CHAPTER - II

II Phenol - Epichlorohydrin - Triethylenetetramine Type Chelating Amphoteric Ion Exchange Resins

EXPERIMENTAL

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

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

II (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 - TT - 20.

II - (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 - TT-21.

The values of void volume fraction of these resins (H^+ form and OH^- form) are presented in Table - TT - 22.

II - (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 - TT - 23 and Table - TT - 24 respectively.

II - (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 - TT - 23.

II - (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. 10 to 15 and presented in Table - TT - 25.

II - (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 Figs. 16 to 18.

The apparent pK_a and pK_b values for these resins are presented in Table - TT - 26.

II - (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 - TT -27.

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 - TT - 28.

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

The study of the effect of varying equilibration temperature on 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 - TT - 29.

II - (j) Oxidation resistance test:

Oxidation resistance test of these resins in free acid and free base form was carried out as described in I - (j). The results are presented in Table - TT - 30 and Table - TT - 31 respectively.

II - (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 - TT - 32 and Table - TT - 33 respectively.

II - (l) Sorption behaviour of some metal bivalent cations on cationic form (NH_4^+ form) of the amphoteric resin 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 - TT - 34.

II Phenol - Epichlorohydrin - Triethylenetetramine Type Chelating Amphoteric Ion-Exchange Resins

RESULTS AND DISCUSSION

We have synthesised chelating amphoteric ion-exchangers from the various phenolic derivatives, epichlorohydrin and triethylenetetramine. The condensate (resins) are insoluble in both benzene and alcohol in which individual components are soluble. Therefore the material (resins) appears to be a condensate product of various phenolic derivatives, epichlorohydrin and triethylenetetramine, particularly because epichlorohydrin is very susceptible to polymerization.

The phenolic derivatives employed for synthesising the resins possess the following structural features.

(a) two phenolic groups in ortho or para positions on a phenyl ring,

(b) one phenolic group and one ring nitrogen,

(c) one phenolic group and one carboxylic group in ortho position on a phenyl ring,

(d) one phenolic group in ortho position to carboxyl group but in meta position to sulfonic group on a phenyl ring,

(e) one phenolic group and one carboxyl group in ortho position on a naphthalene ring,

(f) one phenolic group and one carboxyl group in para position on a phenyl ring,

(g) two phenolic groups in meta position and one carboxyl group in ortho position on a phenyl ring, and

(h) one amino group and one carboxyl group on a phenyl ring.

General Characteristics and Structures:

The chelating exchangers, in general are fairly porous in nature with average physical stability and good chemical resistance to 3N acids and alkalis and all resins are of different colours.

In the present investigation, the polymers were obtained by polycondensation under mild reaction and curing conditions, cross-linking possible by formation of $-\underset{|}{\mathrm{CH}}-$ linkages/ (not shown in Figure), although on the basis of analytical data and other physico-chemical studies, we may have some generalizations viz.,

(a) hydroquinone, salicylic acid, sulfosalicylic acid, and β-resorcylic acid get condensed with triethylenetetramine in molar ratio of 1 : 1.

(b) catechol, 3-hydroxy-2-naphthoic acid, p-hydroxybenzoic acid and anthranilic acid get condensed with triethylenetetramine in molar ratio of 2 : 1.

The most likely structures of these resins on the basis of analytical data and their physico-chemical studies are presented in Figs. I-S-28 to I-S-35.

Moisture retention % :

Percentage moisture of the resins are presented in Table - TT - 20. Percentage moisture of the resins in H-form varies between 1.15 to 6.37. Percentage moisture of the resins in the OH - form varies between 3.52 to 10.10. Low range of percentage moisture suggests that the resins have a fairly good degree of cross-linking.

The moisture content of resins can be related to (a) concentration, valency and solvation tendency of counter ions, (b) concentration and solvation tendency of the fixed ionogenic groups, (c) degree of cross-linking, and (d) electrostatic interaction of ions in the resins. The degree of cross linking in resin is neither controlled nor known, eventhen, it can be suggested that higher degree of cross linking may lead to lower moisture content. Influence of structural feature of condensing agent is however apparent, we find in general that the moisture content of resin increases in terms of the condensing agent (DETA $<$ TETA $<$ TEPA)*

Density of resins:

True density (d_{res}):

The data obtained for the density (d_{res}) of the resins in H - form and OH - form are presented in

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* DETA = ... Diethylenetriamine
TETA = ... Triethylenetetramine
TEPA = ... Tetraethylenepentamine

Table - TT - 21. The values are ranging from 1.10 to 1.55 for H - form and 1.13 to 2.22 for OH - form. With few exceptions, we observed in general that, in the case of resins under study, d_{res} for OH - form is slightly higher than that for H - form.

Apparent (Column) density (d_{col}) :

We have also evaluated the apparent (column) density (d_{col}) of the resins (Table-TT - 21). The values are ranging from 0.21 to 0.45 for H - form and 0.21 to 0.56 for the OH - form. Known values (130) of apparent density for the commercial resins in H - form are 0.69 for IRC - 50/75 and 0.74 for IRC - 84. Thus resins under study have low range of density (d_{col}). 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. Thus, the resins under study have low value of apparent (column) density than that of similar type of commercial resins.

Void volume fraction:

The values of void volume of resins are presented in Table - TT - 22. It is observed that the values of the void volume fraction vary between 0.61 to 0.84 for H - form and 0.70 to 0.88 for OH - form of the resins. 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.

Ion-exchange capacity:

The cation or anion exchange capacity of these resins were calculated using the formula as described in I-(d). The observed capacity CEC_{obs} (cation exchanger) or AEC_{obs} (anion exchanger) can be compared with the calculated CEC_{cal} or AEC_{cal} as reported in Table - TT - 23 and Table - TT - 24 respectively.

For the values of ratio CEC_{obs} / CEC_{cal}, three ranges exist,

(1) value of $\frac{CEC_{obs}}{CEC_{cal}}$ is approximately close to 1,

(2) value of $\frac{CEC_{obs}}{CEC_{cal}}$ is close to 1/2.

Low values ($\sim$ 1/2) of the ratio may be attributed to anyone phenolic group (in such resins) involved in ion exchange.

(3) value of CEC_{obs}/CEC_{cal} is high ($\sim$ 3/2) and may be attributed to contribution of weakly acidic amide group in such resins.

For the values of ratio AEC_{obs}/AEC_{cal}, two ranges exist,

(1) Value of AEC_{obs}/AEC_{cal} is high ($\sim$ 3/2) and may be attributed to contribution of weakly acidic amide group in such resins,

(2) Value of AEC_{obs}/AEC_{cal} is high ($\sim$ 2). We suggest that anion exchange capacity of these resins cannot be related only to primary or secondary amino groups but also to tertiary amine groups.

The results show that total anion exchange capacity of amphoteric resins is quite higher than that of total cation exchange capacity.

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

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

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

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

Total exchange capacity of EP(HQ)TT resin (7.38 meq/gm), EP(SA)TT resin (8.88 meq/gm) and **EP**(BR)TT resin (9.24 meq/gm) as anion exchangers is comparable with that of commercial anion exchanger Duolite A-4 (7.7 meq/gm) (granules), Duolite A-2 (8.4 meq/gm) (granules) and Duolite A-7 (9.10 meq/gm) (granules, weak base amino group, condensation polymer).

Metal (Cu) exchange capacity:

We have studied the copper ion exchange by resins in H-form from ammonical solutions (pH = 10.65).

The observed values of copper ion exchange capacity of these resins are presented in Table - TT - 23.

It is seen that copper ion exchange capacity of these resins ranges between 0.98 to 4.17 meq/gm.

The copper ion exchange capacity of these resins are in the decreasing order as follows:

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

Rate of exchange:

Figs. 10 to 15 represent the rate of exchange of amphoteric resins as cation exchanger as well as anion exchanger.

A perusal of the trends of the rate of exchange for amphoteric resins as cation exchanger and as anion exchanger reveals that the rate of ion exchange is very fast and hence a continuous stirring procedure is adopted.

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

(a) complete exchange occurs in 15 minutes ,

(b) the rate of exchange for these resins are in the decreasing order as follows:

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

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

(a) complete exchange occurs in 15 minutes,
(b) the rate of exchange for these resins are in the decreasing order as follows:

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

It is observed that the rate of exchange of amphoteric resins as anion exchanger is faster than that of cation exchanger.

The shape of the curves also suggest the porous nature of matrices. The dependence of the porosity of the exchanger could not be brought about due to lack of facility.

pH - titration study:

The results of pH-titration curves (Figs.16, 17, 18) reveal the amphoteric nature of ion exchange resins prepared. They exhibit a good cation and anion exchange capacity over the pH range 1 to 12. 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 to 7, resins acted as anion exchanger (Figs. 16 to 18) and curves over this range are characteristic of weakly basic resin and may be compared with pH titration curve of commercially available weakly basic anion exchange resin, Tulsion WB (139). The cation exchange behaviour of these resins is similar to weak acid resin (140).

Apparent pK_a and pK_b values:

The apparent pK_a and pK_b values of the resins under study were obtained from pH titration curves and calculation using equation (9) and (14) as described earlier on pages 66, 68 and are reported in Table - TT-26.

It is seen that the range of pK_a obtained for overall cation exchange process in general for various ion exchangers studied is between 10.86 to 11.23 which is slightly higher than that of a characteristic of phenolic hydroxyl group indicating weakly acidic nature of the matrix and that of pK_b obtained for the overall anion exchange process for these resins lies between 2.9 to 3.2 which is a characteristic of bases of weak strength.

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

EP(3-OH)TT > EP(BR)TT > EP(CA)TT >
EP(SS)TT > EP(AN)TT > EP(HQ)TT >
EP(8-OH)TT > EP(PHB)TT > EP(SA)TT,

where as the pK_b values for the resins are in the following decreasing order,

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

<u>Isoionic point:</u>

The values of isoionic point (i_p) are presented in Table - TT - 26. The values vary in the range of 7.00 to 7.23. Isoionic point for Histidine is 7.59 (141). It is observed that resins under study have slightly low value than that of Histidine.

The isoionic point values are in the decreasing order as,

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

Thermal stability:

The results of thermal stability of amphoteric resins as cation exchanger in free acid form and in salt form such as Na-form at different temperatures are presented in Table - TT - 27 and as anion exchanger in free base form and in salt form such as Cl - form at different temperatures are presented in Table - TT - 28.

It is seen that no change in the total capacity for all the forms (H - , Na - , OH - and Cl - forms) of the resins are observed upto 80°C. Hence the amphoteric can be safely used upto temperature 80°C. Above this temperature, they show increase in capacity when heated resins were tested could be due to (i) destruction of some of the $-\underset{|}{\mathrm{CH}}-$ bridges, creating more gaps in the matrix thereby facilitating the acess to more - NH - groups,

(ii) removal of the decomposition products which had neutralized the ionogenic groups.

Further, it is seen from the Table - TT - 27 and Table - TT - 28 that the salt forms of the resins are more stable than the free acid or base form which is in conformity with the earlier observation of Hall et al (142).

The following order for thermal stability of the cationic form of the amphoteric ion exchangers was observed,

EP(CA)TT > EP(8-OH)TT > EP(HQ)TT >
EP(PHB)TT > EP(SS)TT > EP(AN)TT >
EP(SA)TT > EP(BR)TT > EP(3-OH)TT,

while for anionic form of the resins, the thermal stability decreasing order is,

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

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

The results of the effect of varying temperature of equilibration on the capacity of the resins are reported in Table - TT -29.

From the data, it is revealed that the anion exchange capacity of amphoteric resin increases with the rise in temperature of equilibration. This can be explained as follows:

On heating the resins, certain basic gaseous decomposition products (such as NH_3 resulting from triethylenetetramine used in the preparation of resins) are produced which neutralize a part of the acid during equilibration, thus giving apparently higher value for the anion exchange capacity of the resin.

