Two phenolic groups in ortho or para positions on a phenyl ring,
- (2) one phenolic group and one ring nitrogen,
- (3) one phenolic group and one carboxylic group in ortho position on a phenyl ring,
- (4) one phenolic group in ortho position to carboxylic group but in meta position to sulfonic group on a phenyl ring,
- (5) one phenolic group and one carboxylic group in ortho position on a naphthalene ring,

- (6) one phenolic group and one carboxylic group in para position on a phenyl ring,
- (7) two phenolic groups in meta positions and one carboxyl group in ortho position on a phenyl ring, and
- (8) one amino group and one carboxyl group on a phenyl ring.

#### Gelling and Curing:

The formation of the resin is characterised by the gel point. Gel point or gel period is related to branching ability and hence to the functionality of the monomer involved in condensation (146). If the condensing monomers exhibit functionality of two, a linear chain would result. If the condensing monomers exhibit the functionality greater than two, branching may be obtained and gelation will take place. Greater the functionality (f) exhibited by the monomers, shorter can be the period of gelation. Curing involves the thermosetting of gel. In the series under investigation, gelling time and curing period for all the resins are same, hence we suggest that gelling time and curing period are directly related to phenolic compounds' functionality only.

General Characteristics and Structures:

Generally the chelating exchangers are fairly porous in nature with average physical stability and good chemical resistance to 3 N acids and alkalis and show a change of colour when converted from the free acid or free base form to its corresponding salt (Na- or Cl-) form or vice versa.

In the present investigation, the polymers were obtained by the polycondensation under mild reaction and curing conditions, cross linking is possible by formation of  $-CH_2-$  linkages. On the basis of analytical data and other physico-chemical studies, we have few generalizations, viz.,

- (i) hydroquinone, salicylic acid, sulfosalicylic acid and  $\beta$ -resorcylic acid get condensed with tetraethylenepentamine in the molar ratio of 1 : 1,
- (ii) catechol and p-hydroxybenzoic acid get condensed with tetraethylenepentamine in molar ratio of 2 : 1,
- (iii) anthranilic acid gets condensed with tetraethylene- $\text{C}$  pentamine in molar ratio of 3 : 1.

The most probable structures of these resins on the basis of analytical data and physico-chemical studies are presented in Figs. I-S-36 to Figs. I-S-42.

Moisture retention %

It is known that the degree of cross linking is inversely proportional to the moisture content. Moisture content of the resins under investigation (Table - TP - 37) is found to be ranging from 3.01 to 11.16 for H - form and 3.50 to 14.26 for OH - form. This suggests that the amphoteric resins have a high degree of cross linking.

Density of resins:

(i) True density ( $d_{res}$ ):

The data obtained for the density ( $d_{res}$ ) of the resins in H - form and OH - form are presented in Table - TP - 38. The values vary from 1.15 to 1.88 for H - form and 0.98 to 1.76 for OH - form. With some exceptions, we observed in general that, in the case of resins under study,  $d_{res}$  for H - form is slightly higher than that for OH - form.

(ii) Apparent density ( $d_{col}$ ):

We have also evaluated the apparent (column) density ( $d_{col}$ ) of the amphoteric resins (Table - TP -38).

The values are ranging from 0.14 to 0.30 for H - form and 0.11 to 0.27 for OH - form. Known values (130) of apparent density for commercial resins in H - form are 0.69 for IRC-50/75 and 0.74 for IRC-84. Thus the resins under study have low range of density ( $d_{col}$ ) for H - form.

The column density for the commercial resins are 0.74 for IRA-68 [weak base  $-N(R)_2$ ], 0.67 for IR-45 [weak base  $-N(R)_2$ ,  $-NH(R)_2$ ,  $-NH_2$ ] and 0.64 for IRA-93 [ $-N(R)_2$  weak base] in OH-form. Thus the OH-form of the resins have values lower than that of similar type of commercial resins.

#### Void volume of resins:

The values of void volume of resins are presented in Table - TP - 39. It is observed that the values of void volume fraction vary between 0.78 to 0.89 for cationic form and 0.65 to 0.93 for anionic form of the amphoteric resins. Further, we observed that the void volume fraction of anionic form of the resin is higher than that of cationic form. We suggest that as the resins have a large void volume fraction, the diffusion of ions and hence the rate of ion exchange may be facilitated. The large void volume fraction suggests the porous nature of the resins.

Ion exchange capacity:

The cation or anion exchange capacity of the amphoteric resins can be calculated using the formula described on page.60 .

The observed capacity  $CEC_{obs}$  (cation exchanger) or  $AEC_{obs}$  (anion exchanger) can be compared with the calculated capacity  $CEC_{cal}$  or  $AEC_{cal}$  as reported in Table - TP - 40 and Table - TP - 41 respectively.

Three ranges exist,

- (1) value of  $CEC_{obs}/CEC_{cal}$  is approximately close to 1.
- (2) values of  $CEC_{obs}/CEC_{cal}$  is close to 1/2, low values ( $\sim 1/2$ ) of the ratio may be attributed to only one phenolic group, (in such resins) involved in ion exchange,
- (3) value of  $CEC_{obs}/CEC_{cal}$  is high ( $\sim 3/2$ ). High values ( $\sim 3/2$ ) of the ratio may be attributed to the contribution of weakly acidic amide group in such resins.

The observed capacity  $AEC_{obs}$  can be compared with  $AEC_{cal}$  as presented in Table - TP - 41.

The results (Table - TP - 40 and Table - TP - 41) reveal that the total anion exchange capacity of amphoteric resins is quite higher than the total cation exchange capacity.

Amphoteric resins as cation exchanger show the following decreasing order for cation exchange capacity.

$$\begin{aligned} \text{EP(SA)TP} &> \text{EP(SS)TP} > \text{EP(HQ)TP} \cong \\ \text{EP(BR)TP} &> \text{EP(CA)TP} > \text{EP(PHB)TP} > \\ \text{EP(8-OH)TP} &> \text{EP(3-OH)TP} > \text{EP(AN)TP}. \end{aligned}$$

Amphoteric resins as anion exchanger show the following decreasing order for anion exchange capacity.

$$\begin{aligned} \text{EP(SA)TP} &> \text{EP(HQ)TP} > \text{EP(SS)TP} > \\ \text{EP(BR)TP} &> \text{EP(PHB)TP} > \text{EP(8-OH)TP} > \\ \text{EP(3-OH)TP} &> \text{EP(CA)TP} > \text{EP(AN)TP}. \end{aligned}$$

Total anion exchange capacity of the resins EP(SA)TP (9.80 meq/gm), EP(HQ)TP (8.10 meq/gm) and EP(BR)TP (7.24 meq/gm) is comparable with that of commercial anion exchangers.

#### Concentration of ionogenic groups:

The data regarding the concentration of ionogenic groups are presented in Table - TP - 40 and Table - TP - 41.

for cationic as well as anionic form of amphoteric resins respectively. Excluding few exceptions, the total exchange capacity is related to the concentration of ionogenic groups. Higher the exchange capacity, higher is the concentration of ionogenic groups. The increase in concentration of ionogenic groups may be due to higher concentration of epichlorohydrin.

Metal (Cu) exchange capacity:

Results of copper ion exchange capacity of these resins (H-form) are presented in Table - TP - 40. It is observed that the copper ion exchange capacity of these resins ranges between 0.45 to 3.34 meq/gm.

The decreasing order for the copper ion exchange capacity of these resins was observed as,

$$\begin{array}{l} \text{EP(SA) TP} > \text{EP(SS) TP} > \text{EP(HQ) TP} > \\ \text{EP(BR) TP} > \text{EP(8-OH) TP} > \text{EP(CA) TP} > \\ \text{EP(3-OH) TP} > \text{EP(PHB) TP} > \text{EP(AN) TP.} \end{array}$$

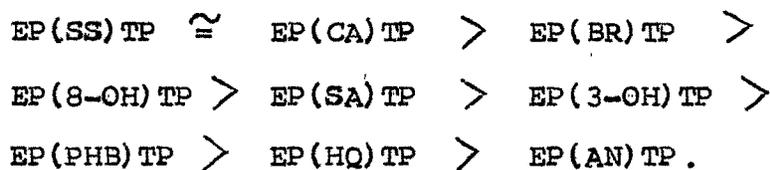
Rate of exchange:

Figs.19 to 24 represent the rate of cation exchange as well as anion exchange of amphoteric resins.

A perusal of the trends of the rate of exchange for amphoteric resins as cation exchanger as well as anion exchanger <sup>reveals that the rate</sup> is very fast.

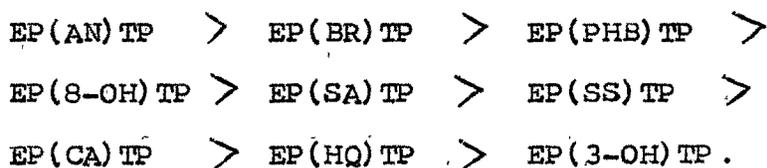
In the case of amphoteric resins as cation exchanger, it is observed that,

- (i) complete exchange occurs in 120 minutes,
- (ii) the rate of exchange for these resins is in the following decreasing order:



In the case of amphoteric resins as anion exchanger, it is observed that,

- (i) complete exchange occurs in 120 minutes,
- (ii) the decreasing order for the rate of exchange of these resins is,



It is also observed that the rate of anion exchange is faster than the rate of cation exchange for these amphoteric resins.

pH titrations:

The pH titration curves for the amphoteric resins are presented in Figs. 25 to 27. These resins exhibit good cation and anion exchange capacities over the pH range 1 - 12. It is evident from the Figs. 25 to 27 that the resins are amphoteric in nature. These resins can be used as anion exchanger as well as cation exchanger, depending upon the pH of the solution.

In the pH range 1 - 7, the resins acted as anion exchanger (Figs. 25 to 27) and curves over this range are characteristic of weakly basic resin and may be compared with the pH titration curve of commercially available weakly basic anion exchanger, Tulsion WB (139).

The cation exchange behaviour of these resins reveals the weakly acidic nature of amphoteric ion exchange resins prepared. As a typical cation exchanger does not have much significance as the phenolic hydroxyl groups ionise only at relatively higher pH values.

Apparent  $pK_a$  and  $pK_b$  values:

The apparent  $pK_a$  and  $pK_b$  values of the resins under study were obtained from the pH titration curves and calculations using equations (9) and (14) as described

earlier on pages 66,68 and are reported in Table - TP - 43.

It is seen that the range of  $pK_a$  values obtained for overall cation exchange process, in general, for various ion exchangers studied, is from 10.280 to 11.025 which is slightly higher than that of characteristic of phenolic hydroxyl group, indicating considerably weakly acidic nature of the phenolic hydroxyl group attached to the matrices.

The range of  $pK_b$  values obtained for the overall anion exchange process for these resins is from 2.400 to 3.115 which is a characteristic of bases of weak strength.

The  $pK_a$  values for the resins are in the following decreasing order:

$$\begin{array}{l} \text{EP (PHB) TP} > \text{EP (AN) TP} > \text{EP (BR) TP} > \\ \text{EP (3-OH) TP} > \text{EP (8-OH) TP} > \text{EP (CA) TP} > \\ \text{EP (HQ) TP} > \text{EP (SA) TP} > \text{EP (SS) TP} . \end{array}$$

While the  $pK_b$  values for the resins are in the decreasing order as,

$$\begin{array}{l} \text{EP (BR) TP} > \text{EP (PHB) TP} > \text{EP (AN) TP} > \\ \text{EP (CA) TP} > \text{EP (HQ) TP} > \text{EP (SA) TP} > \\ \text{EP (8-OH) TP} > \text{EP (3-OH) TP} > \text{EP (SS) TP} . \end{array}$$

Isoionic point:

The values of isoionic point ( $i_p$ ) are presented in Table - TP - 43. The values vary in the range of 6.33 to 7.07. The values are in decreasing order as,

$$\begin{array}{l} \text{EP(PHB) TP} > \text{EP(BR) TP} > \text{EP(AN) TP} > \\ \text{EP(CA) TP} > \text{EP(8-OH) TP} > \text{EP(3-OH) TP} > \\ \text{EP(HQ) TP} > \text{EP(SA) TP} > \text{EP(SS) TP}. \end{array}$$
Thermal stability:

The results of thermal stability of amphoteric resins as cation exchanger in free acid form and in sodium form at different temperatures/are presented in Table - TP - 44 and as anion exchanger in free base form and in chloride form at different temperatures/are presented in Table - TP - 45.

It is seen that no change in total capacity for all the forms (H - , Na - , OH - and Cl - forms) of the resins are observed upto 80°C. Hence the amphoteric resins could be safely used upto temperature 80°C. Above this temperature they show increase in capacity when heated resins were regenerated and tested could be due to

- (i) destruction of some of the - CH - bridges,  
 creating more gaps in the matrix thereby facilitating  
 the access of more - NH - groups,
- (ii) removal of the decomposition products which had  
 neutralised the ionogenic groups.

It is seen from the Table - TP-44 and Table - TP-45  
 that,

- (i) the salt forms of the resins are more stable  
 than the free acid or base form,
- (ii) amphoteric resins as anion exchanger is thermally  
 more stable than the amphoteric resins as cation exchanger.

Amphoteric resins as cation exchanger show the  
 following decreasing order of their thermal stability,

EP(SS) TP > EP(CA) TP > EP(3-OH) TP >  
 EP(AN) TP > EP(SA) TP > EP(8-OH) TP >  
 EP(HQ) TP > EP(PHB) TP > EP(BR) TP.

Amphoteric resins as anion exchanger show the  
 following decreasing order for their thermal stability,

EP(CA) TP > EP(SS) TP > EP(8-OH) TP >  
 EP(HQ) TP > EP(AN) TP > EP(3-OH) TP >  
 EP(BR) TP > EP(SA) TP > EP(PHB) TP.

Effect of temperature of equilibration on the capacity of the resin:

The variations of the capacity of various amphoteric resins with the varying equilibration temperature are presented in Table - TP - 46.

It is clear from the data that the anion exchange capacity of the resin increases with the increasing equilibration temperature. This apparent higher value of anion exchange capacity of the resin is due to an additional neutralization of the part of an acid during equilibration by decomposition products such as  $\text{NH}_3$  resulting from tetraethylenepentamine used for the synthesis of resin. While the lowering of cation exchange capacity of the resin with the increasing temperature of equilibration may be due to the loss of ionogenic groups.

