CHAPTER II

(II) Poly (vinyl chloride) - Phenolic Derivatives Type Ion-Exchange Resins

EXPERIMENTAL

(a) Synthesis of Ion-exchange resins.

1 mole phenolic derivatives such as anthranilic acid, gallic acid , P-hydroxybenzaldehyde, pyrogallol, 8-hydroxyquinoline, salicyclic acid, hydroquinone or β-resorcylic acid were dissolved in 50 ml DMF and taken in 250ml round bottom flask to this 1 mole of poly (vinyl chloride) (k value = 55.57) dissolved in 50ml DMF was added. p-Toluene sulphonic acid (pTSA) was added as initiator. The mixture was vigorously stirred. The whole reaction mixture was refluxed at 150^0 C for 4 hours. Gel formation taken place in about 1 hour. A hard mass was obtained which varied in colour from brown to dark brown to black for different phenolic monomers listed above.

The cured hard mass was then crushed to -60 to 100 BSS mesh size as needed and washed with ethanol to remove unreacted monomers and low molecular weight products from the resins. The resin was dried in an oven below 100^0C and stored in polyethylene bottles.

The resins were conditioned by a alternate treatment with 0.1 N NaCl and 4% NaOH solution. After several regeneration cycles, the resins were washed free of regenerant and dried and stored in polyethylene bottles.

(b) Moisture content of resins

Moisture content of the 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-PC-3.

(c) Density of resins

(i) True density (d_{res})

(ii) Apparent density (d_{col}) and

(iii) Void volume fraction of the 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 the resins (H^+ form and OH^+ form) are presented in Table-PC-4. The values of void volume fraction of these resins (H^+ form and OH^- form) are presented in Table-PC-5.

(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 the resins as cation exchanger as well as anion exchanger were presented in Table-PC-

6A and Table-PC-6B respectively.

(e) Metal (Cu) exchange capacity

Metal (Cu) exchange capacity of the resins (H^+ form) was determined by following the procedure described in I(e) and the values were presented in Table-PC-6A.

(f) Rate of Exchange

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

The values of the capacities of the resins were plotted against time and shown in Figs 2.1 to 2.4 and presented in Table-PC-7.

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

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

The values of the capacities of the resins were plotted against the pH of the solution and shown in Figs 2.5 to 2.7.

(h) 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 (h). The results are presented in Table-PC-9.

(i) Oxidation resistance test

Oxidation resistance test of the resins in free acid and free base form was carried out as described in I(i). The results are presented in Table-PC-10A and Table-PC-10B respectively.

(j) Swelling behaviour

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

The result are presented in Table-PC-11A and Table-PC-11B respectively.

II Poly(vinyl chloride)-Phenolic Derivatives Type Ion-Exchange Resins

Results & Discussion

General

The work embodied in this chapter is concerned with the chemical modification of a very well known polymer poly(vinyl chloride) (PVC), literature on which is indeed very large. PVC is the most widely used domestic plastic of the day but never the less, its thermal instability still is regarded as the most important drawback. Keeping in view the more important attempts to modify PVC, which will be highlighted in the following pages. The present chapter aims at modifying some of the important properties of PVC through incorporation of reactive moieties in the PVC chain by a simple chlorine-displacement reaction. This research is also concerned with the synthesis and characterization of a ion-exchange resin.

We have synthesized ion-exchange resins using various phenolic derivatives, such as anthranilic acid, gallic acid, p-hydroxybenzaldehyde, pyrogallol, 8-hydroxyquinoline, salicylic acid, hydroquinone, β-resorcylic acid with poly(vinyl chloride).

The phenolic derivatives employed for synthesizing the resins possess the following structural characteristics.

(a) One phenolic groups and one amine group in ortho positions on a phenyl ring.

(b) Two phenolic group in meta position and one phenolic group in para position to carboxylic group on phenyl ring.

(c) One phenolic group and one aldehyde group in para position on a phenyl ring.

(d) Three phenolic group on a phenyl ring on 1,2 and 3 position

(e) One phenolic group group and one ring nitrogen.

(f) One phenolic group and one carboxylic group is ortho to each other on a phenyl ring.

(g) Two phenolic groups in para position on phenyl rings.

(h) Two phenolic group meta to each other and one carboxylic group in orth position on a phenyl ring.

General Characteristics and structures

The ion exchangers in general, are fairly porous in nature with average physical stability and good chemical resistance to 3N acids and alkalis and exhibit no colour change when converted from the free acid form to the sodium form or from free base form to chloride form.

The study of these structures leads us to believe that the high molecular weight polymers were obtained by polycondensation under mild reaction and curing conditions, crosslinking is possible by formation of -CH linkages on the basis of analytical data and other physico-chemical studies.

We generalisation that

(1) Phenolic derivatives get condensed with poly(vinyl chloride) in molar ratio of 1:1

The most probable structures of these resins on the basis of analytical data and physico-chemical studies are shown as

(i)	Poly-C-Anthra	(ii)	Poly-C-Galli
(iii)	Poly-C-PHyBe	(iv)	Poly-C-Pyro
(v)	Poly-C-8Hyqui	(vi)	Poly-C-Sali
(vii)	Poly-C-Hyqui	(viii)	Poly-C-βRes

Moisture retention %

Percentage moisture of the resins are presented in Table-PC-3. The percentage moisture of the resins in H^+ form varies between 3.01 to 4.98, while the percentage moisture of the resins in OH^- form varies between 2.33 to 2.57. Known values (77) of percentage moisture for commercial resins in H^+ form are 43.00 to 53.00 for IRC-50/57 (weak acid, Active group $-COO^-$) and 42 to 52 for IRC-84 (weak acid, Active group $-COO^-$). Thus resins under investigation have very low range of percentage moisture. This may be attributed to high degree of cross-linking.

Density of resins

The results of true density (d_{res}) and apparent density (d_{col}) are presented in Table-PC-4. It is observed that the values of dres is ranging from 0.39 to 1.39 gm/cm^3 for H^+ form of resins and from 1.25 to 1.54 gm/cm^3 for OH^- form of resins. We have also measured column or apparent density (d_{col}) of the resins. The values vary between 0.26 to 0.41 for H^+ form of resins and 0.32 to 0.56 gm/ml for OH^- form of resins.

We observed in general that in case of ion-exchange resins under study, the apparent density (d_{col}) of the resin in H^+ form is lower than that of the resin in OH^- form. Further, we suggest that since difference in density (d_{res}) of Poly-C-Anthra and Poly-C-8Hyqui resins in H^+ and OH^- form is small, the resins under study can stand recycling to a good degree.

Void volume fraction

The results of the void volume fraction are presented in Table-PC-5. It is observed that the values of the void volume fraction vary between 0.24 to 0.80 for resins in H^+ form and between 0.55 to 0.78 for resins in OH^- form. The large void volume fraction suggests the porous nature of the resins and hence the diffusion of ions and the rate of ion-exchange may be facilitated.

Ion-exchange capacity

The cation or anion exchange capacity of the resins can be calculated using formula described in I(d)(i)

The resins synthesized are polyfunctional in nature. They contain - COOH, OH and amino nitrogen. The cation or anion exchange capacity of these resins were calculated using 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-PC-6A and Table-PC-6B respectively.

For the values of ratio CEC_{obs} / CEC_{cal} range exist.

(I) Values of CEC_{obs} / CEC_{cal} is less to 1/2 , low values (< 1/2) or the ratio may be attributed to only one phenolic or carboxylic group may be involved in ion exchange. Ion exchange resins as cation exchanger show following decreasing order for cation exchange capacity.

Poly-C-Anthra > Poly-C-PHyBe > Poly-C-8Hyqui > Poly-C-Pyro > Poly-C-βRes > Poly-C-Galli > Poly-C-Hyqui > Poly-C-Sali

Ion-exchange resins show following decreasing order for anion exchange capacity.

Poly-C-Anthra > Poly-C-8Hyqui

Concentration of ionogenic groups

The data on concentration of ionogenic groups are presented in Table-PC-6A and Table-PC-6B. It is seen that, the total exchange capacity is related to the concentration of ionogenic groups. Higher the exchange capacity higher is the concentration of ionogenic groups.

Metal (Cu) exchange capacity

We have studied the copper ion-exchange by resins in H^+ form [ammonical solutions (pH=10.65)]

The observed values of copper ion-exchange capacity of these resins are presented in Table-PC-6A.

It is seen that copper ion-exchange capacity of these resins lies between 0.87 to 3.19 meq/gm.

