Shodex™ Ion Chromatography columns

Anion and cation analysis with suppressor and non-suppressor methods

Shodex™

TECHNICAL NOTEBOOK

No.8

Contents

1. Lineup of Shodex Ion Chromatography Columns

Shodex offers a wide range of columns for ion analysis. Choose a column best suited to your separation needs and equipment.

1-1. Column selection

● **Anion Analysis**	[Suppressor method]	**IC SI-90 4E**	Inorganic anions (standard column)
		IC SI-50 4E	Inorganic anions and organic acids
		IC SI-52 4E	Inorganic anions and oxyhalides Inorganic anions and organic acids
		IC SI-35 4D	Inorganic anions and oxyhalides (rapid analysis)
		IC SI-91 4C	Oxyhalides (post-column method)
		WINE VH-anion 4D	Sulfite ion in wine
	[Non-suppressor method]	**IC NI-424**	Inorganic anions Separable fluoride ion and phosphate ion
		IC I-524A	Inorganic anions (standard column)
● **Cation Analysis**		**IC YS-50**	Higher performance type of YK-421 Transition metals With suppressor and non-suppressor method
		IC YK-421	Monovalent and divalent cations Alkylamines
		IC Y-521	Monovalent or divalent cations

1-2. Specifications

● **Anion analysis**

[Suppressor method]

Product Code	Product Name	Functional Group	Base Material	Plate Number (TP/column)	Particle Size (μm)	Column Size (mm) I.D. x L
F6995244 F6709620	IC SI-90 4E IC SI-90G	Quaternary ammonium	Polyvinyl alcohol	> 5,000 guard column	9 9	4.0 x 250 4.6 x 10
F6995245 F6709625	IC SI-50 4E IC SI-50G	Quaternary ammonium	Polyvinyl alcohol	> 10,000 guard column	5 5	4.0 x 250 4.6 x 10
F6995260 F6709626	IC SI-52 4E IC SI-92G	Quaternary ammonium	Polyvinyl alcohol	> 14,000 guard column	5 9	4.0 x 250 4.6 x 10
F6995290 F6709627	IC SI-35 4D IC SI-95G	Quaternary ammonium	Polyvinyl alcohol	> 13,000 guard column	3.5 9	4.0 x 150 4.6 x 10
F6995280 F6709620	IC SI-91 4C IC SI-90G	Quaternary ammonium	Polyvinyl alcohol	> 2,500 guard column	9 9	4.0 x 100 4.6 x 10
F6995263 F6709623	WINE VH-anion 4D WINE VH-anionG 4A	Quaternary ammonium	Polyvinyl alcohol	> 7,000 guard column	5 9	4.0 x 150 4.6 x 10

[Non-suppressor method]

Product Code	Product Name	Functional Group	Base Material	Plate Number (TP/column)	Particle Size (μm)	Column Size (mm) I.D. x L
F6995243 F6709616	IC NI-424 IC NI-G	Quaternary ammonium	Polyhydroxymethacrylate	> 5,000 guard column	5 5	4.6 x 100 4.6 x 10
F6995240 F6700400	IC I-524A IC IA-G	Quaternary ammonium	Polyhydroxymethacrylate	> 2,000 guard column	12 12	4.6 x 100 4.6 x 10

● **Cation analysis**

Product Code	Product Name	Functional Group	Base Material	Plate Number (TP/column)	Particle Size (μm)	Column Size (mm) I.D. x L
F7122000 F6700530	IC YS-50 IC YS-G	Carboxyl	Polyvinyl alcohol	> 5,500 guard column	5 5	4.6 x 125 4.6 x 10
F7122012 F6709608	IC YK-421 IC YK-G	Carboxyl	Silica	> 2,800 guard column	5 5	4.6 x 125 4.6 x 10
F6995210 F6700230	IC Y-521 IC Y-G	Sulfo	Styrene divinylbenzene copolymer	> 3,000 guard column	12 12	4.0 x 150 4.6 x 10

2. Principles of Ion Chromatography

Ion chromatography, one form of liquid chromatography, separates and quantifies inorganic anions and cations, organic acids, organic bases, and a variety of other ions. Separation mechanisms including ion-exchange, ion-exclusion, and ion-pair chromatography are used. This technical notebook focuses on ion-exchange chromatography, in which ion exchange resin is used to separate counterions.

[Principles of Ion-Exchange Chromatography]

In ion-exchange chromatography, electrostatic interactions resulting from Coulomb forces are used to separate counterions on ion exchange resin. Using anion analysis as an example, below figure presents the principles of ion chromatography.

Prior to sample injection, anions in the mobile phase (eluent) are retained by the modified functional groups (cations).
While moving through the column, eluent anions continuously compete with each other (a process known as ion exchange) [Figure 2-1(1)].

Once injected, the sample anions displace the eluent anions and are retained by the functional groups [Figure 2-1(2)].

Moving through the column, the sample anions compete with the eluent anions and are eventually eluted from the column [Figure 2-1(3)].

An ion with a larger charge and smaller hydrate ionic radii experiences stronger retention by the ion exchange resin.

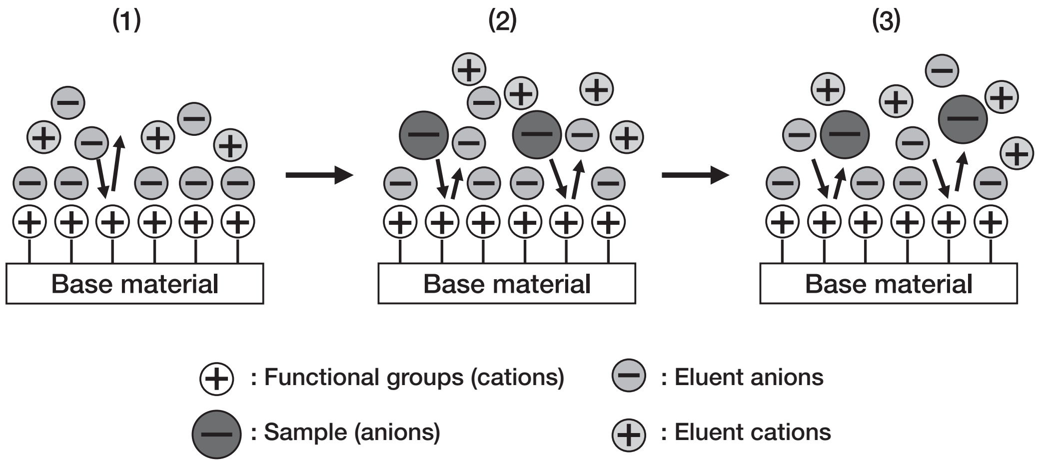


Fig.2-1 Separation mechanism of anion analysis

A conductivity detector is generally used for ion analysis because ions are excellent conductors. Current flows when a voltage is applied across two electrodes immersed in an ionic solution. Conductivity refers to the capacity of an electrolyte to conduct current. The concentration of ions can be determined by comparing the conductivity to that of a standard sample of known concentration of target ions. Ion chromatography employs an electrolytic solution as an eluent, which means that the eluent itself also exhibits conductivity. Eluent with high conductivity (i.e., background conductivity) results in high background noise and consequently decreases sensitivity. There are two methodologies of electrical conductivity detection. Suppressed conductivity method removes counter ions of the eluent after separation, thus reduces background noise. The other methodology, non-suppressed conductivity detection, uses a low-conductivity eluent instead.

[Suppressor Method]

Placing a device called a suppressor between the analytical column and the conductivity detector reduces the background conductivity. Suppressor method makes it possible to detect the analytes at low micrograms per litre range.

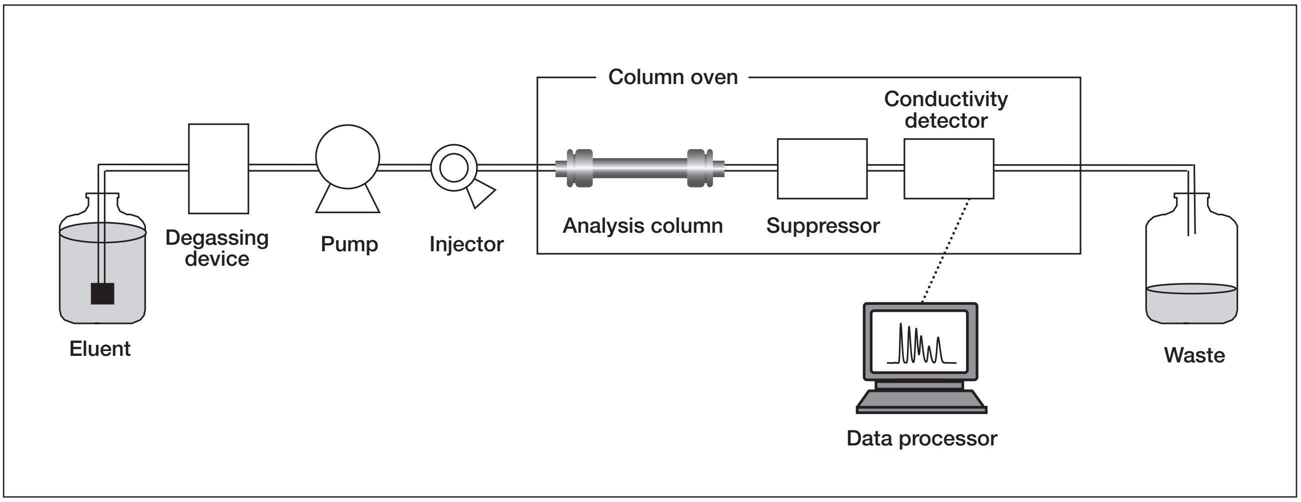


Fig.2-2 System configuration of suppressor method

[Non-suppressor Method]

The configuration of non-suppressor method (i.e., without suppressor) is simple and relatively less expensive than suppressor-method.

