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**RECOMMENDATIONS ON  
ION EXCHANGE NOMENCLATURE**

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## ANALYTICAL CHEMISTRY DIVISION

COMMISSION ON ANALYTICAL NOMENCLATURE†

# RECOMMENDATIONS ON ION EXCHANGE NOMENCLATURE

### INTRODUCTION

This report was prepared by Professor O. Samuelson (Sweden) in close association with E. Bayer (Germany) and F. G. Helfferich (USA) on behalf of the Commission. It was circulated to all members of the Division of Analytical Chemistry and following modification was published as Tentative Nomenclature in January 1970 as Appendix 5 of the *IUPAC Information Bulletin* in the series 'Appendices on Tentative Nomenclature, Symbols, Units and Standards'. This final version is presented by the Commission in the light of all the comments received following the latter publication.

The work was begun in 1965 and has progressed steadily. The Commission has at all times been aware of the need to harmonize its recommendations with existing recommended nomenclature for gas chromatography, liquid-liquid distribution and other separation processes.

1. Ion exchanger :           A solid or liquid, inorganic or organic, containing ions, exchangeable with others of the same sign of charge present in a solution in which the exchanger is considered to be insoluble‡.
2. Ion exchange :           Process of exchanging ions between a solution and an ion exchanger.
3. Counter-ions :           In an ion exchanger, the mobile exchangeable ions.
4. Fixed ions :             In an ion exchanger, the non-exchangeable ions which have a charge opposite to that of the counter-ions.

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‡ It is recognized that there are cases in which liquid exchangers are employed where it may be difficult to distinguish between the separation process as belonging to ion-exchange or liquid-liquid distribution, but the broad definition given here is regarded as that which is most appropriate.

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5. Ionogenic groups: In an ion exchanger, the fixed groupings which are either ionized or capable of dissociation into fixed ions and mobile counter-ions.
6. Co-ions: In an ion exchanger, mobile ionic species with a charge of the same sign as the fixed ions.
7. Cation exchanger: An ion exchanger with cations as counter-ions. The term cation-exchange resin may be used in the case of solid organic polymers.
8. Anion exchanger: An ion exchanger with anions as counter-ions. The term anion-exchange resin may be used in the case of solid organic polymers.
9. Resin matrix: The molecular network of an ion-exchange resin which carries the ionogenic groups.
10. Cation exchange: Process of exchanging cations between a solution and a cation exchanger.
11. Anion exchange: Process of exchanging anions between a solution and an anion exchanger.
12. Acid form of cation exchanger: The ionic form of a cation exchanger in which the counter-ions are hydrogen ions (H-form) or the ionogenic groups have added a proton forming an undissociated acid.
13. Base form of anion exchanger: The ionic form of an anion exchanger in which the counter-ions are hydroxide ions (OH-form) or the ionogenic groups form an uncharged base, e.g.  $\text{—NH}_2$ .
14. Salt form of ion exchanger: The ionic form of an ion exchanger in which the counter-ions are neither hydrogen nor hydroxide ions. When only one valence is possible for the counter-ion, or its exact form or charge is not known, the symbol or the name of the counter-ion without charge is used, e.g. sodium form, Na-form, tetramethylammonium form, orthophosphate form. When one of two or more possible forms is exclusively present, the oxidation state may be indicated by Roman numerals, e.g. Fe(II)-form, Fe(III)-form.
15. Monofunctional ion exchanger: An ion exchanger containing only one type of ionogenic group.
16. Bifunctional ion exchanger: An ion exchanger containing two types of ionogenic group.
17. Polyfunctional ion exchanger: An ion exchanger containing more than one type of ionogenic group.
18. Macroporous ion exchanger: Ion exchangers with pores which are large compared to atomic dimensions.
19. Column volume,  $X$ : Total volume of the part of a column which contains the ion exchanger. It is recommended that the column dimensions be given as the inner diameter and the height or length of the

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- column occupied by the ion exchanger under the applied conditions. If swelling changes occur, the conditions under which the height is determined should be specified. The dimensions should be given in mm or cm.
20. **Bed volume :** Synonymous with column volume for a packed column.
  21. **Theoretical specific capacity,  $Q_0$  :** Milliequivalents of ionogenic group per gramme of dry ion exchanger. If not otherwise stated the capacity should be reported per gramme of the H-form of a cation exchanger and Cl-form of an anion exchanger.
  22. **Volume capacity,  $Q_v$  :** Milliequivalents of ionogenic group per  $\text{cm}^3$  (true volume) of swollen ion exchanger. (The ionic form of the ion exchanger and the medium should be stated.)
  23. **Bed volume capacity :** Milliequivalents of ionogenic group per  $\text{cm}^3$  of bed volume determined under specified conditions (should always be given together with specification of conditions).
  24. **Practical specific capacity,  $Q_A$  :** Total amount of ions expressed in milliequivalents or millimoles taken up per gramme of dry ion exchanger under specified conditions (should always be given together with specification of conditions).
  25. **Break-through capacity of ion exchanger bed,  $Q_B$  :** The practical capacity of an ion-exchanger bed obtained experimentally by passing a solution containing a particular ionic or molecular species through a column containing the ion exchanger, under specified conditions, and measuring the amount of species which has been taken up when the species is first detected in the effluent or when the concentration in the effluent reaches some arbitrarily defined value. The break-through capacity may be expressed in milliequivalents, millimoles or milligrammes taken up per gramme of dry ion exchanger or per  $\text{cm}^3$  of bed volume.
  26. **Weight swelling in solvent,  $w_s$  :** Grammes of solvent taken up by one gramme of dry ion exchanger.  
(e.g.  $w_{\text{H}_2\text{O}}$ )
  27. **Volume swelling ratio :** Ratio of the dry swollen volume to the true dry volume.
  28. **Selectivity coefficient,  $k_{A/B}$  :** Equilibrium coefficient obtained by formal application of mass action law to ion exchange and characterizing quantitatively the relative ability of an ion exchanger to select one of two ions present in the same solution.