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

Poly-C-Pyro > Poly-C-βRes > Poly-C-Galli > Poly-C-PHyBe
Poly-C-Anthra > Poly-C-Hyqui > Poly-C-8Hyqui > Poly-C-Sali

Recovery of copper from industrial waste by ion-exchange was considered from time to time by various research workers (78-84).

Mc Burney (85) patented a resin showing high selectivity for copper. Gregor (86) and pepper (87) synthesized chelating resins and investigated their specificity for copper.

We suggest that at pH range (10.6 to 10.8) under study, resin in H^+form would get transformed in Cu-form via NH_4 form and at equilibrium would be in H^+ form. Hence the overall reaction under experimental condition would be in H^+ form. Hence the overall reaction under experimental condition would be

$$HR + Cu^{+2} \rightleftharpoons [Cu\text{-}R]^+ + H^+$$

$$HR + [CuR]^+ \rightleftharpoons CuR_2 + H^+$$

Rate of exchange

Figs. 2.1 to 2.4 represent the rate of as cation exchange as well as anion exchange resin.

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

In the case of ion-exchange resin as cation exchanger, it is observed that,

(i) Complete exchange occurs in 20-60 minutes

(ii) The rate of exchange for these resins at the same density follows the order

Poly-C-8Hyqui ≒ Poly-C-Sali < Poly-C-Anthra ≒ Poly-C-PHyBe
Poly-C-Hyqui < Poly-C-Galli ≒ Poly-C-βRes < Poly-C-Pyro

In the case of ion-exchange resin as anion exchanger, it is observed that,

(iii) Complete exchange occurs in 20-60 minutes

(iv) The rate of exchange for these resins at the same density follows the order.

Poly-C-8Hyqui < Poly-C-Anthra

It is observed that the rate of exchange of ion-exchange resins as cation exchanger and ion-exchange resins as anion exchanger is almost same.

pH titration study

The results of pH-titration curves fig 2.5 to 2.7 reveals the amphoteric nature of ion-exchange resins (Poly-C-Anthra, Poly-C-8Hyqui) prepared. The 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. 2.5 and 2.6 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 (88). The cation exchange behaviour of these resins is similar to weak acidic resin (94). 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 calculated from pH titration Curves and using equation (9) and (14) respectively as described earlier and are presented in Table-PC-8. It is seen that the range of pK_a obtained for overall cation exchange process in general for various ion exchangers studied varies between 9.74 to 10.61 which is a value of phenolic hydroxyl group and that of pK_b obtained for the overall anion exchange process for these resins lies between 3.96 to 4.63, which is characteristic of bases of high strength (tertiary amine and quarternary ammonium group).

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

Poly-C-Anthra > Poly-C-βRes > Poly-C-Hyqui > Poly-C-PHyBe
Poly-C-Galli > Poly-C-8Hyqui > Poly-C-Sali > Poly-C-Pyro

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

Poly-C-8Hyqui > Poly-C-Anthra

Isoionic Point

The values of isoionic point are presented in Table-PC-8. It can be seen that the value vary in the range of 7.07 to 7.28. Isoionic point for proline is 6.3 and for histidine is 7.3 (95). It is observed that the resins under study have comparable with proline and histidine.

The values are in the following order as Poly-C-Anthra > Poly-C-8Hyqui

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

The data regarding the effect of varying temperature of equilibration on the capacity of the resin are presented in Table-PC-9. It can be seen that the anion exchange capacity of ion-exchange resin increases with increasing temperature of equilibration. This is because, on heating the resin, certain basic gaseous decomposition products (such as NH_3 resulting from anthranilic acid and 8-hydroxyquinoline used for the synthesis of the resin) are produced which neutralise a part of the acid during equilibration, thus giving an apparent higher value of the anion exchanger capacity of the resin.

While the lowering of the cation exchange capacity of the resin with the increasing temperature of equilibration may be due to the loss of the ionogenic groups.

Oxidation resistance

Results of oxidation resistance test of different ion exchangers as cation exchanger as well as anion exchanger are presented in Table-PC-10A and Table-PC-10B respectively.

It is seen from the Table-PC-10A and Table-PC-10B that on oxidative degradation, ion-exchange resins as anion exchanger (Poly-C-Anthra, Poly-C-8Hyqui) show greater increase in percentage water content than the cation exchanger. Hence, it is inferred that the cationic form is less susceptible to oxidation than the anionic form.

Ion-exchange resins as cation exchanger show the following decreasing order for the stability on oxidative degradation.

Poly-C-Pyro > Poly-C-PHyBe > Poly-C-Sali > Poly-C-βRes > Poly-C-Anthra > Poly-C-Hyqui > Poly-A-Galic > Poly-A-8Hyqui

Where as for ion-exchange resins as anion exchanger the stability order is

Poly-C-Anthra > Poly-C-8Hyqui

Swelling behaviour in non-aqueous solvents

The result of behaviour in non aqueous solvents of these resins as cation exchanger and as anion exchanger are reported in Table-PC-11A and Table-PC-11B respectively. It is observed that, Polar solvents produce more extensive swelling than nonpolar hydrocarbons, and the more porous resins swell more than their less porous analogs.

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 ion-exchange resins is as follows.

Poly-C-Anthra > Poly-C-Hyqui > Poly-C-Pyro ≃ Poly-C-8Hyqui > Poly-C-βRes > Poly-C-PHyBe > Poly-C-Galli > Poly-C-Sali

TABLE-PC-1

Abbreviation

No.	Resin			Abbreviation
1	Poly(vinyl chloride)	-	Anthranilic acid	Poly-C-Anthra
2	Poly(vinyl chloride)	-	Gallic acid	Poly-C-Galli
3	Poly(vinyl chloride)	-	p-Hydroxybenzaldehyde	Poly-C-PHyBe
4	Poly(vinyl chloride)	-	Pyrogallol	Poly-C-Pyro
5	Poly(vinyl chloride)	-	8-Hydroxyquinoline	Poly-C-8Hyqui
6	Poly(vinyl chloride)	-	Salicylic acid	Poly-C-Sali
7	Poly(vinyl chloride)	-	Hydroquinone	Poly-C-Hyqui
8	Poly(vinyl chloride)	-	β-Resorcylic acid	Poly-C-βRes

TABLE-PC-2

Analyses, Formula etc. of ion-exchange resins

No.	Resin	Formula	Analysis					
			Calculated			Observed		
			%C	%H	%N	%C	%H	%N
1	Poly-C-Anthra	$C_{17}H_{16}O_4N_2$	60.71	5.32	7.45	60.08	5.72	7.29
2	Poly-C-Galli	$C_{17}H_{14}O_{10}$	51.75	3.85	-	51.88	3.81	-
3	Poly-C-PHyBe	$C_{17}H_{14}O_4$	66.18	4.93	-	66.18	4.89	-
4	Poly-C-Pyro	$C_{15}H_{14}O_6$	57.87	4.82	-	57.77	4.74	-
5	Poly-C-8Hyqui	$C_{21}H_{16}O_2N_2O_2$	70.49	7.24	7.15	70.59	7.24	7.25
6	Poly-C-Sali	$C_{17}H_{14}O_6$	60.98	4.93	--	66.18	4.93	-
7	Poly-C-Hyqui	$C_{15}H_{14}O_4$	63.65	5.30	-	63.83	5.45	-
8	Poly-C-βRes	$C_{17}H_{14}O_8$	55.81	4.16	-	55.89	4.24	-

TABLE-PC-3

% Moisture content of ion-exchange resin

No.	Resin	% Moisture	
		H^+ - form	OH^- - form
1	Poly-C-Anthra	3.70	2.33
2	Poly-C-Galli	4.17	-
3	Poly-C-PHyBe	4.02	-
4	Poly-C-Pyro	4.98	-
5	Poly-C-8Hyqui	4.31	2.57
6	Poly-C-Sali	3.01	-
7	Poly-C-Hyqui	4.96	-
8	Poly-C-βRes	4.01	-

TABLE : PC-4

Density of resins

No.	Resin	True density of resins (d_{res}) (gm/cm^3)		Apparent (column) density of resins (d_{col}) (gm/ml)	
		H^+-form	OH^--form	H^+-form	OH^--form
1	Poly-C-Anthra	1.35	1.54	0.31	0.32
2	Poly-C-Galli	1.37	-	0.40	-
3	Poly-C-PHyBe	1.30	-	0.31	-
4	Poly-C-Pyro	1.39	-	0.36	-
5	Poly-C-8Hyqui	0.39	1.25	0.26	0.56
6	Poly-C-Sali	0.50	-	0.41	-
7	Poly-C-Hyqui	1.10	-	0.27	-
8	Poly-C-βRes	0.52	-	0.39	-

