



**RESEARCH ARTICLE**

**Study of Novel Oligomeric Azo Dyes**

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**ABSTRACT**

Diazotization of p-anisidine and coupling with 3-amino-phenol-Formaldehyde (APF) resin give oligomeric azo dye TAPF, based on 3-amino-phenol-Formaldehyde (APF) polymer. The TAPF was then treated with 5-chloro methyl-8-quinolinol hydrochloride in the presence of a THF in alkaline medium (pH 9-10) at room temperature for 7 hrs. The resultant oligomeric ligand designated as azo polyphenol-formaldehyde-5-chloromethyl-8-quinolinol (AAPFQ) was characterized by elemental analysis, IR spectral studies, and thermogravimetry. The polymeric metal chelates of AAPFQ with Cu<sup>2+</sup>, Zn<sup>2+</sup>, Mn<sup>2+</sup>, Ni<sup>2+</sup>, Fe<sup>3+</sup> and Co<sup>2+</sup> metal ions were prepared and characterised by metal:ligand ratio, IR and reflectance studies, magnetic properties and thermogravimetry. The AAPFQ sample was also screened for its chelating and ion-exchanging properties. Batch equilibration method has been adopted for evolution of ion-exchange properties.

**KEYWORDS**

3-amino-phenol-formaldehyde (APF) polymer, 5-chloromethyl-8-quinolinol, polymeric metal chelates, IR spectra, ion-exchange properties, batch equilibrium method, thermogravimetry.

**INTRODUCTION**

The effluents from mines and metal industries set up the serious problems in removal of heavy toxic metal ions. The contents of these metals in effluent are almost above the valid limit. The ion-exchange resin are of organic polymera and play a pivotal role in various commodity application<sup>1-3</sup>. The ion-exchange resin can be use for metal extraction from ore, analytical reagent, and separation of metal ion and deionization of water<sup>4-10</sup>. Most of commercial ion-exchange resins are sulfonated polystyrene-divinylbenzene copolymer<sup>11-12</sup>. The use of complex ion-formation in ion-exchange resin has been prepared to solve the problem<sup>11-12</sup>. The phenol-formaldehyde type resins have also been reported as ion-exchange resine<sup>13</sup>.

One of the resin 3-amino-phenol-Formaldehyde is reported for the purposes<sup>14-15</sup> but its modification into oligomeric ligand has not been reported. Thus, the aim of the present work to prepare and study the novel ion-exchange resin based on 3-amino phenol. The present paper comprises the studies on novel ion-exchange resin containing a well known metal complexing agent and 8-quinolinol. The synthetic route is shown below.

**MATERIAL AND METHOD**

**MATERIALS**

All the chemicals used were of either pure or analytical grade.

Synthesis of 3-amino-phenol-Formaldehyde (APF) polymer was prepared by method reported in literature<sup>13</sup>. The 5-chloromethyl-8-quinolinol hydrochloride (m.p. 280°C) was prepared by method reported in literature<sup>16</sup>