The loss in cation exchange capacity of the resin with the rise in equilibration temperature may be due to the loss of ionogenic groups.

Oxidation resistance:

Results of oxidation resistance test of different amphoteric exchangers as cation exchanger are presented in Table - TT - 30 and as anion exchanger are presented in Table - TT - 31.

Amphoteric resin EP(3-OH)TT exhibits the lowest increase in percentage water content as cation exchanger and resin EP(CA)TT as anion exchanger and thus they are the most resistant to oxidation. We observed that with few exceptions [EP(CA)TT and EP(PHB)TT], the oxidative degradation for amphoteric resins as anion exchanger exhibit high increase in percentage water content than the amphoteric resins as cation exchanger. Hence we suggest that cationic form is less susceptible to oxidation than the anionic form.

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

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

Amphoteric resins as anion exchanger show the following decreasing order for their stability on oxidative degradation,

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

<u>Behaviour in non aqueous solvents</u>:

The results of behaviour of these resins as cation exchanger as well as anion exchanger in non-aqueous solvents are reported in Table - TT - 32 and Table - TT - 33.

It is observed that,

(1) polar solvents produce more extensive swelling than non polar hydrocarbons,

(2) In polar solvents (H_2O, CH_3OH, CH_3COOH) amphoteric resins as anion exchanger swell more than the cationic type.

(3) percentage swelling of amphoteric resins in acetic acid as anion exchanger as well as cation exchanger is much greater than would be anticipated. This can be explained as follows:

Swelling of amphoteric resins with both weak acid and weak base groups is a function of the pH of the solution and show a characteristic minimum near the isoelectronic point of the resin. Here the active groups of both the types are practically undissociated, so that the osmotic pressure difference is small. When the pH is increased or decreased, either the acid or the base groups dissociate, thus increasing the number of osmotically active particles within the resin. The result is an increase in swelling in either case.

(4) the decreasing order of porosity for amphoteric resins as cation exchanger is as follows:

EP(SA)TT > EP(CA)TT > EP(HQ)TT >
EP(BR)TT > EP(SS)TT > EP(AN)TT >
EP(PHB)TT > EP(8-OH)TT > EP(3-OH)TT,

(5) the decreasing order of porosity for amphoteric resins as anion exchanger is as follows:

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

Distribution studies:

The distribution coefficient (K_d) of the cations are reported in Table - TT - 34.

(1) In all the cases the sorption of metal ions increases and then decreases with the increasing concentrations of NH_4OAc. This is probably due to the preferential sorption of NH_4^+ ions on the exchanger in comparison to the charged anionic species.

(2) Sorption of Cu(II) is high at 0.25 M NH_4OAc as compared to the other metal ions.

(3) The EP(SA)TT and EP(BR)TT resins showed greater uptake of Cu^{+2} ions at 1.0 M NH_4OAc than did other resins. It may be suggested that at higher concentration of NH_4OAc, a stable ammonia complex is formed with Cu^{+2}. This metal amine complex as such may be taken up by the exchanger probably by a process of chelation facilitated by multifunctional nature of this amphoteric exchanger.

(4) From Table - TT - 34, it is clear that Cu^{+2} has

distribution coefficient (K_d) 783.24 as compared to 3.96 for Mg^{+2} at 0.25 M of NH_4OAc, indicating the possibilities of chromatographic separation of these two ions employing EP(BR)TT resin. Similarly, Cu(II) can be separated from Ca (II) or Mg (II) employing EP(SA)TT resin at 0.25 M concentration of NH_4OAc.

These results show the possible application of EP(BR)TT or EP(SA)TT resins for the extraction of copper from industrial alkaline wastes containing copper, and in metallurgical extraction of copper.

A chromatographic separation* of Co^{+2} from Cu^{+2} [Fig 18A] was achieved using a resin EP(BR)TT (NH_4^+ - form) and the results are presented in Table - TT - 34 (A).

(5) Relatively low uptake of Cu^{+2} by EP(8-OH)TT and EP(AN)TT resins, eventhough amino nitrogen is present in the structure, could not be explained by the process of chelation.

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

* Procedure is on page 192

$[NH_4OAC] = 0.02$ M

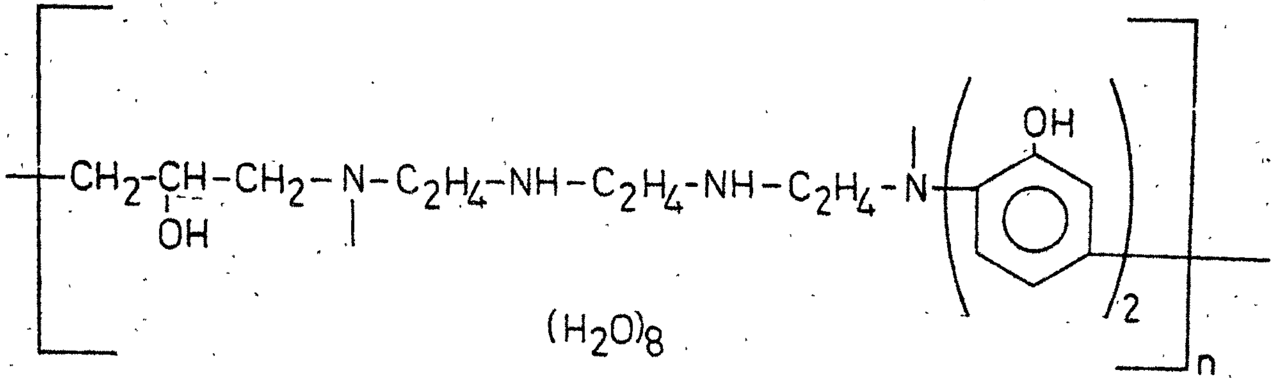
Resin	Sorption order
EP(CA)TT	Cu > Zn > Ni > Ca > Co > Mg
EP(8-OH)TT	Cu > Zn > Ni > Ca > Co > Mg
EP(HQ)TT	Cu > Zn > Ni > Ca > Co > Mg
EP(SA)TT	Cu > Ni > Zn > Ca > Co > Mg
EP(SS)TT	Cu > Zn > Ni > Ca > Co > Mg
EP(3-OH)TT	Cu > Zn > Ni > Ca > Co > Mg
EP(PHB)TT	Cu > Zn > Ni > Co > Ca > Mg
EP(BR)TT	Cu > Ni > Zn > Co > Ca > Mg
EP(AN)TT	Cu > Zn > Ni > Co > Ca > Mg

$[NH_4OAc] = 0.25$ M

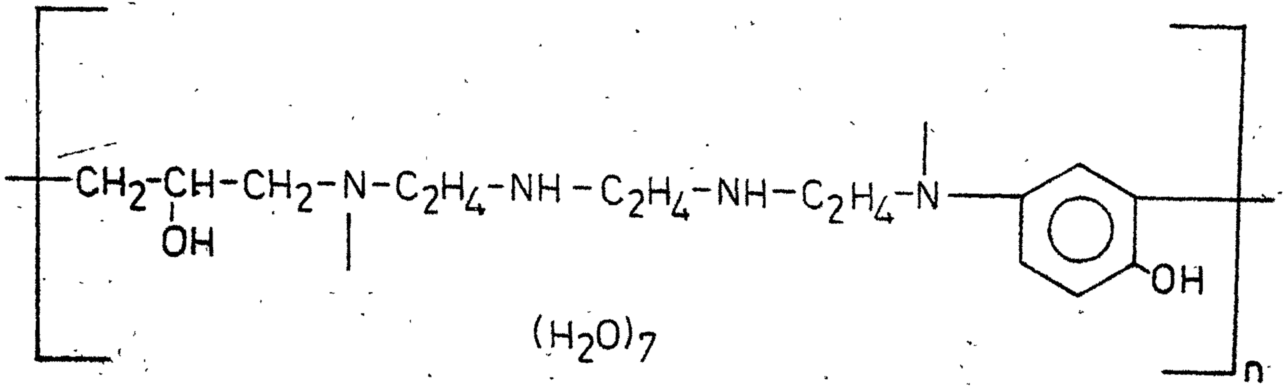
Resin	Sorption order
EP(CA)TT	Cu > Zn > Ni > Co > Ca > Mg
EP(8-OH)TT	Cu > Zn > Ni > Ca > Co > Mg
EP(HQ)TT	Cu > Zn > Ni > Co > Ca > Mg
EP(SA)TT	Cu > Co > Zn > Ni > Ca > Mg
EP(SS)TT	Cu > Co > Zn > Ni > Ca > Mg
EP(3-OH)TT	Cu > Co > Zn > Ni > Ca > Mg
EP(PHB)TT	Cu > Co > Zn > Ni > Ca > Mg
EP(BR)TT	Cu > Ni > Zn > Co > Ca > Mg
EP(AN)TT	Cu > Co > Zn > Ni > Ca > Mg

$[NH_4OAc] = 1.00$ M

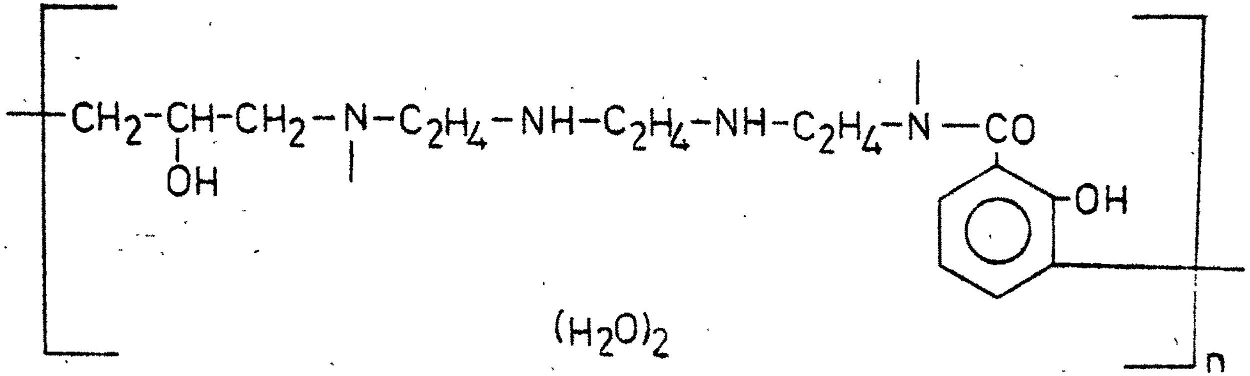
Resin	Sorption order
EP(CA)TT	Cu > Zn > Ni > Co > Ca > Mg
EP(8-OH)TT	Cu > Zn > Ni > Co > Ca > Mg
EP(HQ)TT	Cu > Zn > Ni > Co > Ca > Mg
EP(SA)TT	Cu > Zn > Ni > Ca > Co > Mg
EP(SS)TT	Cu > Ni > Zn > Ca > Co > Mg
EP(3-OH)TT	Cu > Zn > Ni > Co > Ca > Mg
EP(PHB)TT	Cu > Zn > Ni > Ca > Co > Mg
EP(BR)TT	Cu > Ni > Zn > Ca > Co > Mg
EP(AN)TT	Cu > Zn > Ni > Ca > Co > Mg