TABLE-PC-5

Void volume fraction of resins

No.	Resin	Resin in H^+-form d_{col}/d_{res}	Resin in H^+-form void volume fraction $(1-d_{col}/d_{res})$	Resin in OH^--form d_{col}/d_{res}	Resin in OH^--form void volume fraction $(1-d_{col}/d_{res})$
1	Poly-C-Anthra	0.23	0.76	0.21	0.78
2	Poly-C-Galli	0.29	0.70	-	-
3	Poly-C-PHyBe	0.24	0.75	-	-
4	Poly-C-Pyro	0.26	0.74	-	-
5	Poly-C-8Hyqui	0.19	0.80	0.44	0.55
6	Poly-C-Sali	0.22	0.78	-	-
7	Poly-C-Hyqui	0.24	0.75	-	-
8	Poly-C-βRes	0.76	0.24	-	-

TABLE : PC-6A

Capacity and Concentration of ionogenic groups of resins as cation exchange

No.	Resins	Total Capacity $CEC_{obs.}$ (meq/gm)	Total Capacity $CEC_{cal.}$ (meq/gm)	$\frac{CEC_{obs.}}{CEC_{cal.}}$	Concentration of ionogenic group Cr (meq/gm)	Volume Capacity Q gm.eq/l	Cu-exchange Capacity (meq/gm)
1	Poly-C-Anthra	2.22	6.41	0.34	1.30	0.30	1.00
2	Poly-C-Galli	3.94	21.16	0.18	1.32	0.38	2.15
3	Poly-C-PHyBe	2.24	7.09	0.31	1.25	0.30	1.01
4	Poly-C-Pyro	4.90	20.68	0.23	1.32	0.34	3.19
5	Poly-C-8Hyqui	1.79	6.09	0.29	0.37	0.074	0.90
6	Poly-C-Sali	1.07	12.73	0.08	0.49	0.10	0.87
7	Poly-C-Hyqui	1.89	15.50	0.12	1.04	0.26	0.98
8	Poly-C-βRes	3.98	17.34	0.22	0.49	0.37	2.43

TABLE-PC-6B

Capacity and Concentration of ionogenic groups of resins as anion exchanger

No.	Resins	Total Capacity $CEC_{obs.}$ (meq/gm)	Total Capacity $CEC_{cal.}$ (meq/gm)	$\frac{CEC_{obs.}}{CEC_{cal.}}$	Concentration of ionogenic group Cr (meq/gm^3)	Volume Capacity Q (gm.eq/l)
1	Poly-C-Anthra	2.12	6.41	0.33	1.50	0.31
2	Poly-C-8Hyqui	1.53	6.09	0.25	1.22	0.54

TABLE-PC-7

Rate of exchange of resins

No. Resin	Time in Minutes	Cation exchange Capacity realized (meq/gm)	Anion exchange Capacity realized (meq/gm)
1. Poly-C-Anthra	5	0.73	0.99
	10	0.73	1.04
	15	0.73	1.09
	20	0.73	1.09
	40	0.73	1.09
	60	0.97	1.56
	80	0.97	1.56
	100	0.97	1.56
	120	1.07	1.56
2. Poly-C-Galli	5	0.96	-
	10	1.01	-
	15	1.27	-
	20	1.52	-
	40	1.63	-
	60	2.04	-
	80	2.14	-
	100	2.35	-
	120	2.45	-
3. Poly-C-PHyBe	5	1.11	-
	10	1.17	-
	15	1.22	-
	20	1.27	-
	40	1.27	-
	60	1.37	-
	80	1.52	-
	100	1.63	-
	120	1.63	-
4. Poly-C-Pyro	5	1.23	-
	10	1.54	-
	15	1.97	-
	20	2.13	-
	40	2.84	-
	60	3.30	-
	80	3.40	-
	100	3.61	-
	120	3.92	-

CONTINUED.....

No. Resin	Time in Minutes	Cation exchange Capacity realized (meq/gm)	Anion exchange Capacity realized (meq/gm)
5. Poly-C-8Hyqui	5	0.67	0.71
	10	0.67	0.71
	15	0.67	0.71
	20	0.67	0.80
	40	0.67	0.80
	60	0.67	0.80
	80	0.77	-
	100	0.87	-
	120	0.96	-
6. Poly-C-Sali	5	0.43	-
	10	0.43	-
	15	0.47	-
	20	0.68	-
	40	0.68	-
	60	0.72	-
	80	0.72	-
	100	0.72	-
	120	0.82	-
7. Poly-C-Hyqui	5	0.86	-
	10	0.91	-
	15	0.96	-
	20	1.01	-
	40	1.11	-
	60	1.22	-
	80	1.33	-
	100	1.42	-
	120	1.42	-
8. Poly-C-βRes	5	0.66	-
	10	0.81	-
	15	1.22	-
	20	1.47	-
	40	1.73	-
	60	2.14	-
	80	2.44	-
	100	2.85	-
	120	2.85	-

TABLE-PC-8

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	Poly-C-Anthra	10.61	3.96	7.28
2	Poly-C-Galli	10.32	-	-
3	Poly-C-PHyBe	10.47	-	-
4	Poly-C-Pyro	9.74	-	-
5	Poly-C-8Hyqui	10.11	4.63	7.07
6	Poly-C-Sali	9.89	-	-
7	Poly-C-Hyqui	10.51	-	-
8	Poly-C-βRes	10.57	-	-

TABLE-PC-9

Effect of temperature of equilibration on the capacity of the resins

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

No.	Resin	Total AEC (meq/gm) of absolutely dry resin as determined at temperature (^{0}C)			Total CEC (meq/gm) of absolutely dry resin as determined at temperature (^{0}C)		
		30^0	50^0	70^0	30^0	50^0	70^0
1	Poly-C-Anthra	1.56	1.72	1.82	1.07	1.06	1.06
2	Poly-C-Galli	-	-	-	2.45	2.42	2.41
3	Poly-C-PHyBe	-	-	-	1.63	1.60	1.59
4	Poly-C-Pyro	-	-	-	3.92	3.81	3.81
5	Poly-C-8Hyqui	0.80	0.91	1.01	0.96	0.96	0.95
6	Poly-C-Sali	-	-	-	0.82	0.92	0.81
7	Poly-C-Hyqui	-	-	-	1.89	1.89	1.88
8	Poly-C-βRes	-	-	-	2.85	2.83	2.84

TABLE : PC-10A

Oxidation resistance of ion-exchange resins as cation exchanger

No.	Resin	% Moisture		Increase in % water content
		Untreated exchanger	H_2O_2 treated exchanger	
1	Poly-C-Anthra	3.70	7.20	3.49
2	Poly-C-Galli	4.17	7.60	3.42
3	Poly-C-PHyBe	4.02	13.60	9.57
4	Poly-C-Pyro	4.98	14.40	9.91
5	Poly-C-8Hyqui	4.31	7.00	2.69
6	Poly-C-Sali	3.01	8.20	5.78
7	Poly-C-Hyqui	4.06	8.40	3.43
8	Poly-C-βRes	4.01	7.60	3.58

TABLE-PC-10B

Oxidation resistance of ion-exchange resins as anion exchange

No.	Resin	% Moisture		Increase in % water content
		Untreated exchanger	H_2O_2 treated exchanger	
1	Poly-C-Anthra	2.33	10.20	7.86
2	Poly-C-8Hyqui	2.57	10.40	7.82

TABLE-PC-11A

% Swelling of ion-exchange resin as cation exchanger in various solvents

No.	Resin	% Swelling in							
		Glacial Acetic acid	Water	DMF	Dioxane	Alcohol	THF	Benzen	Acetone
1	Poly-C-Anthra	3.3	18.4	4.0	3.0	4.1	1.7	0.3	2.5
2	Poly-C-Galli	1.5	7.2	1.9	1.4	2.2	0.9	0.9	0.8
3	Poly-C-PHyBe	1.6	9.2	1.8	2.0	2.5	1.6	1.2	2.1
4	Poly-C-Pyro	2.1	9.7	2.6	1.4	2.0	1.9	1.1	2.1
5	Poly-C-8Hyqui	3.8	9.7	3.0	2.2	4.5	0.7	0.7	2.7
6	Poly-C-Sali	1.9	6.7	2.7	1.4	2.4	1.0	0.8	2.3
7	Poly-C-Hyqui	4.9	16.7	4.0	2.5	5.6	2.4	0.8	2.5
8	Poly-C-βRes	2.0	9.4	2.5	2.3	2.8	2.0	1.3	2.5

