AG® 50W and AG MP-50 Cation Exchange Resins

Instruction Manual

BIO-RAD

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Section 1
Introduction

AG 50W and AG MP-50 strong acid cation exchange resins are useful for single step purification methods, for concentrating cationic solutes, and for analytical determinations of various mixed cationic solutes.

Section 2
Technical Description

Strong acid cation exchange resin is available as Analytical Grade AG 50W resin, AG MP-50 macroporous resin, and Biotechnology Grade AG 50W resin. The Analytical Grade AG 50W resin has been exhaustively sized, purified, and converted to make it suitable for accurate, reproducible analytical techniques. Biotechnology Grade AG 50W resin is analytical grade resin which is certified to contain less than 100 microorganisms per gram of resin.

AG 50W strong acid cation exchange resin is composed of sulfonic acid functional groups attached to

a styrene divinylbenzene copolymer lattice. The amount of resin crosslinking determines the bead pore size. A resin with a lower crosslinkage has a more open structure permeable to higher molecular weight substances than a highly crosslinked resin. It also has a lower physical resistance to shrinking and swelling, so that it absorbs more water and swells to a larger wet diameter than a highly crosslinked resin of equivalent dry diameter. For example, typical applications of AG 50W-X2 2% crosslinked resin and AG 50W-X4 4% crosslinked resin include separation or concentration of peptides, nucleotides, and amino acids. In high percentage crosslinkage, (AG 50W-X8 8% resin, AG-50W-X12 12% resin, and AG 50W-X16 16% resin) applications include separation of small peptides and amino acids, removal of cations, and metal separations. Table 1 shows the approximate molecular weight exclusion limits in water for resins of various crosslinkages. All AG 50W resins are supplied in the hydrogen form, and selected AG 50W-X8 resins are available in sodium and ammonium forms.

Table 1. Approximate Molecular Weight Exclusion Limits for Ion Exchange Resins in Water

Percent Crosslinking	Approximate MW Exclusion Limit for Globular Molecules
2%	2,700
4%	1,400
8%	1,000
10%	800
12%	400

AG MP-50 resin is the macroporous equivalent of AG 50W resin. Its effective surface area approximates 35 square meters per dry gram, or 30-35% porosity.

The physical properties of the resins are listed in Table 2. The cation exchange resins are thermally stable and resistant to solvents (alcohols, hydrocarbons, etc.), reducing agents, and oxidizing agents.

Table 2. Summary of the Properties of AG 50 and AG MP 50 Resins

Active Group (X8 Resin)	Thermal Stability	Solvent Stability	Resistance to Oxidizing Agents	Resistance to Reducing
$R\text{-}SO_3^-$	Good to 150 °C	Very good	Slowly oxidizes in hot 15% $HN0_3$	Very good

Section 3
Mechanism

In an ion exchange procedure, the counterions on the resin are replaced by sample ions that have the same charge. In applications involving a cation exchange resin, such as AG 50 resin, neutral molecules and anions do not interact with the resin. AG 50 resin is available with H^+, Na^+, or NH_3^+ counterions. A resin can be converted from one ionic form to another. Usually the resin is used in an ionic form with a lower selectivity for the functional group than the sample ions to be exchanged. The sample ions are then exchanged when introduced, and can be eluted by introducing an ion with higher affinity for the resin or a high concentration of an ion with equivalent or lower affinity. Table 3 shows the relative selectivity of various counterions. In general, the lower the selectivity of the counterion the more readily it exchanges for another ion of like charge. The order of selectivity can also be used to estimate the effectiveness for different ions as eluants, with the most highly selective being the most efficient. Finally, the order of selectivity can be used to estimate the difficulty of converting the resin from one form to another. Conversion from a highly selected to a less highly selected form requires an excess of the new ion.

Table 3. Relative Selectivity of Various Counterions

Counterion	Relative Selectivity for AG 50W-X8 Resin	Counterion	Relative Selectivity for AG 50W-X8 Resin
H^+	1.0	Fe^{2+}	2.55
Li^+	0.85	Zn^{2+}	2.7
Na^+	1.5	Co^{2+}	2.8
NH_4^+	1.95	Cu^{2+}	2.9
K^+	2.5	Cd^{2+}	2.95
Rb^+	2.6	Ni^{2+}	3.0
Cs^+	2.7	Ca^{2+}	3.9
Cu^+	5.3	Sr^{2+}	4.95
Ag^+	7.6	Hg^{2+}	7.2
Mn^{2+}	2.35	Pb^{2+}	7.5
Mg^{2+}	2.5	Ba^{2+}	8.7

The AG 50 resins are available in several particle size ranges. The flow rate in a chromatographic column increases with increasing particle size. However, the attainable resolution increases with decreasing particle size and narrower size distribution ranges. Particle size is given either in mesh size or micron size. The larger the mesh size number, the smaller the particle size. Table 4 shows wet mesh and equivalent micron diameters.