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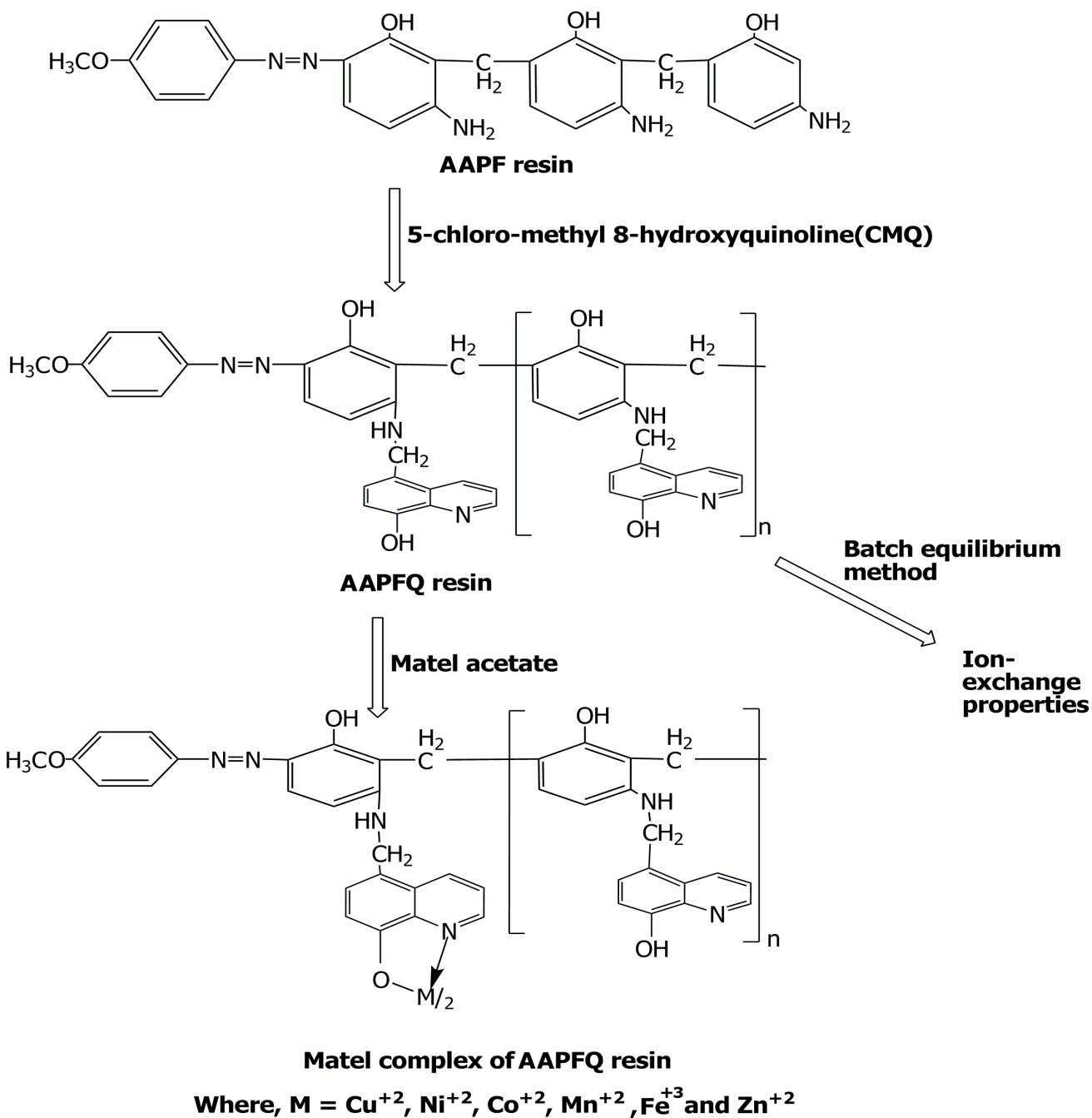
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**SYNTHESIS OF AZO DYES BASED ON 3-AMINO PHENOL-FORMALDEHYDE (TAPF)**

**Preparation of azo coupling of diazonium salt of p-anisidine to phenol-formaldehyde (TAPF):**

Diazonium salt of p-anisidine solution (0.1mole) was slowly added to an alkaline solution of 3-amino-Phenol-Formaldehyde polymer (APF)

(0.1mole) at pH 8.5-9.0 and below 0-5°C. The resultant solution was stirred for 2-2.5 hrs. The dye was precipitated by lowering the pH to 6.0. The precipitated dye (AAPF) was filtered off, wash with water and air-dried. The yield of TAPF was 76% and m.p.172-173°C (uncorrected). The predicted structure and formation of oligomeric ligand is shown in Scheme-1.



Scheme 1

**Synthesis of 6-(*p*-methoxy phenyl) diazo-3-aminophenol-Formaldehyde-5-chloromethyl-8-quinolinol (AAPFQ):** To a mixture of AAPF oligomeric (0.02 mole) and 5-chloromethyl-8-hydroxy quinoline (0.02 mole) in THF (100 ml), conc. NaOH was added with maintaining pH 9-10 of the mixture was heated upto 60°C gently for 5 minute and it was stirred at room temperature for 6.5-7.5 hrs. The resulted gel type material was filtered, washed by water and air-dried. It was powdered to 100 mesh size. Yield was 83%. It did not melt up to 300°C and insoluble in water and common organic solvents.

### **Synthesis of oligomeric chelates:**

The polymeric metal chelates of AAPFQ were synthesized by reaction of AAPFQ with corresponding metal acetates. The detail procedure is as follow.