TABLE-PC-11B

% Swelling of ion-exchange resin as anion exchanger in various solvents

No.	Resin	% Swelling in							
		Glacial Acetic acid	Water	DMF	Dioxane	Alcohol	THF	Benzene	Acetone
1	Poly-C-Anthra	3.1	12.4	4.2	2.98	4.0	2.0	0.2	2.4
2	Poly-C-8Hyqui	2.3	9.8	3.4	2.4	4.3	0.9	0.6	2.6

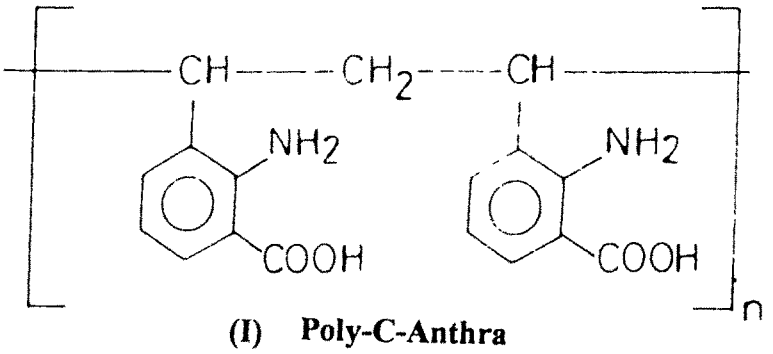
Table-C-I

Major peaks observed in the infrared spectra of resins

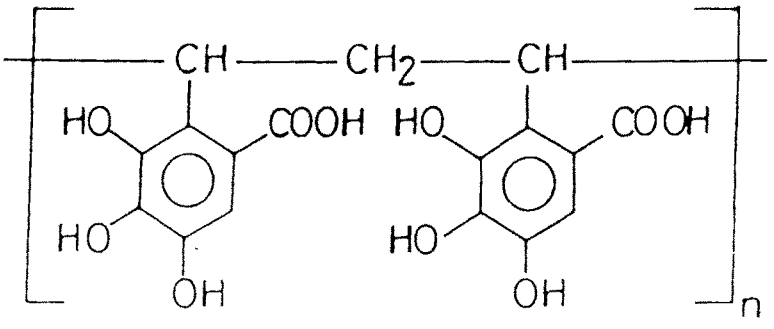
No.	Resin	Wave number cm^{-1}	Nature of peak	Probable assignment
1.	Poly-C-Anthra	3600-2700	broad	NH_2-stretching and -COOH stretching absorption
		1660-1050	medium	-NH bending absorption
2.	Poly-C-Galli	3600-3200	broad	-OH Stretching absorption -COOH and group absorption
		1740-1720	medium	-C=0 group absorption
		1600-1500	medium	aromatic >C=C< absorption
3.	Poly-C-PHyBe	3600-3000	broad	-OH stretching absorption and -C-H stretching absorption of CHO group
		1740-1700	medium	>C=0 of absorption
4.	Poly-C-Pyro	3600-2500	broad	Free -OH stretching absorption
		1600-1500	medium	aromatic >C=C< absorption
5.	Poly-C-8Hyqui	3600-2500	broad	-OH Stretching absorption
		1000-900	medium	$-CH_2$ -CH- stretching absorption
6.	Poly-C-Sali	3400-3200	broad	-OH Stretching absorption
		3000-2500	medium	-COOH group stretching absorption
		1740-1710	medium	>C=O group absorption of -COOH

Continued.....

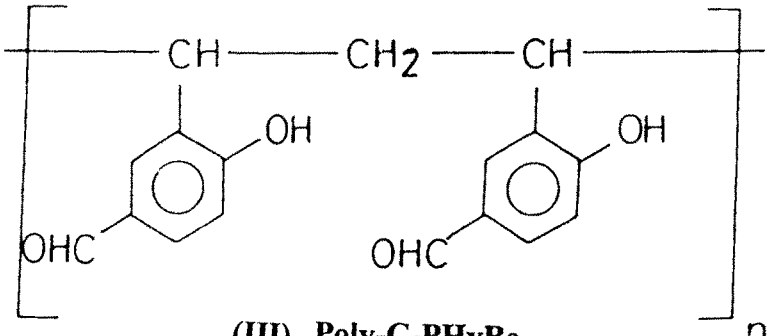
No.	Resin	Wave number cm^{-1}	Nature of peak	Probable assignment
7.	Poly-C-Hyqui	3600-3200	broad	-OH stretching absorption
		1620-1500	medium	$-CH_2-CH-$ absorption
8.	Poly-C-βRes	3600-2500	broad	-OH stretching absorption and - COOH group absorption
		1740-1710	medium	>C=0 group absorption of - COOH



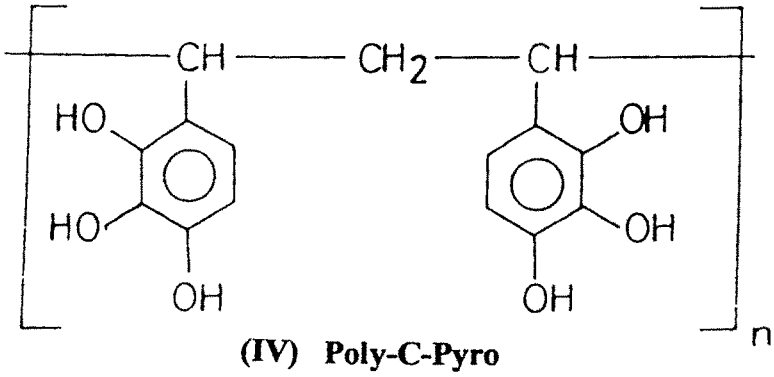
(I) Poly-C-Anthra



(II) Poly-C-Galli

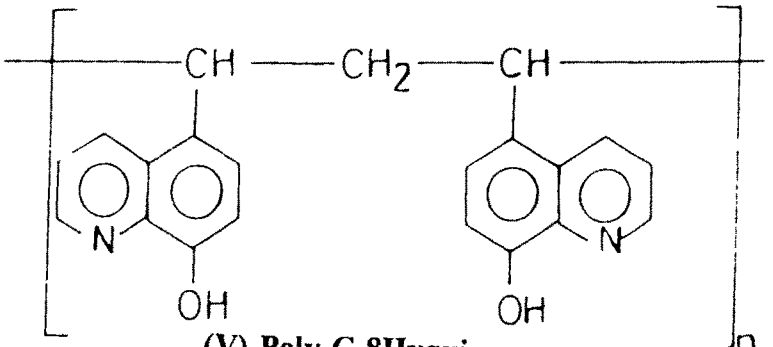


(III) Poly-C-PHyBe

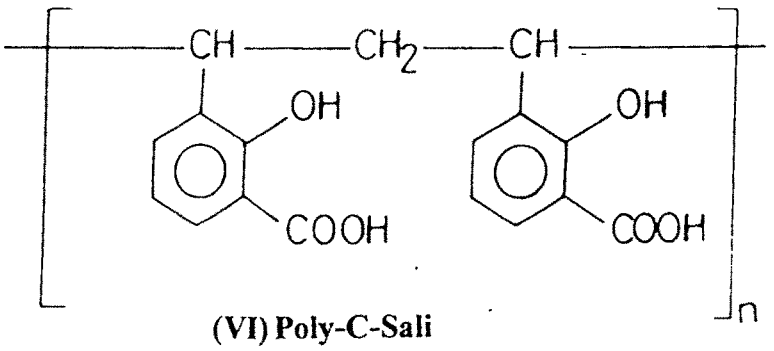


(IV) Poly-C-Pyro

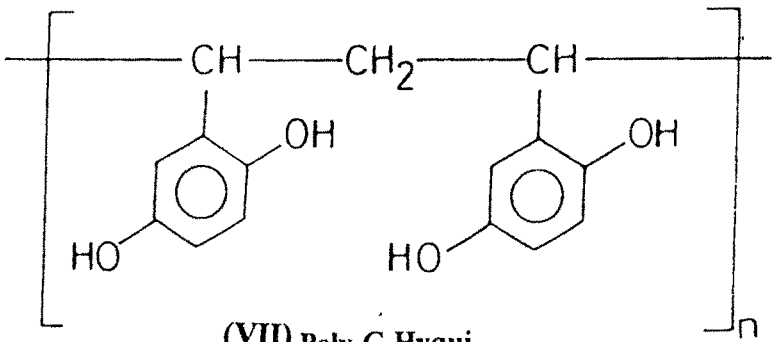
S.2.1.