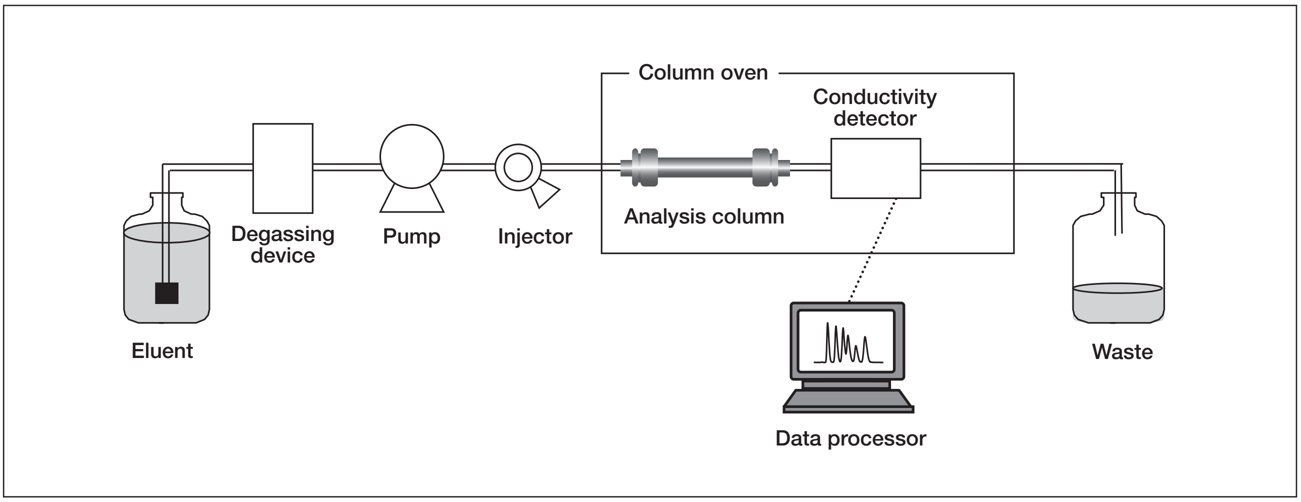


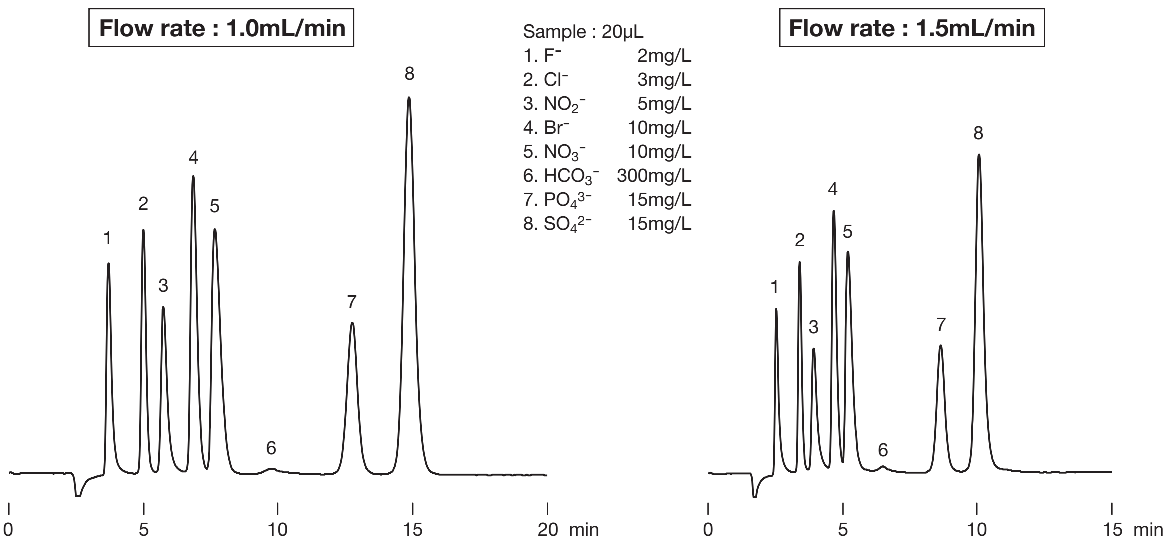
Fig.2-3 System configuration of non-suppressor method

Alternatively, ultraviolet/visible absorbance detectors, electrochemical detectors, mass spectrometers, and other detectors may be used depending on the target ions.

3. Anion analysis

3-1. Suppressor method

IC SI-90 4E is an analysis column for anion analysis with the suppressor method. It provides rapid and robust analysis of seven common anions by using an aqueous solution of 1.8mM sodium carbonate and 1.7mM sodium hydrogen carbonate as the eluent. At a flow rate of 1.5mL/min, sulfate ion elutes at approximately 10minutes. The IC SI-90 4E fulfills U.S. EPA Methods 300.0 (A) requirements.



Column : Shodex IC SI-90 4E (4.0mmI.D. x 250mm)
Eluent : 1.8mM Na_2CO_3 + 1.7mM $NaHCO_3$ aq.
Flow rate : (left); 1.0mL/min (right); 1.5mL/min
Detector : Suppressed conductivity
Column temp. : Room temp.(25°C)

Fig. 3-1 Analysis of seven common anions

By optimizing the eluent conditions, IC SI-90 4E provides sensitive and improved separation of organic acids from inorganic anions.

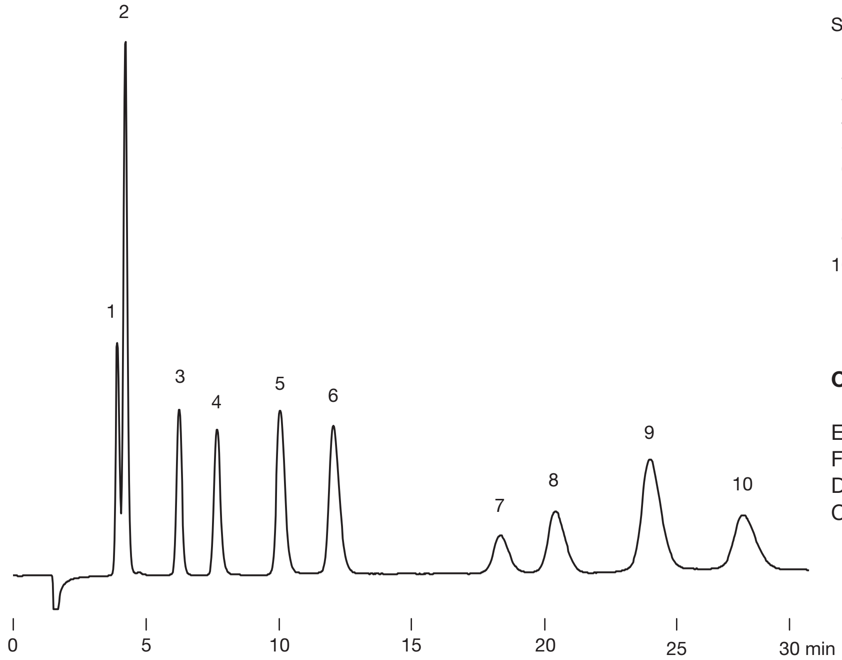
Table 3-1. Retention time of anions

(min)

	(1)	(2)	(3)		(1)	(2)	(3)		(1)	(2)	(3)
F^-	3.5	3.9	4.7	NO_2^-	5.3	6.3	9.0	oxalic acid	14.6	20.6	30.7
acetic acid	3.7	4.2	5.1	Br^-	6.4	7.6	11.5	I^-	14.7	19.8	34.4
formic acid	4.0	4.5	5.6	ClO_3^-	6.3	7.8	12.0	WO_4^{2-}	17.6	25.1	38.2
ClO_2^-	4.2	4.8	6.3	NO_3^-	7.1	8.8	13.4	MoO_4^{2-}	19.0	27.1	42.0
methacrylic acid	4.3	4.9	6.4	PO_4^{3-}	11.3	15.0	14.1	$S_2O_3^{2-}$	18.5	26.4	42.5
BrO_3^-	4.4	5.1	6.7	SO_3^{2-}	12.7	18.2	27.5	CrO_4^{2-}	20.0	28.9	46.0
Cl^-	4.7	5.5	7.2	SO_4^{2-}	13.1	18.4	27.2	SCN^-	23.8	33.8	66.6