Exchange  $[\text{Mg}^{2+} - \text{Ca}^{2+}]$

$$k_{\text{Mg/Ca}} = \frac{[\overline{\text{Mg}}] [\text{Ca}]}{[\overline{\text{Mg}}] [\overline{\text{Ca}}]}$$

Exchange  $[\text{SO}_4^{2-} - \text{Cl}^-]$

$$k_{\text{SO}_4/\text{Cl}} = \frac{[\text{SO}_4]_r [\text{Cl}]^2}{[\text{SO}_4] [\text{Cl}]_r^2}$$

Over-bars or subscript letters, 'r', are used to designate concentrations in the ion exchanger. For exchanges involving counter-ions differing in their charges, the numerical value of  $k_{A/B}$  depends on the choice of the concentration scales in the ion exchanger and the solution (molal scale, molar scale, mole fraction scale, etc.). Concentration units must be clearly stated in exchange of ions of differing charges.

29. Corrected selectivity coefficient,  $k_{A/B}^a$ : Concentrations of external solution in (28) are replaced by activities.
- 30a. Concentration distribution ratio\*,  $D_c$ : The ratio of the total (analytical) concentration of a solute in the ion exchanger to its analytical concentration in the external solution. The concentrations are calculated per  $\text{cm}^3$  of the swollen ion exchanger and  $\text{cm}^3$  of the external solution.
- 30b. Distribution coefficient\*,  $D_g$ : The ratio of the total (analytical) amount of solute per gramme of dry ion exchanger to its concentration (total amount per  $\text{cm}^3$ ) in the external solution.
- 30c. Volume distribution coefficient\*,  $D_v$ : The ratio of the total (analytical) amount of a solute in the ion exchanger calculated per  $\text{cm}^3$  of column or bed volume to its concentration (total amount per  $\text{cm}^3$ ) in the external solution. ( $D_v = D_g \rho$ , where  $\rho$  is the bed density, grammes of dry resin per  $\text{cm}^3$  bed.) This quantity is most conveniently determined from column experiments and it is recommended to use the  $D_v$  values in describing the results from chromatographic separations.
31. Separation factor,  $\alpha_{A/B}$ :  $\alpha_{A/B} = D_A/D_B$   
Ratio between the distribution coefficients of solutes A and B in a specified medium at a specified temperature. In exchange of counter-ions of equal charge the separation factor is equal to the selectivity coefficient provided that only one type of ion represents the analytical concentration (e.g. in exchanges of  $\text{K}^+$  and  $\text{Na}^+$ , but not in systems where several individual

\* NOTE: Definitions 30a, 30b and 30c are used both for ions and non-electrolytes.

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- species are included in the analytical concentrations).
32. Ion exchange isotherm: The concentration of a counter-ion in the ion exchanger expressed as a function of its concentration in the external solution under specified conditions and at constant temperature.
33. Sorption: Uptake of electrolytes or non-electrolytes by ion exchangers through mechanisms other than pure ion exchange.
34. Sorption isotherm: The concentration of a sorbed species in the ion exchanger expressed as a function of its concentration in the external solution under specified conditions and at constant temperature.
35. Diffusion coefficient,  $\bar{D}$ : Diffusion coefficient in the ion exchanger.
36. Ion-exchange membrane: A thin sheet or film of ion-exchange material which may be used to separate two solutions and which allows the preferential transport of either cations (in the case of a cation-exchange membrane) or anions (in the case of an anion-exchange membrane). The membrane material may be made only from ion exchanging material, when it is called a *homogeneous ion-exchange membrane*, or the ion exchanger may be embedded in an inert binder and it is then called a *heterogeneous ion-exchange membrane*.
37. Permselectivity: Permeation of certain ionic species in preference to other species through ion-exchange membranes.
38. Redox polymers: Polymers containing functional groups which can be reversibly reduced or oxidized. 'Electron exchanger' may be used as a synonym.
39. Redox ion exchangers: Conventional ion exchangers in which reversible redox couples have been introduced as counter-ions or by sorption or complex formation. They closely resemble redox polymers in their behaviour.

The following English terms may be accepted from the IUPAC Recommendations on Gas Chromatography [see definitions in *Pure and Applied Chemistry*, **8**, 553 (1964)].

40. Relative retentions:  $r_{A/B}$
41. Adjusted retention volume:  $V_R$
42. Peak: (Elution band may be used synonymously)

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43. Peak base
44. Peak area
45. Peak width
46. Column performance
47. Peak resolution
48. Mobile phase