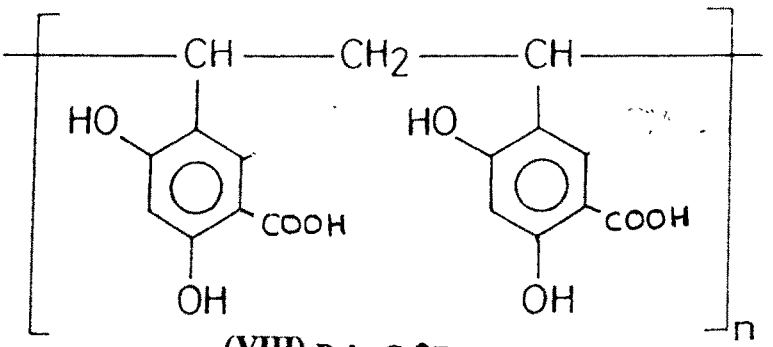
(V) Poly-C-8Hyqui



(VI) Poly-C-Sali



(VII) Poly-C-Hyqui



(VIII) Poly-C-βRes

S.2.2

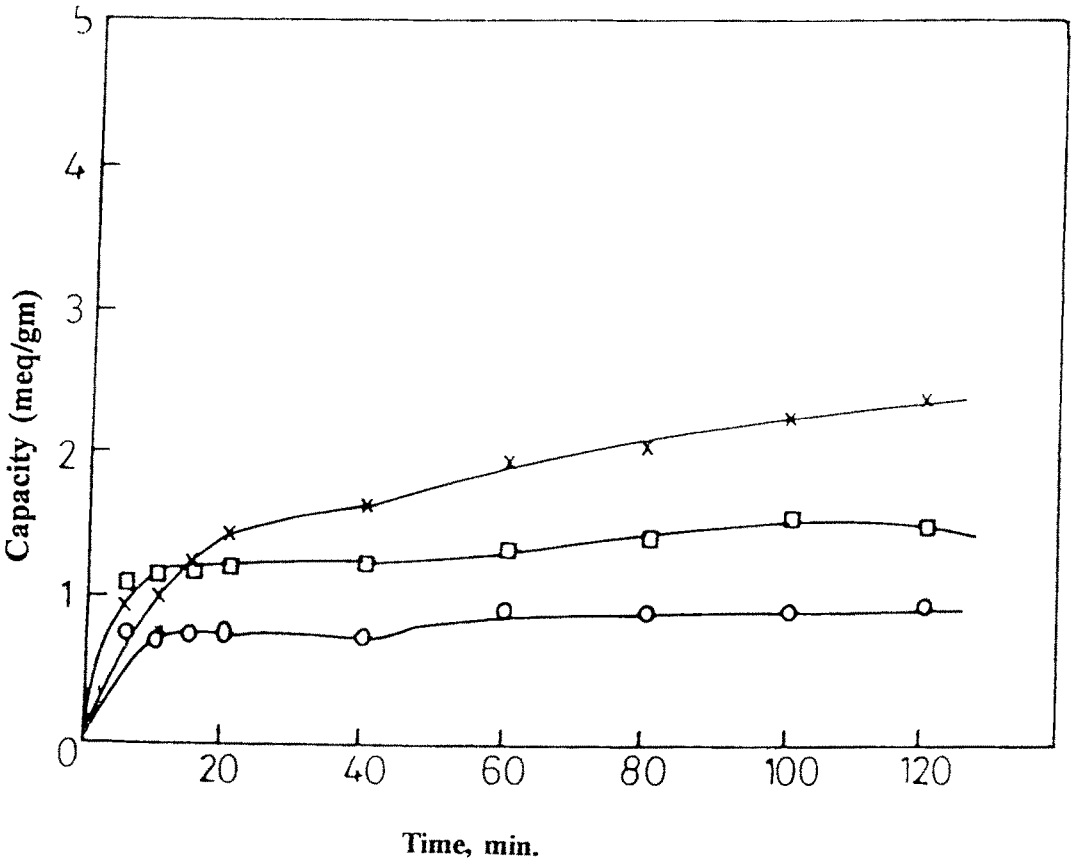


Fig.2.1 **Rate of cation exchange of Poly-C-Anthra (o), Poly-C-Galli (□), Poly-C-PHyBe (×)**

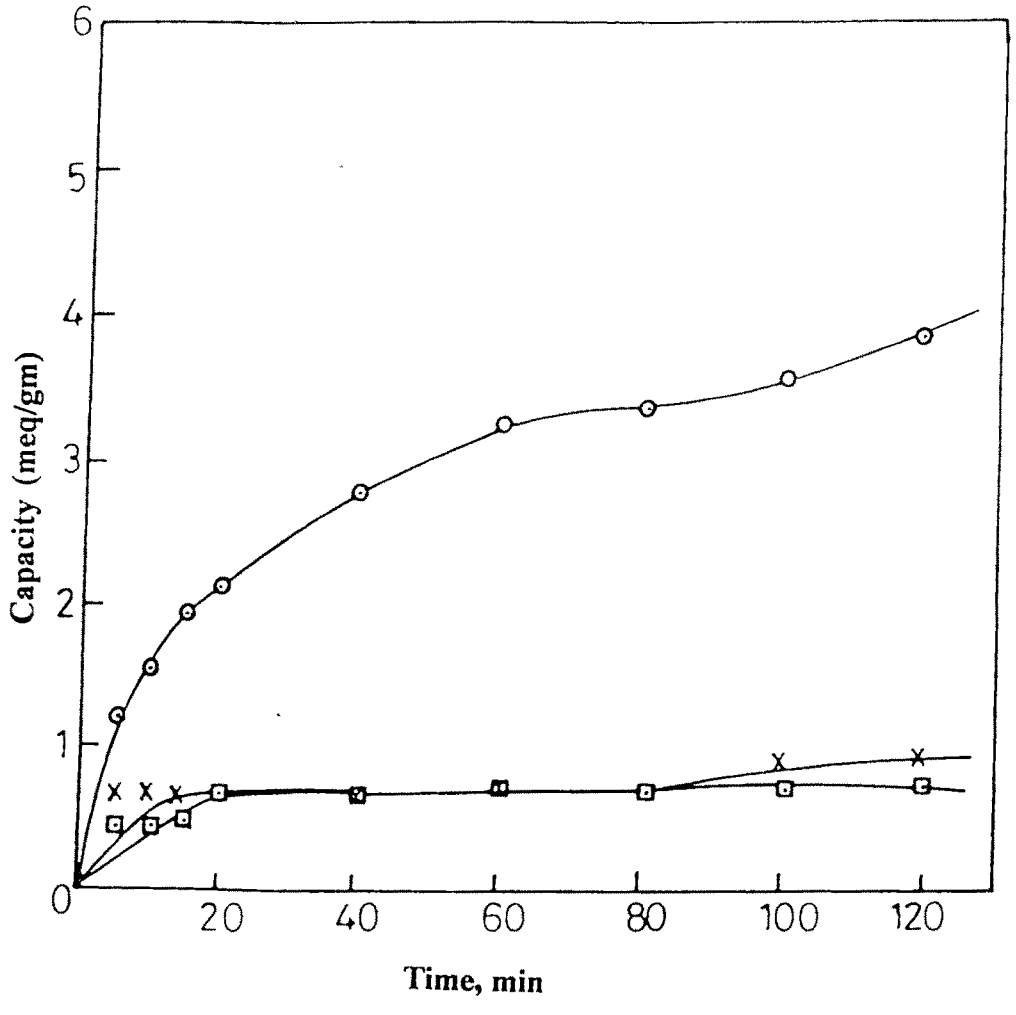


Fig.2.2 Rate of cation exchange of Poly-C-Pyro (⊙), Poly-C-8Hyqui (⊡), Poly-C-Sali (×)

