measured from samples of single and dual-phase materials, operated in a pressure-driven mode, plotted as a function of inverse temperature. This figure is intended to give some appreciation of the fluxes that are attainable; however, they are not normalized to a given partial pressure gradient or thickness of membrane, and thus the fluxes are not directly comparable. Taking a value of between 10 and 100 $L\ m^{-2}\ min^{-1}$ as the level of oxygen flux needed for practical applications, it can be seen that the cobalt-containing single-phase materials give appreciable oxygen fluxes above about 900°C. It is interesting to note on this figure that the dual-phase material, fabricated from $(Bi_2O_3)_{0.75}(Y_2O_3)_{0.25}$–Ag (35 v/v), approaches the lower bound of the practical fluxes at temperatures of 800°C.

It is not sensible to put data for electrical driven COGs on the same figure, given the restrictions mentioned above, however, some comparable figures are interesting. An equivalent flux of 15.8 $L\ m^{-2}\ min^{-1}$ is readily achievable with planar COG stack based on zirconia and operating at 1000°C. Similar performance has been reported for a system based on a CGO-operating temperature of 800°C.

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ION EXCLUSION CHROMATOGRAPHY: LIQUID CHROMATOGRAPHY

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Introduction

Ion exclusion chromatography (IEC) is a relatively old separation technique, attributed to Wheaton and Bauman, which is now staging an impressive comeback for the simultaneous determination of ionic species. IEC provides a useful technique for the separation of ionic and nonionic substances using an ion exchange stationary phase in which ionic substances are rejected by the resin while nonionic or partially ionized substances are retained and separated by partition between the liquid inside the resin particles and the liquid outside the particles. The ionic substances therefore pass quickly through the column, but nonionic (molecular) or partially ionized substances are held up and are eluted more slowly.

IEC is also referred to by several other names, including ion exclusion partition chromatography, ion chromatography-exclusion mode, and Donnan exclusion chromatography. In this article we use the term ion exclusion chromatography.

Generally, anions (usually anions of weak acids) are separated on a strongly acidic cation exchange resin in the hydrogen form and are eluted as the corresponding fully or partially protonated acids, while cations (usually protonated bases) are separated on a strongly basic anion exchange resin in the hydroxide form and are eluted as the corresponding bases. The eluents used are usually water, water/organic solvent mixtures, dilute (high conductivity) acqueous solutions of a strong acid, or dilute (low conductivity) aqueous solutions of a weak acid. A conductivity detector is commonly used to monitor the column effluent and, when the eluent conductivity is extremely high, a suitable suppressor system is generally used. UV-visible detection is also used as a selective detector in the determination of some aliphatic and aromatic carboxylic acids and some inorganic anions, such as nitrite and hydrogen sulfide. Using IEC, it is posssible to separate weakly ionized anions such as fluoride, phosphate, nitrite, aliphatic carboxylic acids, aromatic carboxylic acids, bicarbonate, borate, aliphatic alcohols, sugars, amino acids, water, and others, as well as ammonium, amines, and others, based on a combination of the separation mechanisms of ion-exlusion, adsorption, and/or size-exclusion. Further discussion of these mechanisms may be found elsewhere in the encyclopedia.

More recently, a new concept in IEC has been developed in which a combination of a weakly acidic cation exchange resin and a weak-acid eluent is used for the separation of strong acid anions (such as sulfate, chloride and nitrate) and weak acid anions by an ion exlusion mechanism, together with the simultaneous separation of mono- and divalent cations by a cation exchange mechanism. The application of this method is described in this article.

Comprehensive reviews of IEC may be found in the texts of Haddad and Jackson, and of Gjerde and Fritz (see Further Reading). The goal of the present article is to explain the fundamental theory and some selected applications of IEC and to focus on some recent developments.

Background

Separation Mechanism

In conventional IEC of ionic and nonionic substances, a poly(styrene–divinylbenzene) (PS-DVB) based strongly acidic cation exchange resin in the hydrogen form is used exclusively as the separation column. The resin bed can be considered to consist of three distinct components:

1. a solid resin network with charged functional groups (the membrane);
2. occluded liquid within the resin beads (the stationary phase); and
3. the mobile liquid between the resin beads (the mobile phase or eluent).

The ion exchange resin acts as a hypothetical semipermeable membrane (a Donnan membrane) separating the two liquid phases (2) and (3). This membrane is permeable only for nonionic substances. When a mixture of analytes is injected onto the ion exchange column, anionic analytes are ion-excluded from the occluded liquid phase based on the Donnan membrane equilibrium established by the fixed negative charges on the cation exchange resin and therefore pass quickly through the column. On the other hand, nonionic substances may partition between the two liquid phases (2) and (3) and therefore pass more slowly through the column. Partially ionized analytes experience a lesser degree of repulsion by the membrane and are therefore eluted at retention times intermediate between fully ionized analytes and neutral analytes. This ion exclusion effect can be seen in **Figure 1A**, which shows the separation of aliphatic carboxylic acids.