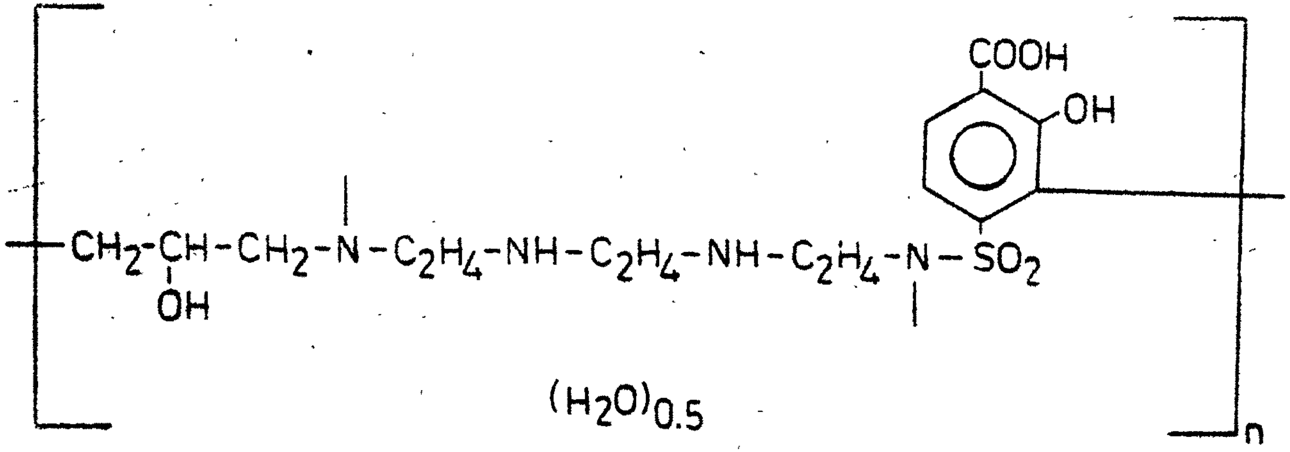
EP(CA)TT (I-S-28)



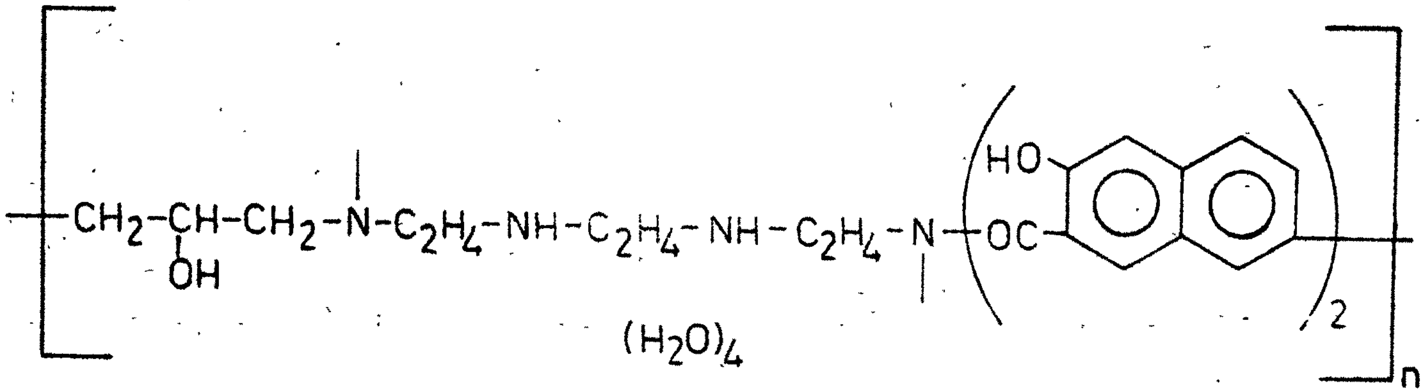
EP(HQ)TT (I-S-29)



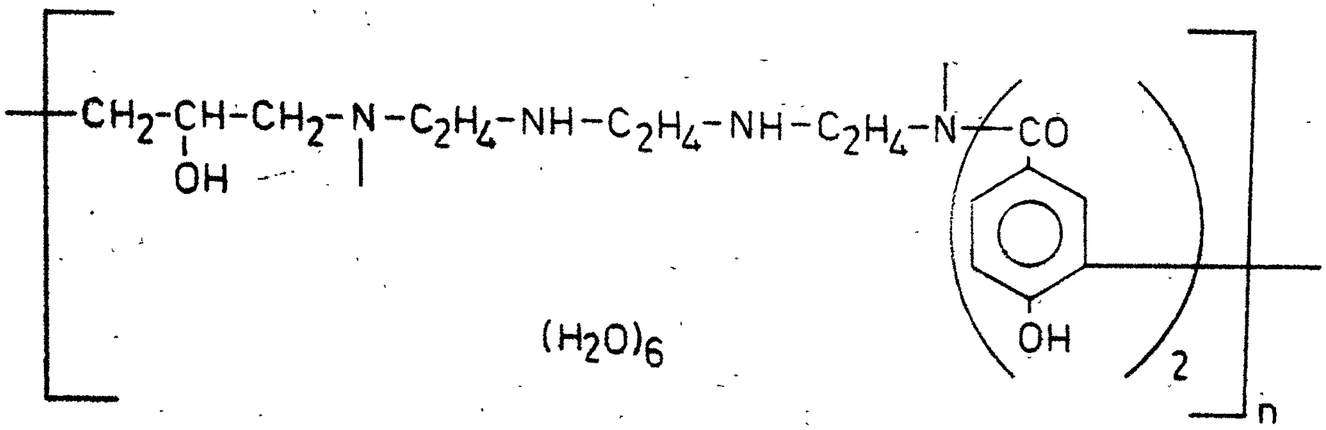
EP(SA)TT (I-S-30)



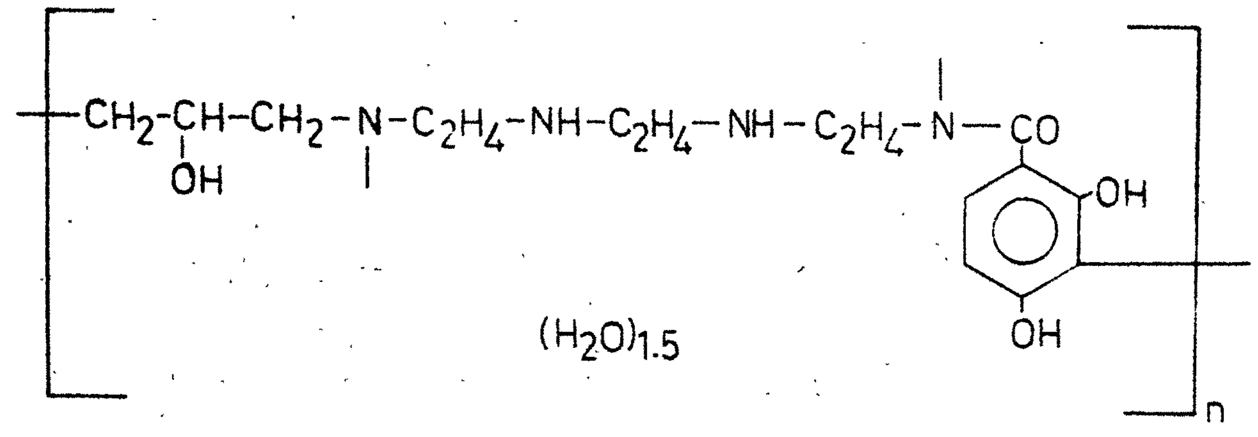
EP(SS)TT (I-S-31)



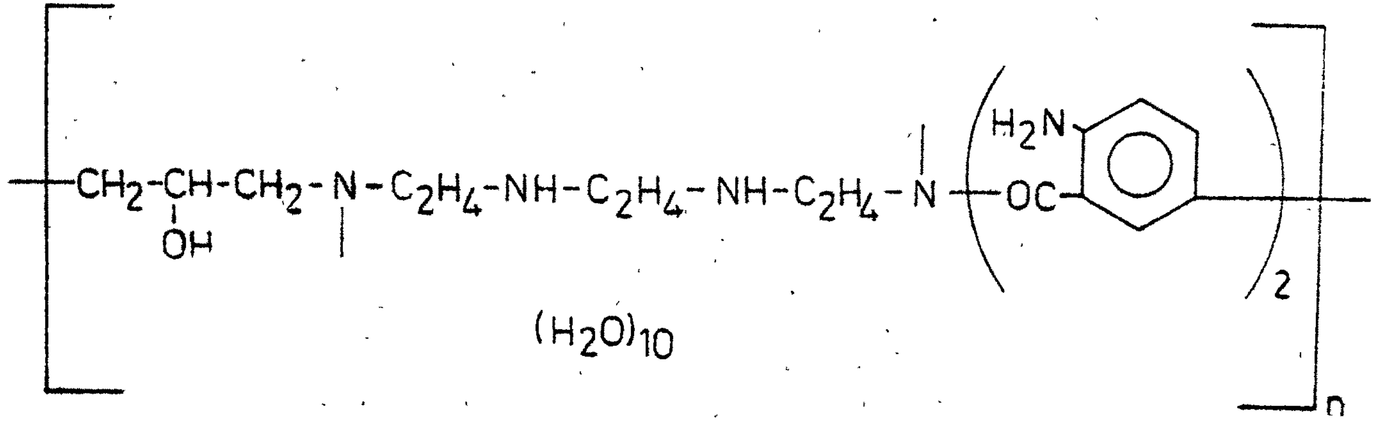
EP(3 OH)TT (I-S-32)



EP(PHB)TT (I-S-33)



EP(BR)TT (I-S-34)



EP(AN)TT (I-S-35)