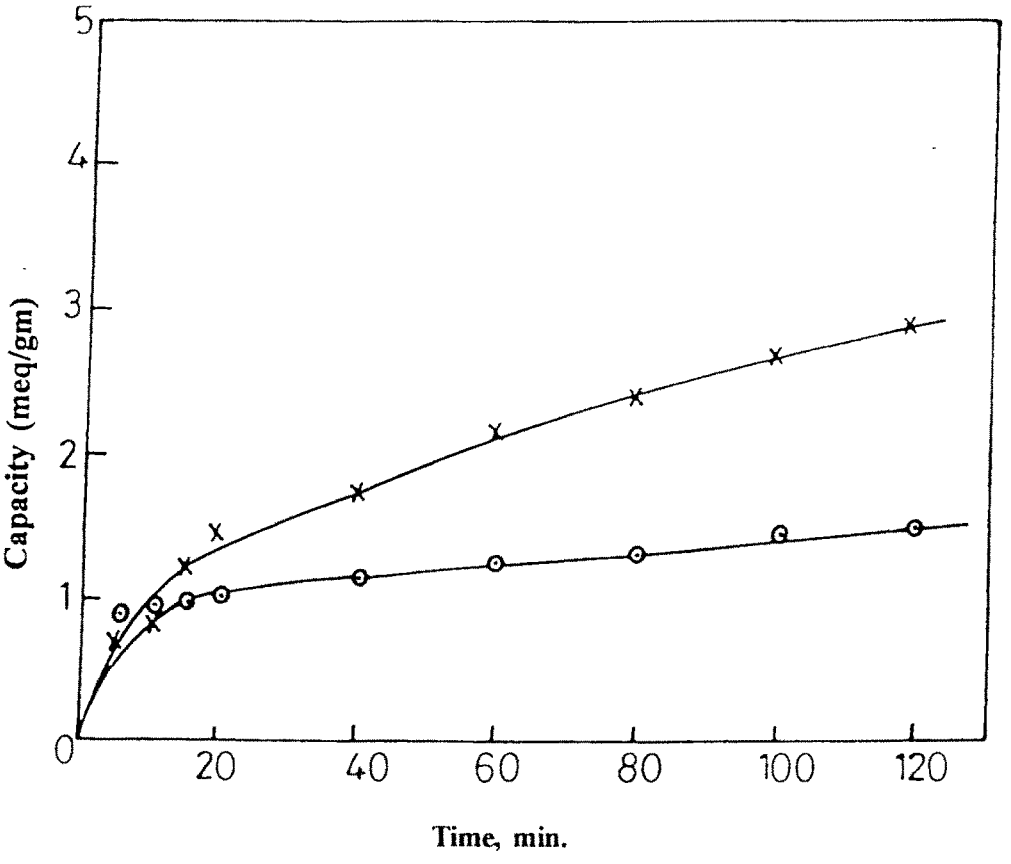


Fig.2.3 Rate of cation exchange of Poly-C-Hyqui (⊙), Poly-C-βRes (×)

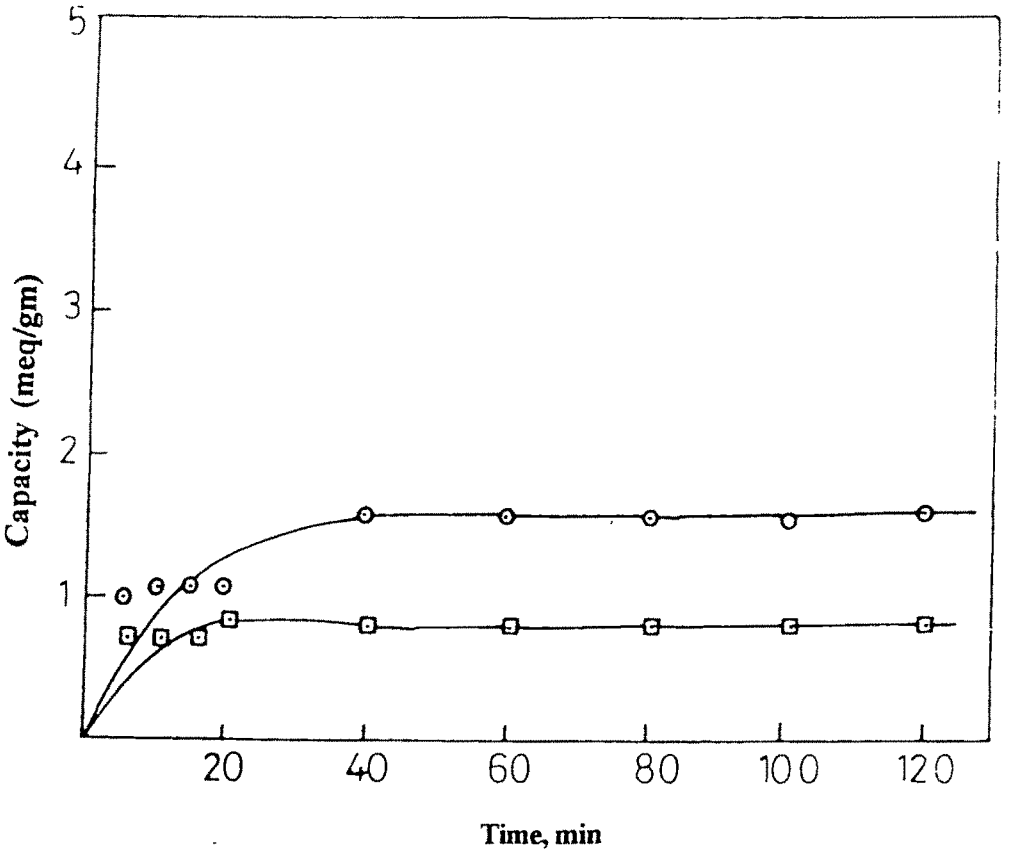


Fig.2.4 Rate of anion exchange of Poly-C-Anthra (⊙), Poly-C-8Hyqui (⊡)

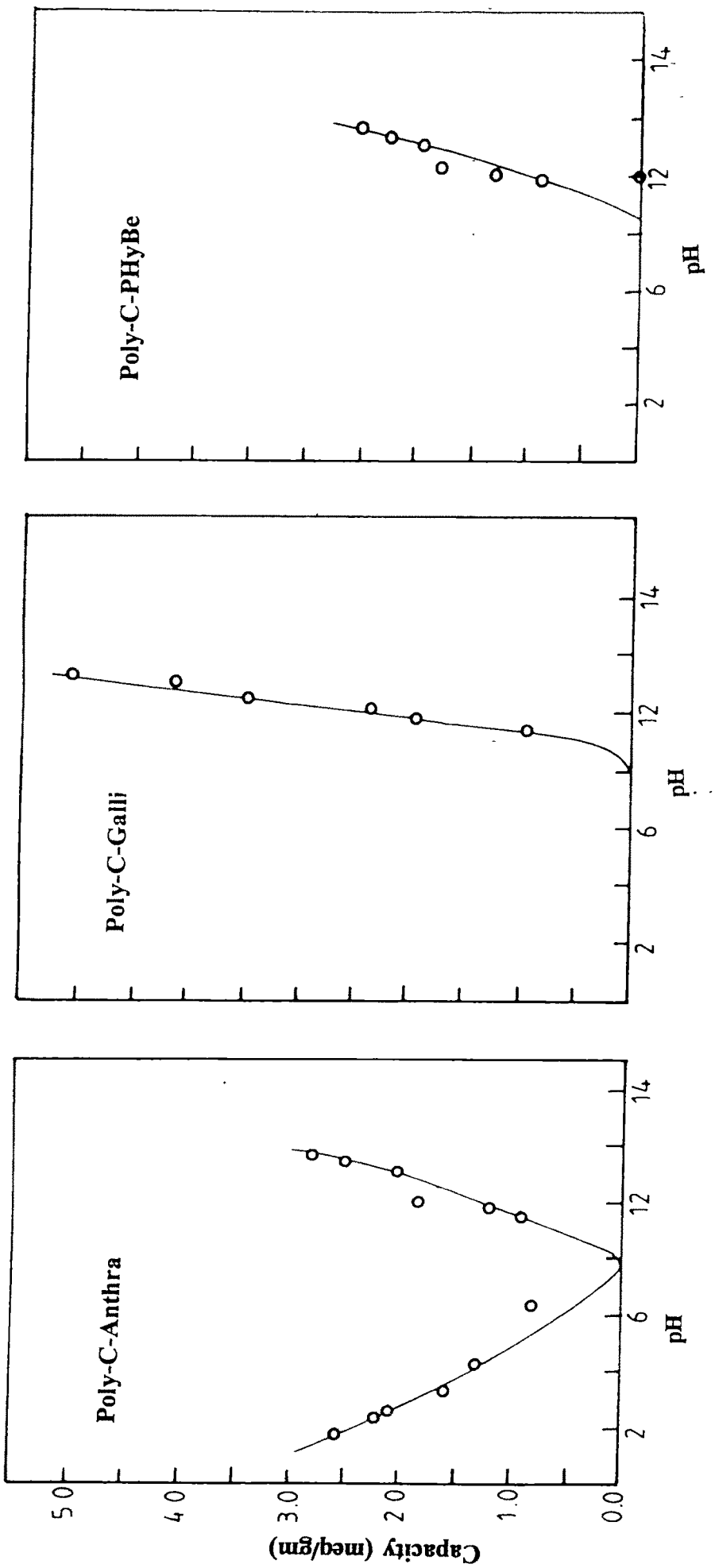

Poly-C-Anthra
Poly-C-Galli
Poly-C-PHyBe
Capacity (meq/gm)
pH
0.0
1.0
2.0
3.0
4.0
5.0
2
6
12
14