In addition to this electrostatic ion exclusion effect, the separation process taking place on the surface of the resin particle may be influenced by hydrophobic adsorption and size exclusion effects, depending on the nature of the solute. These effects can be seen in Figure 1B, which shows the separation of sugars such as mono- and disaccharides by size exclusion, and the separaton of alcohols such as methanol, ethanol, propanol and butanol by hydrophobic adsorption effects (Figure 1C).

Cation exchange resin columns with fairly large dimensions are often used for IEC because the retention volume (V_r) of the analyte is determined by the general equation:

$$V_r = V_0 + K_d V_i \qquad [1]$$

where V_0 is the interstitial volume, V_i is the volume of eluent occluded within the pores of the resin beads, and K_d is a distribution coefficient ranging from 0 to 1. A large V_i value is needed to obtain good separations because of the narrow K_d range, assuming that only the ion exclusion effect is predominant in the separation of ionic and nonionic substances. This equation is essentially the same as the general equation for size exclusion chromatography.

When the V_r values of analytes measured on a strongly acidic cation exchange resin by elution with water are plotted against pK_{a1} (first dissociation constant), the plot shown in **Figure 2** is obtained. V_r values of strong acids, which are fully ionized, are independent of pK_{a1}, showing that the strong acid anions have been completely ion-excluded by the fixed sulfonate ions of the resin. V_r values of the weak acids such as phosphoric, hydrofluoric, formic, and acetic acids increase proportionally with pK_{a1}, which shows that the weak acids have been partially ion-excluded by the fixed sulfonate ions of the resin and there has been some permeation of these analytes into the occluded liquid phase inside the resin. This permeation correlated with the pK_{a1} values of the analytes between 1.3 and 6.4. The V_r values of very weak acids such as carbonic and boric acids are independent of pK_{a1}. From Figure 2 and eqn [1], it is clear that the V_r values of the strong acids correspond to V_0 and the difference between V_r values of the strong acids and the very weak acids corresponds to V_i.

The K_d values of strong acids, weak acids, and very weak acids calculated from eqn [1] are between 0 and 1, except for weak acids having a hydrophobic nature, such as propionic, butyric and hydrogen sulfide. For these species, an adsorption effect is evident. As an example, propionic acid is eluted at a larger retention volume than expected from consideration of its pK_{a1} value alone, with the additional retention being attributable to hydrophobic adsorption of the analyte on the unfunctionalized regions of the stationary phase.