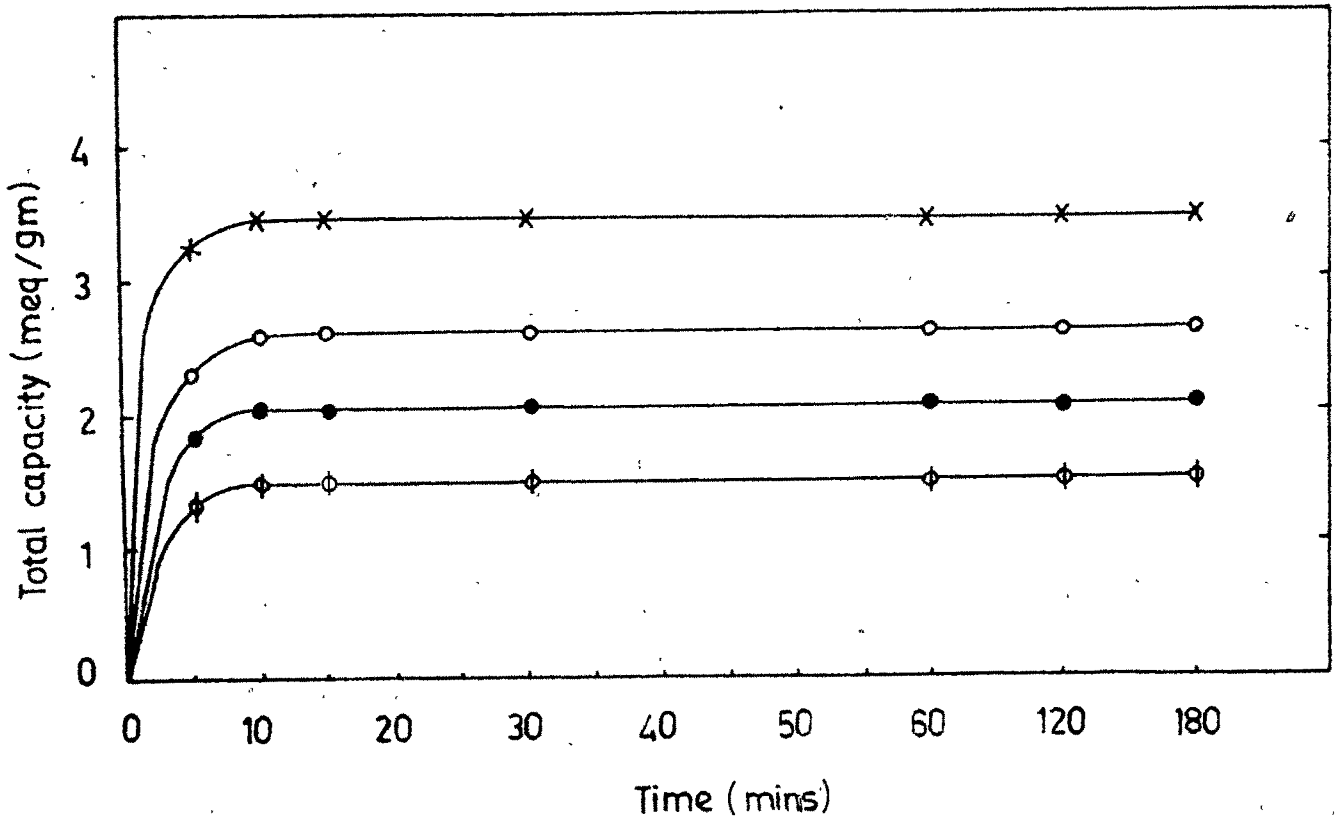


FIG 10 — RATE OF CATION EXCHANGE OF EP(BR)TT [×—×], EP(AN)TT [○—○], EP(8-OH)TT [●—●] AND EP(CA)TT [ϕ—ϕ] RESINS

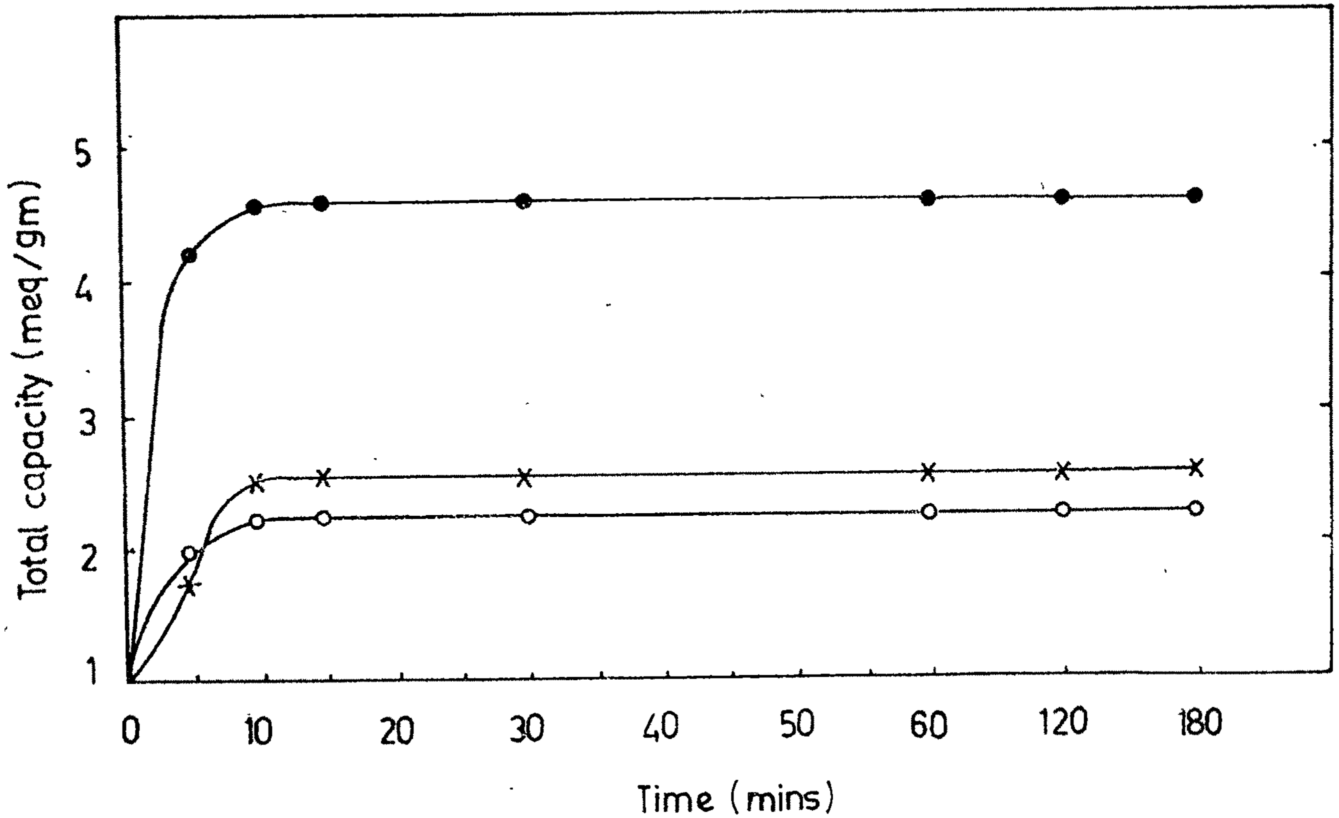


FIG 11 – RATE OF CATION EXCHANGE OF EP(SA)TT [●—●], EP(SS)TT [x—x] AND EP(HQ)TT [○—○] RESINS

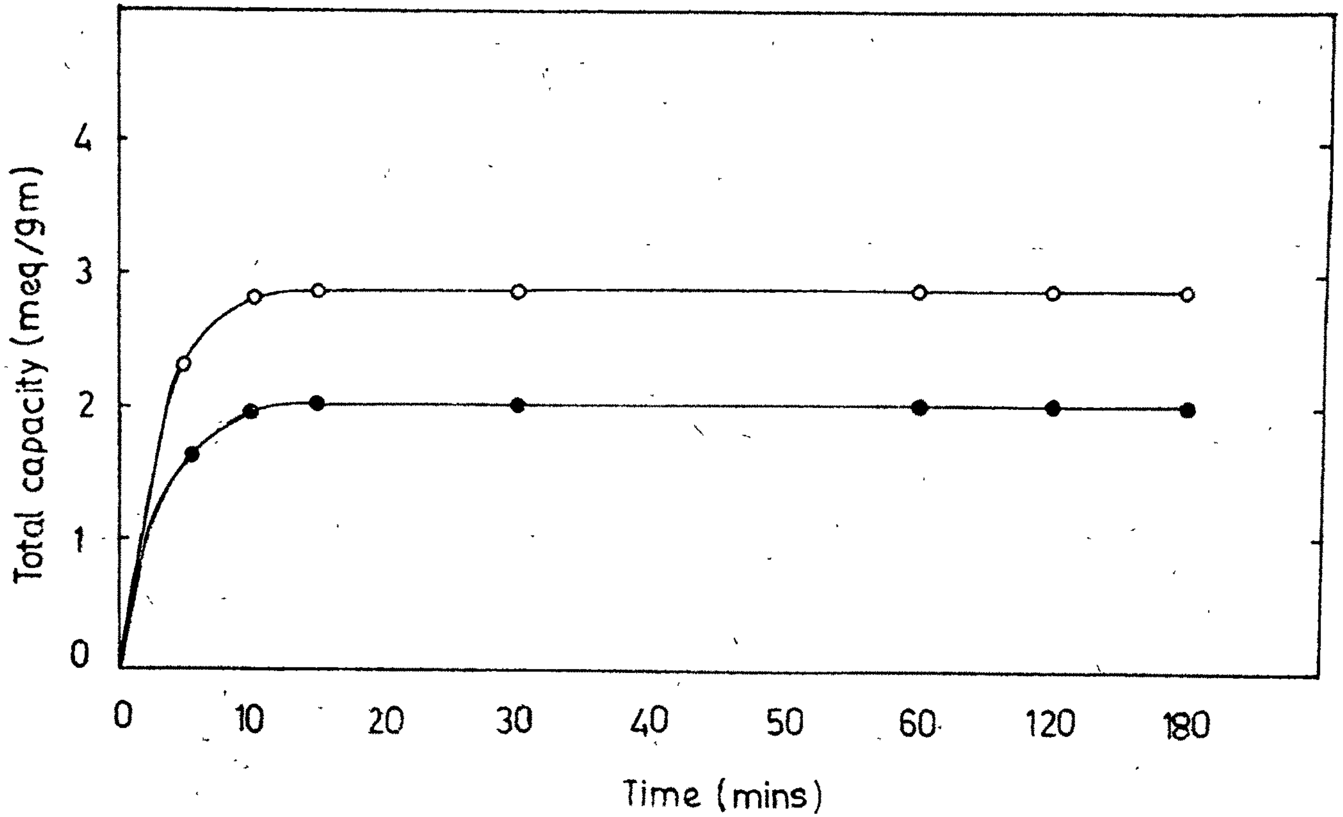


FIG 12 – RATE OF CATION EXCHANGE OF EP(3-OH)TT [○—○] AND EP(PHB)TT [●—●] RESINS

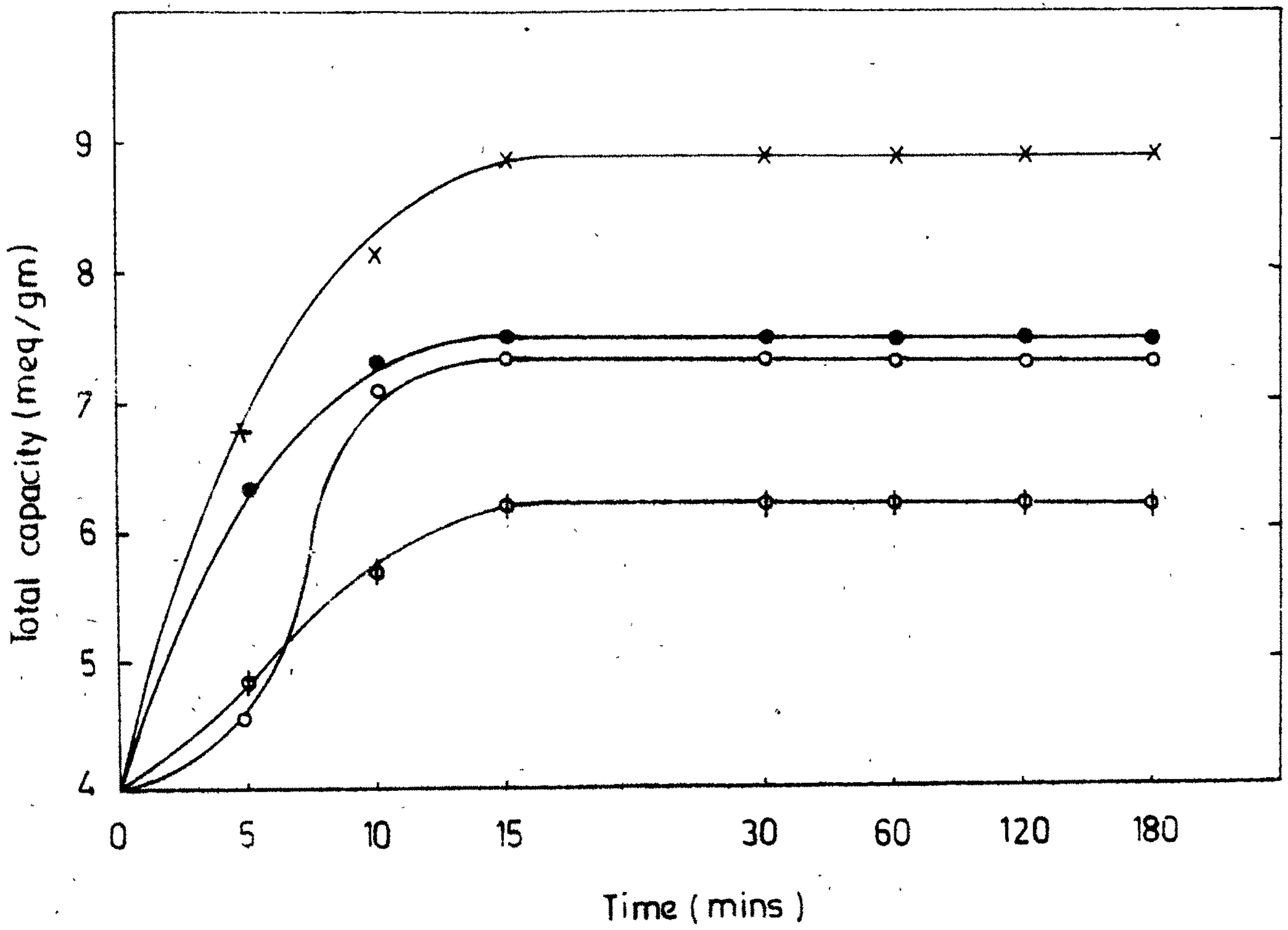