Column : Shodex IC SI-90 4E (4.0mmI.D. x 250mm)
Eluent : (1) 1.8mM Na_2CO_3 + 1.7mM $NaHCO_3$ aq.
(2) 1.0mM Na_2CO_3 + 4.0mM $NaHCO_3$ aq.
(3) 12mM $NaHCO_3$ aq.
Flow rate : 1.0mL/min
Detector : Suppressed conductivity
Column temp. : 25°C

Phosphate (HPO_4^{2-}), phosphite (HPO_3^{2-}), and hypophosphite (HPO_2^{2-}) ions were simultaneously analyzed with seven common anions. An aqueous solution of 12mM sodium hydrogen carbonate ($NaHCO_3$) as the eluent provided the strongest retention among the three eluents in Table 3-1. However, absorption of carbon dioxide into carbonate-based eluents causes a change in pH and consequently, retention times. The eluent should therefore be prepared at least once per day on an as-needed basis to ensure good reproducibility.



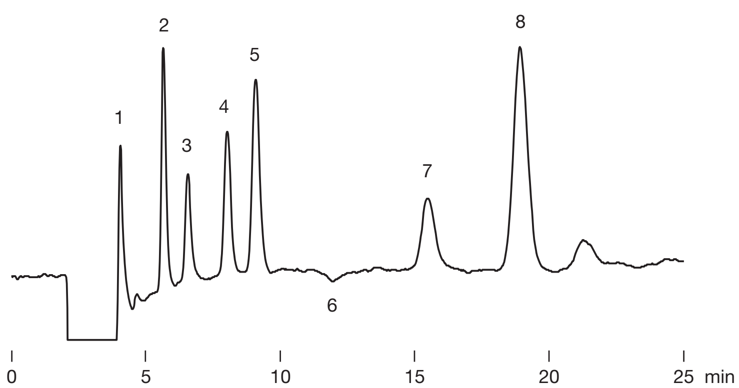
Sample : 20μL

1. F^- 2mg/L
2. HPO_2^{2-} 10mg/L
3. Cl^- 3mg/L
4. NO_2^- 5mg/L
5. Br^- 10mg/L
6. NO_3^- 10mg/L
7. HPO_4^{2-} 15mg/L
8. HPO_3^{2-} 10mg/L
9. SO_4^{2-} 10mg/L
10. Oxalic acid 10mg/L

Column : Shodex IC SI-90 4E (4.0mmI.D. x 250mm)
Eluent : 12mM $NaHCO_3$ aq.
Flow rate : 1.2mL/min
Detector : Suppressed conductivity
Column temp. : 25°C

Fig.3-2 Phosphate, phosphite and hypophosphite ions

High-sensitivity analysis for seven common anions was conducted. An eluent containing 1mM sodium carbonate and 4mM sodium hydrogen carbonate is recommended for low-concentration analyte injection volume of more than 50μL or samples with high carbonate concentrations.



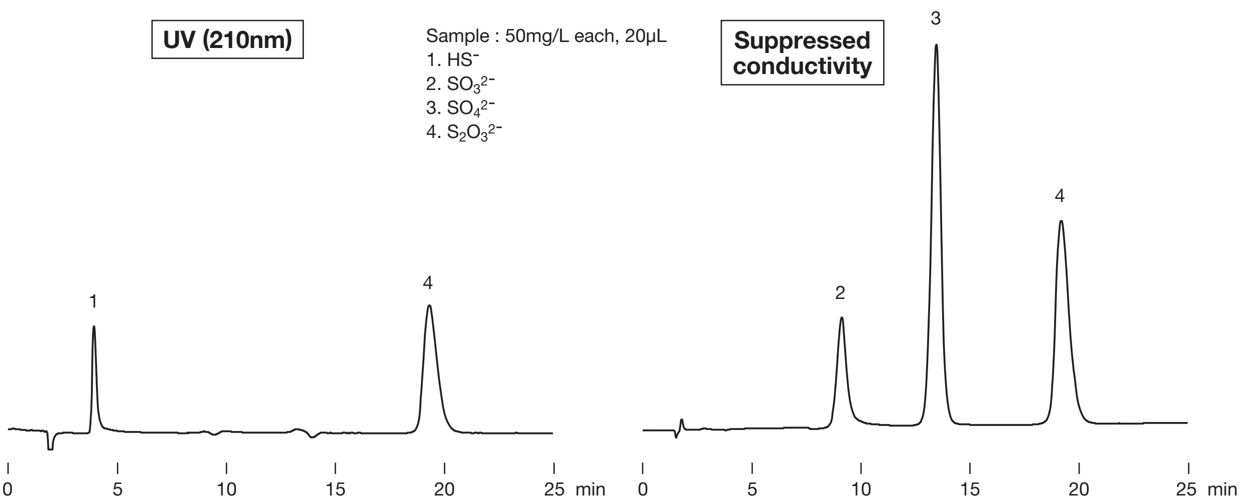
Sample : 100μL

1. F^- 2μg/L
2. Cl^- 3μg/L
3. NO_2^- 5μg/L
4. Br^- 10μg/L
5. NO_3^- 10μg/L
6. HCO_3^- (system peak)
7. PO_4^{3-} 15μg/L
8. SO_4^{2-} 15μg/L

Column : Shodex IC SI-90 4E (4.0mmI.D. x 250mm)
Eluent : 1mM Na_2CO_3 + 4mM $NaHCO_3$ aq.
Flow rate : 1.0mL/min
Detector : Suppressed conductivity
Column temp. : 25°C

Fig. 3-3 High-sensitivity analysis using IC SI-90 4E

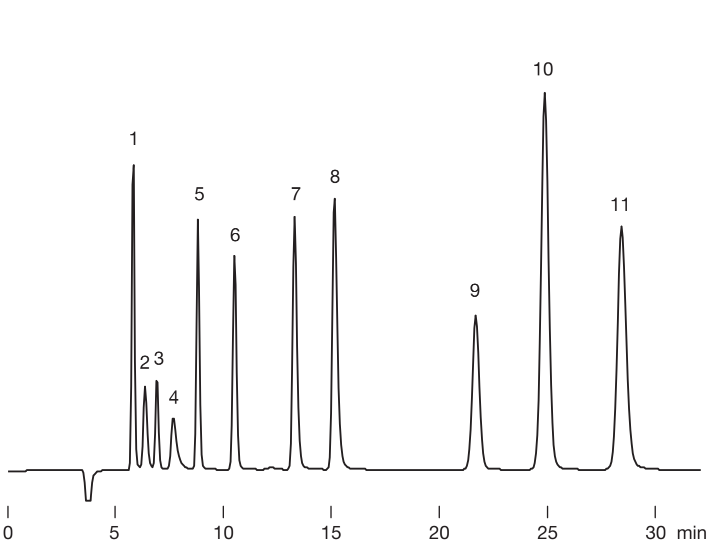
Conductivity detectors are not suitable for the reliable detection of hydrogen sulfide ion. A conductivity detector is connected in series with an ultraviolet absorption detector (UV) for the simultaneous separation and detection of following ions:



Column : **Shodex IC SI-90 4E (4.0mmI.D. x 250mm)**
Eluent : 1mM Na_2CO_3 + 4mM $NaHCO_3$ + 5% Acetone
Flow rate : 1.5mL/min
Detector : UV (210nm), Suppressed conductivity
Column temp. : 25˚C

Fig. 3-4 Analysis of hydrogen sulfide, sulfite, sulfate and thiosulfate

IC SI-50 4E, an analytical column for anion analysis with the suppressor method, is used to analyze organic acids and anions simultaneously. IC SI-50 4E provides improved resolution compare to IC SI-90 4E; IC SI-50 4E completely separate acetic acid, formic acid, and methacrylic acid. The IC SI-50 4E fulfills U.S. EPA Methods 300.0 (A) requirements.