Oxidation resistance:

Data on oxidation resistance of different amphoteric ion exchangers as cation exchanger as well as anion exchanger, are presented in Table - TP - 47 and Table - TP - 48 respectively.

It is seen from the Table - TP - 48 that on oxidative degradation, amphoteric resins as anion exchanger show greater increase in percentage water content than the amphoteric resins as cation exchanger. Hence, it is inferred that the cationic form is less susceptible to oxidation than the anionic form.

Amphoteric resins as cation exchanger show the following decreasing order for the stability on oxidative degradation:

$$\begin{array}{l} \text{EP(CA) TP} > \text{EP(BR) TP} > \text{EP(PHB) TP} > \\ \text{EP(3-OH) TP} > \text{EP(SA) TP} > \text{EP(8-OH) TP} > \\ \text{EP(HQ) TP} > \text{EP(AN) TP} > \text{EP(SS) TP}, \end{array}$$

whereas for amphoteric resins as anion exchanger the stability order is,

$$\begin{array}{l} \text{EP(PHB) TP} > \text{EP(HQ) TP} > \text{EP(8-OH) TP} > \\ \text{EP(SA) TP} > \text{EP(AN) TP} > \text{EP(BR) TP} > \\ \text{EP(3-OH) TP} > \text{EP(CA) TP} > \text{EP(SS) TP}. \end{array}$$

#### Swelling behaviour in non aqueous solvents:

The results of behaviour in non aqueous solvents of these resins as cation exchanger and as anion exchanger are reported in Table - TP - 49 and Table - TP - 50 respectively.

It is observed that,

- (i) polar solvents produce more extensive swelling than non-polar hydrocarbons, and the more porous resins swell more than their less porous analogs.
- (ii) In polar solvents, amphoteric resins EP(CA)TP, EP(8-OH)TP, EP(HQ)TP, EP(3-OH)TP and EP(BR)TP as cation exchanger swell more than anionic type and amphoteric resins EP(SA)TP, EP(SS)TP, EP(PHB)TP and EP(AN)TP as anion exchanger swell more than the cationic type.
- (iii) Amphoteric resins EP(CA)TP and EP(SA)TP as anion exchanger swell somewhat more in hydrocarbon (benzene) than do the amphoteric resins as cation exchanger.

The amount of resin-swelling is always an important consideration in designing equipment.

The use of ion exchange resins in such applications as solvent purification and catalysis of organic reaction has directed the attention of investigators.

The decreasing order of porosity for amphoteric resins as cation exchanger is as follows:

EP(SS) TP > EP(SA) TP > EP(3-OH) TP >  
 EP(HQ) TP > EP(CA) TP > EP(BR) TP >  
 EP(AN) TP > EP(8-OH) TP > EP(PHB) TP.

The decreasing order of porosity for anionic form of the resins is,

EP(SS) TP > EP(SA) TP > EP(AN) TP >  
 EP(PHB) TP > EP(3-OH) TP  $\cong$  EP(HQ) TP >  
 EP(CA) TP > EP(8-OH) TP  $\cong$  EP(BR) TP.

Sorption behaviour of some bivalent metal cations on cationic form ( $\text{NH}_4^+$  form) of the amphoteric resins from ammonium acetate - dimethylformamide media:

The values of distribution co-efficients ( $K_d$ ) of the cations are reported in Table-TP-51.

(1) It is seen from the Table-TP-51 that, the sorption of metal ions decreases with the increasing concentration of  $\text{NH}_4\text{OAc}$  [concentration of DMF(v/v) being constant] except for the resins EP(PHB)TP, EP(PHB)TP, and EP(AN)TP. This can be explained as follows:

As the concentration of  $\text{NH}_4\text{OAc}$  is increased, acetate ion replaces the co-ordinating water molecules

resulting in the formation of a small positive charge or neutral metal acetate and consequently  $K_d$  value is lowered.

(2) For the resins EP(PHB)TP, EP(BR)TP and EP(AN)TP, the sorption of metal ion increases with the increasing concentration of  $\text{NH}_4\text{OAc}$  and further decreases as the concentration of  $\text{NH}_4\text{OAc}$  is increased. This can be explained on the basis of the formation of charged species or neutral species.

(3) All the resins under study have shown the highest sorption of Cu(II) at all the molar concentrations of  $\text{NH}_4\text{OAc}$  as compared to the other metal ions. This may be attributed to greater ability of copper to form covalent bond.

(4) The alkaline earth metal ions [Ca(II) and Mg(II)] showed lower sorption.

It is seen from the Table-TP-51 that the carboxylic resins select Cu(II) over Ca(II) as compared to sulfonic acid resins.

(5) On the basis of the data presented in Table-TP-51, we suggest the possibility of ion exchange column chromatographic separations of Cu(II) from Ca(II) and Mg(II) employing EP(SA)TP and EP(SS)TP resins at all the molar concentrations of  $\text{NH}_4\text{OAc}$ .

(6) The chromatographic separations of Ca(II) from Cu(II) at 0.25 M concentration of  $\text{NH}_4\text{OAc}$  employing EP(SS)TP resin ( $\text{NH}_4^+$  - form), Mg (II) from Cu(II) as well as Mg(II) from Ni(II) at 0.25 M concentration of  $\text{NH}_4\text{OAc}$  employing EP(SA)TP resin ( $\text{NH}_4^+$  - form) were successfully achieved. The results are reported in Table-TP-51(A), Table-TP-51(B) and Table-TP-51(C) respectively and presented in Figs. 27 (A), 27(B) and 27(C) respectively.

The following variation of sorption of cations with the concentration of ammonium acetate was observed.

$$\underline{[\text{NH}_4\text{OAc}] = 0.02 \text{ M}}$$

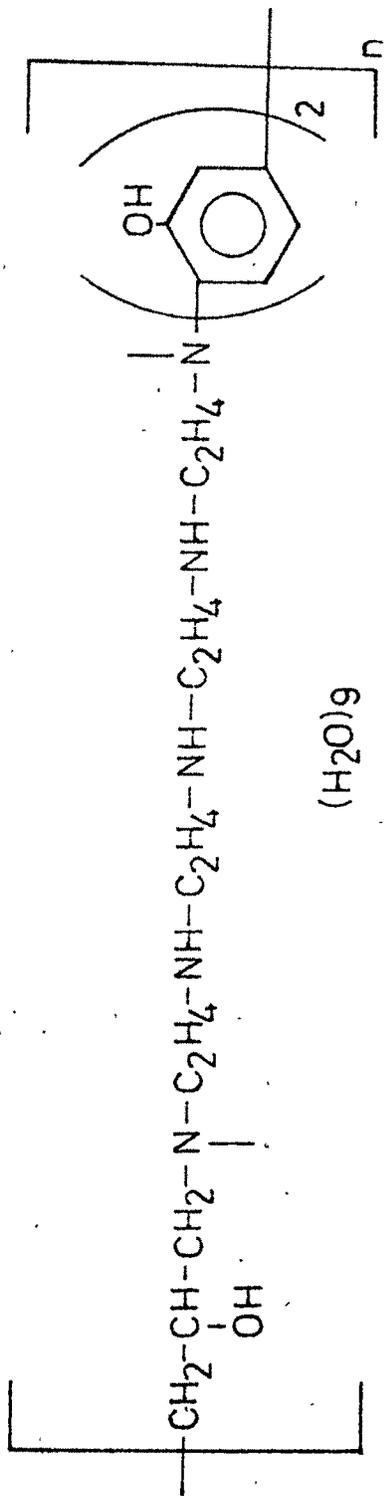
<u>Resin</u>	<u>Sorption Order</u>
EP(CA) TP	Cu > Zn > Ni > Co > Ca > Mg
EP(8-OH) TP	Cu > Zn > Ni > Co > Ca > Mg
EP(HQ) TP	Cu > Zn > Ni > Co > Ca > Mg
EP(SA) TP	Cu > Ni > Zn > Co > Ca > Mg
EP(SS) TP	Cu > Ni > Zn > Co > Ca > Mg
EP(3-OH) TP	Cu > Ni > Co > Zn > Ca > Mg
EP(PHB) TP	Cu > Co > Zn > Ni > Ca > Mg
EP(BR) TP	Cu > Zn > Ni > Ca > Co > Mg
EP(AN) TP	Cu > Ni $\approx$ Zn > Co > Ca > Mg



<u>Resin</u>	<u>Sorption Order</u>										
EP (CA) TP	Cu	>	Ni	>	Co	>	Zn	>	Ca	>	Mg
EP (8-OH) TP	Cu	>	Co	>	Ni	>	Zn	>	Ca	>	Mg
EP (HQ) TP	Cu	>	Ni	>	Co	>	Zn	>	Ca	>	Mg
EP (SA) TP	Cu	>	Ni	>	Zn	>	Co	>	Ca	>	Mg
EP (SS) TP	Cu	>	Ni	>	Zn	>	Co	>	Mg	>	Ca
EP (3-OH) TP	Cu	>	Ni	>	Co	>	Zn	>	Ca	>	Mg
EP (PHB) TP	Cu	>	Co	>	Zn	>	Ca	>	Ni	>	Mg
EP (BR) TP	Cu	>	Zn	>	Ni	>	Co	>	Ca	>	Mg
EP (AN) TP	Cu	>	Zn	>	Ni	>	Co	>	Ca	>	Mg

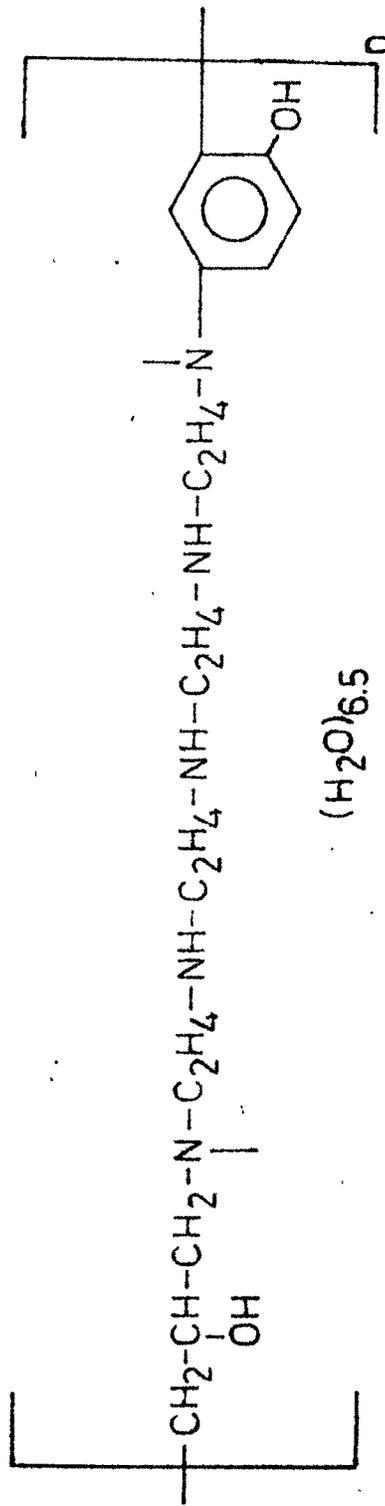


<u>Resin</u>	<u>Sorption Order</u>										
EP (CA) TP	Cu	>	Co	>	Ni	>	Zn	>	Ca	>	Mg
EP (8-OH) TP	Cu	>	Co	>	Ni	>	Zn	>	Ca	>	Mg
EP (HQ) TP	Cu	>	Co	>	Ni	>	Zn	>	Ca	>	Mg
EP (SA) TP	Cu	>	Co	>	Ni	>	Zn	>	Mg	>	Ca
EP (SS) TP	Cu	>	Co	>	Ni	>	Zn	>	Mg	>	Ca
EP (3-OH) TP	Cu	>	Co	>	Ni	>	Zn	>	Ca	>	Mg
EP (PHB) TP	Cu	>	Co	>	Ni	>	Zn	>	Ca	>	Mg
EP (BR) TP	Cu	>	Zn	>	Ni	>	Ca	>	Co	>	Mg
EP (AN) TP	Cu	>	Ni	>	Zn	>	Co	>	Ca	>	Mg



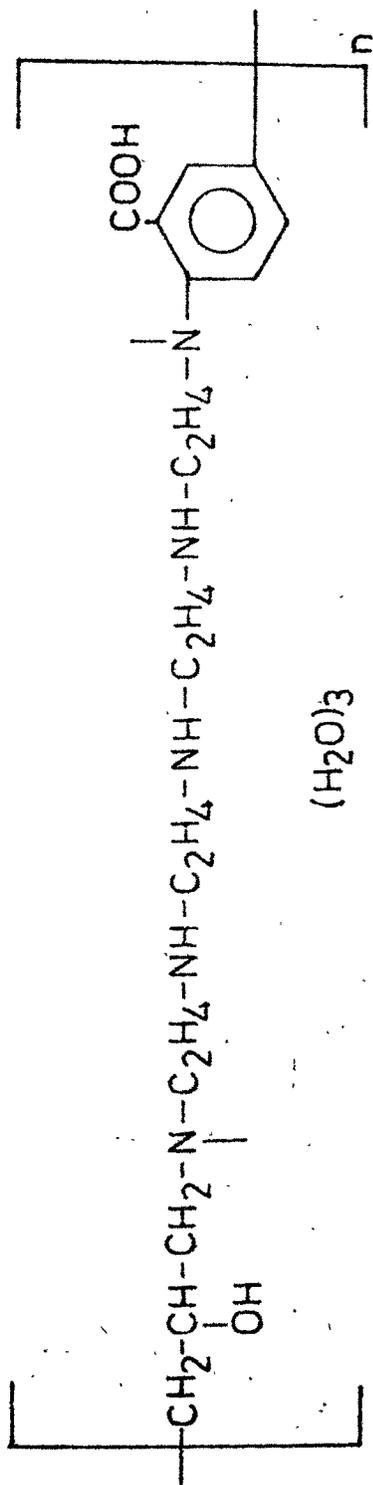
(H<sub>2</sub>O)<sub>9</sub>

EP(CA)TP (I-S-36)