Large mesh material (20-50 and 50-100 mesh) is used primarily for large preparative applications and batch operations where the resin and sample are slurried together. Medium mesh resin (100-200 mesh) is used primarily in column chromatography for analytical and laboratory scale preparative applications. Fine mesh material (200-400 and minus 400 mesh) is used for high resolution analytical separations.

Table 4. Wet Mesh and Equivalent Micron Diameters

Wet Mesh											
(U.S. Standard)	16	20	40	50	80	100	140	200	270	325	400
µm Diameter											
(1 µm=0.001msm)	1,180	850	425	300	180	150	106	75	53	45	38

Section 4
Resin Conversion

Table 5 outlines common techniques for converting ion exchange resins from one ionic form to another. Resin conversion is most efficiently carried out in the column mode. However, when choosing a column,

remember that the resin may shrink, or it may swell as much as 100%, depending on the conversion.

Conversions to ionic forms not listed in Table 5 can be achieved using the information supplied in Table 3, which lists relative selectivities of various counterions for AG 50 resin. To convert a resin to an ionic form with a higher selectivity, wash the resin with 2-3 bed volumes of a 1 M solution of the desired counterion. For conversion to an ionic form with a lower relative selectivity for the resin, the necessary volume of counterion solution will depend on the difference in selectivity. As a general rule, use 1 bed volume of 1 M counterion solution for each unit difference in relative selectivity. For example, converting AG 50W-X8 resin from the K^+ form (relative selectivity 2.5) to the H^+ form (relative selectivity 1.0) would require 2-3 bed volumes of 1 M HCl. The conversion is complete when all the K^+ ions are displaced by the H^+ ions.

Table 5. Techniques for AG Resin Conversion

	AG 50 resin	Bio-Rex® MSZ 50 resin
Conversion from → to	$H^+ \rightarrow Na^+$	$H^+ \rightarrow$ pyridinium
Reagent used	1 M NaOH	1 M pyridine (wash with H_2O before pyridine)
Volumes of sol'n/ vol. of resin	2	2
Flow rate[2] ml/min/cm² of bed	2	1
Type of exchange[1]	N	N
Test for completeness of conversion	pH 9[3]	—
Rinse: vol. DI water/ vol. resin	4	—
Test for completion of rinsing	pH<9	—

1. N = Neutralization
2. For 50-100 or finer mesh resin. For 20-50 mesh, about ½ the flow rate is recommended.
3. Test for pH 4.8 – pH paper or methyl orange (red pH 1, yellow pH 4.8). Test for pH 9 – pH paper or thymolphthalein (blue pH 10, colorless at pH 9).

Section 5
Instructions for Use

AG 50 and AG MP-50 resin may be used in either a batch method or a column method. The batch method consists of adding the resin directly to the sample and stirring. The column method requires preparing a column filled with resin, and passing the sample through.

5.1 Batch Method

The batch method is performed by adding the resin directly into the sample and stirring. The resin should be in the correct ionic form prior to beginning.

1. Weigh out about 5 grams of resin for every 100 ml of sample. For larger scale applications or when an exact amount of resin is needed, calculate the resin volume based on the resin capacity.
2. Add resin to the sample and stir or shake gently for 1 hour.
3. Filter or decant the sample from the resin.

5.2 Column Method

The column method involves pouring a column with the resin and passing the sample through to achieve the separation. Particle size will determine the flow rate, which will affect the separation. The resin should be in the correct ionic form and equilibrated prior to adding the sample.

1. Calculate the amount of resin required based on the expected resin capacity and sample concentration. If the sample ionic concentration is unknown, begin with 5 grams of resin for 100 ml of sample, and then optimize the volumes after obtaining the results.
2. Insure that the resin is in the ionic form which will allow the sample ions to be exchanged onto the resin. If conversion of the resin into another ionic form is necessary, use the guidelines described above for resin conversion (see Table 5).
3. Prepare the initial buffer, so that the pH and ionic concentration will allow the sample ions to be exchanged onto the column. For unknown solutions, use deionized water.