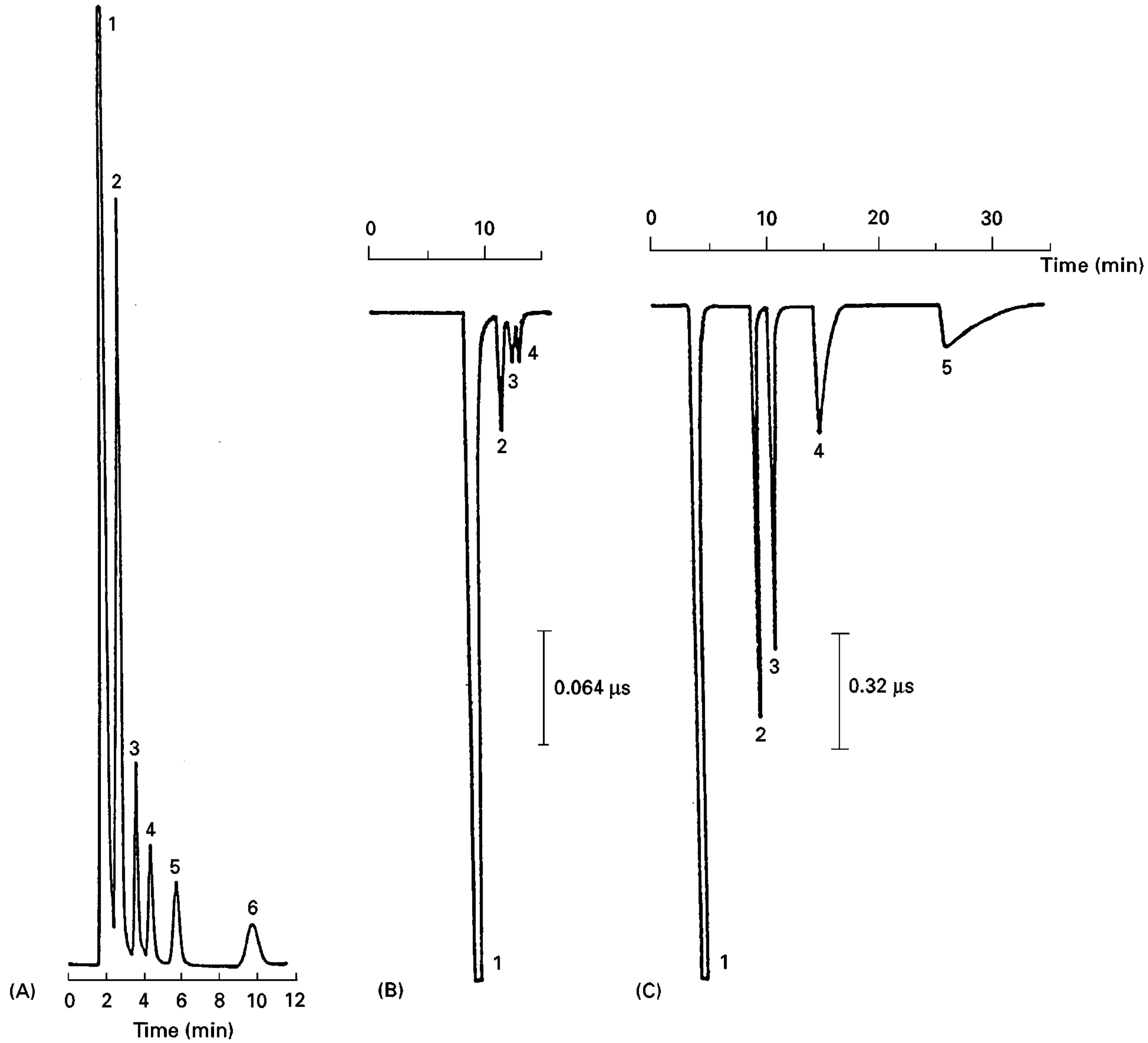

Figure 1 IEC separation of (A) aliphatic carboxylic acids by elution with 0.5 mmol L^{-1} benzoic acid/5% acetonitrile and (B) alcohols and (C) sugars by elution with 1 mmol L^{-1} sulfuric acid/water on a PS-DVB-based strongly acidic cation exchange resin column (8 mm i.d. × 20 cm long).

(A) Peaks: 1, sulfuric acid (V_0); 2, formic acid; 3, acetic acid; 4, propionic acid; 5, butyric acid; 6, valeric acid. (B) Peaks: 1, dip; 2, sucrose; 3, glucose; 4, fructose. (C) Peaks: 1, dip; 2, methanol; 3, ethanol; 4, propanol; 5, butanol. (Figure 1A reproduced with permission from Fritz, 1988, and Figures 1B and 1C from Tanaka and Fritz 1986.)

In addition to the use of PS-DVB-based cation exchange resin, new IEC methods on polymethacrylate-based weakly acidic cation exchange resin and hydrophilic unfunctionalized silica gel have recently been developed to separate some of the more hydrophobic carboxylic acids. **Figure 3** shows the IEC separation of some hydrophobic aliphatic and aromatic carboxylic acids on PS-DVB (Figure 3A) and polymethacrylate-based cation exchange resins (Figure 3B), and on unfunctionalized silica gel (Figure 3C), using 5 mmol L^{-1} sulfuric acid as eluent. As can be seen from Figure 3, the V_r values of hydrophobic carboxylic acids increase with increasing hydrophobicity of the stationary phase (PS-DVB > polymethacrylate > silica).

Turning now to IEC of bases (cations) performed on strong anion exchange resins in the hydroxide form, some similar retention trends to those described above can be noted. Ionic analytes such as sodium and potasium ions are completely ion-excluded from the fixed postive charged resin phase and are eluted at a retention volume of V_0, while nonionic

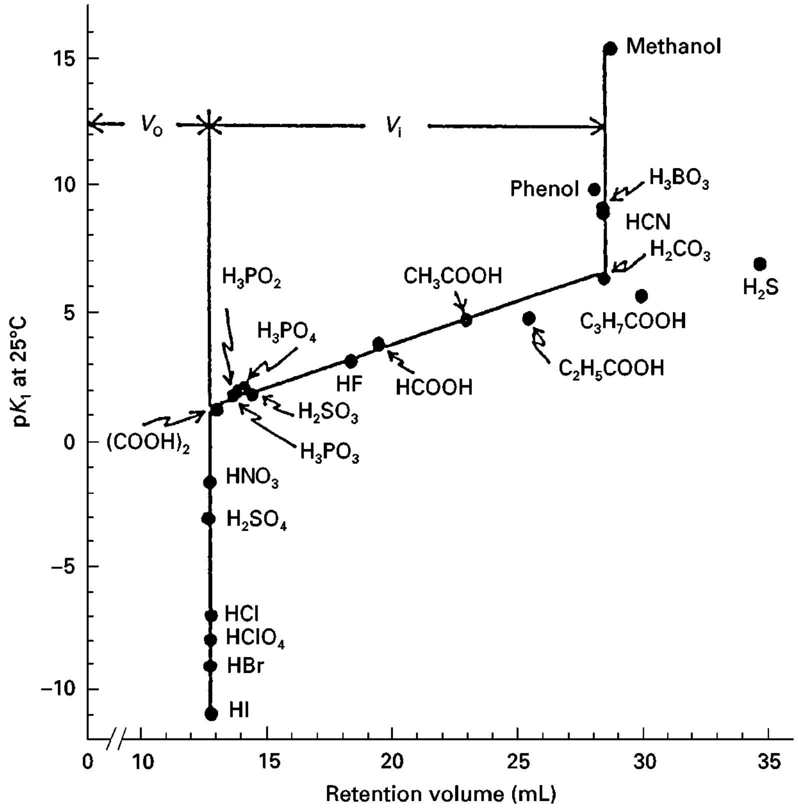

Figure 2 Relationship between retention volumes and their first dissociation constants for inorganic anions, carboxylic acids and nonionic substances on a PS-DVB-based strongly acidic cation exchange resin column (8 mm i.d. × 55 cm long) by elution with water. (Reproduced with permission from Tanaka *et al.*, 1979.)

substances will permeate into the resin phase and are eluted at a retention volume of $V_0 + V_i$. Weak bases, such as ammonia and amines, are eluted at intermediate retention volumes, depending on their pK_b values and their hydrophobicity. As a result, wealkly ionized cations can be separated from strongly ionized cations by the ion exclusion mechanism.