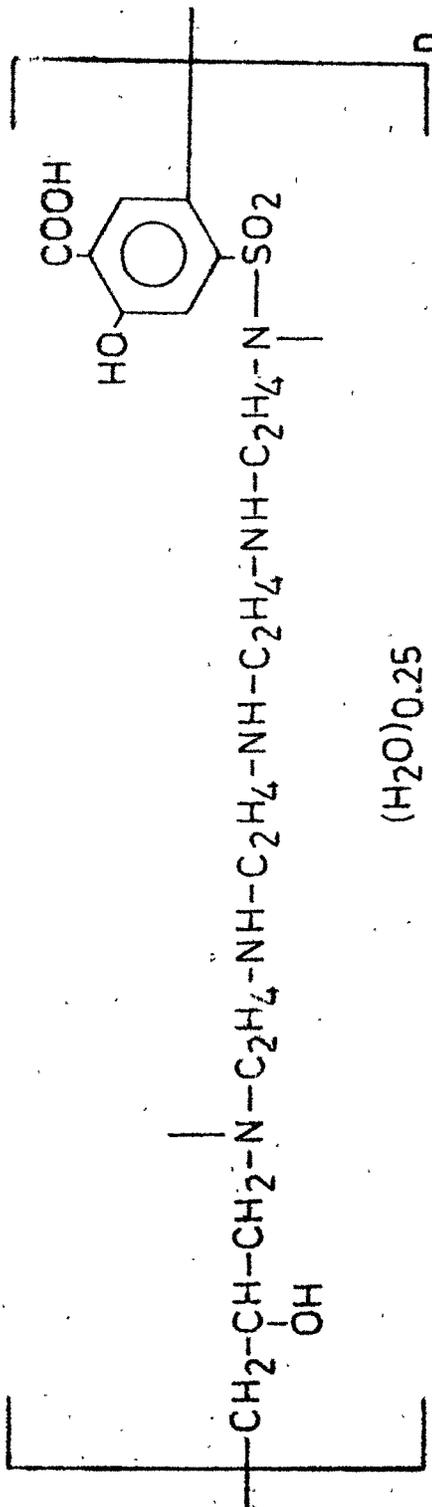
(H<sub>2</sub>O)<sub>6.5</sub>

EP(HQ)TP (I-S-37)



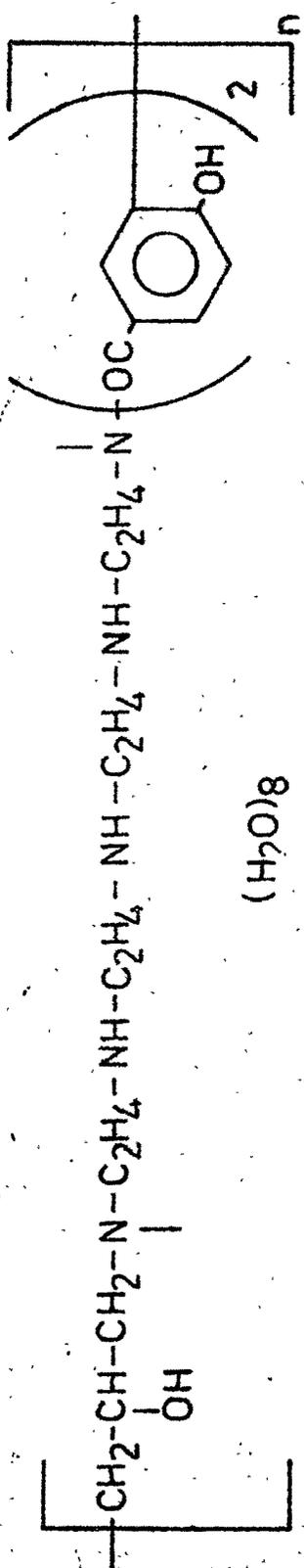
(H<sub>2</sub>O)<sub>3</sub>

EP(SA)TP (I-S-38)



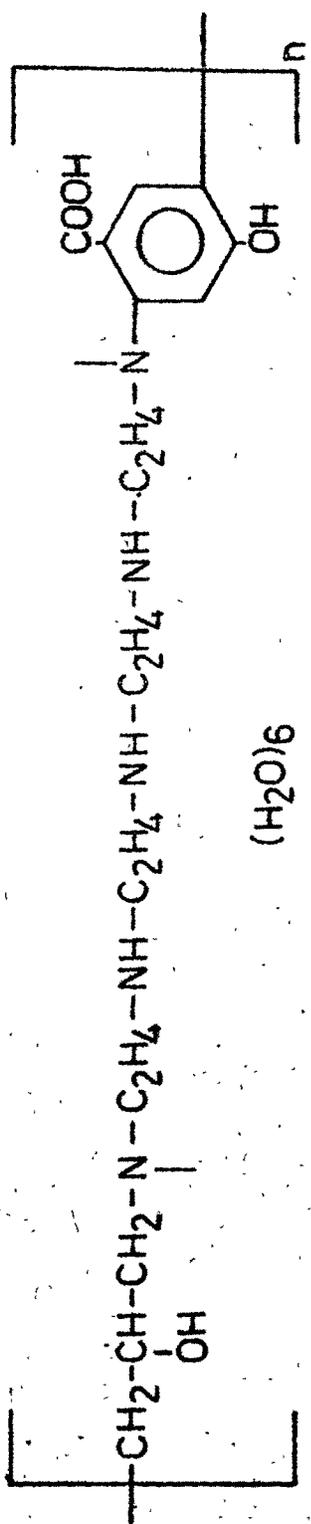
(H<sub>2</sub>O)<sub>0.25</sub>

EP(SS)TP (I-S-39)



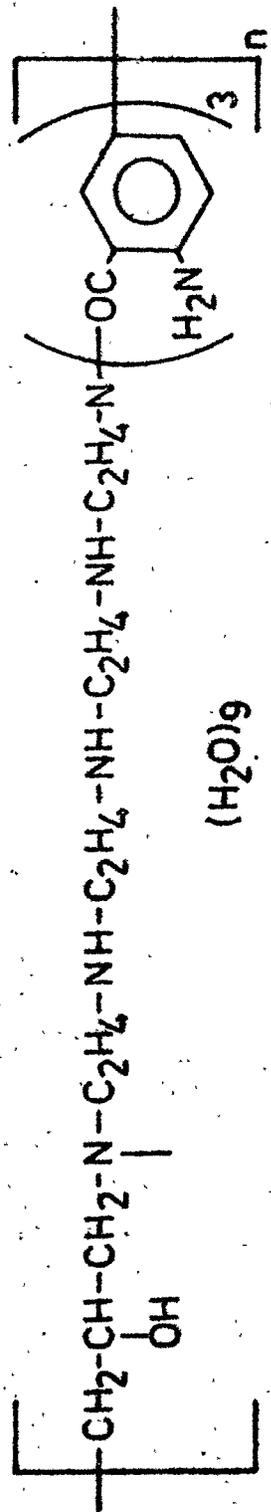
(H<sub>2</sub>O)<sub>8</sub>

EP(PHB)TP (I-S-40)



(H<sub>2</sub>O)<sub>6</sub>

EP(BR)TP (I-S-41)



(H<sub>2</sub>O)<sub>9</sub>

EP(AN)TP (I-S-42)

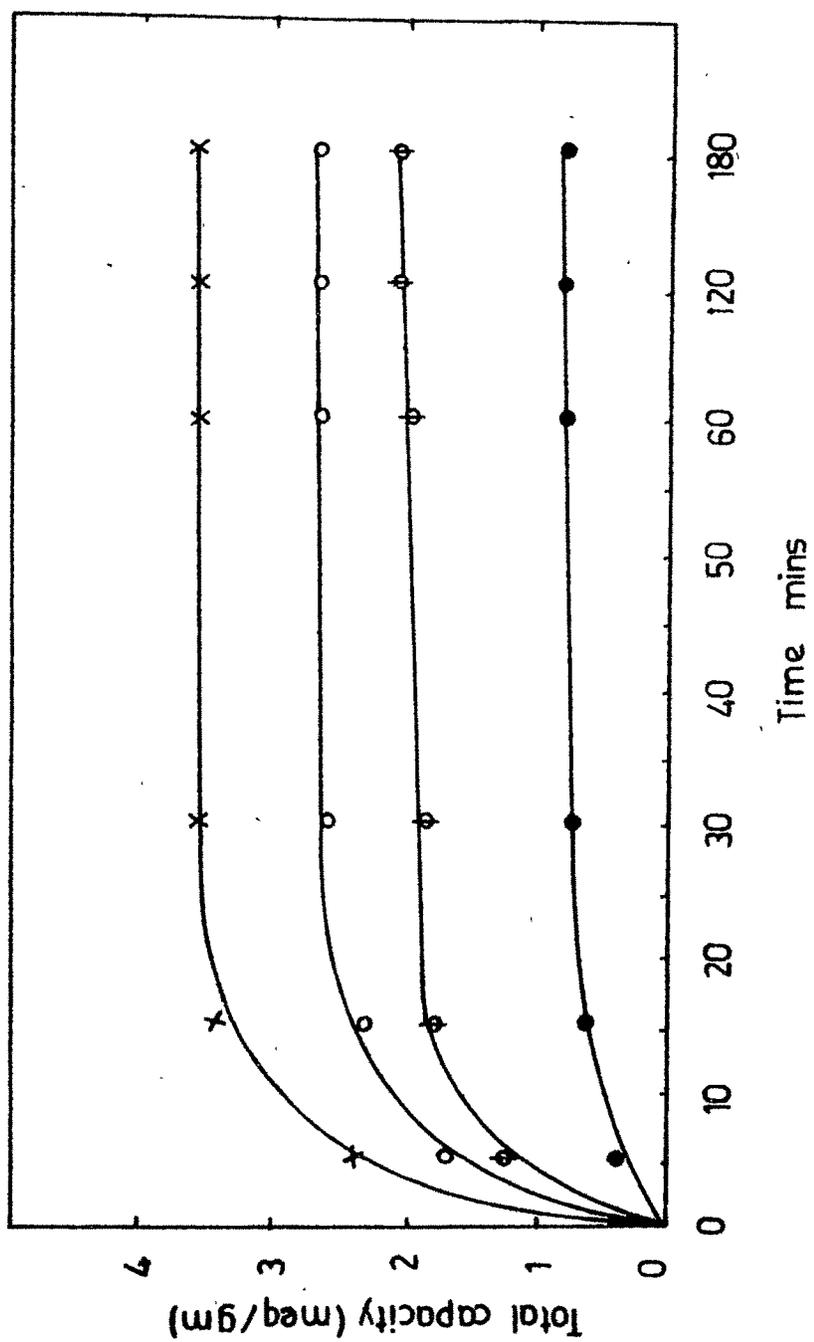


FIG 19 - RATE OF CATION EXCHANGE OF EP(SS)TP [x-x], EP(CA)TP [o-o], EP(3-OH)TP [phi-phi] AND EP(AN)TP [bullet-bullet] RESINS