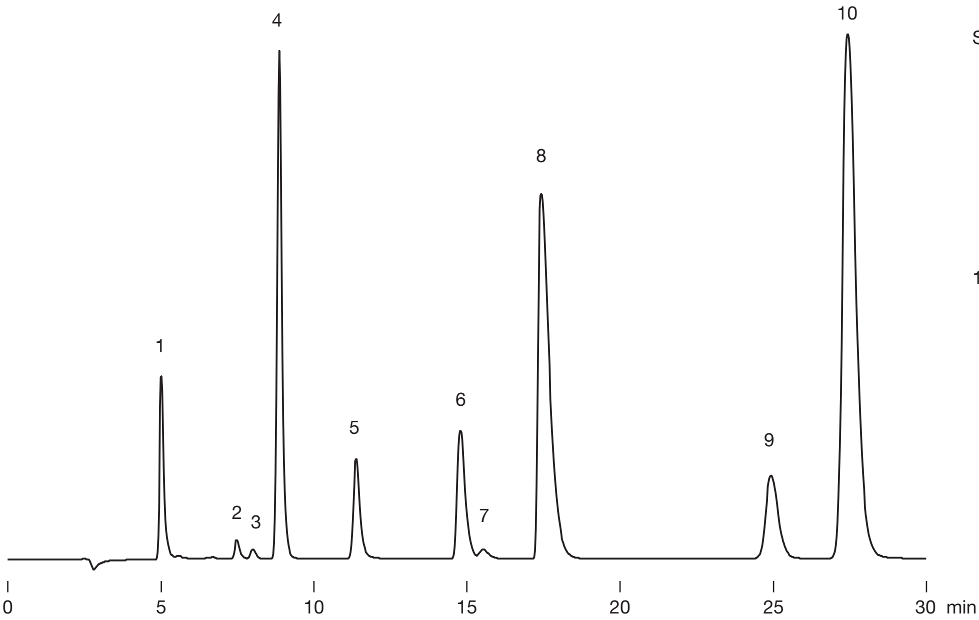
Sample : 20μL

1.	F^-	2mg/L
2.	Acetic acid	10mg/L
3.	Formic acid	2mg/L
4.	Methacrylic acid	10mg/L
5.	Cl^-	3mg/L
6.	NO_2^-	5mg/L
7.	Br^-	10mg/L
8.	NO_3^-	10mg/L
9.	PO_4^{3-}	15mg/L
10.	SO_4^{2-}	15mg/L
11.	Oxalic acid	15mg/L

Column : **Shodex IC SI-50 4E (4.0mmI.D. x 250mm)**
Eluent : 3.2mM Na_2CO_3 + 1.0mM $NaHCO_3$ aq.
Flow rate : 0.7mL/min
Detector : Suppressed conductivity
Column temp. : 25˚C

Fig. 3-5 Analysis of organic acids and seven common anions using IC SI-50 4E

IC SI-52 4E, an analytical column for anion analysis with the suppressor method, is suitable for the simultaneous analysis of oxyhalides and anions. IC SI-52 4E provides baseline separations of chlorite (ClO_2^-) and bromate (BrO_3^-) ions, and bromide (Br^-) and chlorate (ClO_3^-) ions which were not possible using IC SI-90 4E nor IC SI-50 4E.
The IC SI-52 4E fulfills U.S. EPA Methods 300.0 (A) and (B) requirements.



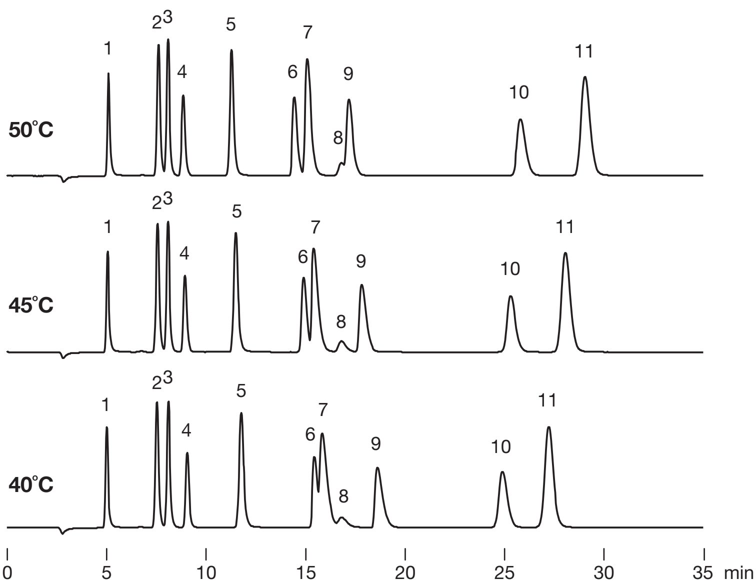
Sample : 50μL

1.	F^-	2mg/L
2.	ClO_2^-	1mg/L
3.	BrO_3^-	1mg/L
4.	Cl^-	10mg/L
5.	NO_2^-	5mg/L
6.	Br^-	10mg/L
7.	ClO_3^-	1mg/L
8.	NO_3^-	30mg/L
9.	PO_4^{3-}	15mg/L
10.	SO_4^{2-}	40mg/L

Column : Shodex IC SI-52 4E (4.0mmI.D. x 250mm)
Eluent : 3.6mM Na_2CO_3 aq.
Flow rate : 0.8mL/min
Detector : Suppressed conductivity
Column temp. : 45℃

Fig. 3-6 Analysis of oxyhalides and seven common anions using IC SI-52 4E

The elution time of the ions are influenced by the column temperature. For the analysis of oxyhalides and anions using IC SI-52 4E, column temperature of 45℃ is recommended to achieve separation of chlorate (ClO_3^-) from bromide (Br^-).



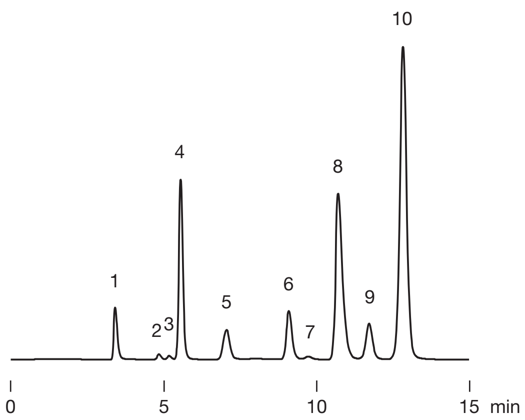
Sample : 50μL

1.	F^-	2mg/L
2.	ClO_2^-	10mg/L
3.	BrO_3^-	20mg/L
4.	Cl^-	3mg/L
5.	NO_2^-	10mg/L
6.	Br^-	10mg/L
7.	ClO_3^-	20mg/L
8.	Dichloroacetic acid	5mg/L
9.	NO_3^-	10mg/L
10.	PO_4^{3-}	20mg/L
11.	SO_4^{2-}	15mg/L

Column : Shodex IC SI-52 4E (4.0mmI.D. x 250mm)
Eluent : 3.6mM Na_2CO_3 aq.
Flow rate : 0.8mL/min
Detector : Suppressed conductivity

Fig. 3-7 Temperature-dependent properties of IC SI-52 4E

IC SI-35 4D provides rapid analysis of oxyhalides and inorganic anions; 50% faster than the IC SI-52 4E. This IC SI-35 4D fulfills U.S. EPA Methods 300.0 (A) and (B) requirements.



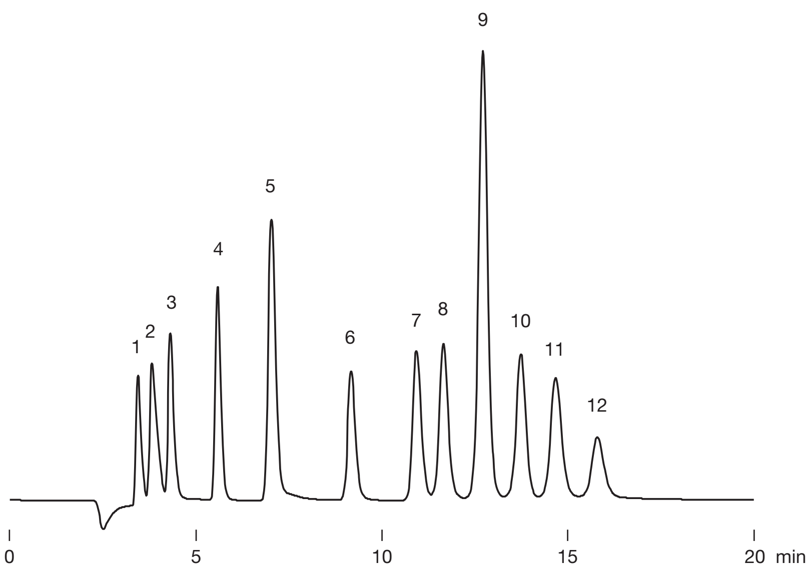
Sample : 20μL

1.	F^-	2mg/L
2.	ClO_2^-	1mg/L
3.	BrO_3^-	1mg/L
4.	Cl^-	10mg/L
5.	NO_2^-	5mg/L
6.	Br^-	10mg/L
7.	ClO_3^-	1mg/L
8.	NO_3^-	30mg/L
9.	PO_4^{3-}	15mg/L
10.	SO_4^{2-}	40mg/L

Column : Shodex IC SI-35 4D (4.0mmI.D. x 150mm)
Eluent : 3.6mM Na_2CO_3 aq.
Flow rate : 0.6mL/min
Detector : Suppressed conductivity
Column temp. : 45˚C

Fig. 3-8 Analysis of oxyhalides and seven common anions using IC SI-35 4D

Not only inorganic ions and oxyhalides, but IC SI-35 4D is suitable for the separation of organic acids. The long elution time (i.e., more than 30 minutes for succinic acid and malonic acid) required by IC SI-52 4E was shorten to 15minutes using IC SI-35 4D.