4. Slurry and pour the resin into the column. Equilibrate the resin in the initial buffer using 3 bed volumes of buffer. Poorly equilibrated resin will not give reproducible results. Alternatively, equilibration can be done by the batch technique, prior to pouring the column. First, convert the resin to the appropriate form, then suspend it in the starting buffer. Check the pH with a pH meter while stirring continuously. Adjust the pH by adding acid or base dropwise to the buffer until the desired pH is obtained. Then transfer the resin to the column, and pass 1 bed volume of the starting buffer through the column.
5. Add the initial buffer and allow excess buffer to pass through the column, leaving enough buffer to just cover the top of the resin bed.
6. Apply the sample dropwise to the top of the column without disturbing the resin bed. Drain the sample into the top of the bed and apply several small portions of starting eluant, being very careful to rinse down the sides of the column and to avoid stirring up the bed. Drain each portion to the level of the resin bed before the next portion is added. Never allow the liquid level to drain below the top of the resin bed.

7. The actual flow rate that is used will depend upon the application, the resin, and the column cross section. To obtain flow rates for any given size column, multiply the suggested flow rates in Table 6 by the column cross-sectional area. Table 6 gives typical flow rates of analytical grade resins.
8. If a cation-free solution is the goal, collect the effluent. If the concentrated cations are of interest, allow all of the sample to pass through the column, then elute the metals with a solution containing a counterion of higher selectivity than the bound cation.

Table 6. Suggested Flow Rates for Ion Exchange Resin Columns

Application	Flow Rates cm/min
Removing trace ions	5-10
Separations with very few components	1-3
Separations of multi-component samples	0.3-1.0
Using high resolution resins with small particle size	0.1-0.2

Section 6
Sample Protocol for Cation Exchange Resins

6.1 Determination of Total Salts in Tap Water

Approximately 85% of the Continental United States is afflicted with hard water (3 grains or greater/gal). The following is a rapid method of determining the total ionic content of tap water as well as a good illustration of the potential of ion exchange techniques. If the water containing dissolved ions is allowed to flow over a cation exchange resin, the metal ions will be quantitatively exchanged for the hydrogen ions of the resin. These hydrogen ions will appear in the eluant and may then be titrated with standardized NaOH. Because of the electroneutrality of the dissolved salts, the milliequivalents of cations also represent the milliequivalents of salts.

6.2 Materials

AG 50W-X8 resin, 50-100 mesh, hydrogen form–10 grams

Econo-Column® chromatography column, 1.0 x 0.79 cm

Methyl orange indicator solution (0.1%)

20 mM NaOH standard solution

3 M HCl

Flask–250 ml

6.3 Protocol

1. Pass approximately 150 ml of tap water through the resin column.
2. Discard the first 20 ml of effluent.
3. Collect a 100 ml aliquot of effluent in a 250 ml flask.
4. Titrate with 20 mM NaOH to methyl orange end point (yellow).
5. Calculate the salt content from the equivalents of base used.

6.4 Calculation

Meq dissolved salts = ml of base x normality of base.

6.5 Notes

The experimental error is only that inherent in the titration procedure. The error due to the ion exchange itself is less than that of the titration. To avoid the error due to interfering carbonate ions, neutralize alkaline tap water with 0.1 M HCl, one drop at at time, to the methyl orange end point.

The column may be used several times before regeneration is necessary. To regenerate the resin, wash it by passing approximately 50 ml of 3 M HCl through the column, followed by 75 ml of distilled water.

Section 7
Applications

Strong cation exchange resins are used for sample preparation, metal separations, weak acid separations, peptide separations, amino acid separations, and nucleotide separations. Tables 7-10 summarize the applications.

Section 8
Storage

The resins are stable for at least 2 years when stored in the original, unopened container at room temperature and protected from ultraviolet light.

Section 9
Stability

The resins are stable in acid, base, and organic solvents, and may be autoclaved. To prevent bacterial growth during prolonged storage of a poured column, use a preservative such as 0.05% sodium azide or thimerosol or 20% organic solvent such as methanol or ethanol.

Table 7. Cation Exchangers for Sample Preparation

Application	Resin	Reference
Cation removal from monosaccharides	AG 50W-X8 resin	Ochiai, M., *J. Chromatog.*, **194,** 224 (1980).
Removal of cations from sulfate	AG 50W-X8 resin	Hoffer, E. M., Kothny, E. L. and Appel, B. R., *Atmospheric Environment*, **13,** 303 (1979).