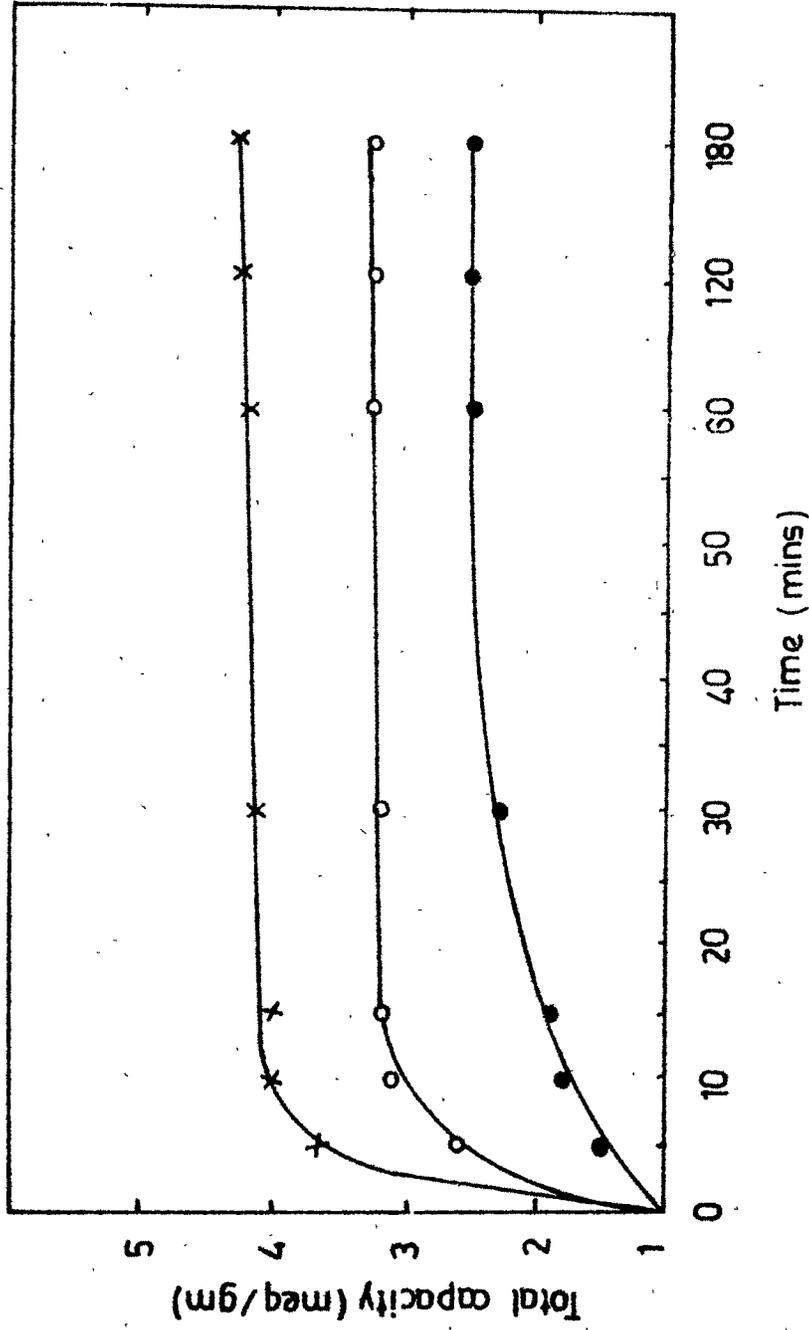


FIG 20 - RATE OF CATION EXCHANGE OF EP(SA)TP [x-x]  
EP(BR)TP [o-o] AND EP(PHB)TP [•-•] RESINS

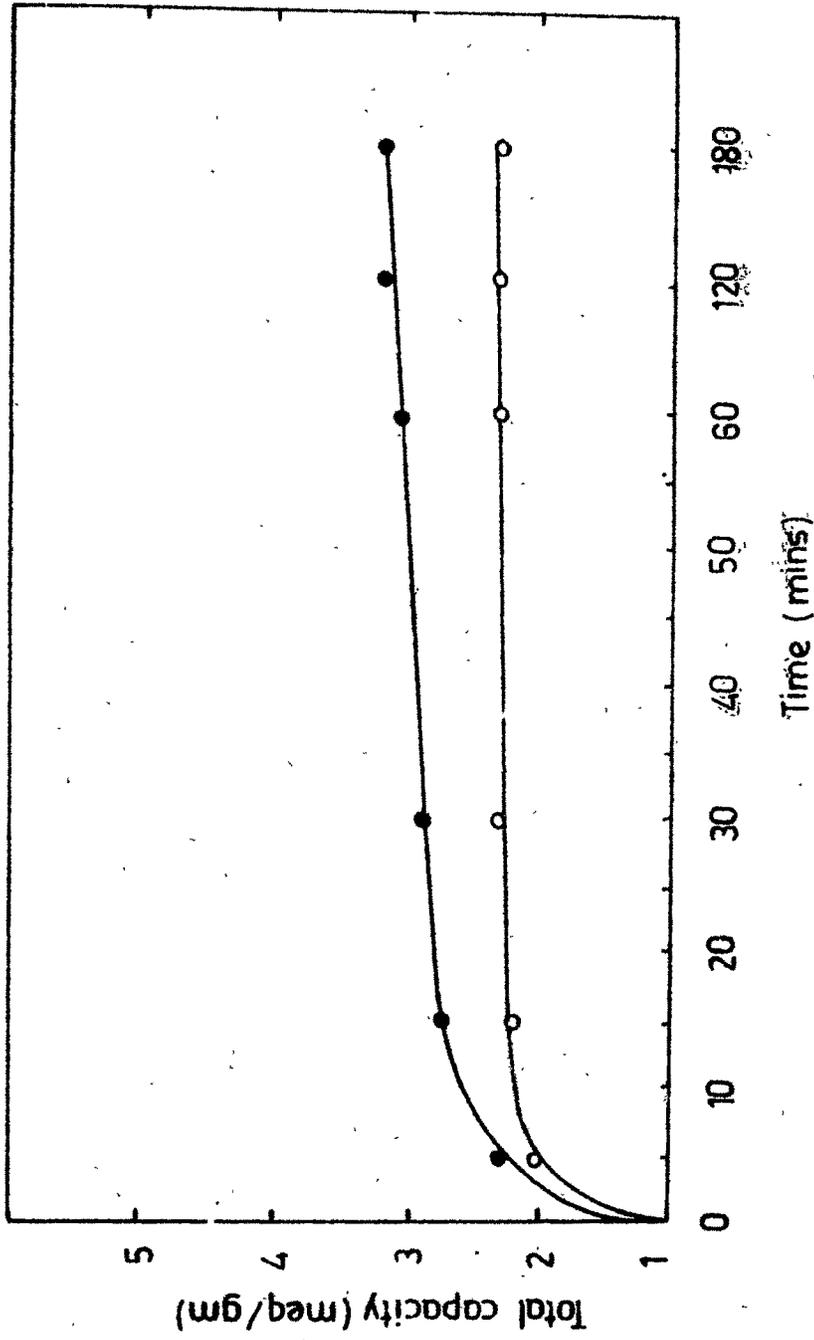


FIG 21 - RATE OF CATION EXCHANGE OF EP(HQ)TP [●-●] AND EP(8OH)TP [○-○] RESINS

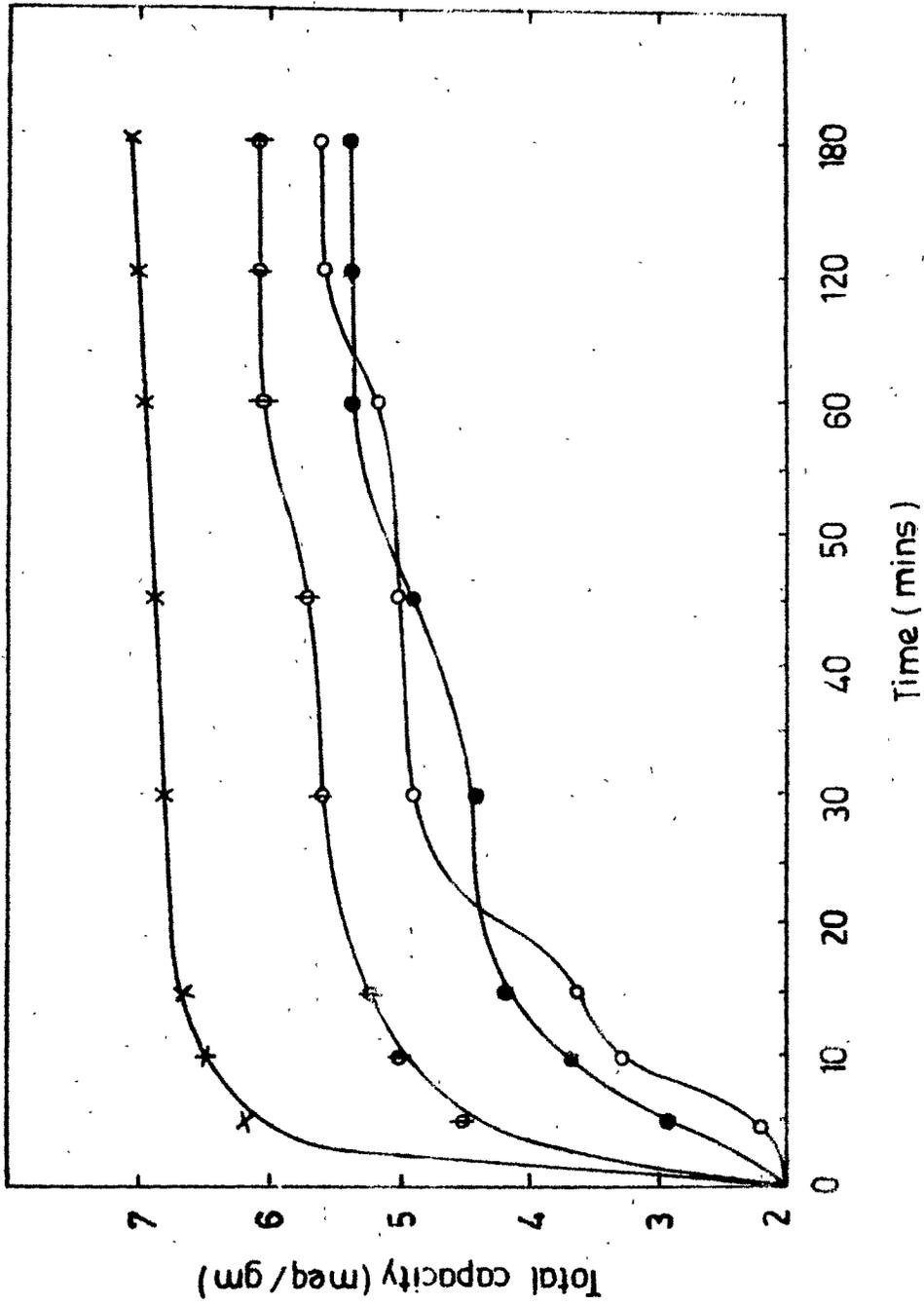


FIG 22 - RATE OF ANION EXCHANGE OF EP(PHB)TP [x—x], EP(8-OH)TP [◊—◊], EP(3-OH)TP [○—○] AND EP(CA)TP [◻—◻] RESINS

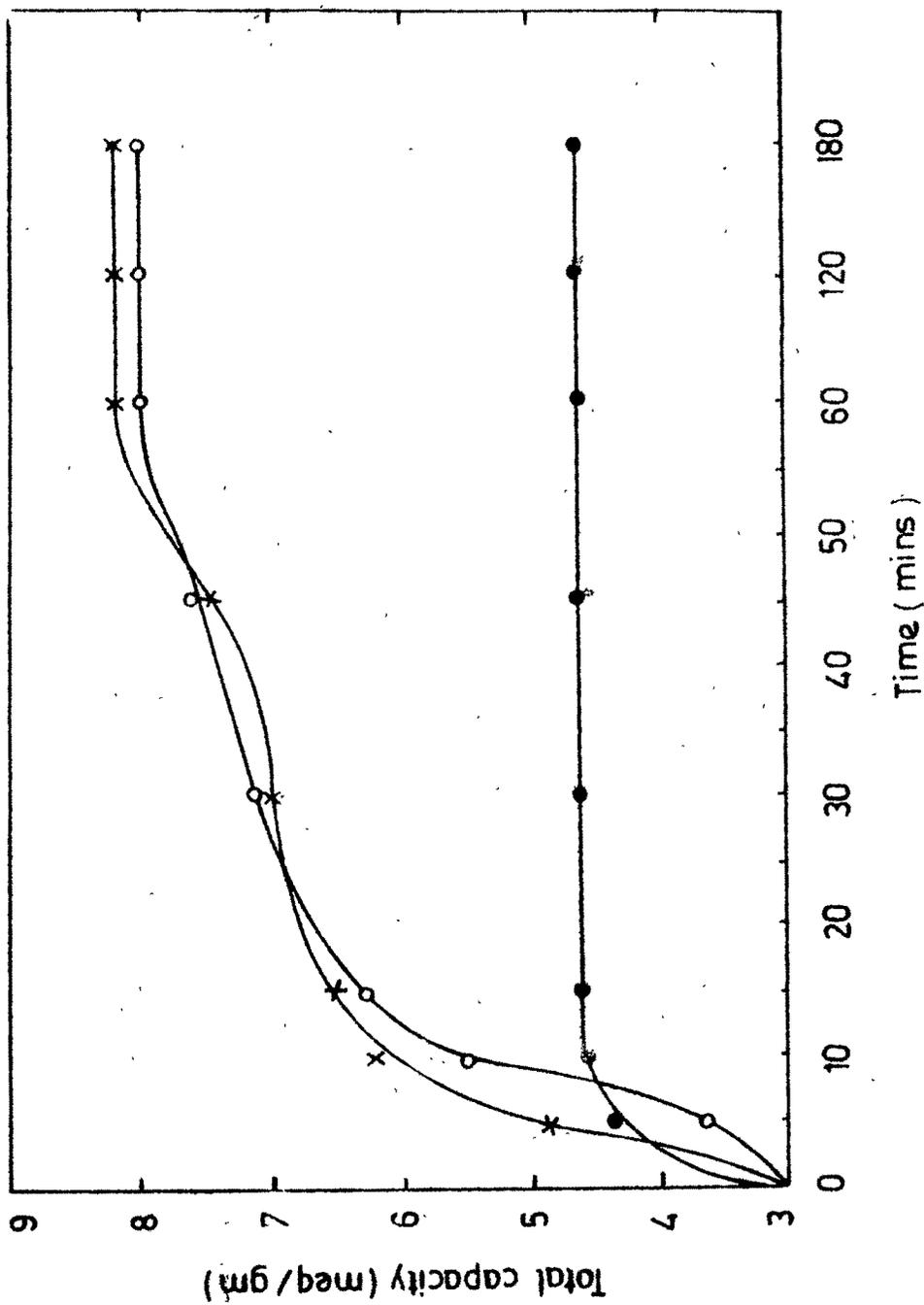


FIG 23 - RATE OF ANION EXCHANGE OF EP(HQ)TP [x-x]  
 EP(SS)TP [o-o] AND EP(AN)TP [•-•] RESINS

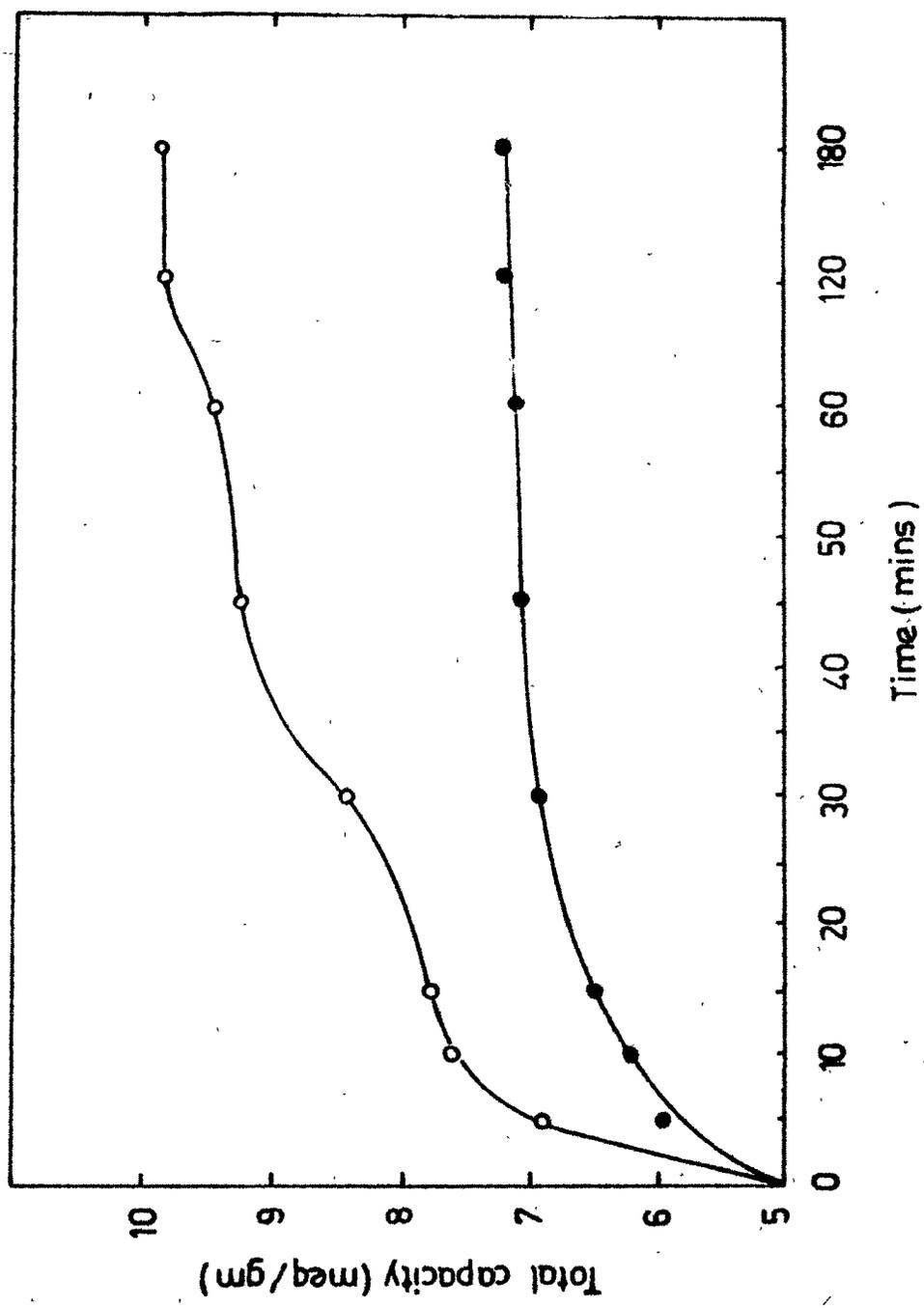


FIG 24 - RATE OF ANION EXCHANGE OF EP(SA)TP [○-○] AND EP(BR)TP [●-●] RESINS

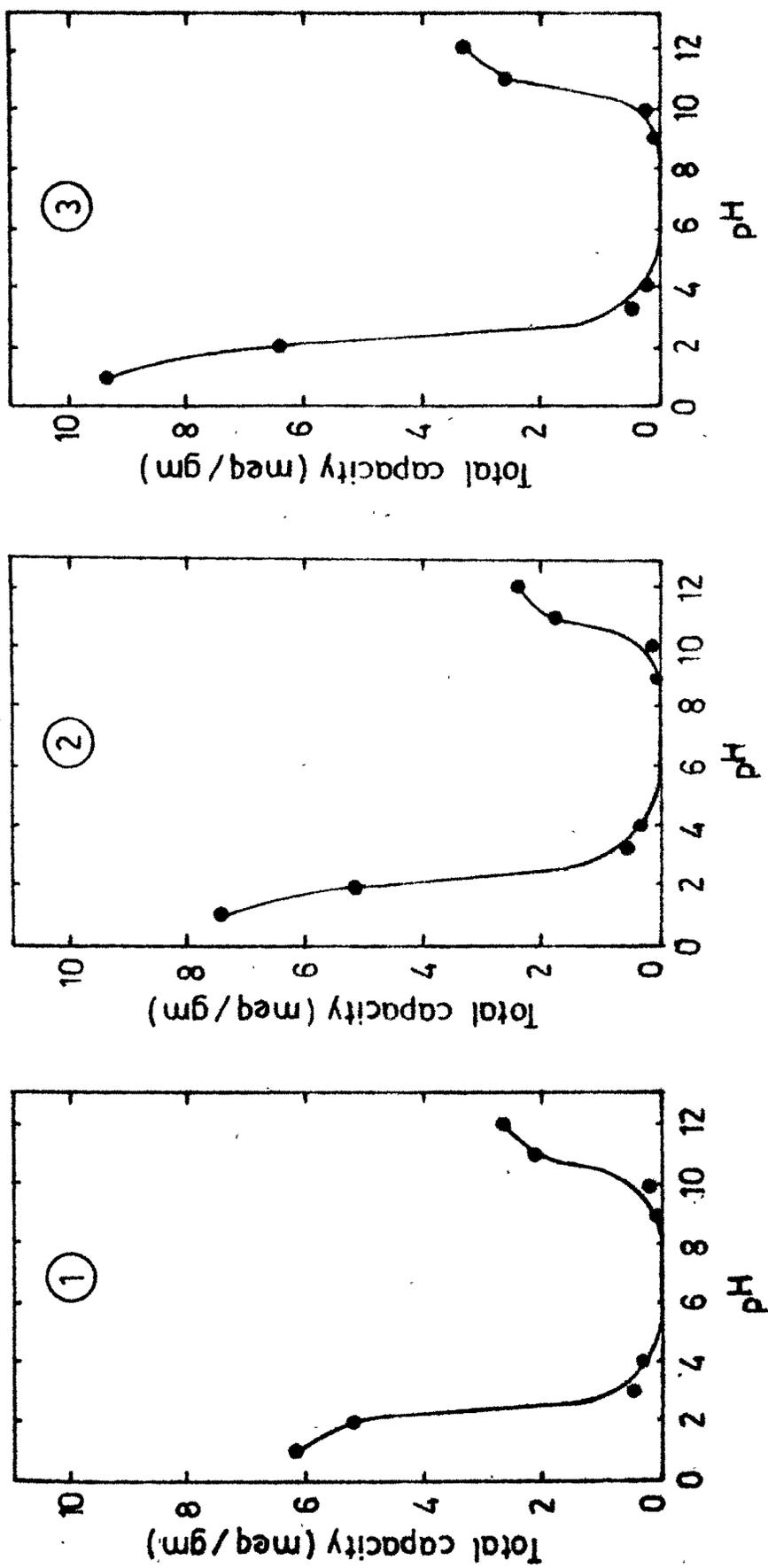


FIG 25 - pH-TITRATION CURVES OF ① EP(CA)TP ② EP(8-OH)TP ③ EP(HQ)TP RESINS

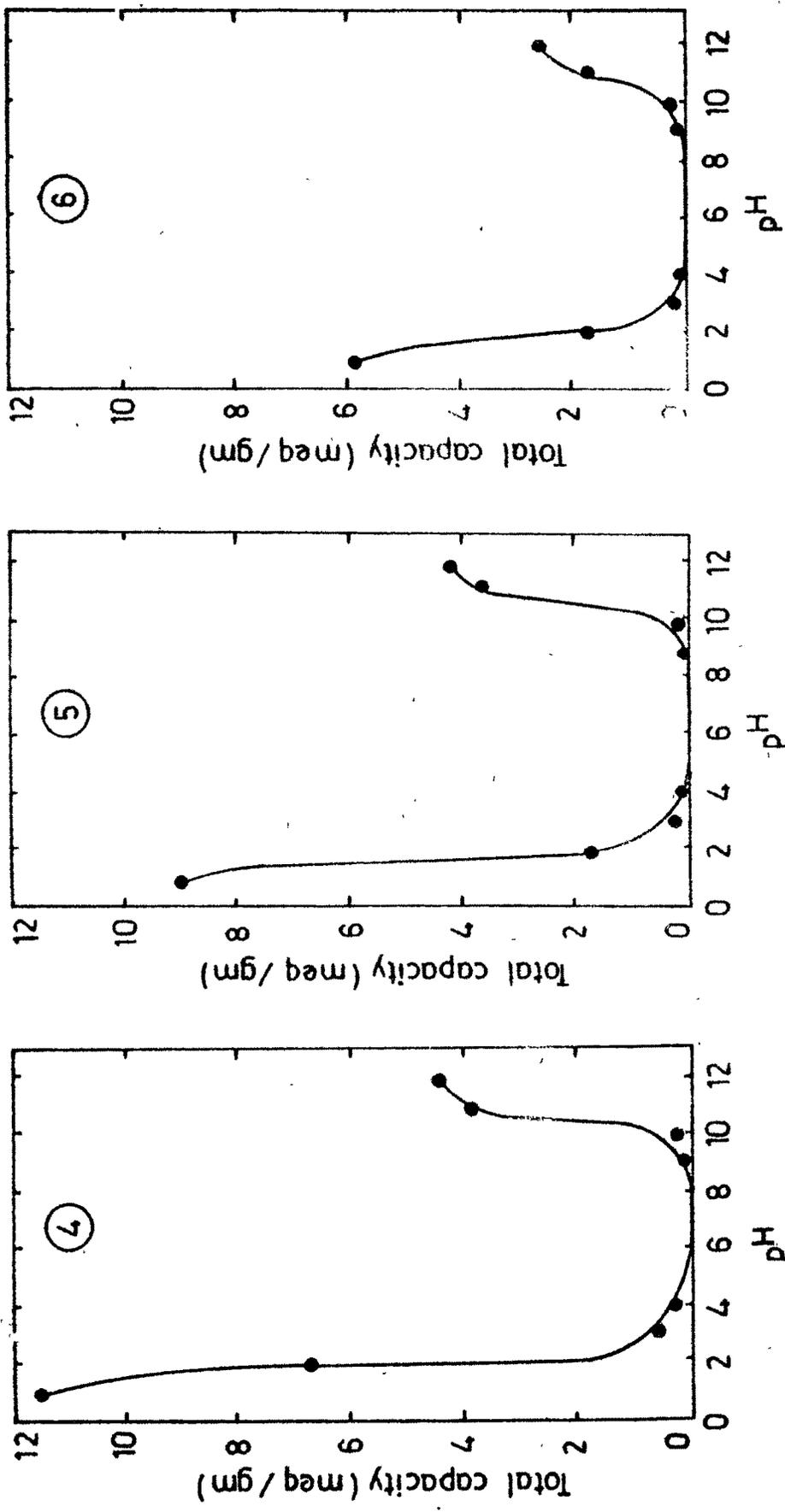


FIG 26 -- PH-TITRATION CURVES OF ④ EP(SA)TP ⑤ EP(SS)TP ⑥ EP(3-OH)TP RESINS

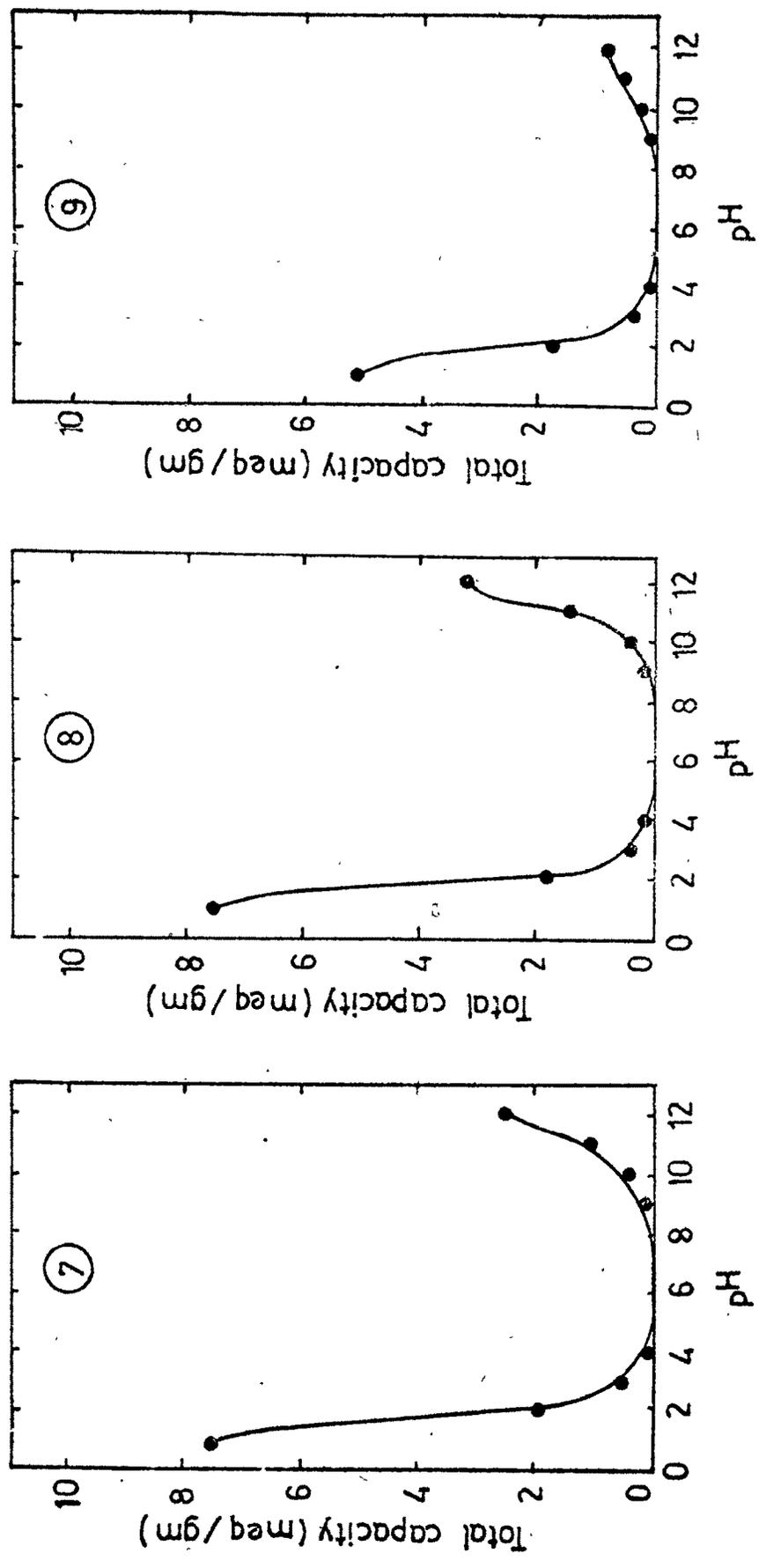