Instrumentation, Stationary Phases and Eluents

Ion exclusion chromatographic systems consist of the same components as any high performance liquid chromatography instrument. A UV detector is often used for the sensitive and selective detection of UV-absorbing substances such as aliphatic and aromatic carboxylic acids. However, this detector is insensitive to some aliphatic carboxylic acids, sugars and alcohols. Although a refractive index detector can be used as a bulk detector, the detection response is not high and the detector is flow- and temperature-sensitive. The most popular and universal detection method for IEC is conductivity. In order to decrease or suppress the eluent background conductivity, a membrane suppressor system can be used (normally when the eluent is highly conducting), or alternatively a weak-acid eluent (aliphatic or aromatic carboxylic acids) of low conductivity can be used.

The most common resins used in ion exclusion chromatography are high capacity PS-DVB-based strongly acidic cation exchange resins of 5 μm particle size. As discussed earlier, polymethacrylate-based weakly acidic cation exchange resin or unfunctionalized silica gel can also be employed.

Although the IEC separation of ionic and nonionic substances may be carried out simply by using water as the eluent, dilute aqueous solutions of some mineral acids or weak carboxylic acids give greatly improved peak shape and are therefore preferred for high resolution separations. Decreasing the pH of the eluent increases the retention of weakly ionized analytes such as carboxylic acids owing to a decrease in the fraction of the ionized analyte present. Therefore, the eluent pH is a very important factor in regulating retention volumes in IEC. Organic modifiers such as methanol and acetonitrile are often used to reduce hydrophobic interactions of the analytes with the resin. A further approach that may be used