Sample : 20μL

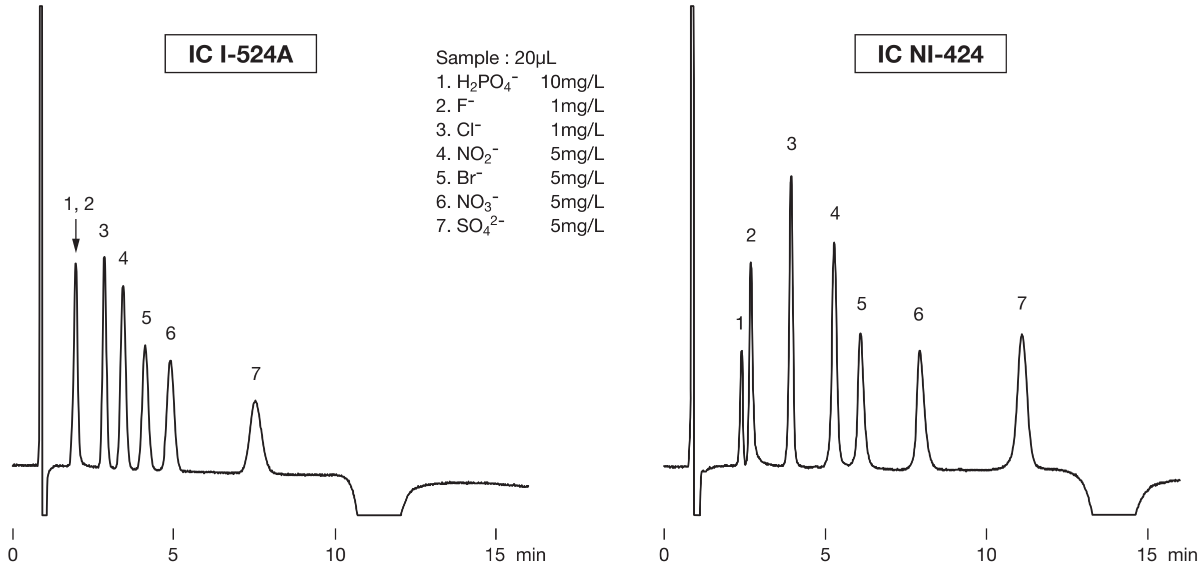
1.	F^-	1mg/L
2.	Lactic acid	10mg/L
3.	Formic acid	5mg/L
4.	Cl^-	2mg/L
5.	NO_2^-	6mg/L
6.	Br^-	4mg/L
7.	NO_3^-	4mg/L
8.	PO_4^{3-}	10mg/L
9.	SO_4^{2-}	8mg/L
10.	Malonic acid	10mg/L
11.	Succinic acid	20mg/L
12.	Adipic acid	20mg/L

Column : Shodex IC SI-35 4D (4.0mmI.D. x 150mm)
Eluent : 3.6mM Na_2CO_3 aq.
Flow rate : 0.6mL/min
Detector : Suppressed conductivity
Column temp. : 45˚C

Fig. 3-9 Analysis of organic acids and common anions using IC SI-35 4D

3-2. Non-suppressor method

Seven common anions were analyzed by non-suppressor method. High-performance IC NI-424 has a theoretical plate number about twice that of IC I-524A. IC NI-424 separates phosphate and fluride ions, which is difficult by IC I-524A.



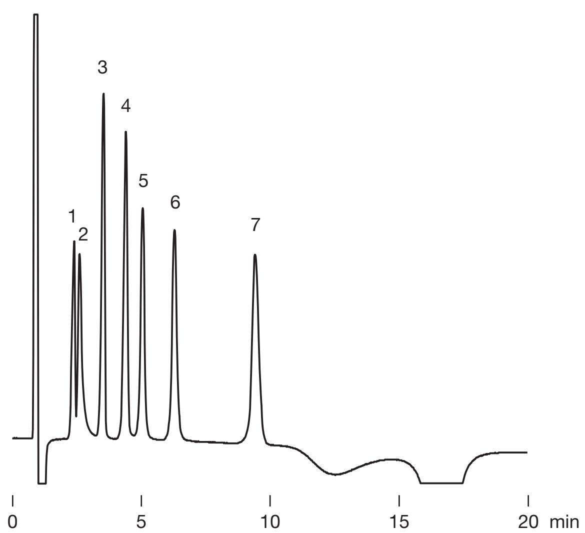
Column : Shodex IC I-524A (4.6mmI.D. x 100mm)
Eluent : 2.5mM Phthalic acid
+ 2.3mM Tris(hydroxymethyl)aminomethane aq.
Flow rate : 1.2mL/min
Detector : Non-suppressed conductivity
Column temp. : 40℃

Column : Shodex IC NI-424 (4.6mmI.D. x 100mm)
Eluent : 8mM 4-Hydroxybenzoic acid
+ 2.8mM Bis-Tris + 2mM Phenylboronic acid
+ 0.005mM *CyDTA aq.
Flow rate : 1.0mL/min
Detector : Non-suppressed conductivity
Column temp. : 40℃

* CyDTA : trans-1,2-Diaminocyclohexane-N,N,N',N'-tetraacetic acid

Fig. 3-10 Comparison of IC NI-424 and IC I-524A

Phthalate eluent improves the peak height to twice that achieved with hydroxybenzoate eluents, but six anions, from $H_2PO_4^-$ to NO_3^-, elutes closely. (No.1-6 peaks in Figure 3-11).

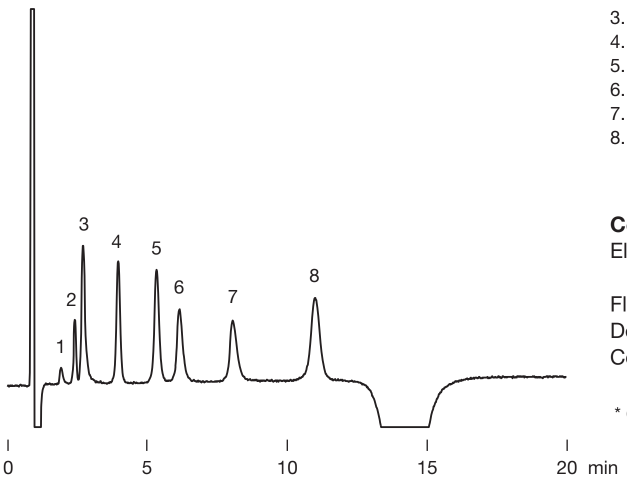


Sample : 100μL each
1. $H_2PO_4^-$ 10mg/L
2. F^- 1mg/L
3. Cl^- 1mg/L
4. NO_2^- 5mg/L
5. Br^- 5mg/L
6. NO_3^- 5mg/L
7. SO_4^{2-} 5mg/L

Column : Shodex IC NI-424 (4.6mmI.D. x 100mm)
Eluent : 2.1mM Phthalic acid
+ 2.9mM Amino-n-capronic acid
+ 6mM Phenylboronic acid aq.
Flow rate : 1.0mL/min
Detector : Non-suppressed conductivity
Column temp. : 40℃

Fig. 3-11 Seven common anions analysis with phthalate eluents (IC NI-424)

IC NI-424 is not only capable of separating phosphate and fluoride ions but also capable of separating carbonate ion from phosphate.



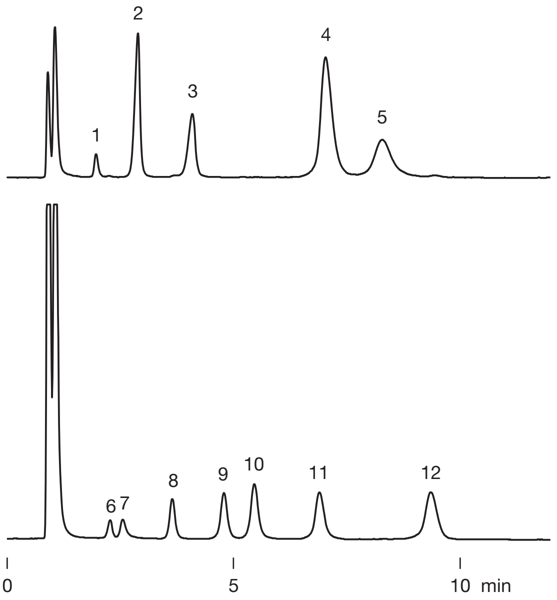
Sample : 50μL
1. HCO_3^- 100mg/L
2. $H_2PO_4^-$ 10mg/L
3. F^- 1mg/L
4. Cl^- 1mg/L
5. NO_2^- 2mg/L
6. Br^- 2mg/L
7. NO_3^- 2mg/L
8. SO_4^{2-} 2mg/L

Column : Shodex IC NI-424 (4.6mmI.D. x 100mm)
Eluent : 8mM 4-Hydroxybenzoic acid + 2.8mM Bis-Tris + 2mM Phenylboronic acid + 5μM *CyDTA aq.
Flow rate : 1.0mL/min
Detector : Non-suppressed conductivity
Column temp. : 40°C

* CyDTA : trans-1,2-Diaminocyclohexane-N,N,N',N'-tetraacetic acid

Fig. 3-12 Analysis of carbonate ion using IC NI-424

IC NI-424 is also suitable for the analysis of organic acids.