Table 7 (Continued)

Application	Resin	Reference
Metal removal	AG 50W-X8 resin	Siemer, D. D., *Anal. Chem.*, **52,** 1874 (1980).
Cyclic nucleotide extraction	AG 50W-X8 resin	Schwartz, J. P., Morris, N. R. and Breckenridge, B. M., *J. Biol. Chem.*, **248,** 2699 (1973); Kuo, W., Hodgins, D. S. and Kuo, J. F., *J. Biol. Chem.*, **248,** 2705 (1973).
Concentration of vitamin B-6	AG 50W-X8 resin	Tryfiates, G. P. and Sattsangi, S., *J. Chromatog.*, **227,** 181 (1982).
Concentration of amino acids	AG 50W-X8 resin	Ford, C. W., *J. Sci. Food Agric.*, **35,** 881 (1984).
Removal of contaminants from I^{125}	AG 50W-X8 resin	Auf'mkolk, M., Koehrle, J., Hesch, R. D. and Cody, V., *J. Biol. Chem.*, **261,** 11623 (1986).
Concentration of chloramphenicol	AG 50W-X8 resin	Schwartz, D. P. and McDonough, F. E., *J. Assoc. Off. Anal. Chem.*, **67,** 583 (1984).
Removal of ethidium bromide from plasmids	AG 50W-X8 resin	Rodriguez, R. L. and Tait, R. C., Recombinant DNA Techniques: An Introduction, p. 153-154 Addison-Wesley Publishing Company (1983).
Concentration of isomers of trans-2, 3-cis-3,4-dihydroxyl-L-proline	AG 50W-X8 resin	Linblad, W. J. and Diegelmann, R. F., *J. Chromatog.*, **315,** 447 (1984).
Isolation of neutral and cationic metabolites	AG 50W-X8 resin; AG 1-X8 resin	Terry, R. C. and Simon, M., *J. Chromatog.*, **232,** 261(1982).

Table 7 (Continued)

Application	Resin	Reference
Deionization of N-nitro-sodiethanol-amine	AG 50W-X8 resin	Wigfield, Y. Y. and Lanouette, M., *J. Assoc. Off. Anal. Chem.*, **68,** 1142 (1985).
Deionization of carbohydrates	AG 50W-X8 resin; AG 2-X8 resin	Cullen, M. P., Turner, C. and Haycock, G. B., *J. Chromatog.*, **337,** 29 (1985).
Concentration of nucleotide fragments	AG 50W-X2 resin	Kapian, B. B., Schachter, B. S., Osterburg, H. H., de Velis, J. S. and Finch, C. E., *Biochemistry*, **17,** 5516 (1978).
Concentration of 3-methyl-L-histidine	AG 50W-X4 resin	Robert, J. C. and Serog, P., *Clin. Chim. Acta*, **142,** 161 (1984).
Separation of adenosyl-L-methionine from amino-cyclopropane carboxylic acid	AG 50W-X4 resin	Miura, G. A. and Chiang, D. K., *Anal. Biochem.*, **147,** 217 (1985).
N-acetyl-L-[^{35}S] Met purification	AG 50W resin	Martin, D. J. and Rubenstein, P. A., *J. Biol.Chem.*, **262,** 6350 (1987).
Nitrite determination in meat	AG 50W-X12 resin	Kordorouba, V. and Pelletier, M., *Mitt. Geb. Lebensmitteiunters. Hyg.*, **79,** 90 (1988).
Glycopeptide and oligosaccharide purification	AG 50W-X2 resin	Nishikawa, Y., et al., *J. Biol Chem.*, **263,** 8270 (1988).
Aldehyde and ketone separation	AG 50W-X2 resin	Rendina, A. R. and Cleland, W. W., *Anal. Biochem.*, **117,** 213 (1981).
Diethyl acetal purification	AG 50W-X8 resin	Cho, Y. K., et al., *Biochemistry*, **27,** 3320 (1988).