A dried AAPFQ oligomer (0.02 mole) was dispersed in 200 ml aqueous solution of 20% aqueous formic acid and warmed on a water bath for 10 minutes. To this dispersed solution a warm solution of metal acetate (0.02 mole) in 50% aqueous formic acid solution was added drop wise with constant stirring. The reaction mixture as made alkaline with dilute ammonia solution in order to coagulate oligomeric chelates. The resultant contents were further digested on water bath for an hour. Finally the solid polymer chelates were filtered off Washed with hot water followed by acetone. DMF and dried in air. The polymer chelates of AAPFQ with Cu<sup>2+</sup>, Co<sup>2+</sup>, Ni<sup>2+</sup>, Mn<sup>2+</sup>, Fe<sup>3+</sup> and Zn<sup>2+</sup> transition metal ions.

### **Measurements:**

Elemental analyses for C, H and N content were carried out on TF 1101 elemental analyzer (Italy). IR spectra of oligomer ligand and their metal chelates were scanned on a NICOLET 760 DR FTIR spectrophotometer in KBr phase. The metal content of polychelates was performed by decomposing a weighed amount of each polymer chelate followed by EDTA titration as reported in literature<sup>17</sup>.

Magnetic susceptibility measurements of all the polychelates were carried out at room temperature by the Gouy method using Mercury tetrathiocyanato cobaltate (II) Hg[Co (NCS)<sub>4</sub>] as a calibrant. The diffuse reflectance spectra of all the solid polychelates were recorded on a Backman DK-2A spectrophotometer with solid reflectance attachments. MgO was employed as the reference attachments. MgO was employed as the reference compound. Thermal behaviour of these metal chelates was studied by TGA performed on thermogravimetric analyzer.

The batch equilibration method was adopted for the ion-exchanging properties<sup>18-19</sup>. The evaluation of the influence of different electrolytes on metal uptake by the polymer, the rate of metal uptake under specified conditions and distribution of various metal ions of different PH values were carried out following the details of the procedures described earlier<sup>18-19</sup>.

## **RESULTS AND DISCUSSION**

The oligomer sample AAPFQ was in form of dark brown powder and insoluble in common organic solvents. It swells up to some extent in conc. NaOH solution. It did not melt up to 300°C. The elemental contents shown in Table-1 are consistent with the predicted structure. The IR spectrum of AAPFQ shows a broad band extending from 3400-3100 cm<sup>-1</sup> with maxima at 3400, 3330 cm<sup>-1</sup> attributed to -OH group and NH<sub>2</sub> group. The weak bands at 2932 cm<sup>-1</sup> and 2850 cm<sup>-1</sup> are attributed to asymmetric and symmetric stretching vibrations of methylene groups (-CH<sub>2</sub>-). The bands around at 1420, 1480, 1588 and 1600 cm<sup>-1</sup> are due to 8-quinolinol moiety<sup>20</sup>. These features confirm the proposed structure of ligand AAPFQ. The TGA of AAPFQ contains single step degradation. The degradation starts from 280°C, loss rapidly between 300 to 500 and almost lost 87% at 650°C.

### **Characterization of Polymeric Chelates:**

The polymeric chelates of AAPFQ with different metal ions such as Cu<sup>2+</sup>, Ni<sup>2+</sup>, Co<sup>2+</sup>, Mn<sup>2+</sup>, Fe<sup>3+</sup> and Zn<sup>2+</sup> vary in color from dark red

to brown. They generally resemble each other. Comparison of IR spectra of the parent ligand with their polymer chelates has revealed certain characteristics differences as mentioned below.

One of the significant differences to be expected between IR spectrum of parent ligand and its metal chelates is the present at sharp  $3400\text{ cm}^{-1}$  due to Sec. NH stretching vibration frequencies in IR spectrum of polymer chelates. However the band due to absence of as the oxygen O-H of parent ligand has not been predicated due to presence of already OH group of resin. However this band has explicable by the fact that water

molecules might have strongly absorbed to the chelates during the formation. Another noticeable difference is that the bands due to C=N stretching vibration of 8-quinolionol at  $1606\text{ cm}^{-1}$  in IR spectrum of AAPFQ has assigned to in plane O-H deformation and this is shifted towards higher frequency in the spectra of polymer chelates indication the formation of metal-oxygen bonds<sup>21-23</sup>. This has been further confirmed by a weak band at  $1100\text{ cm}^{-1}$ . Corresponding to C-O-M stretching frequency<sup>21-23</sup>. All these characteristic features of IR suggest the general structure of polymer chelates as shown in Scheme I.