FIG 27 — PH-TITRATION CURVES OF 7 EP(PHB)TP 8 EP(BR)TP 9 EP(AN)TP RESINS

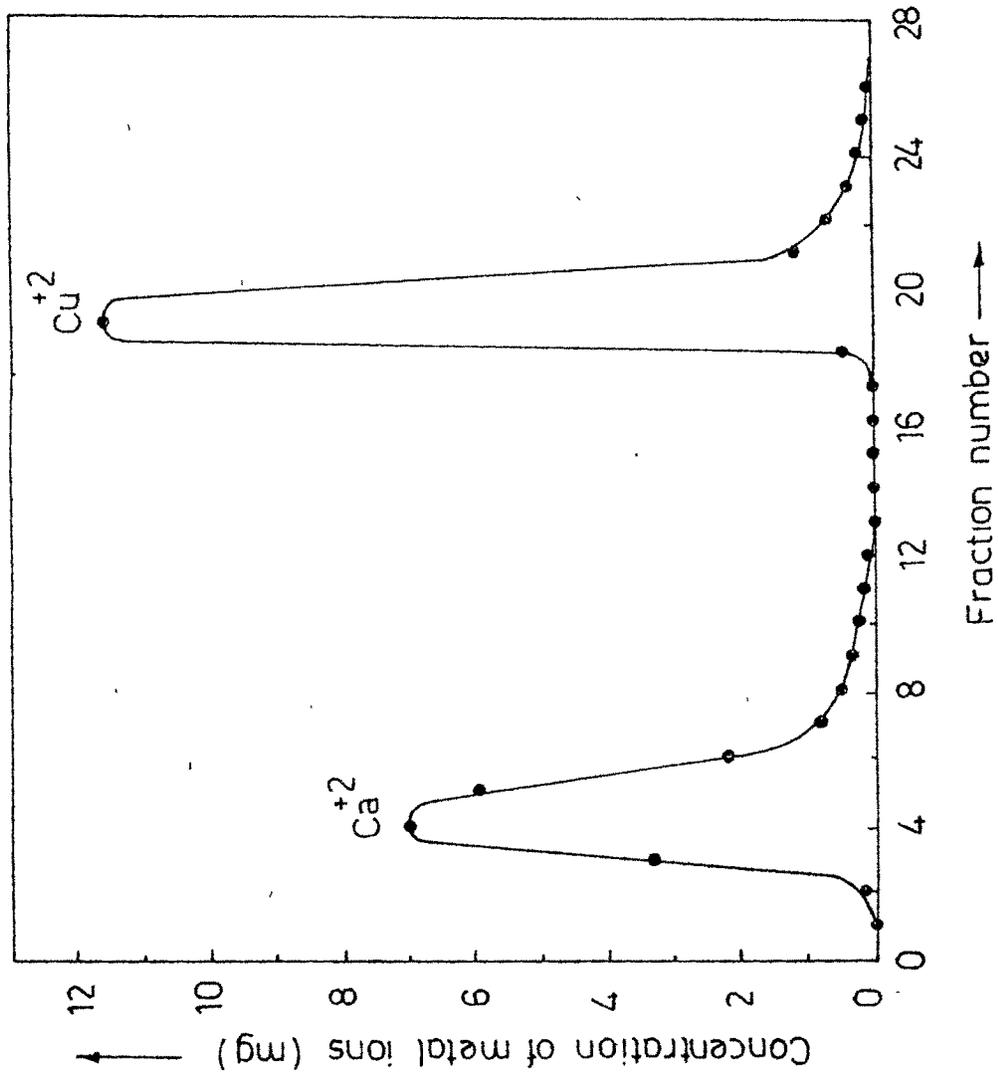


FIG-27 (A)

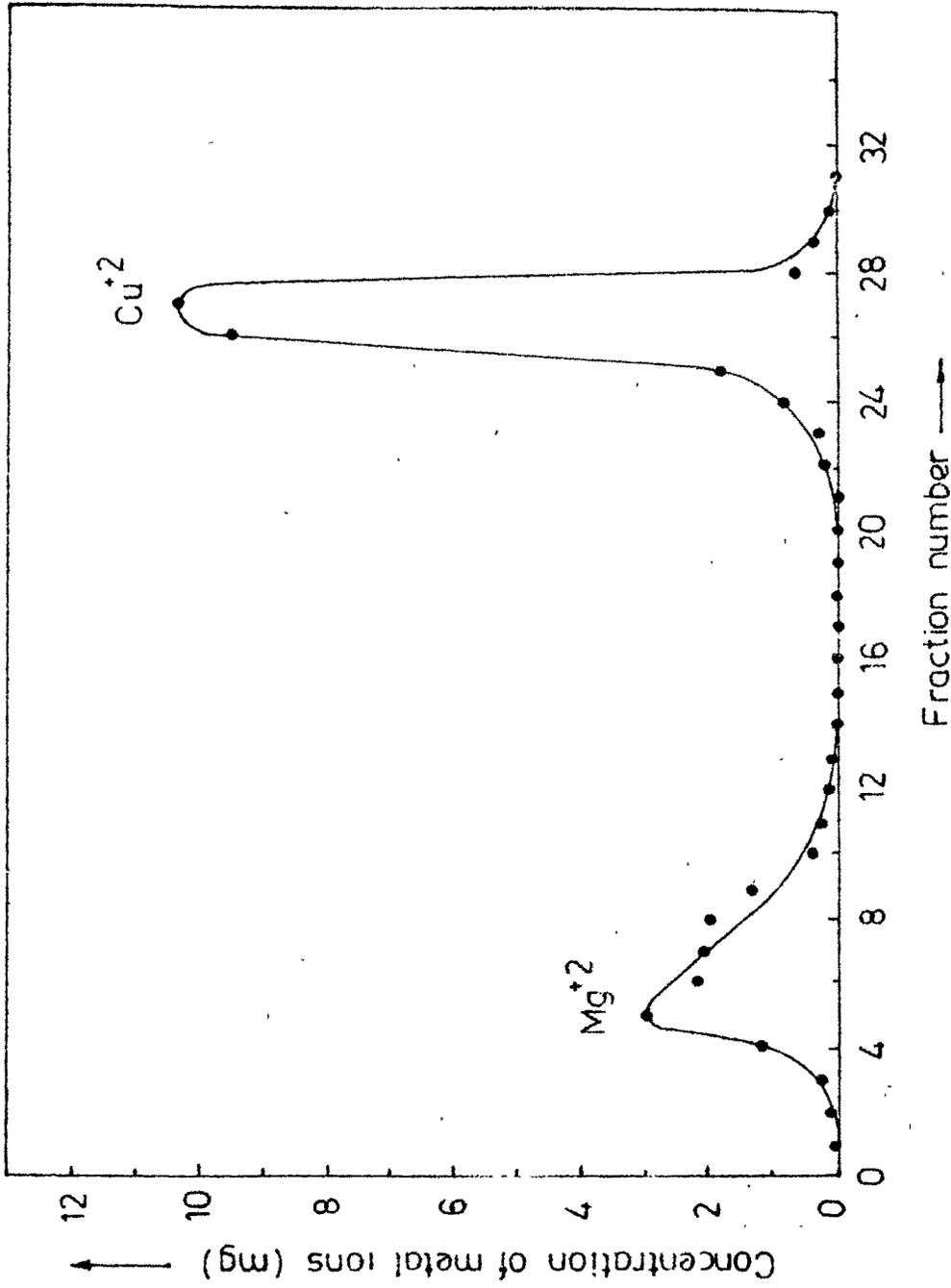


FIG-27 (B)

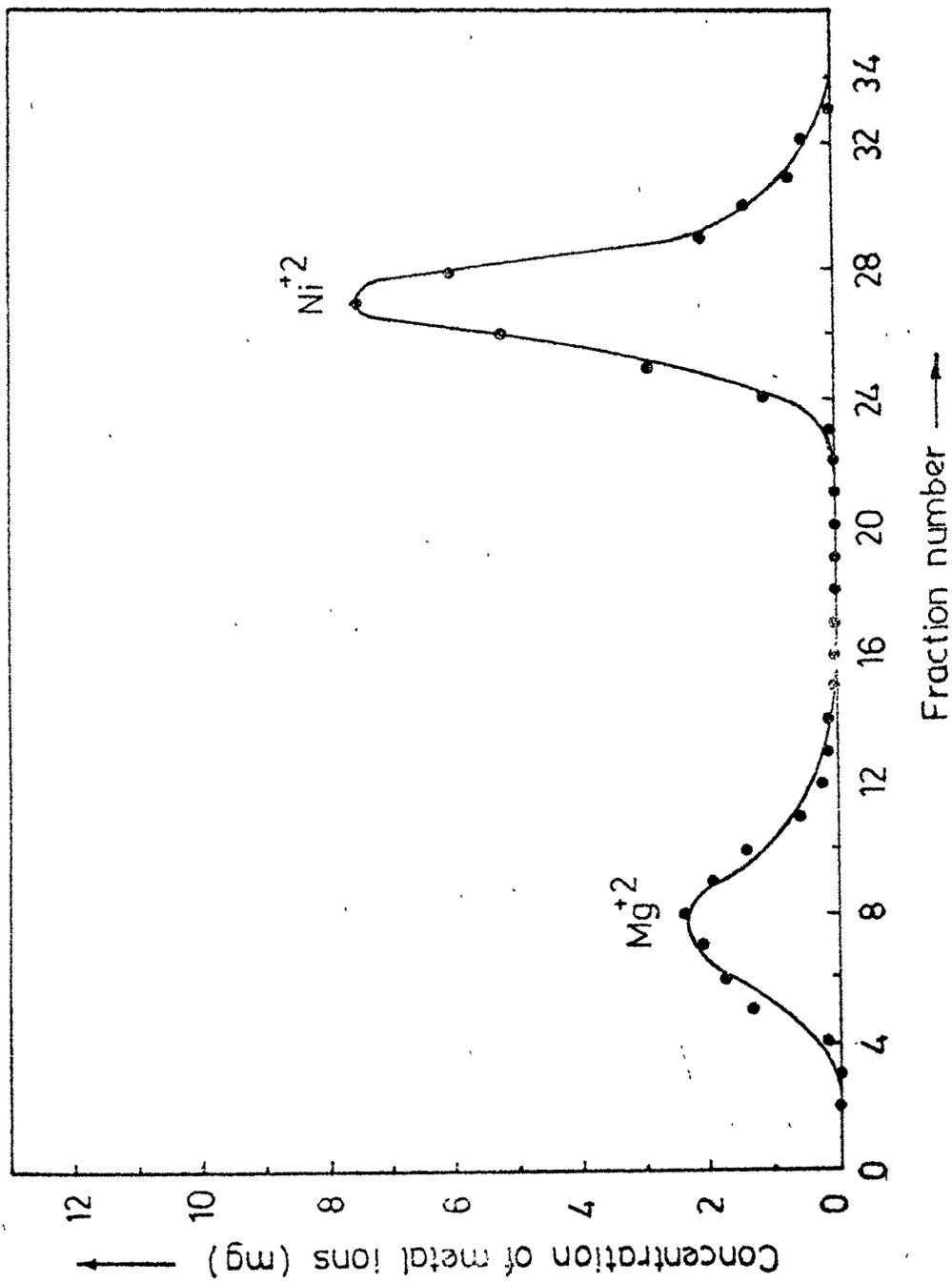


FIG-27 (C)

TABLE - TP - 35

## Abbreviation

No.	Resin	Abbreviation
1	Epichlorohydrin - Catechol - Tetraethylenepentamine	EP (CA) TP
2	Epichlorohydrin - 8-hydroxyquinoline - Tetraethylenepentamine	EP (8-OH) TP
3	Epichlorohydrin - Hydroquinone - Tetraethylenepentamine	EP (HQ) TP
4	Epichlorohydrin - Salicylic acid - Tetraethylenepentamine	EP (SA) TP
5	Epichlorohydrin - Sulfosalicylic acid - Tetraethylenepentamine	EP (SS) TP
6	Epichlorohydrin - 3-hydroxy-2-naphthoic acid - Tetraethylenepentamine	EP (3-OH) TP
7	Epichlorohydrin - p-hydroxybenzoic acid - Tetraethylenepentamine	EP (PHB) TP
8	Epichlorohydrin - $\beta$ -resorcylic acid - Tetraethylenepentamine	EP (BR) TP
9	Epichlorohydrin - Anthranilic acid - Tetraethylenepentamine	EP (AN) TP

TABLE - TP - 36