Table 7 (Continued)

Application	Resin	Reference
Ammonia determination in plasma	AG 50W-X8 resin	Forman, D. T., *Clinical Chem.*, **10,** 497 (1964).
Metal removal	AG 50W-X8 resin	Graf, E., *J. Agric. Food Chem.*, **31,** 851 (1983).
Boron cleanup	AG 50W-X8 resin	Gregorie, D., *Anal. Chem.*, **59,** 2479 (1987).
Amino acid concentration	AG 50W-X8 resin	Stabler, S. P., et al., *Anal. Biochem.*, **162,** 185 (1987).
Peptide-Ch 6-S purification	AG 50W-X8 resin	Takagaki, K., et al., *J. Biol. Chem.*, **263,** 7000 (1988).
Cationic metabolite isolation	AG 50W-X8 resin	Terry R. C. and Simon, M., *J. Chromatog.*, **232,** 261 (1982).
Deionization of N-ni trosodiethanolamine	AG 50W-X8 resin	Wigfield, Y. Y. and Lanouette, M., *J. Assoc. Off. Anal. Chem.*, **68,** 1142 (1985).
Free calcium removal from bound Ca-G-actin	AG SCW-X8 resin	Zimmerle, C. T. and Frieden, C., *Biochemistry*, **27,** 7759 (1988).
Aspartic acid purification	AG 50 resin	MacKenzie, S. L. and Tenaschuk, J., *J. Chromatog.*, **322,** 228 (1985).
Glutamic acid K	AG 50 resin	MacKenzie, S. L. and Tenaschuk, J., *J. Chromatog.*, **322,** 228 (1985).
Tetrabutylammonium fluoride removal	AG 50W-X2 resin	Chou, S-H., et al., *Biochemistry*, **28,** 2422 (1989).
Peptide cleanup	AG 50W-X2 resin	Schiffmann, E., et al., *J. Immunol.*, **114,** 1831 (1975).

Table 7 (Continued)

Application	Resin	Reference
L-Tryptophan purification	AG 50W-X2 resin	Yoshida, R., et al., *J. Immunol.*, **141,** 2819 (1988).
Iron detection in wine	AG 50W-X8 resin	Ajlec, R. and Stupar, J., *Analyst*, **114,** 137 (1989).
Taurine cleanup	AG 50W-X8 resin	Stephan, Z. F., et al., *J. Biol. Chem.*, **262,** 6069 (1987).
Glyphosate quantitation	AG 50W-X8 resin	Thompson, et al., *JAOAC*, **72,** 355 (1989).
cAMP purification	AG 50W-X8 resin	Nemecek, G. M., et al., *J. Biol. Chem.*, **254,** 598 (1979).

Table 8. Metal Separations on Cation Exchangers

Metals	Recommended Resin	Eluant and Eluted ions	Reference
Bi, Cd, Fe, Cu, Mn, Ni	AG 50W-X8 resin	Bi-50% acetone, 0.1 M HCl; Cd-70% acetone, 0.2 M HCI; Fe - 80% acetone, 0.5 M HCI; Cu-90% acetone, 0.5 M HCI; Mn-92% acetone, 1 M HCI; Ni-aqueous 3 M HCI	Fritz, J. S. and Fettig, T. A., *Anal. Chem.*, **34,** 1562 (1962).

Table 8 (Continued)

Metals	Recommended Resin	Eluant and Eluted ions	Reference
V, U, Sc, Y	AG 50W-X8 resin	V - 0.25 M H_2SO_4; U - 0.5 M H_2SO_4; Sc - 1 M H_2SO_4; Y 4 N HCl	Strelow, F. W. E., Rethemeyer, R. and Bothma,C. J. C., *Anal. Chem.*, **37,** 106 (1965).
Be, Ba, Sr	AG 50W X8 resin	Be, Ba-9 M $HClO_4$; Sr-5 M HNO_3	Nelson, F., Murase, T. and Kraus, K. A., *J. Chromatog.*, **13,** 503 (1984).
K, Ti, Sc	AG 50W X8 resin	K-9 M $HClO_4$; Ti-9 M HCI; Sc-4 M HCI, 0.1 M HF	Nelson, F., Murase, T. and Kraus, K. A., *J. Chromatog.*, **13,** 504 (1964).

Application	Resin	Reference
Metal separation (Pm, Y, Eu, Co, Fe, Am, Cm, Nd)	AG 50W-X12 resin	Jerome, S. M., *The Science of the Total Environment,* **70,** 275 (1988).
^{111}In separated from cyclotron target	AG 50W-X4 resin	Van der Walt, T. N., et al., *Int. J. Appl. Radiat. Isot.*, **36** (6), 501 (1985).
Cobalt separation	AG 50W-X4 resin	Victor, A. H., *S. Afr. J. Chem.*, **36** (2), 76 (1983).
Trace metal separation	AG 50W-X4 resin	Van der Walt, T. N. and Strelow, F. W. E., *Anal. Chem.*, **55** (2), 212 (1983).
Thorium detection	AG 50W-X4 resin	Victor, A. H. and Strelow, F. W. E., *Anal. Chim. Acta,* **138,** 285 (1982).