FIG 13 – RATE OF ANION EXCHANGE OF EP(SA)TT [×—×], EP(HQ)TT [●—●], EP(SS)TT [○—○] AND EP(8-OH)TT [⦶—⦶] RESINS

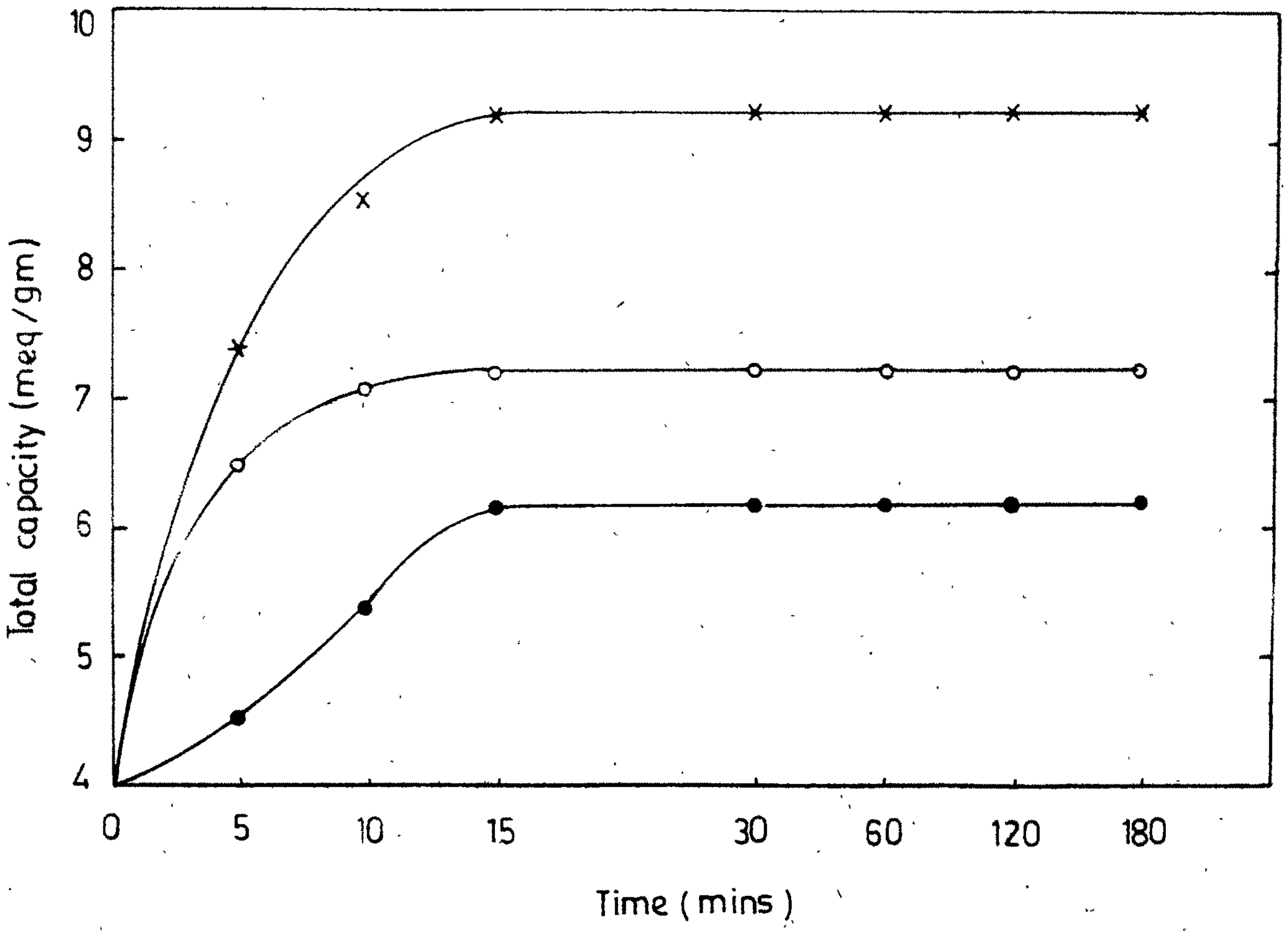


FIG 14 – RATE OF ANION EXCHANGE OF EP(BR)TT [×—×]
EP(PHB)TT [○—○] AND EP(AN)TT [●—●] RESINS

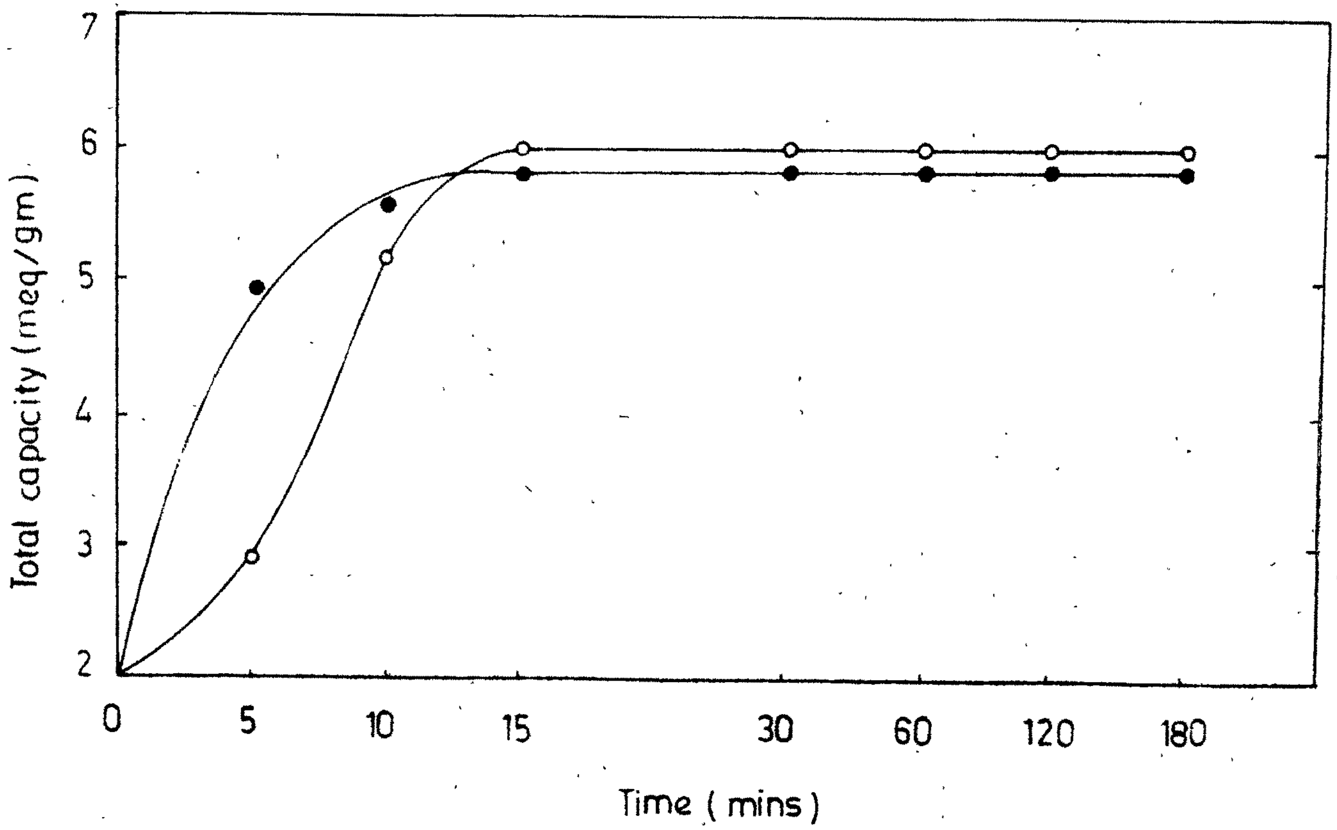


FIG 15 — RATE OF ANION EXCHANGE OF EP(3-OH)TT [○—○] AND EP(CA)TT [●—●] RESINS

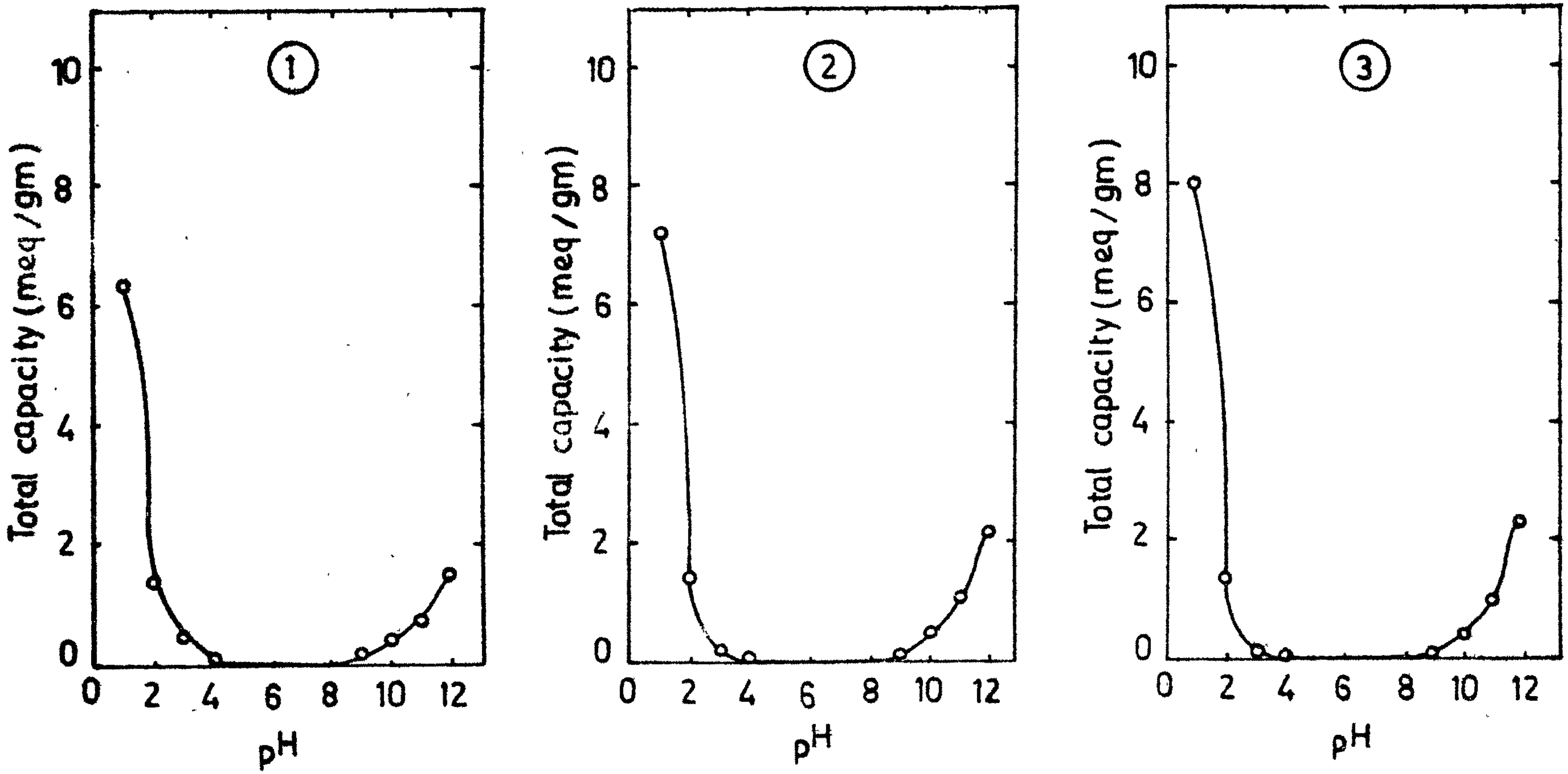