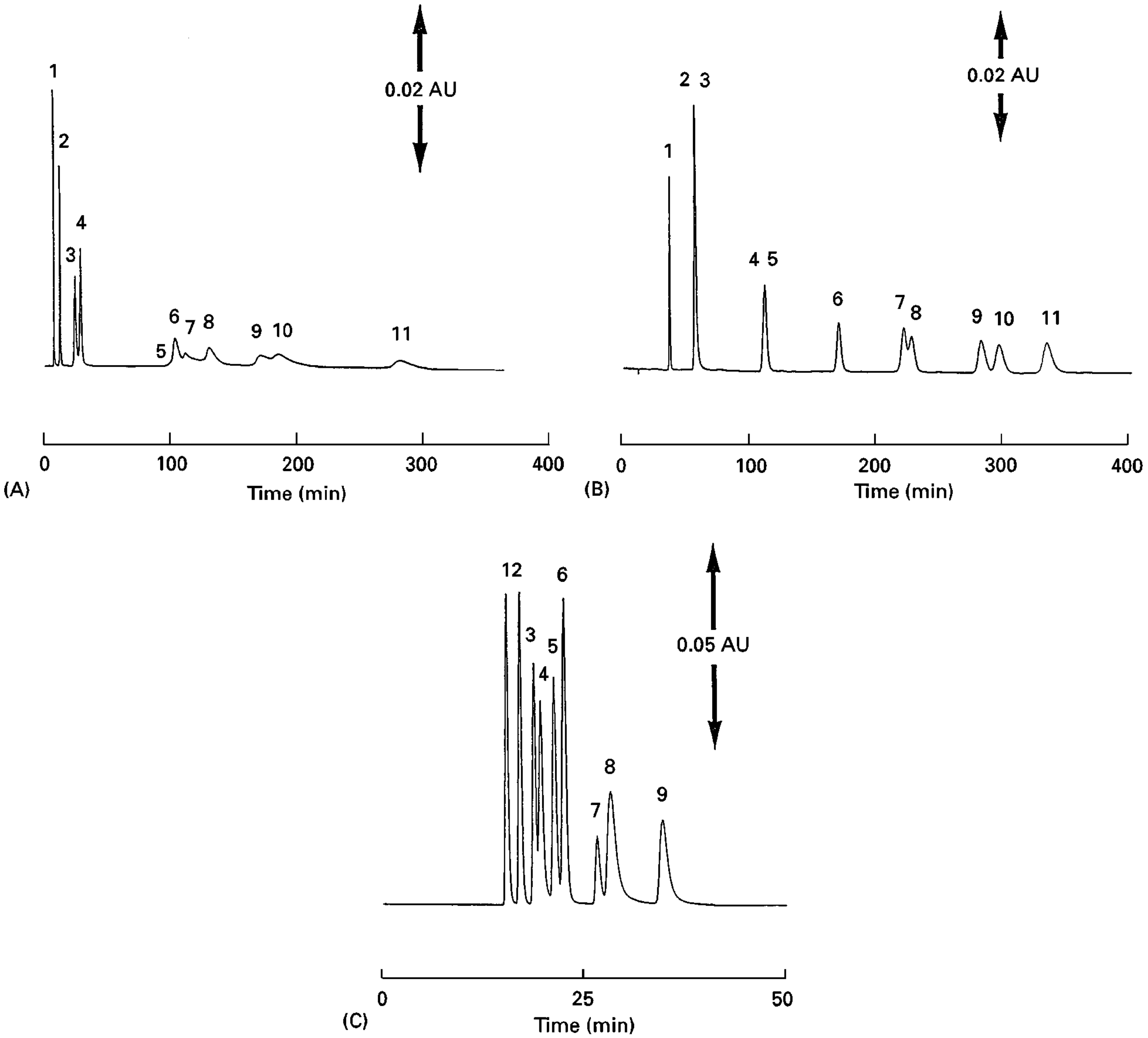

Figure 3 IEC separation of aromatic carboxylic acids on (A) PS-DVB-based strongly acidic cation exchange resin column, (B) polymethacrylate-based weakly acidic cation exchange resin, and (C) unfunctionalized silica gel by elution with 5 mmol L^{-1} sulfuric acid at 1 mL min^{-1}. Column size: 7.8 mm i.d. × 30 cm long for all.

(A) Peaks: 1, pyromellitic acid; 2, trimellitic acid; 3, hemimellitic acid; 4, phthalic acid; 5, trimesic acid; 6, *m*-hydroxybenzoic acid; 7, phenol; 8, *p*-hydroxybenzoic acid; 9, terephthalic acid; 10, isophthalic acid; 11, benzoic acid. (B) Peaks: 1, hemimellitic; 2, pyromellitic acid; 3, phthalic acid; 4, trimellitic acid; 5, phenol; 6, benzoic acid; 7, *m*-hydroxybenzoic acid; 8, *p*-hydroxybenzoic acid; 9, isophthalic acid; 10, salycylic acid; 12, trimesic acid. (C) Peaks: 1, pyromellitic acid; 2, trimellitic acid; 3, hemimellitic acid; 4, terephthalic acid; 5, isophthalic acid; 6, phthalic acid; 7, phenol; 8, salicylic acid; 9, benzoic acid. (Reproduced with permission from Ohta *et al*., 1996.)

to decrease the hydrophobic adsorption of analytes onto the resin is the addition of hydrophilic species, such as sugars, polyols and polyvinyl alcohol, to the eluent.

Optimization of Ion Exclusion Chromatographic Separation

To optimize an IEC separation, careful selection of the following experimental parameters must be made:

1. the type of matrix used as the stationary phase (PS-DVB, polymethacrylate or silica);
2. the nature of the functional group (e.g. strong or weak acid);
3. the ion exchange capacity (low or high);
4. the nature of the eluent (e.g. strong or weak acids);
5. the pH of the eluent;

6. the amount of organic modifier present in the eluent; and
7. the type of detector used (universal or selective).

Selected Applications

Carboxylic Acids

Separation of carboxylic acids is probably the most common use of IEC. Carboxylic acids such as formic, acetic, propionic, butyric, valeric, citric, tartaric, oxalic, malonic, benzoic, salicylic, and others have been determined using UV and conductivity detection. **Table 1** lists some recent applications of IEC for these analytes. These methods have been applied to a wide variety of very complex sample martices, such as biological materials, foods, beverages, pharmaceuticals, environmental materials and others. The separation is almost always performed on a PS-DVB-based cation exchange resin in the hydrogen form; examples of such separations may be found elsewhere in the encyclopedia. As an example of the use of alternative stationary phases, the separation of aliphatic carboxylic acids on a silica gel column by elution with 5 mmol L^{-1} sulfuric acid is shown in **Figure 4**.

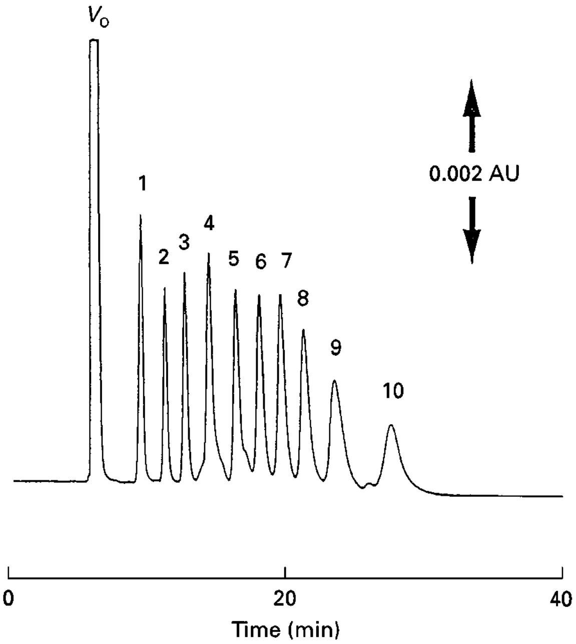

Figure 4 IEC separation of aliphatic carboxylic acids on silica gel column (7.8 mm i.d × 30 cm long) by elution with 0.05% heptanol/0.5 mmol L^{-1} sulfuric acid at 1 mL min^{-1}. Peaks: V_0, nitric acid; 1, formic acid; 2, acetic acid, 3, propionic acid; 4, butyric acid; 5, valeric acid; 6, caproic acid; 7, heptanoic acid; 8, caprylic acid; 9, pelargonic acid; 10, capric acid. (Reproduced with permission from Ohta *et al.*, 1996.)