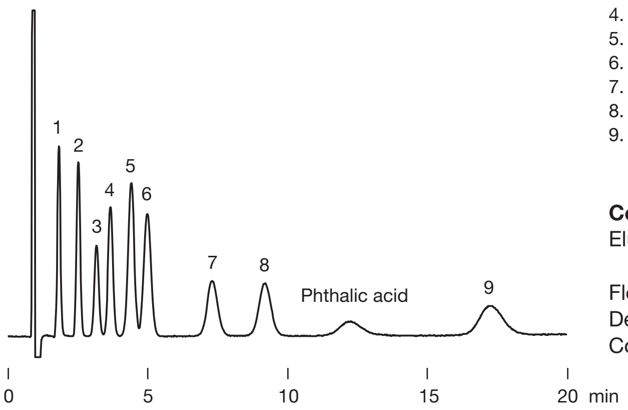
Sample : 20μL
1. Acetic acid 20.0mg/mL
2. Formic acid 20.0mg/mL
3. Malic acid 20.0mg/mL
4. Tartaric acid 20.0mg/mL
5. Oxalic acid 20.0mg/mL
6. $H_2PO_4^-$ 20.0mg/L
7. F^- 1.5mg/L
8. Cl^- 2.5mg/L
9. NO_2^- 6.0mg/L
10. Br^- 10.0mg/L
11. NO_3^- 10.0mg/L
12. SO_4^{2-} 10.0mg/L

Column : Shodex IC NI-424 (4.6mmI.D. x 100mm)
Eluent : 8mM 4-Hydroxybenzoic acid + 2.8mM Bis-Tris + 2mM Phenylboronic acid + 5μM *CyDTA aq.
Flow rate : 1.0mL/min
Detector : Non-suppressed conductivity
Column temp. : 40°C

* CyDTA : trans-1,2-Diaminocyclohexane-N,N,N',N'-tetraacetic acid

Fig. 3-13 Analysis of organic acids using IC NI-424

IC I-524A, a column for anion analysis, was used to separate nine anions including hydrophobic ions. Phthalate eluent is suitable for the acidic condition analysis. The response of phosphate ion is nearly eliminated under this condition.

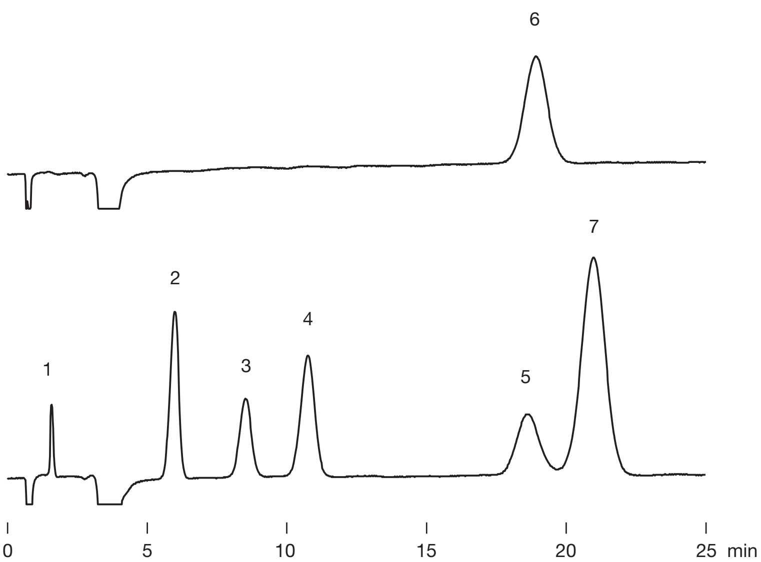


Sample : 40μL
1. F^- 5mg/L
2. Cl^- 5mg/L
3. NO_2^- 5mg/L
4. Br^- 10mg/L
5. NO_3^- 15mg/L
6. SO_4^{2-} 10mg/L
7. $S_2O_3^{2-}$ 10mg/L
8. I^- 20mg/L
9. SCN^- 20mg/L

Column : Shodex IC I-524A (4.6mmI.D. x 100mm)
Eluent : 2.5mM Phthalic acid + 2.9mM Tris(hydroxymethyl)aminomethane aq.
Flow rate : 1.2mL/min
Detector : Non-suppressed conductivity
Column temp. : 40°C

Fig. 3-14 Analysis of hydrophobic ions using IC I-524A

This example illustrates conditions ideal for separating ions that elute faster than the chloride ion when using the IC I-524A. Nitrate, sulfate, and other ions elute very slowly under this condition. When the sample to be analyzed contains these ions, 200 to 300μL of 0.1M tartaric acid must be injected after each sample analysis to remove any residual nitrate and other ions from the column.

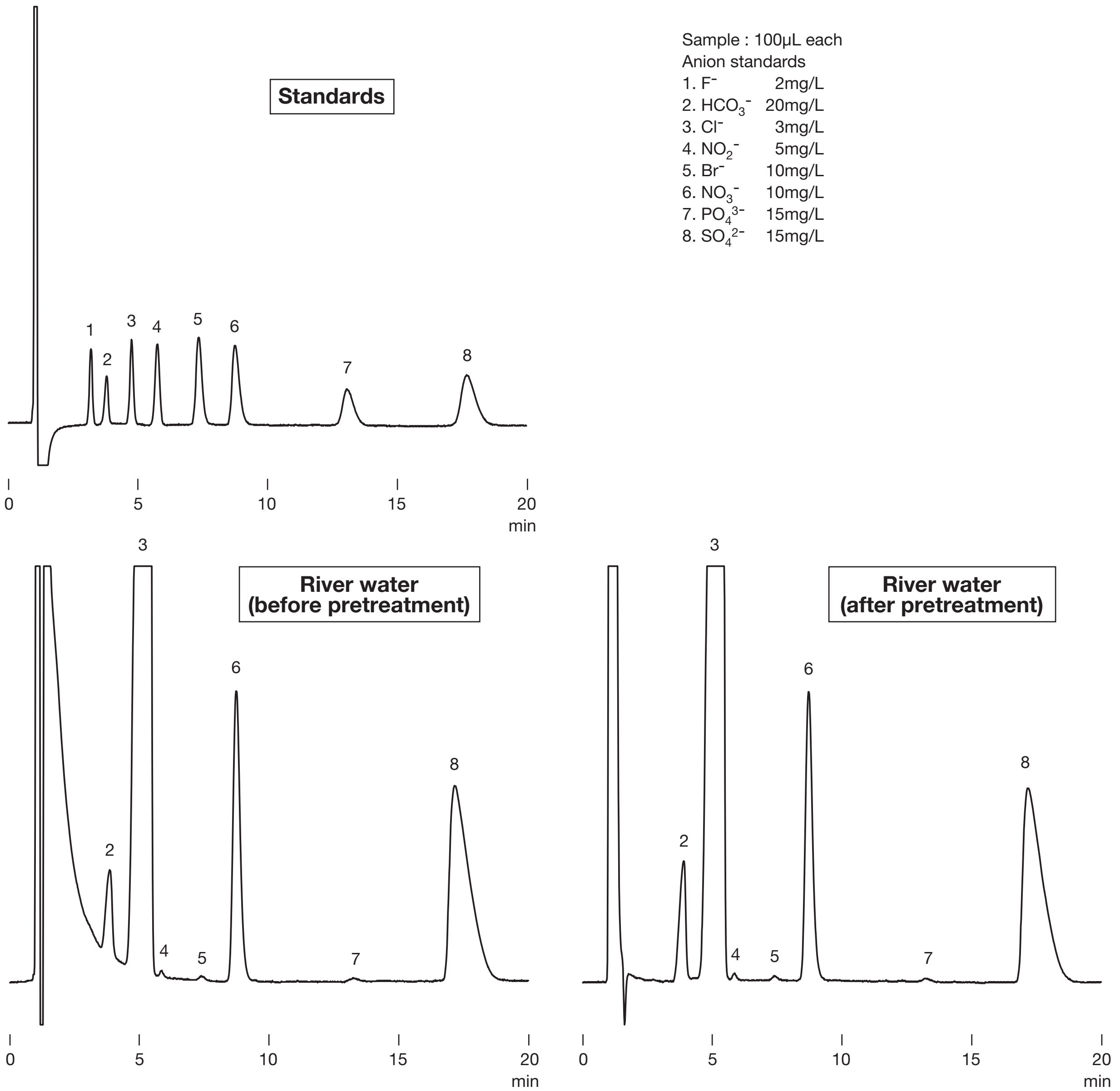


Sample : 10mg/L each, 50μL
1. Acetic acid
2. $H_2PO_4^-$
3. $H_2PO_2^-$
4. $H_2PO_3^-$
5. ClO_2^-
6. BrO_3^-
7. Cl^-