FIG 16 — pH-TITRATION CURVES OF ① EP(CA)TT ② EP(8-OH)TT ③ EP(HQ)TT RESINS

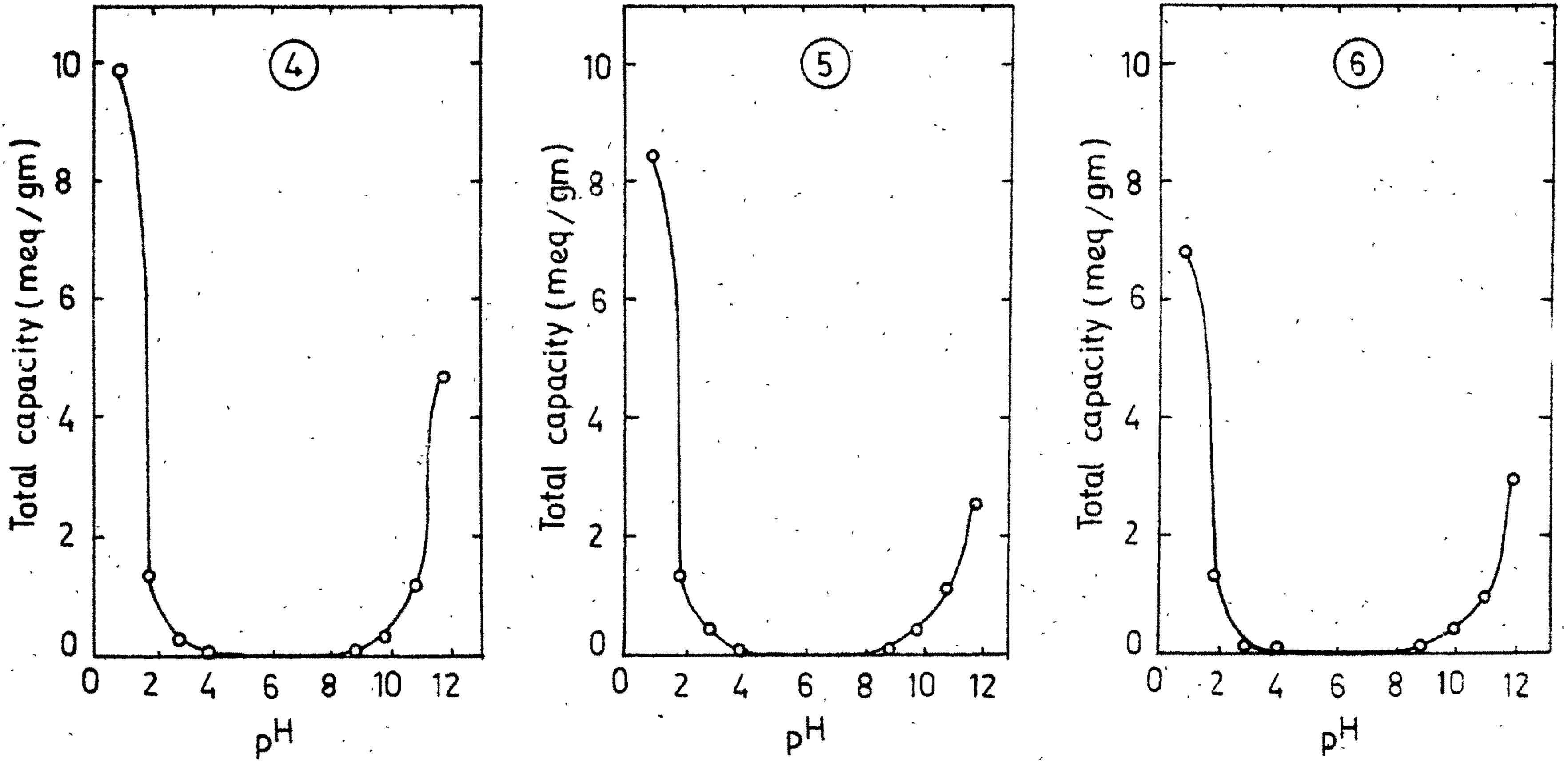


FIG 17 — p^H-TITRATION CURVES OF ④ EP(SA)TT ⑤ EP(SS)TT ⑥ EP(3-OH)TT RESINS

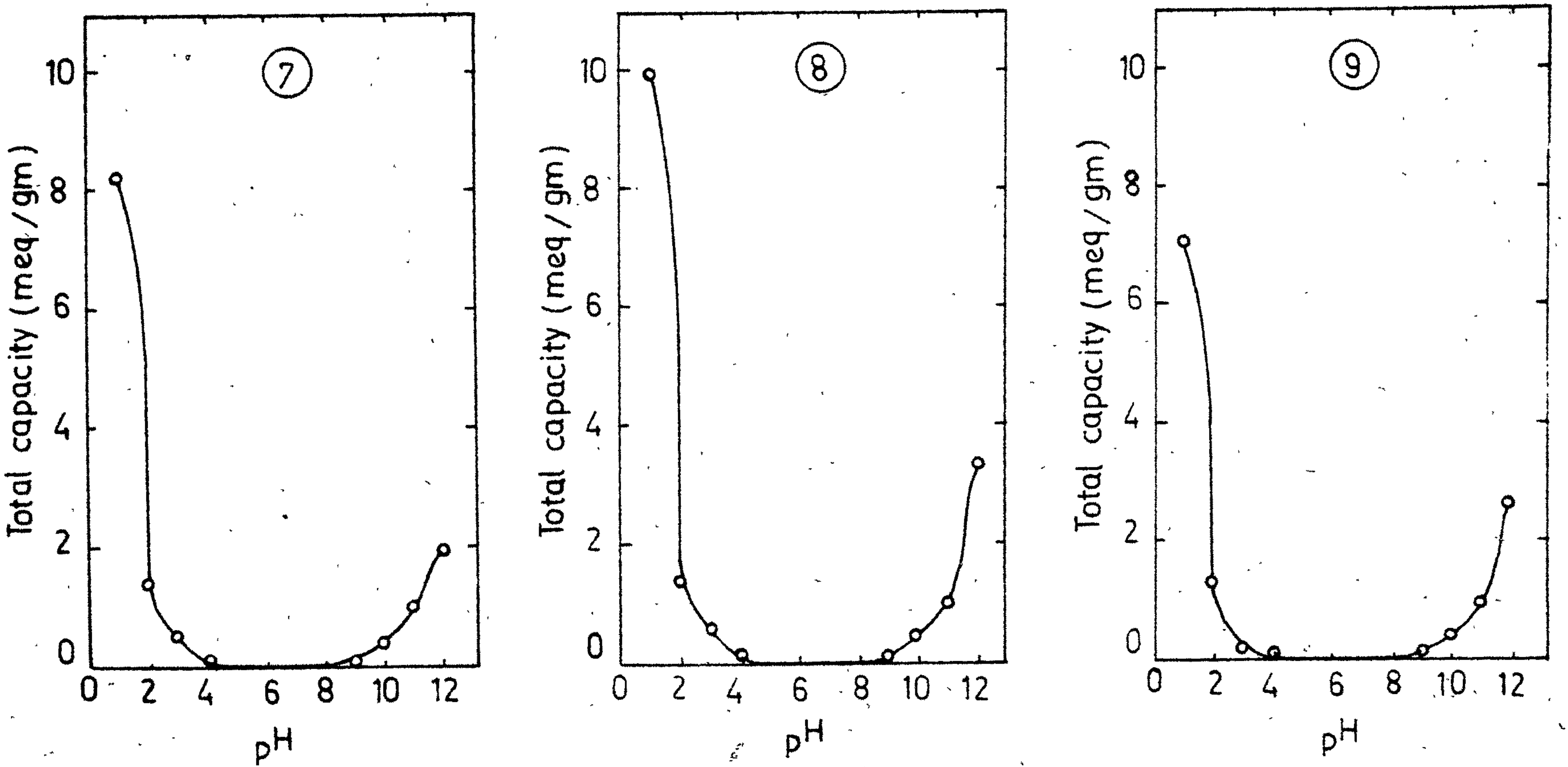


FIG 18 — pH-TITRATION CURVES OF ⑦ EP(PHB)TT ⑧ EP(BR)TT ⑨ EP(AN)TT RESINS

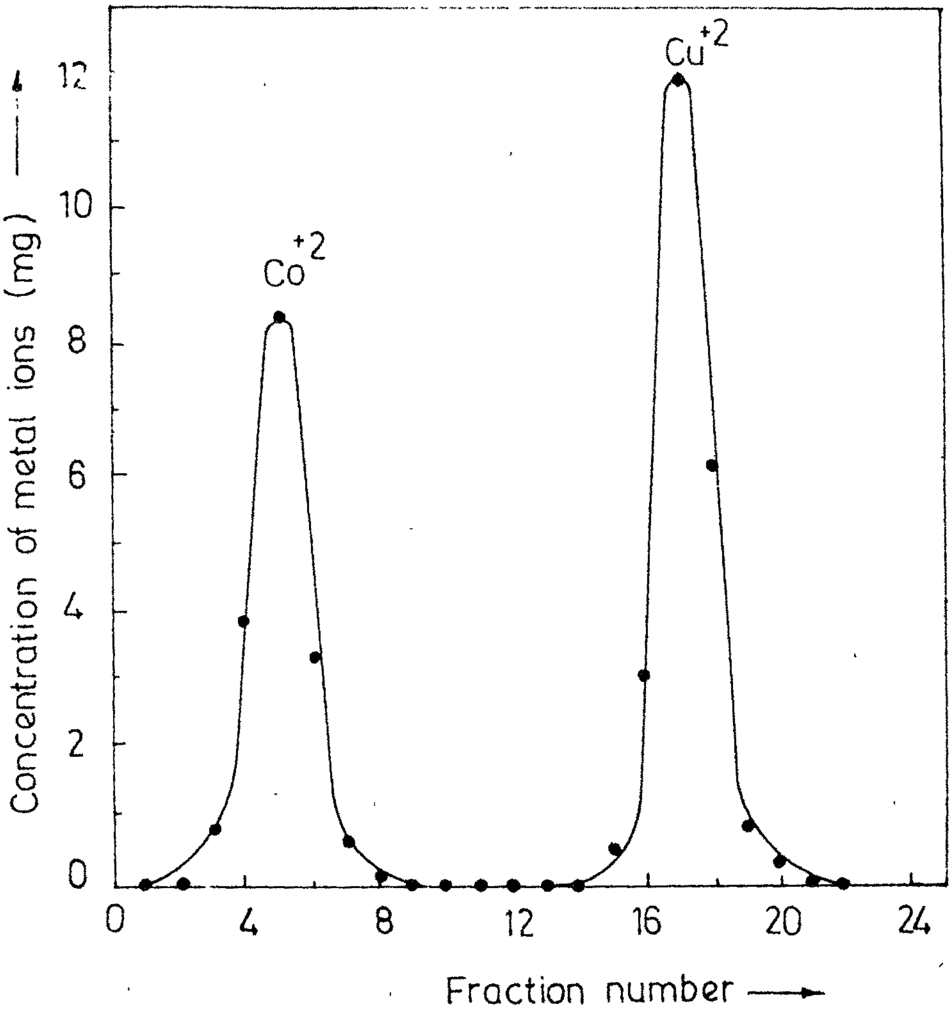

Concentration of metal ions (mg)
0
2
4
6
8
10
12
Co^{+2}
Cu^{+2}
0
4
8
12
16
20
24
Fraction number