## Analyses, Formulae etc. of Amphoteric resins

No.	Resin	Formula	Analysis					
			Calculated			Observed		
			% C	% H	% N	% C	% H	% N
1	EP(CA)TP	$(C_{23}H_{51}O_{12}N_5)_n$	46.86	8.66	11.88	46.84	8.60	11.73
2	EP(8-OH)TP	-	-	-	-	-	-	-
3	EP(HQ)TP	$(C_{17}H_{42}O_{8.5}N_5)_n$	45.13	9.29	15.48	44.92	9.09	15.31
4	EP(SA)TP	$(C_{18}H_{35}O_6N_5)_n$	51.80	8.39	16.78	51.50	8.14	16.70
5	EP(SS)TP	$(C_{18}H_{29.5}O_{6.25}N_5)_n$	48.27	6.59	15.64	48.01	6.35	15.34
6	EP(3-OH)TP	-	-	-	-	-	-	-
7	EP(PHB)TP	$(C_{32}H_{51}O_{14}N_5)_n$	52.67	6.99	9.60	52.40	6.74	9.32
8	EP(BR)TP	$(C_{18}H_{41}O_{10}N_5)_n$	44.35	8.41	14.37	44.07	8.19	14.21
9	EP(AN)TP	$(C_{32}H_{58}O_{13}N_8)_n$	50.39	7.61	14.70	50.10	7.30	14.53

TABLE - TP - 37

% Moisture content of Amphoteric resins

No.	Resin	% Moisture	
		H <sup>+</sup> form	OH <sup>-</sup> form
1	EP(CA)TP	11.16	8.80
2	EP(8-OH)TP	6.48	14.26
3	EP(HQ)TP	4.10	9.30
4	EP(SA)TP	4.19	9.44
5	EP(SS)TP	3.01	6.90
6	EP(3-OH)TP	5.70	5.00
7	EP(PHB)TP	6.30	13.20
8	EP(BR)TP	5.54	3.50
9	EP(AN)TP	4.20	3.80