Table 8 (Continued)

Application	Resin	Reference
Trace element separation from manganese	AG 50W-X8 resin	Faisca, A. M. M. M., et al., *Anal. Chim. Acta,* **215,** 317 (1988).
Rare earth element separation	AG 50W-X8 resin	Juras, S. J., et al., *Chem. Geol.*, **64** (1-2), 143 (1987).
Platinum and palladium determination	AG 50W-X8 resin	Brown, R. J. and Biggs, W. R., *Anal. Chem.*, **56** (4), 646 (1984).
Chromium thiocyanate hydrate analysis	AG 50W-X8 resin	Collins, C. H. and Lancas, F. M., *Radiochem. Radioanal. Lett.*, **56** (2), 117 (1983).
Copper determination	AG 50W-X8 resin	Victor, A. H., *Geostand. Newsl.*, **7** (1), 227 (1983).
Rare earth element determination	AG 50W-X8 resin	Savoyant, L., Persin, F. and Dupuy, C., *Geostsnd. Newsl.*, **8** (2), 159 (1984).
Lead separations	AG MP-50 resin	Strelow, F. W. E., *Anal. Chem.*, **57** (12), 2268 (1985).
Copper detection	AG 50 resin	Lazaro, F., et al., *Anal. Chim. Acta,* 214, 217 (1988).
Iron detection in wine	AG 50W-X8 resin	Ajlec, R. and Stupar, J., *Analyst,* **114,** 137 (1989).
Rare earth metal separation	AG 50W-X8 resin	Hiramatsu, K. and Yamada, T., Jpn. Kokai Tokkyo Koho, September 1988.

Table 9. Cation Exchange Resins in Nucleic Acid Analysis

Application	Resin	Reference
Separation of adenosine and riboflavin nucleotides	AG 50W-X4 resin	Brunius, G ., *J. Chromatog.*, **170,** 486 (1979).
Separation of cyclic nucleotides from gastrointestinal tissues and fluids	AG 50W-X8 resin	Swartzel, E. H., Bachman, S. and Levine, R. A., *Anal. Biochem.*, **78,** 395 (1977).
Preparation of chromatin from chick embryo Iivers	AG 50W-X2 resin	Goel, S. B. and Modak, S. P., *Nucleic Acids Res.*, **12,** 1391 (1984).
Purification of chromatin	AG 50W-X2 resin	Nielsen, P. E., *Biochem.*, **24,** 2298 (1985).
Separation of nucleoside mono-, di-, and triphosphates on ion exclusion exchange columns	AG 50W-X4 resin	Leigh, C. P. H. and Cashion, P. J., *J. Chromatog.*, **192,** 490 (1980).
Purification of gramicidin	AG MP-50 resin	Rottenberg, H. and Koeppe, R. E., *Biochemistry*, **28,** 4355 (1989).
Nucleic acid stripping	AG 50W-X2 resin	Chandrasekaran, E. V., Spolter, L. and Marx, W., *Prep. Biochem.*, **5,** 281 (1975).
Nucleotide separation	AG 50W-X4 resin	Blattner, F. R. and Erickson, H. P., *Anal. Biochem.*, **18,** 220 (1967).