Table1: Elemental analyses of polymeric metal Chelates of AAPFQ and their metal chelates.

Sample designation	Elemental Analysis					Elemental Analysis					
	N%		M%		$\mu_{\text{eff}}$	%Weight loss at different temperature °C					
	Cald	Found	Cald	Found		200	300	400	500	600	700
	B.M										
AAPFQ	11.42	11.4	-----	----	-----	200	300	400	500	600	700
AAPFQ (Cu <sup>2+</sup> )	11.06	11.0	3.41	3.3	1.89	9.3	12.5	28.2	50.2	65.2	81.2
AAPFQ (Ni <sup>2+</sup> )	11.08	11.0	3.16	2.1	2.84	8.2	17.7	23.1	54.3	68.1	90.2
AAPFQ (Co <sup>2+</sup> )	11.09	11.0	3.17	3.1	3.92	8.7	20.0	22.6	62.4	70.5	92.5
AAPFQ (Mn <sup>2+</sup> )	11.11	11.1	2.97	2.9	4.63	9.0	14.8	23.7	60.5	72.4	93.3
AAPFQ (Fe <sup>3+</sup> )	12.54	12.5	3.01	3.0	4.91	8.8	15.5	24.4	63.3	73.2	96.2
AAPFQ (Zn <sup>2+</sup> )	11.05	11.0	3.50	3.4	D	8.4	18.2	26.5	55.1	63.4	90.6

Examination of data about metal content in each polymer chelates (Table I and II) has revealed 1:2 metal: ligand stoichiometry for divalent metal ions and 1:3 metal: ligand stoichiometry for  $\text{Fe}^{3+}$  polychelates. Magnetic moment ( $\mu_{\text{eff}}$ ) data of polymer chelates given in Table I has reveals that all metal chelates like  $\text{Cu}^{2+}$ ,  $\text{Ni}^{2+}$  and  $\text{Co}^{2+}$  are paramagnetic, while that of  $\text{Zn}^{2+}$  is diamagnetic in nature. The electronic spectral data assignments are shown in Table-3. The electronic spectra of AAPFQ with  $\text{Cu}^{2+}$  ions show two broad bands at 14956 and 23534  $\text{cm}^{-1}$  due to  $2T_{1g} \rightarrow {}^2E_g$  transition and charge transfer spectra respectively suggesting a distorted octahedral structure for AAPFQ polymer chelates. The AAPFQ with  $\text{Ni}^{2+}$  and  $\text{Co}^{2+}$  ion polychelates give two absorption bands respectively at 14928, 24099  $\text{cm}^{-1}$  and 14929, 22476  $\text{cm}^{-1}$  corresponding to  ${}^4T_g \rightarrow {}^2T_{1g}$ ,  ${}^4T_{1g} \rightarrow {}^4T_{1g}(P)$  transition. Thus, absorption band of diffuse reflectance spectral and the values of magnetic moment ( $\mu_{\text{eff}}$ ) have indicated an octahedral configuration for the  $\text{Ni}^{2+}$  and  $\text{Co}^{2+}$  poly chelates. The spectra of polychelates of  $\text{Mn}^{2+}$  ion show two weak bands at 17246  $\text{cm}^{-1}$  and 25037  $\text{cm}^{-1}$  assigned to the transition  ${}^6A_{1g} \rightarrow {}^4T_{2g}$  (4G) and  ${}^6T_{1g} \rightarrow {}^4T_{1g}$  (4G) respectively and assigned an octahedral structure for AAPFQ chelates. As the spectrum of the  $\text{Zn}^{2+}$  chelates is not well resolved it is not interpreted but its  $\mu_{\text{eff}}$  value reveals its diamagnetic nature as expected. The TGA data (TG thermograms not shown) of all polymeric chelates are shown in Table-2. The TGA data as thermograms reveals that the rate of decomposition of all polymeric chelates is initially low up to 200°C temperature and rapidly increases to maximum in the range 400-500°C. This might be due to accelerated catalytically by 'insitu' formation of metal oxide of thermal stability of all these polychelates is quite similar.