Fig.2.5

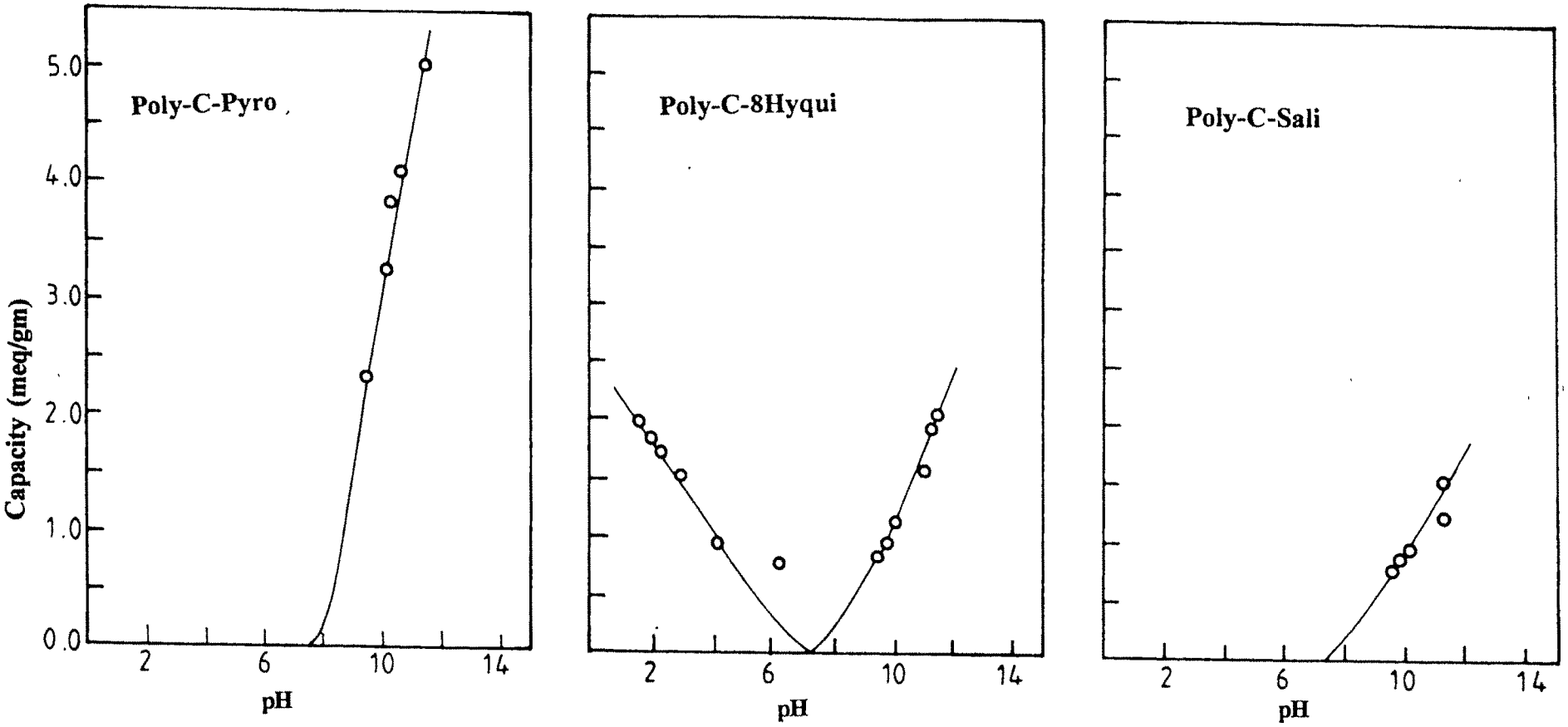

Poly-C-Pyro
Poly-C-8Hyqui
Poly-C-Sali
Capacity (meq/gm)
5.0
4.0
3.0
2.0
1.0
0.0
2
6
10
14
pH