Table 10. Separation of Organic Acids and Amines

Application	Resin	Reference
Separation of maleic and fumaric acids	AG 50W-X4 resin	Richards, M., *J. Chromatog.*, **115,** 259 (1975).
Separation of 1-amino cyclopropane-1-carboxylic acid from S-adenosyl-L (carboxyl) methionine	AG 50W-X4 resin	Miura, G. A. and Chiang, P. K., *Anal. Biochem.*, **147,** 217 (1985).
Separation of diaminopimelate from Iysine	AG 50W-X8 resin	Kelland, J. G., Palcic, M. M., Pickand, M. A. and Vederas, J. C., *Biochemistry*, **24,** 3263 (1985).
Separation of cysteinyl-dopamine and dicysteinyl-dopamine	AG 50W-X2 resin	Ito, S. and Fujita, K., *J. Chromatog.*, **375,** 134 (1986).
Concentration of dopamine hydrochloride	AG 50W-X12 resin	Miller, S. M. and Klinman, J. P., *Biochemistry*, **24,** 2114 (1985).
Separation of oxo-L-proline from proline	AG 50W-X8 resin	Seddon, A. P. and Meister, A., *J. Biol. Chem.*, **261,** 11538 (1986).
Amine separation	AG 50W-X8 resin	Charest, R. and Dunn, A., *Anal. Biochem.*, **136** (2), 421(1984).
Diaminopimelate from Iysine separation	AG 50W-X8 resin	Kelland, J. G., et al., *Biochemistry*, **24,** 3263 (1985).
Trimethyllysine separation from trimethylornithine	AG 50W-X8 resin	Lehman, L. J., et al., *Anal. Biochem.*, **162,** 137 (1987).
Dihydroxyl-L-proline isomer concentration	AG 50W-X8 resin	Linblad, W. J. and Diegelmann, R. F., *J. Chromatog.*, **315,** 447 (1984).

Table 11. Cation Exchange Resins in Enzymatic Assays

Application	Resin	Reference
Separation of acetyl-glutamate from glutamate	AG 50W-X8 resin	Alonso, E. and Rubio, V., *Anal. Biochem.*, **146,** 252 (1985).
Adenylate cyclase assay	AG 50W-X4 resin	Marcus, R. and Orner, F., *Endocrinol.*, **101,** 1570 (1977).
Adenylate cyclase assay	AG 50W-X4 resin	Salomon, Y., et al., *Anal. Biochem.*, **58,** 541 (1974).
GABA aminotransferase assay	AG 50W-X8 resin	Silverman, R. S. and George, C., *Biochemistry*, **27,** 3285 (1988).
cAMP separation from ATP	AG 50W-X4 resin	Kowluru, R. A., et al., *Biochemistry*, **28,** 2220 (1989).
Metal separation (Th, Fr, UO)	AG 50W-X8 resin	Paunescu, N., *J. Radioanal. Nucl. Chem.*, **104,** 205 (1986).

Section 10
Product Information

Catalog Number	Mesh Size	Ionic Form	Pkg. Size	Capacity (meq/ml) Nominal	Diameter (µm)	Density (g/ml) Nominal
AG 50W-X2 Resin						
142-1231	50-100	Hydrogen	500 g	0.6	300-1,180	0.70
142-1241	100-200	Hydrogen	500 g	0.6	106-300	0.70
142-1251	200-400	Hydrogen	500 g	0.6	075-180	0.70
AG 50W-X4 Resin						
142-1331	50-100	Hydrogen	500 g	1.1	180-425	0.80
142-1341	100-200	Hydrogen	500 g	1.1	106-250	0.80
142-1351	200-400	Hydrogen	500 g	1.1	075-150	0.80
AG 50W-X8 Resin						
142-1421	20-50	Hydrogen	500 g	1.7	0,300-1,180	0.80
142-1431	50-100	Hydrogen	500 g	1.7	180-425	0.80
142-1441	100-200	Hydrogen	500 g	1.7	106-250	0.80
142-1451	200-400	Hydrogen	500 g	1.7	063-150	0.80

Catalog Number	Mesh Size	Ionic Form	Pkg. Size	Capacity (meq/ml) Nominal	Diameter (µm)	Density (g/ml) Nominal
AG 50W-X12 Resin						
142-1641	100-200	Hydrogen	500 g	2.1	106-250	0.85
142-1651	200-400	Hydrogen	500 g	2.1	053-106	0.85
AG 50W-X16 Resin						
142-1751	200-400	Hydrogen	500 g	2.4	053-106	0.85
AG 50W-X2 Resin, Biotechnology Grade						
143-5241	100-200	Hydrogen	100 g	0.6	106-300	0.70
AG 50W-X4 Resin, Biotechnology Grade						
143-5341	200-400	Hydrogen	100 g	1.1	075-150	0.80
AG 50W-X8 Resin, Biotechnology Grade						
143-5441	100-200	Hydrogen	100 g	1.7	106-250	0.80
AG 50W-X8 Resin, Biotechnology Grade						
143-5451	200-400	Hydrogen	100 g	1.7	063-150	0.80
AG MP-5O Resin						
143-0841	100-200	Hydrogen	500 g	1.5	075-150	0.80

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