TABLE - TP - 38

## Density of resins

No.	Resin	Resin in H <sup>+</sup> form		Resin in OH <sup>-</sup> form	
		true density ( $d_{res}$ ) (gm/cm <sup>3</sup> )	apparent (column) density ( $d_{col}$ ) (gm/ml)	true density ( $d_{res}$ ) (gm/cm <sup>3</sup> )	apparent (column) density ( $d_{col}$ ) (gm/ml)
1	EP (CA) TP	1.3260	0.2900	1.3190	0.2040
2	EP (8-OH) TP	1.3060	0.2570	1.2980	0.2080
3	EP (HQ) TP	1.1540	0.2140	1.1530	0.1770
4	EP (SA) TP	1.3310	0.1400	1.2600	0.1150
5	TP (SS) TP	1.4220	0.1580	1.2200	0.0780
6	EP (3-OH) TP	1.8870	0.2530	0.9810	0.2260
7	EP (PHB) TP	1.6410	0.3050	1.7699	0.2689
8	EP (BR) TP	1.5090	0.2956	1.2658	0.2790
9	EP (AN) TP	1.5460	0.2707	1.4530	0.1833

TABLE - TP - 39

Void volume fraction of resins

No.	Resin	Resin in H <sup>+</sup> form		Resin in OH <sup>-</sup> form	
		$d_{col}/d_{res}$	Void volume fraction (1 - $d_{col}/d_{res}$ )	$d_{col}/d_{res}$	Void volume fraction (1 - $d_{col}/d_{res}$ )
1	EP (CA) TP	0.2190	0.7810	0.1550	0.8450
2	EP (8-OH) TP	0.1970	0.8030	0.1610	0.8390
3	EP (HQ) TP	0.1860	0.8140	0.1540	0.8460
4	EP (SA) TP	0.1060	0.8940	0.0910	0.9090
5	EP (SS) TP	0.1120	0.8880	0.0640	0.9360
6	EP (3-OH) TP	0.1340	0.8660	0.2300	0.7700
7	EP (PHB) TP	0.1858	0.8140	0.3492	0.6510
8	EP (BR) TP	0.1959	0.8040	0.2204	0.7800
9	EP (AM) TP	0.1751	0.8250	0.1261	0.8740

TABLE - TP - 40

Capacity and concentration of ionogenic groups of Amphoteric resins as cation exchanger

No.	Resin	Total capacity CEC <sub>obs</sub> (meq/gm)	Total capacity CEC <sub>cal</sub> (meq/gm)	$\frac{CEC_{obs}}{CEC_{cal}}$	Concentration of ionogenic groups Cr (meq/cm <sup>3</sup> )	Volume capacity Q (gm.eq/l)	Cu-exchange capacity (meq/gm)
1	EP (CA) TP	2.643	1.698	1.557	3.115	0.682	1.670
2	EP (8-OH) TP	2.297	-	-	2.860	0.563	1.700
3	EP (HQ) TP	3.230	2.212	1.460	3.576	0.663	3.024
4	EP (SA) TP	4.280	2.398	1.780	5.457	0.575	3.340
5	EP (SS) TP	3.762	4.469	0.841	5.188	0.577	3.093
6	EP (3-OH) TP	2.050	-	-	3.649	0.490	1.273
7	EP (PHB) TP	2.535	1.372	1.847	3.900	0.724	1.260
8	EP (BR) TP	3.230	4.100	0.788	4.604	0.902	1.830
9	EP (AN) TP	0.780	1.312	0.594	1.155	0.202	0.450

TABLE - TP - 41

Capacity and concentration of ionogenic groups of Amphoteric resins as anion exchanger

No.	Resin	Total capacity AEC <sub>obs</sub> (meq/gm)	Total capacity AEC <sub>cal</sub> (meq/gm)	$\frac{\text{AEC}_{\text{obs}}}{\text{AEC}_{\text{cal}}}$	Concentration of ionogenic groups Cr <sub>3</sub> (meq/cm <sup>3</sup> )	Volume capacity Q (gm.eq/l)
1	EP(CA)TP	5.390	1.692	1.587	6.486	1.003
2	EP(8-OH)TP	6.102	-	-	6.793	1.091
3	EP(HQ)TP	8.196	2.200	1.852	8.576	1.316
4	EP(SA)TP	9.835	2.386	2.050	11.226	1.025
5	EP(SS)TP	8.096	2.225	1.811	9.102	0.581
6	EP(3-OH)TP	5.560	-	-	5.182	1.194
7	EP(PHB)TP	7.200	1.546	2.624	11.062	3.863
8	EP(BR)TP	7.240	2.045	1.760	8.840	1.948
9	EP(AN)TP	4.650	1.309	1.181	6.500	0.820

TABLE - TP - 42

Rate of exchange of resins

No.	Resin	Time in minutes	Cation exchange capacity realized (meq/gm)	Anion exchange capacity realized (meq/gm)
1	EP (CA) TP	5	1.742	2.908
		10	2.016	3.640
		15	2.305	4.188
		30	2.616	4.386
		45	2.629	4.943
		60	2.642	5.390
		180	2.643	5.390
2	EP (8-OH) TP	5	2.083	4.480
		10	2.135	4.997
		15	2.190	5.217
		30	2.246	5.562
		45	2.258	5.735
		60	2.271	6.102
		180	2.297	6.102
3	EP (HQ) TP	5	2.294	4.841
		10	2.604	6.177
		15	2.712	6.333
		30	2.866	7.000
		45	2.908	7.512
		180	3.230	8.196

(TABLE - TP - 42 contd.....)

No.	Resin	Time in minutes	Cation exchange capacity realized (meq/gm)	Anion exchange capacity realized (meq/gm)
4	EP (SA) TP	5	3.653	6.917
		10	3.910	7.565
		15	4.017	7.740
		30	4.121	8.400
		45	4.208	9.242
		60	4.225	9.355
		120	4.280	9.835
5	EP (SS) TP	180	4.280	9.835
		5	2.422	3.567
		10	2.702	5.483
		15	3.453	6.388
		30	3.762	7.099
		45	3.762	7.559
		60	3.762	8.096
6	EP (3-OH) TP	120	3.762	8.096
		180	3.762	8.096
		5	1.313	2.164
		10	1.552	3.297
		15	1.789	3.570
		30	1.839	4.901
		45	1.908	4.981
6	EP (3-OH) TP	60	1.944	5.160
		120	2.050	5.560
		180	2.050	5.560

(TABLE - TP - 42 contd.....)

No.	Resin	Time in minutes	Cation exchange capacity realized (meq/gm)	Anion exchange capacity realized (meq/gm)
		5	1.500	6.150
		10	1.734	6.500
		15	1.894	6.636
7	EP(PHB) TP	30	2.268	6.851
		45	2.390	6.927
		60	2.460	7.062
		120	2.535	7.100
		180	2.535	7.200
		5	2.600	5.910
		10	3.070	6.200
		15	3.144	6.480
		30	3.176	6.890
8	EP(BR) TP	45	3.204	6.972
		60	3.229	7.114
		120	3.230	7.220
		140	3.230	7.240
		5	0.400	4.400
		10	0.630	4.500
		15	0.730	4.530
9	EP(AN) TP	30	0.780	4.540
		45	0.780	4.545
		60	0.780	4.560
		120	0.780	4.620
		180	0.780	4.650

TABLE - TP - 43

Apparent  $pK_a$  and  $pK_b$  values and Isoionic point  
of resins

No.	Resin	Apparent $pK_a$ values	Apparent $pK_b$ values	Isoionic point
1	EP (CA) TP	10.590	2.810	6.700
2	EP (8-OH) TP	10.740	2.640	6.690
3	EP (HQ) TP	10.390	2.800	6.590
4	EP (SA) TP	10.370	2.690	6.530
5	EP (SS) TP	10.280	2.380	6.330
6	EP (3-OH) TP	10.800	2.400	6.600
7	EP (PHB) TP	11.025	3.115	7.070
8	EP (BR) TP	10.859	3.119	6.989
9	EP (AN) TP	10.886	2.841	6.863

TABLE - TP - 44

Thermal Stability of Amphoterics resins as cation exchanger

Temp. °C	Resin	Original capacity (meq/gm) of absolutely dry resin	Gain in capacity of absolutely dry resin as determined after heating, %		Gain in capacity of absolutely dry resin as determined after regeneration, %	
			H-form	Na-form	H-form	Na-form
			H-form	Na-form	H-form	Na-form
80°	EP (CA) TP	2.643	NIL	NIL	NIL	NIL
	EP (8-OH) TP	2.297	NIL	NIL	NIL	NIL
	EP (HQ) TP	3.230	NIL	NIL	NIL	NIL
	EP (SA) TP	4.280	NIL	NIL	NIL	NIL
	EP (SS) TP	3.762	NIL	NIL	NIL	NIL
	EP (3-OH) TP	2.050	NIL	NIL	NIL	NIL
	EP (PHB) TP	2.535	NIL	NIL	NIL	NIL
	EP (BR) TP	3.229	NIL	NIL	NIL	NIL
	EP (AN) TP	0.780	NIL	NIL	NIL	NIL

(TABLE - TP - 44 contd.....)

Temp. °C	Resin	Original capacity (meq/gm) of absolutely dry resin	Gain in capacity of absolutely dry resin as determined after heating,%		Gain in capacity of absolutely dry resin as determined after regeneration,%	
			H-form	Na-form	H-form	Na-form
100°	EP(CA) TP	2.643	10.56	7.60	9.80	6.22
	EP(8-OH) TP	2.297	13.89	10.51	13.02	8.13
	EP(HQ) TP	3.230	14.43	11.32	13.79	9.11
	EP(SA) TP	4.280	13.41	9.15	12.52	6.03
	EP(SS) TP	3.762	2.68	1.84	1.53	1.26
	EP(3-OH) TP	2.050	11.41	8.62	11.06	5.95
	EP(PHB) TP	2.535	14.51	10.25	16.30	14.70
	EP(BR) TP	3.229	15.31	8.65	17.40	11.26
	EP(AN) TP	0.780	13.10	11.20	19.70	15.10

(TABLE - TP - 44 contd..... )

Temp. °C	Resin	Original capacity (meq/gm) of absolutely dry resin	Gain in capacity of absolutely dry resin as determined after heating,%		Gain in capacity of absolutely dry resin as determined after regeneration,%	
			H-form	Na-form	H-form	Na-form
120°	EP (CA) TP	2.643	11.80	9.26	13.48	10.55
	EP (8-OH) TP	2.297	19.33	15.02	23.62	18.21
	EP (HQ) TP	3.230	6.50	4.15	7.84	5.26
	EP (SA) TP	4.280	2.57	2.10	2.95	2.36
	EP (SS) TP	3.762	4.25	3.31	4.77	3.78
	EP (3-OH) TP	2.050	16.10	12.07	18.70	14.12
	EP (PHB) TP	2.535	17.31	13.90	21.40	17.20
	EP (BR) TP	3.229	18.23	10.88	21.65	14.17
	EP (AN) TP	0.780	17.25	15.02	24.01	19.80

(TABLE - TP - 44 contd.....)

Temp °C	Resin	Original capacity (meq/gm) of absolutely dry resin	Gain in capacity of absolutely dry resin as determined after heating, %		Gain in capacity of absolutely dry resin as determined after regeneration, %	
			H-form	Na-form	H-form	Na-form
140°	EP (CA) TP	2.643	51.46	42.10	52.07	42.62
	EP (8-OH) TP	2.297	48.41	39.60	49.36	40.08
	EP (HQ) TP	3.230	18.02	15.41	19.43	17.10
	EP (SA) TP	4.280	11.26	8.13	13.01	9.92
	EP (SS) TP	3.762	13.88	10.24	15.15	11.38
	EP (3-OH) TP	2.050	45.37	34.69	47.40	36.79
	EP (PHB) TP	2.535	23.13	17.80	40.00	18.50
	EP (BR) TP	3.229	20.20	13.76	42.10	14.53
	EP (AN) TP	0.780	36.41	17.24	38.90	19.08

TABLE - TP - 45

Thermal Stability of Amphoteric resins as anion exchanger

Temp. °C	Resin	Original capacity (meq/gm) of absolutely dry resin	Gain in capacity of absolutely dry resin as determined after heating,%		Gain in capacity of absolutely dry resin as determined after regeneration,%	
			OH - form	Cl - form	OH - form	Cl - form
80°	EP (CA) TP	5.390	NIL	NIL	NIL	NIL
	EP (8-OH) TP	6.102	NIL	NIL	NIL	NIL
	EP (HQ) TP	8.196	NIL	NIL	NIL	NIL
	EP (SA) TP	9.835	NIL	NIL	NIL	NIL
	EP (SS) TP	8.096	NIL	NIL	NIL	NIL
	EP (3-OH) TP	5.560	NIL	NIL	NIL	NIL
	EP (PHB) TP	7.200	NIL	NIL	NIL	NIL
	EP (BR) TP	7.240	NIL	NIL	NIL	NIL
	EP (AN) TP	4.650	NIL	NIL	NIL	NIL

(TABLE - TP - 45 contd..... )

Temp. °C	Resin	Original capacity (meq/gm) of absolutely dry resin	Gain in capacity of absolutely dry resin as determined after heating,%		Gain in capacity of absolutely dry resin as determined after regeneration,%	
			OH - form	Cl - form	OH - form	Cl - form
100°	EP (CA) TP	5.390	2.23	2.01	1.65	1.76
	EP (8-OH) TP	6.102	8.08	6.10	7.39	5.20
	EP (HQ) TP	8.196	8.92	5.36	6.90	3.94
	EP (SA) TP	9.835	10.72	5.47	6.75	3.99
	EP (SS) TP	8.096	5.83	4.59	3.47	2.87
	EP (3-OH) TP	5.560	9.42	7.82	8.26	5.73
	EP (PHB) TP	7.200	11.82	6.57	12.54	8.10
	EP (BR) TP	7.240	9.80	5.81	10.90	6.72
	EP (AN) TP	4.650	9.07	7.10	10.81	8.75

(TABLE - TP - 45 contd..... )

Temp. °C	Resin	Original capacity (meq/gm) of absolutely dry resin	Gain in capacity of absolutely dry resin as determined after heating,%		Gain in capacity of absolutely dry resin as determined after regeneration,%	
			OH - form	Cl - form	OH - form	Cl - form
120°	EP (CA) TP	5.390	12.24	10.90	14.51	11.87
	EP (8-OH) TP	6.102	10.95	7.62	11.69	8.49
	EP (HQ) TP	8.196	4.44	3.98	6.01	4.81
	EP (SA) TP	9.835	1.68	1.13	3.24	1.76
	EP (SS) TP	8.096	3.38	2.68	5.82	4.05
	EP (3-OH) TP	5.560	3.23	2.99	4.12	3.89
	EP (PHB) TP	7.200	14.60	9.14	16.01	11.50
	EP (BR) TP	7.240	12.10	7.79	15.00	9.40
	EP (AN) TP	4.650	13.00	10.12	15.36	12.68

(TABLE - TP - 45 contd.....)