Weak Inorganic Acids and Bases

IEC has found increasing use for the determination of weakly ionized inorganic anions such as fluoride, nitrite, phosphate, sulfite, arsenite, arsenate, bicarbonate, borate and cyanide. This approach is very effective for the determination of weakly ionized anions in samples containing a high concentration of ionic species, e.g. seawater and wastewaters. **Figure 5** shows the separation of bicarbonate in tap waters by IEC with conductimetric detection by elution with water. The monitoring of bicarbonate ion is very important for the quality control of tap water and for

Table 1 Some applications of the determination of carboxylic acids by IEC

Sample	*Column*	*Eluent*	*Detection*[a]
Fermentation plants	Dionex HPICE-AS6	0.4/0.6 mmol L^{-1} heptafluoro-butyric acid	CD/S
Wine	Waters Radial Pak 5	0.2 mmol L^{-1} potassium dihydrogen phosphate	UV
Food	Shim-Pak SCR-102H	2 mmol L^{-1} toluenesulfonic acid	CD
Wine	TSKgel OA-Pak	0.75 mmol L^{-1} sulfuric acid	UV
Beverage	Shim-Pak IE	5 mmol L^{-1} sulfuric acid	UV
Silage liquor	Dionex lonPac-IEC AS-5	0.9/3.2 mmol L^{-1} perfluorobutyric acid	CD/S
Air	Dionex HPICE-AS1	2 mmol L^{-1} hydrochloric acid	CD/S
Ground water	Interaction Ion-300	0.2 mmol L^{-1} octansulfonic acid	CD/UV
Wine	Bio-Rad Aminex HPX 87-H	1 mmol L^{-1} camphorsulfonic acid	P/UV
Rainwater	Dionex HPICE-AS1	0.05 mmol L^{-1} sulfuric acid	CD
Rainwater	Hamilton PRPX-300	5 mmol L^{-1} sulfuric acid	UV
Air	Aminex-HPX 87H	0.25 mmol L^{-1} sulfuric acid/benzoic acid	CD
Bread/cake	TSKgel SCX	2 mmol L^{-1} phophoric acid	UV
Antarctic ice	Bio-Rad HPX-87H	5 mmol L^{-1} methansulfonic acid	UV
Beverages	TSKgel SCX	5/10 mmol L^{-1} sulfuric acid	CD
Sewage	Yokogawa SCX-252	2 mmol L^{-1} sulfuric acid	CD/S
Rat plasma	Hitachi Gelpak C-620-10	0.3% phosphoric acid	FL

[a] CD, conductivity; S, suppressor; UV, UV spectrometry; P, potentiometry; FL, fluorimetry.

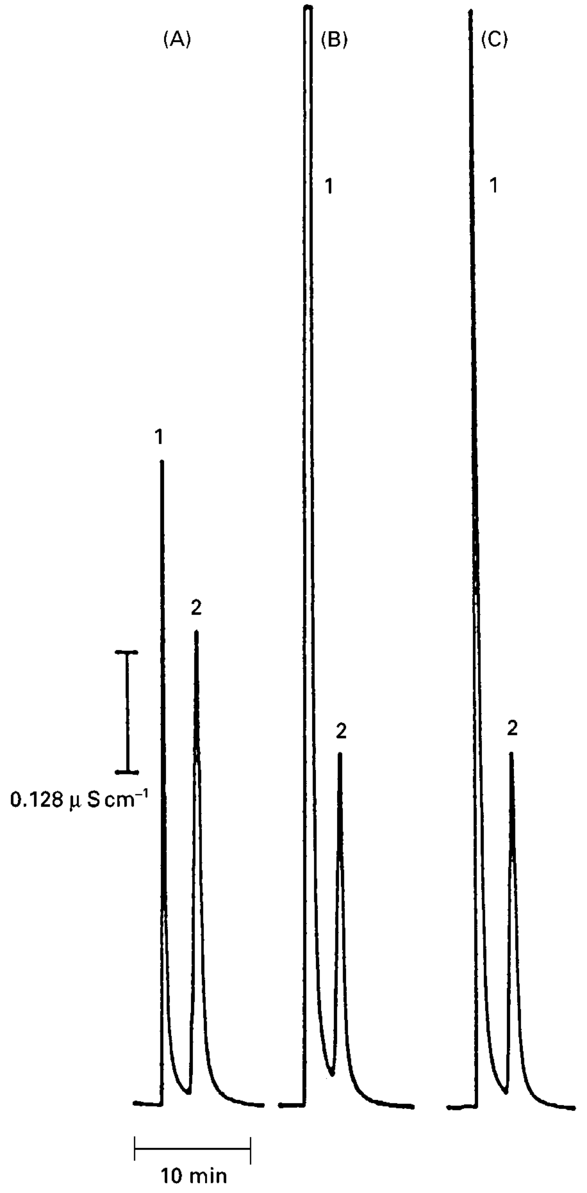

Figure 5 IEC separation of bicarbonate in tap waters on a PS-DVB-based strongly acidic cation exchange resin column (7.5 mm i.d. × 10 cm long) by elution with water. (A) Raw tap water) (10-fold dilution); (B) tap water after softening treatment; (C) tap water (10-fold dilution). Peaks: 1, strong acid anions; 2, bicarbonate ion. (Reproduced with permission from Tanaka and Fritz, 1987.)