### ION-EXCHANGE PROPERTIES

The examination of data presented in Table-2 reveals that the amount of metal ions taken up by a given amount of the AAPFQ polymer depends upon the nature and concentration of

the electrolyte present in the solution. The amounts of  $\text{Fe}^{3+}$  and  $\text{Cu}^{2+}$  ions taken up by the polymer sample increase with the increase in concentration of ions taken up by the polymer sample increase with the increase in concentration of ions like chloride, chlorate and nitrate but decrease with the increase in concentration of the sulfate ions. The amounts of the remaining three metal ions  $\text{Co}^{2+}$ ,  $\text{Mn}^{2+}$  and  $\text{Zn}^{2+}$  taken by the polymer sample decrease with the increase in concentration of chlorate, chloride, nitrate and sulfate ions.

a. Volume of electrolyte solution 40 ml, time 24h, volume of metal ion solution 1ml, temp. 25 °C

b. Wt. of PATS polymer 25 mg.

### RATE OF METAL UPTAKE

The rates of metal absorption by the AAPFQ sample were measured for  $\text{Cu}^{2+}$  and  $\text{Mn}^{2+}$  ions presence of 1 M  $\text{NaHCO}_3$  to know the time required to reach the stage of equilibrium. All experiments were carried out at pH 3. The examination of the results presented in Table.3 shows that  $\text{Fe}^{3+}$  ions required slightly more than three hours for the establishment of equilibrium and  $\text{Cu}^{2+}$  and  $\text{Mn}^{2+}$  ions required about five hrs for the purpose. In the experiments with solution containing  $\text{Fe}^{3+}$  ion, more than 70% of equilibrium was established in the first hrs. This reveals that the rate of uptake of metal ions follows the order  $\text{Fe}^{3+} > \text{Cu}^{2+} > \text{Mn}^{2+}$ . The rates of uptake of  $\text{Zn}^{2+}$  and  $\text{Co}^{2+}$  ions have been found to be very low at pH 3. Hence the values are no reported.

### DISTRIBUTION RATIO OF METAL IONS AT DIFFERENT PH VALUES

The results described in Table.4 reveal that the amount of metal ions taken up by the polymer sample AAPFQ at equilibrium increases with the increase in pH. The selectivity of the polymer sample  $\text{Fe}^{3+}$  ion are higher than that for each of the remaining metal ions. The lower values of the distribution ratio for  $\text{Fe}^{3+}$  ions requires its attachment with proper sites on three different polymer chains.

Table 2: Evaluation of the influence of different electrolytes in the uptake of several metal ions; ([Mt (NO<sub>3</sub>)<sub>2</sub>] = 0.1 mole·l<sup>-1</sup>)<sup>a</sup>

Metal ions	pH	[Electrolyte] (mole · l <sup>-1</sup> )	Adsorption of mmol·10 <sup>1</sup> of the metal ion on AAPFQ polymer <sup>b</sup> .			
			NaClO <sub>4</sub>	NaNO <sub>3</sub>	NaCl	Na <sub>2</sub> SO <sub>4</sub>
Cu <sup>2+</sup>	5.5	0.01	0.12	0.08	0.16	0.31
		0.05	0.23	0.13	0.18	0.29
		0.1	0.16	0.19	0.18	0.28
		0.5	0.31	0.21	0.23	0.25
		1.0	0.48	0.26	0.29	0.23
Fe <sup>3+</sup>	2.75	0.01	0.11	0.15	0.05	0.16
		0.05	0.25	0.19	0.06	0.05
		0.1	0.27	0.17	0.09	0.09
		1.0	0.35	0.27	0.26	0.06
Co <sup>2+</sup>	5.5	0.01	0.17	0.18	0.08	0.08
		0.05	0.16	0.19	0.16	0.12
		0.1	0.09	0.18	0.11	0.09
		0.5	0.08	0.10	0.09	0.07
		1.0	0.04	0.05	0.07	0.04
Mn <sup>2+</sup>	5.5	0.01	0.25	0.28	0.23	0.18
		0.05	0.22	0.25	0.18	0.16
		0.1	0.19	0.22	0.24	0.09
		0.5	0.16	0.23	0.19	0.08
		1.0	0.18	0.18	0.17	0.07
Zn <sup>2+</sup>	5.5	0.01	0.15	0.11	0.10	0.16
		0.05	0.17	0.09	0.09	0.09
		0.1	0.13	0.08	0.06	0.12
		0.5	0.09	0.07	0.08	0.07
		1.0	0.08	0.05	0.05	0.05
Ni <sup>2+</sup>	5.5	0.01	0.10	0.14	0.08	0.19
		0.1	0.22	0.16	0.07	0.08
		0.5	0.18	0.19	0.06	0.12
		1.0	0.34	0.26	0.25	0.06