Column : Shodex IC I-524A (4.6mmI.D. x 100mm)
Eluent : 1mM Tartaric acid aq.
Flow rate : 1.2mL/min
Detector : Non-suppressed conductivity
Column temp. : 40°C

Fig. 3-15 Analysis of phosphate, hypophosphite and phosphate ions using IC I-524A

The carbonate ion, present in almost all aqueous samples, influences the ionic balance. The simultaneous analysis of the carbonate ion and seven common anions is thus an important part of ion chromatography.
IC SI-90 4E is a standard column for analysis with the suppressor method. In the following example, this column is used for high-sensitivity baseline separation of the carbonate ion and seven common anions with the non-suppressor method in a p-hydroxybenzoate eluent.
When the concentration of magnesium ion is 10mg/L or higher or the concentration of calcium ion is 20mg/L or higher under these conditions, these divalent cations form complexes with the components of the eluent. The complexes form broad peaks that overlap the peaks of target ions, making quantitative analysis difficult. To prevent this, the samples should be first passed through a pretreatment cartridge containing Na^+ cation exchange resin to replace the divalent cations with sodium ions.



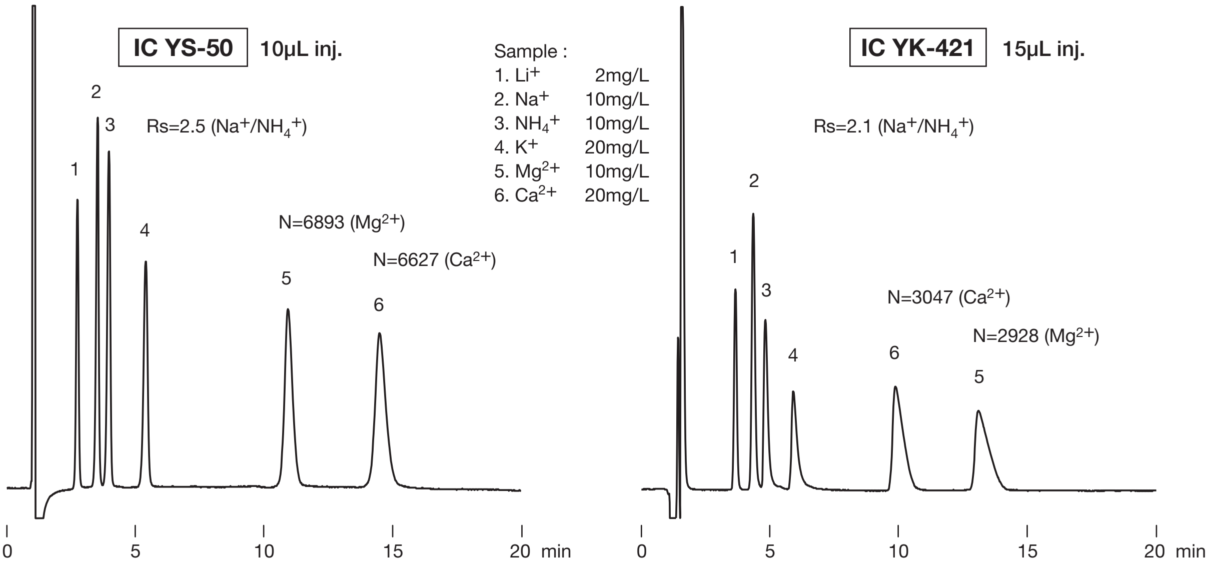
Column : **Shodex IC SI-90 4E (4.0mmI.D. x 250mm)**
Eluent : 5mM p-Hydroxbenzoic acid
+ 5.3mM N,N-Diethylethanolamine aq.
Flow rate : 1.0mL/min
Detector : Non-suppressed conductivity
Column temp. : Room temp.

Pretreatment procedure:
A pretreatment cartridge containing Na^+ -type cation exchange resin is first conditioned with 3mL of methanol and 3mL of water.
Then, 3mL of the sample is applied to the cartridge.
The first milliliter is discarded, and the remaining 2mL is used for HPLC.

Fig. 3-16 Simultaneous analysis of carbonate ion and seven common anions

4. Cation analysis

The performance of IC YS-50 and IC YK-421, its predecessor of YS-50, were compared for the analysis of six common monovalent and divalent cations by non-suppressor method. IC YS-50 provided approximately 1.2-hold higher resolution for Na^+ and NH_4^+ than that of IC YK-421, and the theoretical plate number (N) for the divalent cations, the magnesium and calcium ions, was approximately 2-fold higher.

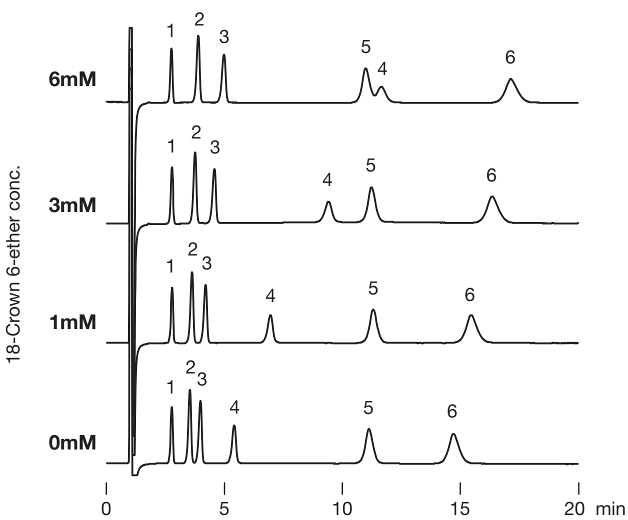


Column	**: Shodex IC YS-50 (4.6mmI.D. x 125mm)**
Eluent	: 4mM Methanesulfonic acid aq.
Flow rate	: 1.0mL/min
Detector	: Non-suppressed conductivity
Column temp.	: 40˚C

Column	**: Shodex IC YK-421 (4.6mmI.D. x 125mm)**
Eluent	: 5mM Tartaric acid + 1mM Dipicolinic acid + 1.5g/L Boric acid aq.
Flow rate	: 1.0mL/min
Detector	: Non-suppressed conductivity
Column temp.	: 40˚C

Fig. 4-1 Analysis of six common monovalent and divalent cations using IC YS-50 and IC YK-421

It is known that 18-Crown-6-ether forms complexes with cations. Formation of complex influences the elution of cations. Elution time of cations can be controlled by adding 18-Crown-6-ether to eluent. Potassium ions (K^+) form complexes more readily and show larger change in elution position than other cations. Addition of 18-Crown-6-ether controls K^+ elution, more over improves the separation of sodium (Na^+) and ammonium ions (NH_4^+)

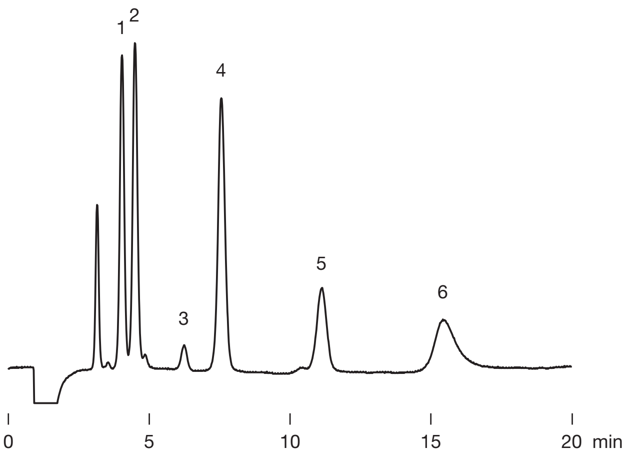


Sample : 10μL
1. Li^+ 2mg/L
2. Na^+ 10mg/L
3. NH_4^+ 10mg/mL
4. K^+ 20mg/mL
5. Mg^{2+} 10mg/L
6. Ca^{2+} 20mg/L

Column	**: Shodex IC YS-50 (4.6mmI.D. x 125mm)**
Eluent	: 4mM Methanesulfonic acid + nmM 18-Crown 6-ether aq.
Flow rate	: 1.0mL/min
Detector	: Non-suppressed conductivity
Column temp.	: 40˚C

Fig. 4-2 Effect of 18-Crown-6-ether for cation separation using IC YS-50

IC YS-50 is generally used for simultaneous analysis of monovalent and divalent ions.
By the use of an eluent containing 6mM tartaric acid and 4mM oxalic acid, the analysis of transition metal ions is also possible.