the evaluation of the buffering capacity of natural waters.

Ethanolamines and ammonium ion may be successfully determined by IEC with UV or conductimetric detection on a PS-DVB-based strongly basic anion exchange resin in the hydroxide form. Industrial and environmental applications of the determination of ammonium ion are also common and include samples such as biological treatment process waters and urban river waters, as shown in **Figure 6**. **Table 2** lists some of the recent applications of IEC in the analysis of weak inorganic acids and bases.

Strong Inorganic Acids

More recently, a simple and highly sensitive method involving simultaneous ion exclusion/cation exchange chromatography with conductimetric detection on a polymethacrylate-based weakly acidic cation exchange resin in the hydrogen form has been developed for the determination of inogranic strong acid anions such as sulfate, nitrate and chloride ions, and strong base cations such as sodium, ammonium potassium, magnesium and calcium ions commonly found in acid rainwater. Use of a weak acid eluent (such as tartrate) permits both the anions and the cations to be determined, based on a simultaneous

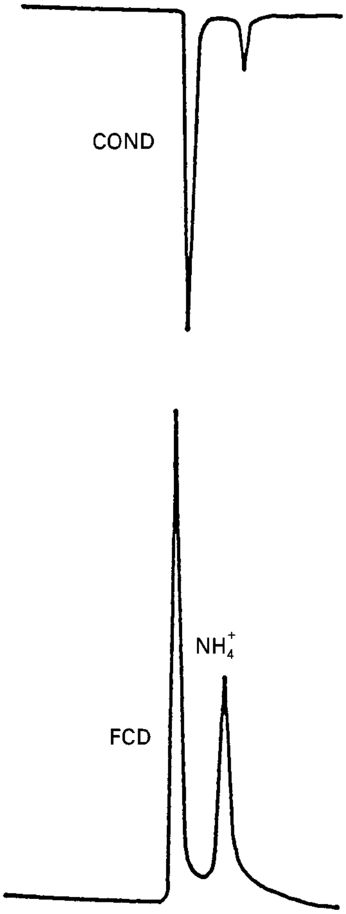

Figure 6 IEC separation of ammonium ion in biological treatment process water on a PS-DVB-based strongly basic anion exchange resin column (8 mm i.d. × 550 mm long) by elution with water at 1 mL min^{-1}.
First peak is alkali- and alkaline earth metal cations. FCD, flow coulometric detector; COND, conductivity detector. (Reproduced with permission from Tanaka *et al.*, 1979.)

Table 2 Some applications of the determination of inorganic anions and cations by IEC

Ion(s)	*Sample*	*Column*	*Eluent*	*Detection*[a]
F^-, HCO_3^-	Beverages	Shim-pak SCR-102H	0.5 mmol L^{-1} toluene/sulfonic acid	CD
F^-	Wastewater	Hitachi-2613	20% methanol/water	CL/CD
HCO_3^-	Natural water	TSKgel SCX	Water	CD
HCO_3^-	Natural water	Develosil 30-5 (silica gel)	Water/borate	CD
NO_3^-, NO_2^-	Wastewater	Hitachi 2613	10% methanol/water	UV
NO_2^-	Drinking water	Anion exclusion	5 mmol L^{-1} sulfuric acid	EC
As(V), As(III)	Sulfuric acid	Dionex HPICE AS-1	10 mmol L^{-1} phosphoric acid	UV
As(III)	Mineral water	Aminex HPX-85H	0.01 mol L^{-1} phosphoric acid	EC
Silica	Seawater	Dionex Ionpak ICE-AS1	Water	ICP-M
Silica	Natural water	Yokogawa SCX1-251	6.6 mmol L^{-1} perchloric acid	CL
Borate	–	Excelpak ICS-R3G/ICS-R 35	1 mmol L^{-1} sulfuric acid	VIS
Borate	Soil	Wescan Ion exclusion	0.3 mol L^{-1} D-sorbitol	CD
CN^-	Tap water	Sulfonated PS/DVB gel	1 mmol L^{-1} sulfuric acid	VIS
SO_3^{2-}	Beer	Dionex HPICE-AS1	10 mmol L^{-1} sulfuric acid	EC
PO_4^{3-}	Wastewater	Hitachi-2613	40% acetone/water	EC
SO_4^{2-}, NO_3^-, Cl^-, Na^+, NH_4^+, K^+, Mg^{2+}, Ca^{2+}[b]	Rainwater	TSKgel OA-PAK	5 mmol L^{-1} tartaric acid/7.5% methanol	CD
NH_4^+	Wastewater	Hitachi 2632	Water	CD/E

[a] CD, conductivity; UV, UV spectrometry; EC, electrochemical; ICP-MS, inductively coupled plasma–mass spectrometry; CL, chemiluminescence; VIS, visible spectrometry.