FIG - 18 (A)

TABLE - TT - 18

Abbreviation

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

TABLE - TT - 19

Analyses, Formulae etc. of Amphoteric resins

No.	Resin	Formula	Analysis					
			Calculated			Observed		
			%C	% H	% N	% C	% H	% N
1	EP(CA)TT	$(C_{21}H_{44}O_{11}N_4)_n$	47.72	8.33	10.60	48.11	8.52	10.45
2	EP(8-OH)TT	-	-	-	-	-	-	-
3	EP(HQ)TT	$(C_{16}H_{38}O_9N_4)_n$	44.65	8.84	13.02	45.01	8.59	12.86
4	EP(SA)TT	$(C_{16}H_{28}O_5N_4)_n$	53.93	7.86	15.73	53.59	8.04	15.76
5	EP(SS)TT	$(C_{16}H_{25}O_{6.5}N_4S)_n$	46.94	6.11	13.69	46.71	5.90	14.16
6	EP(3-OH)TT	$(C_{31}H_{40}O_9N_4)_n$	60.78	6.53	9.15	60.37	6.74	9.12
7	EP(PHB)TT	$(C_{23}H_{40}O_9N_4)_n$	53.48	7.75	10.85	53.11	8.02	10.57
8	EP(BR)TT	$(C_{16}H_{27}O_{5.5}N_4)_n$	52.89	7.43	15.42	52.61	7.52	15.21
9	EP(AN)TT	$(C_{23}H_{50}O_{13}N_6)_n$	44.66	8.09	13.59	44.31	8.29	13.24

TABLE - TT - 20

% Moisture content of Amphoteric resins

No.	Resin	% Moisture	
		H^+ form	OH^- form
1	EP(CA)TT	6.37	10.10
2	EP(8-OH)TT	3.76	7.80
3	EP(HQ)TT	2.90	7.60
4	EP(SA)TT	3.35	7.74
5	EP(SS)TT	5.29	6.50
6	EP(3-OH)TT	1.15	5.20
7	EP(PHB)TT	4.00	8.60
8	EP(BR)TT	2.74	4.40
9	EP(AN)TT	1.90	3.52

TABLE - TT - 21

Density of resins

No.	Resin	Resin in H^+ form		Resin in OH^- form	
		true density (d_{res}) (gm/cm^3)	apparent (column) density (d_{col}) (gm/ml)	true density (d_{res}) (gm/cm^3)	apparent (column) density (d_{col}) (gm/ml)
1	EP(CA)TT	1.1460	0.3641	1.5950	0.3804
2	EP(8-OH)TT	1.1080	0.4212	1.2610	0.5643
3	EP(HQ)TT	1.1000	0.3808	1.5240	0.4467
4	EP(SA)TT	1.5510	0.2337	1.4350	0.2845
5	EP(SS)TT	1.1640	0.3749	2.0800	0.4037
6	EP(3-OH)TT	1.2650	0.4454	2.5000	0.3858
7	EP(PHB)TT	1.1670	0.3326	1.1360	0.3250
8	EP(BR)TT	1.2180	0.2122	1.8080	0.2108
9	EP(AN)TT	1.2390	0.4528	2.2200	0.3744

TABLE - TT - 22

Void volume fraction of resins

No.	Resin	Resin in H^+ form		Resin in OH^- 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)TT	0.3177	0.6823	0.2385	0.7615
2	EP(8-OH)TT	0.3801	0.6199	0.4475	0.5525
3	EP(HQ)TT	0.3462	0.6538	0.2930	0.7060
4	EP(SA)TT	0.1507	0.8493	0.1982	0.8018
5	EP(SS)TT	0.3221	0.6779	0.1941	0.8059
6	EP(3-OH)TT	0.3521	0.6479	0.1543	0.8457
7	EP(PHB)TT	0.2850	0.7150	0.2861	0.7139
8	EP(BR)TT	0.1742	0.8258	0.1166	0.8834
9	EP(AN)TT	0.3654	0.6346	0.1686	0.8314

TABLE - TT - 23

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

No.	Resin	Total Capacity CEC_{obs} (meq/gm)	Total Capacity CEC_{cal} (meq/gm)	$\frac{CEC_{obs}}{CEC_{cal}}$	Concentration of ionogenic groups C_r (meq/cm^3)	Volume capacity Q gm.eq/l	Cu-exchange capacity (meq/gm)
1	EP(CA)TT	1.440	1.890	0.76	1.545	0.491	0.98
2	EP(8-OH)TT	2.040	-	-	2.175	0.827	1.47
3.	EP(HQ)TT	2.200	2.325	0.94	2.350	0.813	1.75
4.	EP(SA)TT	4.600	2.809	1.63	6.900	1.039	4.17
5	EP(SS)TT	2.534	2.440	1.04	2.794	0.900	1.82
6	EP(3-OH)TT	2.833	1.634	1.73	3.546	1.247	1.53
7	EP(PHB)TT	1.950	1.937	1.01	2.185	0.623	1.32
8	EP(BR)TT	3.440	2.754	1.25	4.075	0.710	2.47
9	EP(AN)TT	2.610	1.618	1.61	3.172	1.159	2.01

TABLE - TT - 24

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

No.	Resin	Total capacity AEC_{obs} (meq/gm)	Total capacity AEC_{cal} (meq/gm)	$\frac{AEC_{obs}}{AEC_{cal}}$	Concentration of ionogenic groups C_r (meq/cm^3)	Volume capacity Q gm.eq/l
1	EP(CA)TT	5.85	3.780	1.54	8.388	2.000
2	EP(8-OH)TT	6.16	-	-	7.162	3.205
3	EP(HQ)TT	7.38	4.650	1.59	10.390	3.045
4	EP(SA)TT	8.88	5.618	1.58	11.760	2.330
5	EP(SS)TT	7.27	4.880	1.49	14.140	2.744
6	EP(3-OH)TT	6.03	3.268	1.84	14.290	2.205
7	EP(PHB)TT	7.25	3.876	1.87	7.530	2.153
8	EP(BR)TT	9.24	5.509	1.67	15.970	1.862
9	EP(AN)TT	6.18	4.854	1.27	13.240	2.232

TABLE - TT - 25

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)TT	5	1.346	4.950
		10	1.440	5.550
		15	1.440	5.850
		30	1.440	5.850
		60	1.440	5.850
		120	1.440	5.850
		180	1.440	5.850
2	EP(8-OH)TT	5	1.850	4.780
		10	2.040	5.670
		15	2.040	6.160
		30	2.040	6.160
		60	2.040	6.160
		120	2.040	6.160
		180	2.040	6.160
3	EP(HQ)TT	5	2.000	6.330
		10	2.200	7.330
		15	2.200	7.450
		30	2.200	7.450
		60	2.200	7.450
		120	2.200	7.450
		180	2.200	7.450

(TABLE - TT - 25 contd......)

No.	Resin	Time in minutes	Cation exchange capacity realized (meq/gm)	Anion exchange capacity realized (meq/gm)
4	EP(SA)TT	5	4.250	6.753
		10	4.600	8.110
		15	4.600	8.880
		30	4.600	8.880
		60	4.600	8.880
		120	4.600	8.880
		180	4.600	8.880
5	EP(SS)TT	5	1.813	4.500
		10	2.534	7.090
		15	2.534	7.270
		30	2.534	7.270
		60	2.534	7.270
		120	2.534	7.270
		180	2.534	7.270
6	EP(3-OH)TT	5	2.250	2.885
		10	2.833	5.200
		15	2.833	6.030
		30	2.833	6.030
		60	2.833	6.030
		120	2.833	6.030
		180	2.833	6.030

(TABLE - TT - 25 contd......)

No.	Resin	Time in minutes	Cation exchange capacity realized (meq/gm)	Anion exchange capacity realized (meq/gm)
7	EP(PHB)TT	5	1.640	6.550
		10	1.950	7.100
		15	1.950	7.250
		30	1.950	7.250
		60	1.950	7.250
		120	1.950	7.250
		180	1.950	7.250
8	EP(BR)TT	5	3.240	7.500
		10	3.440	8.590
		15	3.440	9.240
		30	3.440	9.240
		60	3.440	9.240
		120	3.440	9.240
		180	3.440	9.240
9	EP(AN)TT	5	2.290	4.505
		10	2.610	5.360
		15	2.610	6.180
		30	2.610	6.180
		60	2.610	6.180
		120	2.610	6.180
		180	2.610	6.180

TABLE - TT - 26

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)TT	11.094	2.939	7.016
2	EP(8-OH)TT	10.918	3.092	7.005
3	EP(HQ)TT	10.998	3.141	7.069
4	EP(SA)TT	10.787	3.232	7.009
5	EP(SS)TT	11.025	3.160	7.092
6	EP(3-OH)TT	11.232	3.020	7.126
7	EP(PHB)TT	10.866	3.151	7.008
8	EP(BR)TT	11.231	3.234	7.232
9	EP(AN)TT	11.012	2.988	7.000

TABLE - TT - 27

Thermal Stability of Amphoteric 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
80°	EP(CA) TT	1.440	NIL	NIL	NIL	NIL
	EP(8-OH) TT	2.040	NIL	NIL	NIL	NIL
	EP(HQ) TT	2.200	NIL	NIL	NIL	NIL
	EP(SA) TT	4.600	NIL	NIL	NIL	NIL
	EP(SS) TT	2.534	NIL	NIL	NIL	NIL
	EP(3-OH) TT	2.833	NIL	NIL	NIL	NIL
	EP(PHB) TT	1.950	NIL	NIL	NIL	NIL
	EP(BR) TT	3.440	NIL	NIL	NIL	NIL
	EP(AN) TT	2.610	NIL	NIL	NIL	NIL

(TABLE - TT - 27 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)TT	1.440	9.11	7.41	29.30	9.58
	EP(8-OH)TT	2.040	11.62	9.05	32.01	10.17
	EP(HQ)TT	2.200	13.10	11.17	23.20	10.70
	EP(SA)TT	4.600	17.41	15.09	22.12	11.32
	EP(SS)TT	2.534	15.00	13.11	18.27	14.40
	EP(3-OH)TT	2.833	19.61	16.07	35.40	19.31
	EP(PHB)TT	1.950	13.34	12.15	22.38	17.16
	EP(BR)TT	3.440	18.47	15.67	27.30	21.32
	EP(AN)TT	2.610	16.50	14.89	26.17	19.19

(TABLE - TT - 27 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)TT	1.440	11.35	9.91	31.81	11.98
	EP(8-OH)TT	2.040	13.92	11.25	34.10	12.56
	EP(HQ)TT	2.200	15.60	13.67	25.78	12.95
	EP(SA)TT	4.600	19.61	17.58	24.63	13.80
	EP(SS)TT	2.534	17.50	15.62	20.78	16.82
	EP(3-OH)TT	2.833	21.84	18.56	37.92	21.49
	EP(PHB)TT	1.950	15.94	14.66	24.91	19.59
	EP(BR)TT	3.440	20.57	17.97	29.97	23.90
	EP(AN)TT	2.610	18.93	16.00	28.45	22.00