Temp. °C	Resin	Original capacity (meq/gm) of absolutely dry resin	Gain in capacity of absolutely dry resin as determined after heating,%		Gain in capacity of absolutely dry resin as determined after regeneration,%	
			OH - form	Cl - form	OH - form	Cl -form
140°	EP (CA) TP	5.390	20.22	16.03	23.10	17.41
	EP (8-OH) TP	6.102	19.17	14.53	21.63	16.00
	EP (HQ) TP	8.196	9.32	7.46	11.50	9.04
	EP (SA) TP	9.835	3.20	2.84	5.04	4.60
	EP (SS) TP	8.096	11.59	6.75	13.85	7.90
	EP (3-OH) TP	5.560	5.76	4.07	9.08	5.67
	EP (PHB) TP	7.200	19.13	13.61	22.60	15.12
	EP (BR) TP	7.240	16.57	10.74	33.12	12.03
	EP (AN) TP	4.650	18.20	14.06	23.19	15.37

TABLE - TP - 46

Effect of temperature of equilibration on the capacity of the resin

		Equilibration period = 2 hrs.			Normality of HCl / NaCl = 0.098 N		
		Amount of resin = 0.5 gm			Normality of NaOH / NaCl = 0.097 N		
No.	Resin	Total AEC (meq/gm) of absolutely dry resin as determined at temp., (°C)			Total CEC (meq/gm) of absolutely dry resin as determined at temp., (°C)		
		30°	50°	70°	30°	50°	70°
1	EP (CA) TP	5.390	6.050	6.289	2.643	2.220	1.913
2	EP (8-OH) TP	6.102	6.597	6.737	2.297	2.005	1.569
3	EP (HQ) TP	8.196	9.130	9.226	3.230	2.841	2.137
4	EP (SA) TP	9.835	10.460	10.600	4.280	4.149	3.679
5	EP (SS) TP	8.096	8.782	9.366	3.762	3.515	3.299
6	EP (3-OH) TP	5.560	5.756	5.928	2.050	1.750	1.644
7	EP (PHB) TP	7.200	7.300	7.490	2.535	2.348	2.240
8	EP (BR) TP	7.240	7.351	7.520	3.230	3.020	2.870
9	EP (AN) TP	4.650	4.740	4.890	0.780	0.650	0.570

TABLE - TP - 47

Oxidation resistance of Amphoteric resins  
as cation exchanger

No.	Resin	% Moisture		Increase in % water content
		Untreated exchanger	H <sub>2</sub> O <sub>2</sub> treated exchanger	
1	EP(CA) TP	11.16	18.66	7.50
2	EP(8-OH) TP	6.48	16.22	9.74
3	EP(HQ) TP	4.10	14.47	10.37
4	EP(SA) TP	4.19	13.90	9.71
5	EP(SS) TP	3.01	14.90	19.71
6	EP(3-OH) TP	5.70	15.32	9.62
7	EP(PHB) TP	6.30	15.48	9.18
8	EP(BR) TP	5.54	14.69	9.15
9	EP(AN) TP	4.20	17.89	13.69

TABLE - TP - 48  
 Oxidation resistance of Amphoteric resins  
 as anion exchanger

No.	Resin	% Moisture		Increase in % water content
		Untreated exchanger	H <sub>2</sub> O <sub>2</sub> treated exchanger	
1	EP (CA) TP	8.80	31.33	22.53
2	EP (8-OH) TP	14.26	25.42	11.16
3	EP (HQ) TP	9.30	19.97	10.67
4	EP (SA) TP	9.44	20.63	11.19
5	EP (SS) TP	6.90	38.39	31.49
6	EP (3-OH) TP	5.00	21.39	16.39
7	EP (PHB) TP	13.20	17.56	4.36
8	EP (BR) TP	3.50	16.61	13.11
9	EP (AN) TP	3.80	16.27	12.47

TABLE - TP - 49

Swelling of Amphoteric resins as cation exchanger in various solvents

No.	Resin	% Swelling in				
		Glacial Acetic acid	Water	Methanol	Benzene	Acetone
1	EP (CA) TP	390.0	200.0	112.2	0	0
2	EP (S-OH) TP	212.5	140.0	112.5	0	0
3	EP (HQ) TP	222.0	220.0	122.2	0	0
4	EP (SA) TP	520.0	460.0	110.0	0	0
5	EP (SS) TP	480.0	508.0	240.0	0	0
6	EP (3-OH) TP	512.5	280.0	111.0	0	0
7	EP (PHB) TP	110.0	80.0	40.0	0	0
8	EP (BR) TP	242.8	185.7	57.0	0	0
9	EP (AN) TP	233.3	141.7	83.3	0	0

TABLE - TP - 50

Swelling of Amphoteric resins as anion exchanger in various solvents

No.	Resin	% Swelling in					
		Glacial Acetic acid	Water	Methanol	Benzene	Acetone	
1	EP (CA) TP	214.0	112.5	43.0	7.70	0	
2.	EP (8-OH) TP	160.0	100.0	50.0	0	0	
3.	EP (HQ) TP	225.0	183.0	83.0	0	0	
4	EP (SA) TP	1100.0	508.0	140.0	15.0	0	
5	EP (SS) TP	525.0	617.0	150.0	0	0	
6	EP (3-OH) TP	400.0	183.0	33.3	0	0	
7	EP (PHB) TP	325.0	275.0	133.0	0	0	
8	EP (BR) TP	237.5	100.0	80.0	0	0	
9	EP (AN) TP	933.3	400.0	218.0	0	0	

TABLE - TP - 51

Values of distribution coefficients ( $K_d$ ) in  $\text{NH}_4\text{OAc}$  - DMF media ( $35 \pm 1^\circ\text{C}$ )

No.	Resin	$[K_d]_A^*$						
		Ca(II)	Mg(II)	Co(II)	Ni(II)	Cu(II)	Zn(II)	
1	EP(CA)TP	6.12	2.97	16.63	18.77	42.34	22.83	
2	EP(8-OH)TP	4.46	1.92	11.96	12.92	31.76	18.78	
3	EP(HQ)TP	4.08	2.47	26.90	27.15	103.11	41.40	
4	EP(SA)TP	6.66	2.76	48.86	84.63	385.67	72.68	
5	EP(SS)TP	3.21	2.19	46.40	71.67	335.67	54.72	
6	EP(3-OH)TP	3.97	1.94	13.57	16.77	47.05	12.75	
7	EP(PHB)TP	11.49	1.65	17.19	12.60	61.00	13.52	
8	EP(BR)TP	11.39	2.09	6.55	24.28	105.80	31.40	
9	EP(AN)TP	8.88	1.61	13.06	35.45	227.30	35.41	

\* A = 0.02 M (concentration of  $\text{NH}_4\text{OAc}$ )

(TABLE - TP - 51 contd.....)

No.	Resin	$[K_d]_B^*$							
		Ca(II)	Mg(II)	Co(II)	Ni(II)	Cu(II)	Zn(II)		
1	EP(CA)TP	5.83	1.97	18.39	21.51	83.37	15.32		
2	EP(8-OH)TP	3.58	1.65	13.94	12.63	64.72	10.87		
3	EP(HQ)TP	3.90	1.64	43.17	43.92	216.64	42.28		
4	EP(SA)TP	2.54	2.47	79.86	111.57	646.63	84.09		
5	EP(SS)TP	1.56	1.91	63.75	100.20	447.46	66.90		
6	EP(3-OH)TP	3.27	1.53	15.12	17.06	73.81	10.41		
7	EP(PHB)TP	14.08	2.81	65.33	13.52	75.73	15.35		
8	EP(BR)TP	16.74	2.21	22.72	37.65	143.45	42.70		
9	EP(AN)TP	16.51	2.40	34.84	51.04	304.03	59.30		

\* B = 0.25 M (concentration of  $NH_4OAc$ )

(TABLE - TP - 51 contd.....)

No.	Resin	$[K_d]_C^*$							
		Ca(II)	Mg(II)	Co(II)	Ni(II)	Cu(II)	Zn(II)		
1	EP(CA)TP	4.98	1.77	40.20	20.14	51.91	10.27		
2	EP(8-OH)TP	2.22	1.10	23.23	14.84	34.60	6.11		
3	EP(HQ)TP	1.23	1.09	59.21	32.64	68.16	27.86		
4	EP(SA)TP	0.30	1.10	143.04	89.46	229.46	20.04		
5	EP(SS)TP	0.61	0.92	128.29	79.97	209.67	12.07		
6	EP(3-OH)TP	0.94	0.53	29.26	16.48	48.90	6.85		
7	EP(PHB)TP	9.08	2.23	22.89	10.81	52.22	9.34		
8	EP(BR)TP	13.96	1.86	13.24	32.72	127.47	34.36		
9	EP(AN)TP	11.24	2.18	20.36	47.72	209.00	37.00		

\* C = 1.00 M (concentration of  $NH_4OAc$ )

TABLE - TP - 51 (A)

Chromatography of mixture of  $\text{Ca}^{+2}$  and  $\text{Cu}^{+2}$  on  
 EP(SS)TP amphoteric resin - ( $\text{NH}_4^+$  - form)

Fraction No.	Volume, ml	mg of metal ion	
		$\text{Ca}^{+2}$	$\text{Cu}^{+2}$
Elution with 0.25 M $\text{NH}_4\text{OAc}$			
1	2.5	0.000	
2	2.5	0.120	
3	2.5	3.407	
4	2.5	7.054	
5	2.5	6.012	
6	2.5	2.240	
7	2.5	0.801	
8	2.5	0.521	
9	2.5	0.361	
10	2.5	0.240	
11	2.5	0.160	
12	2.5	0.120	
13	2.5	0.000	
Elution with 2.0 M HCl			
14	2.5		0.000
15	2.5		0.000

TABLE - TP - 51 (A) Contd.....

Fraction No.	Volume, ml	mg of metal ion	
		Ca <sup>+2</sup>	Cu <sup>+2</sup>
16	2.5		0.000
17	2.5		0.000
18	2.5		0.508
19	2.5		11.690
20	2.5		8.896
21	2.5		1.207
22	2.5		0.700
23	2.5		0.381
24	2.5		0.300
25	2.5		0.190
26	2.5		0.000
Total metal ions recovered from resin bed		21.036	23.872
Total metal ions in the influent		21.082	23.920

Column diameter = 1.0 cm                      Bed height = 14.0 cms.

Mesh size = -60 + 100

TABLE - TP - 51 (B)

Chromatography of mixture of  $Mg^{+2}$  and  $Cu^{+2}$  on  
EP(SA)TP amphoteric resin -  $(NH_4^+ - \text{form})$

Fraction No.	Volume, ml	mg of metal ion	
		$Mg^{+2}$	$Cu^{+2}$
Elution with			
0.25 M $NH_4OAc$			
1	2.5	0.000	
2	2.5	0.000	
3	2.5	0.194	
4	2.5	1.216	
5	2.5	3.015	
6	2.5	2.237	
7	2.5	2.110	
8	2.5	1.990	
9	2.5	1.410	
10	2.5	0.365	
11	2.5	0.243	
12	2.5	0.170	
13	2.5	0.097	
14	2.5	0.072	
15	2.5	0.048	
16	2.5	0.000	

TABLE - TP - 51 (B) Contd.....

Fraction No.	Volume, ml	mg of metal ion	
		Mg <sup>+2</sup>	Cu <sup>+2</sup>
Elution with			
2.0 M HCl			
17	2.5		0.000
18	2.5		0.000
19	2.5		0.000
20	2.5		0.000
21	2.5		0.000
22	2.5		0.190
23	2.5		0.317
24	2.5		0.826
25	2.5		1.906
26	2.5		9.658
27	2.5		10.357
28	2.5		0.572
29	2.5		0.381
30	2.5		0.190
31	2.5		0.000
Total metal ions recovered from resin bed		13.167	24.397
Total metal ions in the influent		13.190	24.780
Column diameter = 1.0 cm		Bed height = 16.0 cms.	
Mesh size = -60 + 100			

TABLE - TP - 51 (C)

Chromatography of mixture of  $Mg^{+2}$  and  $Ni^{+2}$  on  
 EP(SA)TP amphoteric resin - ( $NH_4^+$  - form)

Fraction No.	Volume, ml	mg of metal ion	
		$Mg^{+2}$	$Ni^{+2}$
Elution with			
0.25 M $NH_4OAc$			
1	2.5	0.000	
2	2.5	0.000	
3	2.5	0.000	
4	2.5	0.194	
5	2.5	1.435	
6	2.5	1.775	
7	2.5	2.190	
8	2.5	2.456	
9	2.5	2.018	
10	2.5	1.483	
11	2.5	0.632	
12	2.5	0.316	
13	2.5	0.219	
14	2.5	0.170	
15	2.5	0.121	
16	2.5	0.097	
17	2.5	0.073	
18	2.5	0.000	

TABLE - TP - 51 (C) Contd.....

Fraction No.	Volume, ml	mg of metal ion	
		Mg <sup>+2</sup>	Ni <sup>+2</sup>
Elution with			
2.0 M HCl			
19	2.5		0.000
20	2.5		0.000
21	2.5		0.000
22	2.5		0.000
23	2.5		0.000
24	2.5		1.174
25	2.5		2.994
26	2.5		5.284
27	2.5		7.574
28	2.5		6.106
29	2.5		2.055
30	2.5		1.446
31	2.5		0.734
32	2.5		0.469
33	2.5		0.000
Total metal ions recovered from resin bed		13.179	27.836
Total metal ions in the influent		13.190	27.887
Column diameter = 1.0      Bed height = 19.0 cms.			
Mesh size = -60 + 100			