[b] Simultaneous ion-exclusion cation-exchange.

ion exclusion and cation exchange mechanism on the same stationary phase. The conductimetric detector responses are positive for the anions (which are separated by IEC and detected directly) and negative for the cations (which are separated by ion exchange and are detected indirectly). The effectiveness of this method has been demonstrated in its application to acid rain, as shown in **Figure 7**.

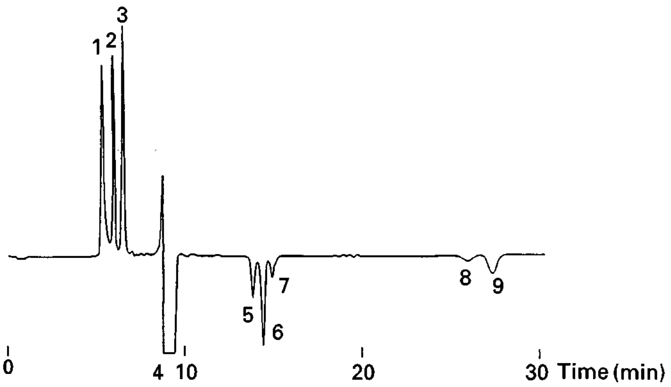

Figure 7 Simultaneous ion exclusion/cation exchange chromatographic separation of strong acid anions and mono- and divalent cations in acid rain at pH 4.7 on a polymethacrylate-based weakly acidic cation exchange resin column (7.8 mm i.d. × 300 cm long) by elution with 6 mmol L^{-1} tartaric acid–7.5% methanol/water at 1.2 mL min^{-1}. Peaks: 1, SO_4^{2-}; 2, Cl^-; 3, NO_3^-; 4, dip; 5, Na^+; 6, NH_4^+; 7, K^+; 8, Mg^{2+}; 9, Ca^{2+}. (Reproduced with permission from Tanaka *et al.*, 1994.)

Table 3 Some applications of the determination of nonionic substances by IEC

Analyte	*Sample*	*Column*	*Eluent*	*Detection*[a]
Sugar	Wine, beer	TSKgel SCX	5 mmol L^{-1} sulfuric acid	CD
Sugar	–	Merck Polyspher OA-YH	10 mmol L^{-1} sulfuric acid	UV
Sugar	Juice, milk	Bio-Rad HPLX 87-H Aminex	0.1 mol L^{-1} sodium hydroxide	EC
Sugar	Corn syrup	PS-DVB sulfonate resin	Water	RI
Poloyol	–	Bio-Rad HPX-87H	Water	EC
Alcohol	Wine, beer	TSKgel SCX	5 mmol L^{-1} sulfuric acid	CD
Formaldehyde	Air	Rezex RFQ	1 mmol L^{-1} sulfuric acid	EC
Dimethyl sulfoxide	Seawater	Bio-Rad HPX-87H	5 mmol L^{-1} phosphoric acid	UV
Water	Organic solvents	Bio-Rad Aminex Q-150S	Acetonitrile/methanol	UV
p-Benzoquinone	Wastewater	TSKgel SCX	20% methanol	UV
Ketone	–	TSKgel SCX	5 mmol L^{-1} sulfuric acid	CD
Trichloroethanol	Plasma, urine	Aminex A-15	10 mmol L^{-1} K_2SO_4, 10 mmol L^{-1} KOH	RI

[a] CD, conductivity; EC, electrochemical; UV, UV absorption; RI, refractive index.

Neutral Compounds

Neutral compounds such as sugars and alcohols can be separated by IEC, as shown earlier in Figure 1B and 1C. **Table 3** lists some of the recent applications of IEC in this field. One of the more significant applications of IEC is its use for the determination of water. Using a short column packed with PS-DVB-based cation exchange resin in the hydrogen form and eluting with methanol containing a small amount of strong acid, a peak for water can be obtained with a spectrophotometric detector at 310 nm. This method is applicable to the determination of water in some organic solvents.

Conclusion

Despite the fact that IEC is a relatively old separation technique, new and diverse applications continue to emerge. IEC remains the method of choice for the separation of low molecular weight carboxylic acids. The separation mechanism of IEC is complicated by the fact that a wide range of processes are known to contribute to retention. At present there is no comprehensive mathematical retention model that accounts for all of the retention processes in IEC. For this reason, optimization of separations is generally performed on an empirical basis rather than through the use of computerized optimization routines such as those employed in many other forms of chromatography. However, there has been considerable recent activity in the study of retention processes in IEC and it can be expected that suitable computer optimization methods will soon appear.

See also: **II/Chromatography:Liquid:** Mechanisms: Ion Chromatography. **III/Acids:** Liquid Chromatography. **Porous Polymers: Liquid Chromatography.**

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