Table 3: Comparison of the rates of metal (Mt) ion uptake <sup>a</sup>

Time (h)	Attainment of equilibrium state <sup>b</sup>		
	Fe <sup>3+</sup>	Cu <sup>2+</sup>	Mn <sup>2+</sup>
0.5	62.6	35.0	22.2
1	71.7	51.7	46.7
2	88.7	63.6	62.5
3	91.6	74.8	76.6
4	90.5	84.0	84.2
5	---	89.5	85.7
6	---	94.3	92.3
7	---	93.4	97.7

a. [Mt (NO<sub>3</sub>)<sub>2</sub>] = 0.1 mole·l<sup>-1</sup>, volume 1 ml [NaNO<sub>3</sub>] = 1 mol · l<sup>-1</sup>, volume 40 ml, pH = 3, temp 25° C, wt of PATS polymer 25 mg.

b. Related to the amount of metal ions taken up at the state of equilibrium assumed to be established in 24 h and assumed to be 100%.

Among the remaining metal ions, Cu<sup>2+</sup> has a high value of distribution ration at pH 6 while the other three metal ions Co<sup>2+</sup>, Zn<sup>2+</sup> and Mn<sup>2+</sup> have a low distribution ration over a pH range from 4 to 6. Further work in the direction of wide range at such polymers and their ion exchanging properties are under progress.

## CONCLUSION

In present communication we prepare novel ion-exchange resin based on 3-amino phenol i.e. AAPFQ. The novel ion-exchange resin containing a well known metal complexing agent and 8-quinolinol. The AAPFQ sample shows good chelating and ion-exchanging properties. Batch equilibration method has been adopted for evolution of ion-exchange properties.

Table 4: Distribution rations, D, of different metal ions as a function of the pH

pH	Distribution ratio <sup>a</sup> of metal ions <sup>b</sup>				
	Cu <sup>2+</sup>	Fe <sup>3+</sup>	Co <sup>2+</sup>	Mn <sup>2+</sup>	Zn <sup>2+</sup>
1.5	----	----	----	----	----
1.75	138	138	----	----	----
2.0	175	175	---	----	----
2.5	461	467	---	----	----
3.0	959	968	----	----	----
4.0	---	---	11	85	88
5.0	----	----	93	149	152
6.0	---	---	348	272	273

a. mmol of metal ions taken up by 1 g of polymer/ mmol of ions present in 1 ml of solution [Mt(NO<sub>3</sub>)<sub>2</sub>] = 0.1 mol l<sup>-1</sup>, volume: 1 ml; wt. of polymer: 25 mg ; [NaNO<sub>3</sub>] = 1 mol l<sup>-1</sup>, volume: 44 ml; temp.: 25 0C, time 24 h (equilibrium state).

b. Error +/- 5%.

## REFERENCES

1. Sen AK, Roy S, Juvekar VA, "On the Importance of Purification of Sodium Polystyrene Sulfonate", International Scholarly Research Network, 2012, Article ID 514509, doi:10.5402/2012/514509.
2. Alexandratos SD, "Ion-Exchange Resins: A Retrospective from Industrial and Engineering Chemistry Research," Ind. Eng. Chem. Res., 2009, 48 (1), 388-398.
3. Seliman AF, Samadi A, Husson SM, Borai EH, DeVol TA, "Preparation of Polymer-Coated, Scintillating Ion-Exchange Resins for Monitoring of 99-Tc in Ground water", Anal. Chem., 2011, 83 (12), 4759-4766.
4. Bento LSM, "Sugar liquors purification using anionic resins with regenerant recovery", Proc. Sugar process. Res. Conf., 1991, 99-115.