Fig.2.6

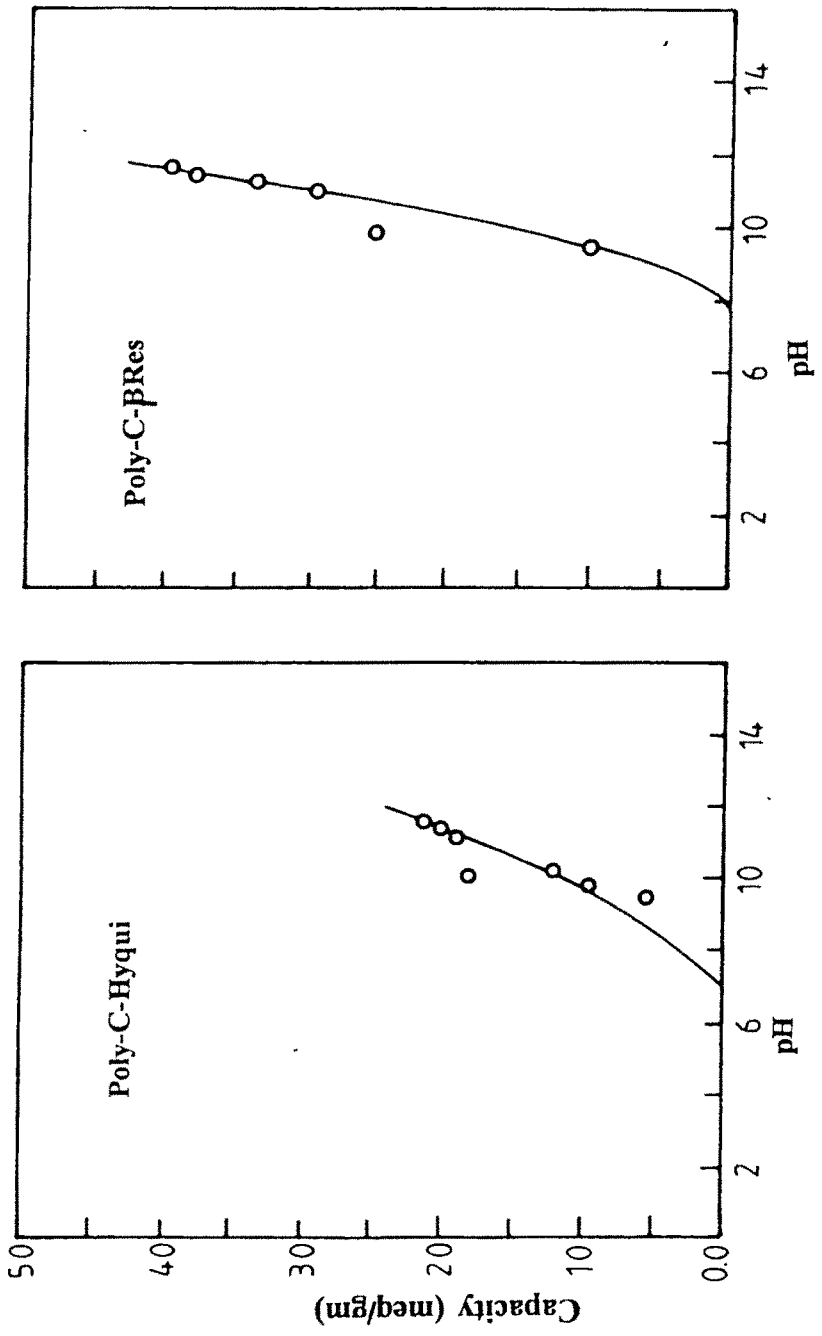
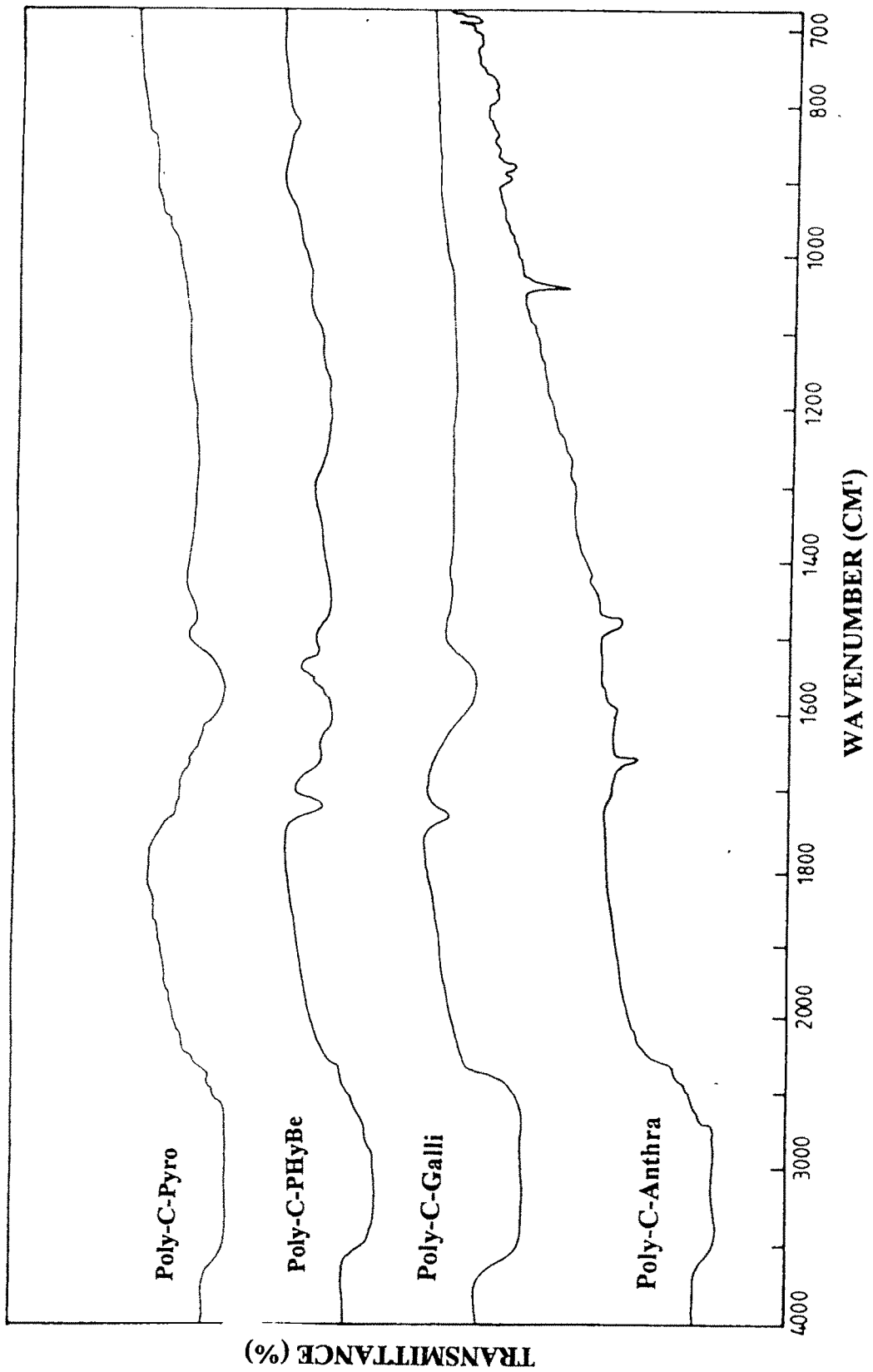
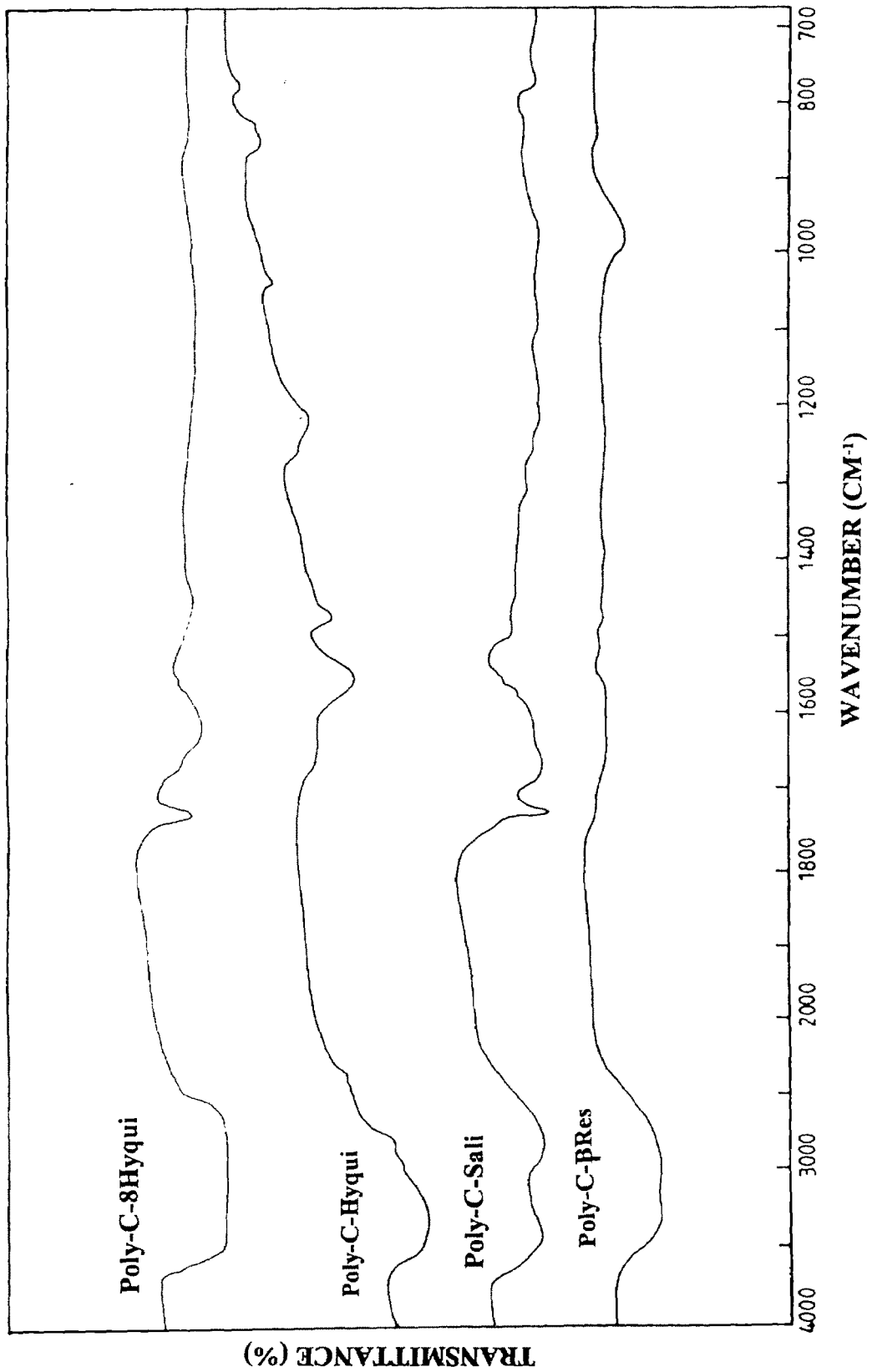

Poly-C-BRes
Poly-C-Hyqui
Capacity (meq/gm)
pH
pH
0.0
10
20
30
40
50
2
6
10
14

Fig.2.7


Poly-C-Pyro
Poly-C-PHyBe
Poly-C-Galli
Poly-C-Anthra
TRANSMITTANCE (%)
4000
3000
2000
1800
1600
1400
1200
1000
800
700
WAVENUMBER (CM⁻¹)


Poly-C-8Hyqui
Poly-C-Hyqui
Poly-C-Sali
Poly-C-βRes
4000
3000
2000
1800
1600
1400
1200
1000
800
700
WAVENUMBER (CM-1)
TRANSMITTANCE (%)