(TABLE - TT - 27 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)TT	1.440	16.54	15.01	37.00	17.04
	EP(8-OH)TT	2.040	18.93	16.32	39.22	17.81
	EP(HQ)TT	2.200	20.74	18.76	31.00	18.02
	EP(SA)TT	4.600	24.72	22.81	29.36	19.04
	EP(SS)TT	2.534	22.61	20.75	26.12	21.91
	EP(3-OH)TT	2.833	26.90	23.66	43.03	25.96
	EP(PHB)TT	1.950	20.92	20.15	26.08	24.00
	EP(BR)TT	3.440	25.76	23.42	35.13	29.17
	EP(AN)TT	2.610	24.11	21.89	33.50	27.59

TABLE - TT - 28

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)TT	5.850	NIL	NIL	NIL	NIL
	EP(8-OH)TT	6.160	NIL	NIL	NIL	NIL
	EP(HQ)TT	7.450	NIL	NIL	NIL	NIL
	EP(SA)TT	8.880	NIL	NIL	NIL	NIL
	EP(SS)TT	7.270	NIL	NIL	NIL	NIL
	EP(3-OH)TT	6.030	NIL	NIL	NIL	NIL
	EP(PHB)TT	7.250	NIL	NIL	NIL	NIL
	EP(BR)TT	9.240	NIL	NIL	NIL	NIL
	EP(AN)TT	6.180	NIL	NIL	NIL	NIL

(TABLE - TT - 28 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)TT	5.850	4.85	3.46	6.71	3.18
	EP(8-OH)TT	6.160	4.96	3.91	7.82	4.46
	EP(HQ)TT	7.450	6.42	4.42	9.63	4.97
	EP(SA)TT	8.880	8.68	5.67	10.72	6.60
	EP(SS)TT	7.270	6.98	4.54	9.94	5.59
	EP(3-OH)TT	6.030	5.88	4.16	8.61	4.63
	EP(PHB)TT	7.250	4.37	3.92	8.20	4.81
	EP(BR)TT	9.240	9.60	5.84	11.67	6.34
	EP(AN)TT	6.180	6.69	4.52	8.87	5.63

(TABLE - TT - 28 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)TT	5.850	12.32	7.01	16.30	9.15
	EP(8-OH)TT	6.160	13.22	8.46	18.24	11.13
	EP(HQ)TT	7.450	18.17	9.02	25.71	13.20
	EP(SA)TT	8.880	22.39	11.00	28.70	15.34
	EP(SS)TT	7.270	18.75	10.02	26.01	14.20
	EP(3-OH)TT	6.030	17.38	8.74	24.11	11.90
	EP(PHB)TT	7.250	16.40	8.57	21.50	10.23
	EP(BR)TT	9.240	19.65	10.90	24.49	11.62
	EP(AN)TT	6.180	17.45	9.09	21.20	10.87

(TABLE - TT - 28 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)TT	5.850	21.34	16.54	23.75	17.51
	EP(8-OH)TT	6.160	23.00	18.25	25.93	19.79
	EP(HQ)TT	7.450	28.13	20.59	33.92	22.81
	EP(SA)TT	8.880	33.42	24.62	41.34	27.30
	EP(SS)TT	7.270	29.90	22.90	35.73	24.34
	EP(3-OH)TT	6.030	27.85	19.83	29.96	22.30
	EP(PHB)TT	7.250	25.80	19.14	28.80	20.42
	EP(BR)TT	9.240	29.02	21.29	29.95	20.15
	EP(AN)TT	6.180	26.63	19.54	27.12	19.87

TABLE - TT - 29

Effect of temperature of equilibration on the capacity of the resin

Equilibration period = 2 hrs.
Amount of resin = 0.5 gm

Normality of HCl / NaCl = 0.098 N
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)TT	5.850	5.983	6.195	1.440	0.854	0.748
2	EP(8-OH)TT	6.160	6.390	6.620	2.040	1.870	1.613
3	EP(HQ)TT	7.380	7.640	7.851	2.200	1.753	1.648
4	EP(SA)TT	8.880	9.320	9.663	4.600	3.882	3.621
5	EP(SS)TT	7.270	7.401	7.719	2.534	2.428	2.322
6	EP(3-OH)TT	6.030	6.262	6.530	2.833	2.316	1.671
7	EP(PHB)TT	7.250	7.459	7.880	1.950	1.771	1.667
8	EP(BR)TT	9.240	9.491	9.750	3.440	2.928	2.776
9	EP(AN)TT	6.180	6.277	6.392	2.610	1.835	1.631

TABLE - TT - 30

Oxidation resistance of Amphoteric resins
as cation exchanger

No.	Resin	% Moisture		Increase in % water content
		Untreated exchanger	H_2O_2 treated exchanger	
1	EP(CA)TT	6.37	18.32	11.95
2	EP(8-OH)TT	3.76	15.44	11.68
3	EP(HQ)TT	2.90	16.56	13.66
4	EP(SA)TT	3.35	17.54	14.19
5	EP(SS)TT	5.29	15.94	10.65
6	EP(3-OH)TT	1.15	11.28	10.13
7	EP(PHB)TT	4.00	15.93	11.93
8	EP(BR)TT	2.74	15.78	13.04
9	EP(AN)TT	1.90	14.10	12.20

TABLE - TT - 31

Oxidation resistance of Amphoteric resins as anion exchanger

No.	Resin	% Moisture		Increase in % water content
		Untreated exchanger	H_2O_2 treated exchanger	
1	EP(CA)TT	10.10	16.11	6.01
2	EP(8-OH)TT	7.80	19.48	11.68
3	EP(HQ)TT	7.60	24.27	16.67
4	EP(SA)TT	7.74	25.00	17.26
5	EP(SS)TT	6.50	18.14	11.64
6	EP(3-OH)TT	5.20	17.90	12.70
7	EP(PHB)TT	8.60	18.02	9.42
8	EP(BR)TT	4.40	18.94	14.54
9	EP(AN)TT	3.52	17.56	14.04

TABLE - TT - 32

Swelling of Amphoteric resins as cation exchanger in various solvents

No.	Resin	% Swelling in				
		Glacial Acetic acid	Water	Methanol	Benzene	Acetone
1	EP(CA)TT	230.0	160.0	70.0	0	0
2	EP(8-OH)TT	121.4	50.0	21.4	0	0
3	EP(HQ)TT	250.0	137.5	87.5	0	0
4	EP(SA)TT	287.5	275.0	88.4	0	0
5	EP(SS)TT	100.0	92.3	30.8	0	0
6	EP(3-OH)TT	130.4	47.8	17.4	0	0
7	EP(PHB)TT	60.0	53.3	33.2	0	0
8	EP(BR)TT	173.3	126.6	80.0	0	0
9	EP(AN)TT	171.4	53.6	28.6	0	0

TABLE - TT - 33

Swelling of Amphoteric resins as anion exchanger in various solvents

No.	Resin	% swelling in				
		Glacial Acetic acid	Water	Methanol	Benzene	Acetone
1	EP(CA)TT	400.0	183.3	166.7	0	0
2	EP(8-OH)TT	217.6	157.1	57.0	0	0
3	EP(HQ)TT	371.4	200.0	175.0	0	0
4	EP(SA)TT	866.6	375.0	325.0	0	0
5	EP(SS)TT	320.0	200.0	160.0	0	0
6	EP(3-OH)TT	233.3	144.4	100.0	0	0
7	EP(PHB)TT	180.0	155.0	75.0	0	0
8	EP(BR)TT	260.0	230.0	138.5	0	0
9	EP(AN)TT	300.0	210.0	70.0	0	0

TABLE - TT - 34

Values of distribution coefficients (K_d) in NH_4OAc - DMF media (35 ± 1°C)

No.	Resin	$[K_d]_{A^*}$					
		Ca(II)	Mg(II)	Co(II)	Ni(II)	Cu(II)	Zn(II)
1	EP(CA)TT	6.36	2.87	5.67	25.80	44.50	30.28
2	EP(8-OH)TT	10.23	2.79	3.04	15.53	24.96	19.35
3	EP(HQ)TT	8.33	2.76	4.22	42.92	66.22	48.34
4	EP(SA)TT	11.12	2.77	4.03	33.48	136.65	23.45
5	EP(SS)TT	9.46	3.43	9.00	25.51	54.80	44.52
6	EP(3-OH)TT	7.32	3.29	3.98	12.00	29.54	15.48
7	EP(PHB)TT	10.26	2.80	11.50	30.67	67.00	35.34
8	EP(BR)TT	8.32	2.76	8.70	79.34	356.67	45.27
9.	EP(AN)TT	7.45	3.34	8.65	23.57	33.68	27.82

* A = 0.02 M (concentration of NH_4OAc)

(TABLE - TT - 34 contd.....)

No.	Resin	$[K_d]_B$*					
		Ca(II)	Mg(II)	Co(II)	Ni(II)	Cu(II)	Zn(II)
1	EP(CA)TT	9.57	4.11	17.63	27.13	159.70	31.71
2	EP(8-OH)TT	12.36	3.39	7.55	20.26	53.93	24.36
3	EP(HQ)TT	12.06	3.96	28.00	63.07	136.02	69.57
4	EP(SA)TT	13.65	3.36	57.90	35.11	665.03	40.05
5	EP(SS)TT	10.40	4.06	69.80	40.25	131.36	45.40
6	EP(3-OH)TT	8.18	3.89	24.76	18.66	72.43	22.56
7	EP(PHB)TT	12.20	3.40	58.30	40.60	109.13	45.90
8	EP(BR)TT	9.21	3.96	48.60	147.53	783.24	86.70
9	EP(AN)TT	9.24	3.82	57.04	40.06	65.54	45.27

* B = 0.25 M (concentration of NH_4OAc)

(TABLE - TT -34 contd......)

No.	Resin	$[K_d]_C$*					
		Ca(II)	Mg(II)	Co(II)	Ni(II)	Cu(II)	Zn(II)
1	EP(CA)TT	4.39	3.48	14.14	17.51	132.90	21.53
2	EP(8-OH)TT	3.50	2.21	6.29	16.03	38.58	19.86
3	EP(HQ)TT	7.46	3.35	12.00	48.13	102.00	53.78
4	EP(SA)TT	12.62	2.38	3.78	32.00	325.70	36.62
5	EP(SS)TT	6.78	3.43	3.82	34.20	93.76	29.93
6	EP(3-OH)TT	5.20	2.24	7.35	17.63	44.57	21.48
7	EP(PHB)TT	9.33	1.80	2.79	32.21	92.50	36.94
8	EP(BR)TT	7.45	3.00	3.77	124.58	542.07	36.40
9	EP(AN)TT	5.79	2.76	4.75	31.79	52.90	36.25

* C = 1.00 M (concentration of NH_4OAc)

TABLE - TT - 34 (A)

Chromatography of mixture of Co^{+2} and Cu^{+2} on EP(BR)TT amphoteric resin - (NH_4^+ - form)

Fraction No.	Volume, ml	mg of metal ion	
		Co^{+2}	Cu^{+2}
Elution with 0.3 M CH_3COOH			
1	10	0.000	
2	10	0.088	
3	10	0.884	
4	10	3.978	
5	10	8.546	
6	10	3.389	
7	10	0.736	
8	10	0.177	
9	10	0.088	
10	10	-	
11	10	-	
12	10	-	
Elution with 1.0 M HCl			
13	10		0.000
14	10		0.000
15	10		0.635
16	10		3.177
17	10		12.073
18	10		6.354
19	10		0.953
20	10		0.318
21	10		0.000
Total metal ion recovered from resin bed		17.886	23.510
Total metal ions in the influent		17.976	23.573

Column diameter = 1.0 cm   Bed height = 23.0 cms

Mesh size = -60 + 100