- Holy A, Rosenberg I, "Synthesis of isomeric and enantiomeric O-phosphonyl methyl derivatives of 9-(2,3-dihydroxypropyl)adenine", *Collect. Czech. Chem. Commun.*, 1987, 52, 2775-2791.
- Chanda M, Roy SK, "Polymer in special use Industrial Polymers Specialty" *Polymers and Their Applications*, 2008, 2-1-2-163, DOI: 10.1201/9781420080599.ch2.
- Yeh JD, "Heavy Metallic and Organometallic Ions Scavenging Using Silica-Based Adsorbent Functionalized with Ligands Containing Sulfur and Nitrogen Elements", *J. Chin. Chem. Soc.*, 2012, 59, 98-106.
- Ahmed FE, Young BD, Bryson AW, "Comparison and modelling of the adsorption kinetics of gold cyanide onto activated carbon and resin in a silica slurry", *Hydro metallurgy*, 1992, 30(1-3), 257-275.
- Ritter JA, Bibler JP, "Removal of Mercury from Waste Water: Large Scale Performance of an Ion Exchange", *Process water Sci. Techno.*, 1992, 25(3), 165-172.
- Shimpi N, Borane M, Mishra S, Kadam M, "Biodegradation of polystyrene (PS)-poly(lactic acid) (PLA) nanocomposites using *Pseudomonas aeruginosa*" *Macromol. Res.*, 2012, 20, 181-187.
- Pirogov AV, Chernova MV, Nemtseva DS, Shpigun OA, "Sulfonated and sulfoacylated poly(styrene-divinylbenzene) copolymers as packing materials for cation chromatography", *Anal Bioanal Chem.*, 2003, 376(5), 745-52.
- Wiley RH, Mathews WK, O'driscoll KF, "Monomer Reactivity Ratios for the Copolymerization of Styrene with Pure Meta-and Pure Para- Divinyl benzenes", *Journal of Macromolecular Science: Part A - Chemistry*, 1967, 1(3), 503-516.
- Patel PS, Patel SR, "Synthesis, characterization and curing of m-Diethylamino phenol formaldehyde resin", *British Polymer Journal*, 1988, 20(1), 13-17.
- Patel JR, Nimavat KS, Vyas KB, "Novel Oligomeric azo dyes: Synthesis, Characterization and IonExchanging Properties", *J. Chem. Pharm. Res.*, 2011, 3(6), 483.
- Patel JR, Nimavat KS, Vyas KB, "Synthesis, characterization and ion-exchanging properties of novel oligomeric azo dyes", *Der Pharma Chemica*, 2011, 3(4), 102-109.
- Shah TB, Raj LM, Dixit RB, "Polymeric chelates of epoxy based polyesters containing oxine as pendent groups", *International Journal of Polymeric Materials*, 2003, 52(1), 9-20.
- Vogel AI, *Textbook of Quantitative Chemical Analysis*, (ELBS 4thEdn.London), 1972, 317.
- Burkanudeen A, Azarudeen R, Vijayan N, "Synthesis and Analytical Applications of a Chelating Resin", *International Journal of Chemical and Environmental Engineering*, 2010, 1(1), 29-34.
- Singh A, Parmar V, "Studies on new ion-exchange resin for effluent treatment of metal industries," *Oriental Journal of Chemistry.*, 2009, 25(4), 1005-1010.
- Patel HS, Patel DJ, "Coordination Polymers Based on Bis-Ligand-Containing Indole and 8-hydroxyquinoline Moieties," *Synthesis and Reactivity in Inorganic, Metal-Organic, and Nano-Metal Chemistry*, 2010, 59(5), 307-317.
- Gosai DR, Nimavat KS, Vyas KB, "Azo dyes based on salicylic acid- formadehyde polymer as a polymeric ligands," *Der Pharma Chemica*, 2011, 3(4), 491-500.
- Shah SM, Bux FB, Singh A, "Studies On Oligomeric Polymers of Phenol formaldehyde," *Rasayan J. Chem.*, 2010, 3(3), 461-466.
- Shah AI, Shukla HM, "Co-ordination polymers of Hetero nuclear bisligand," *Der Chemica Sinica*, 2010, 1(3), 70-76.