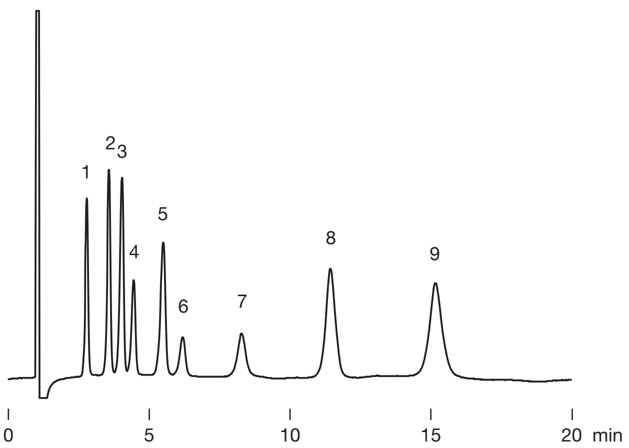


Sample : 20μL
1. Zn^{2+} 10mg/L
2. Co^{2+} 10mg/L
3. Fe^{2+} 10mg/L
4. Mn^{2+} 10mg/L
5. Cd^{2+} 10mg/L
6. Pb^{2+} 30mg/L

* Each ion samples were prepared to 1000mg/L with 0.1M nitric acid and the final sample was mixed to each ion concentration with eluent.

Column : **Shodex IC YS-50 (4.6mmI.D. x 125mm)**
Eluent : 6mM Tartaric acid + 4mM Oxalic acid aq.
Flow rate : 1.0mL/min
Detector : Non-suppressed conductivity
Column temp. : 40℃

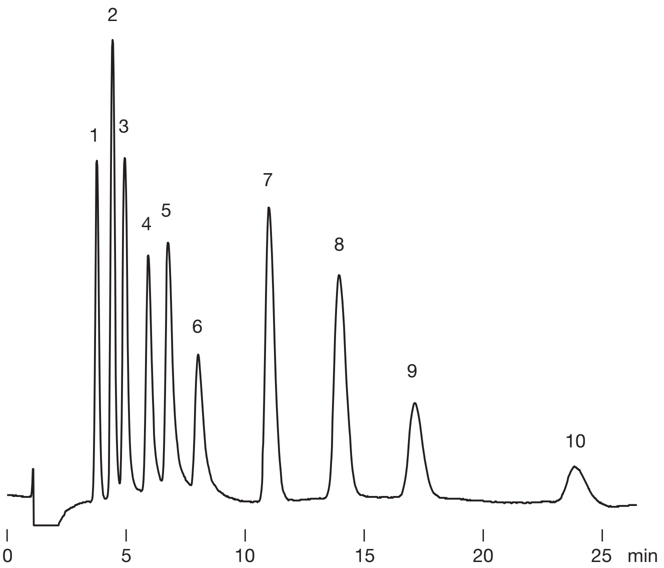
Fig. 4-3 Analysis of transition metal ions using IC YS-50



Sample : 10μL
1. Li^{+} 2mg/L
2. Na^{+} 10mg/L
3. NH_4^{+} 10mg/L
4. Methylamine 10mg/L
5. K^{+} 20mg/L
6. Trimethylamine 20mg/L
7. Triethylamine 20mg/L
8. Mg^{2+} 10mg/L
9. Ca^{2+} 20mg/L

Column : **Shodex IC YS-50 (4.6mmI.D. x 125mm)**
Eluent : 4mM Methanesulfonic acid aq.
Flow rate : 1.0mL/min
Detector : Non-suppressed conductivity
Column temp. : 40℃

Fig. 4-4 Analysis of cations and alkyl amines using IC YS-50



Sample : 10μL
1. Li^{+} 1mg/L
2. Na^{+} 5mg/L
3. NH_4^{+} 5mg/L
4. K^{+} 10mg/L
5. Rb^{+} 30mg/L
6. Cs^{+} 30mg/L
7. Ca^{2+} 10mg/L
8. Mg^{2+} 5mg/L
9. Sr^{2+} 10mg/L
10. Ba^{2+} 10mg/L

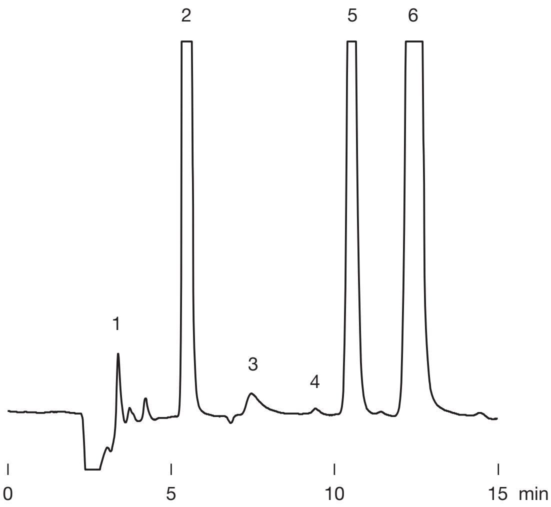
Column : **Shodex IC YK-421 (4.6mmI.D. x 125mm)**
Eluent : 5mM Tartaric acid + 1mM Dipicolinic acid + 1.5g/L Boric acid aq.
Flow rate : 1.0mL/min
Detector : Non-supressed conductivity
Column temp. : 50℃

Fig. 4-5 Analysis of ten cations using IC YK-421

5. Applications

5-1. Environment

Ministerial Notification No.386 of the Japanese Ministry of Health, Labour and Welfare requires the addition of 1mL ethylenediamine solution (50mg/mL) to 1L of sample collected. This prevents chlorous acid from reacting with residual chlorine to form chloric acid. The following examples show analysis of anions, oxyhalides, and monovalent and divalent cations in tap water spiked with ethylenediamine.



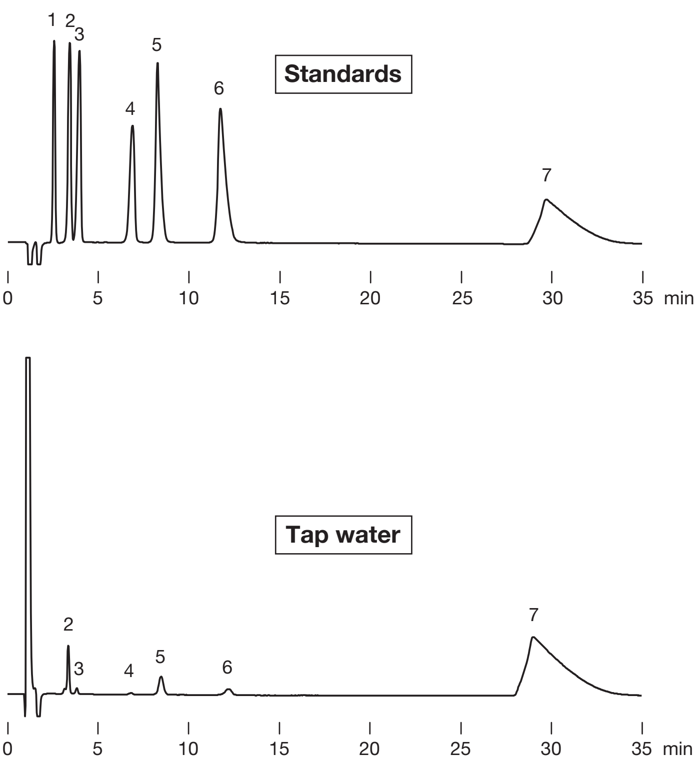
53ug/L of chlorate was detected in tap water.

Sample : Tap water 20µL
1. F^-
2. Cl^-
3. HCO_3^-
4. ClO_3^-
5. NO_3^-
6. SO_4^{2-}

* 1mL of ethylendiamine solution (50mg/mL) was added to 1L of sample.

Column : Shodex IC SI-35 4D (4.0mmI.D. x 150mm)
Eluent : 3.6mM Na_2CO_3 aq.
Flow rate : 0.6mL/min
Detector : Suppressed conductivity
Column temp. : 45˚C

Fig. 5-1 Analysis of anions and oxyhalides in tap water using IC SI-35 4D



Sample : 50µL each
Cation standards

1. Li^+	2mg/L
2. Na^+	10mg/L
3. NH_4^+	10mg/L
4. K^+	20mg/L
5. Mg^{2+}	10mg/L
6. Ca^{2+}	20mg/L
7. Ethylenediamine	50mg/L

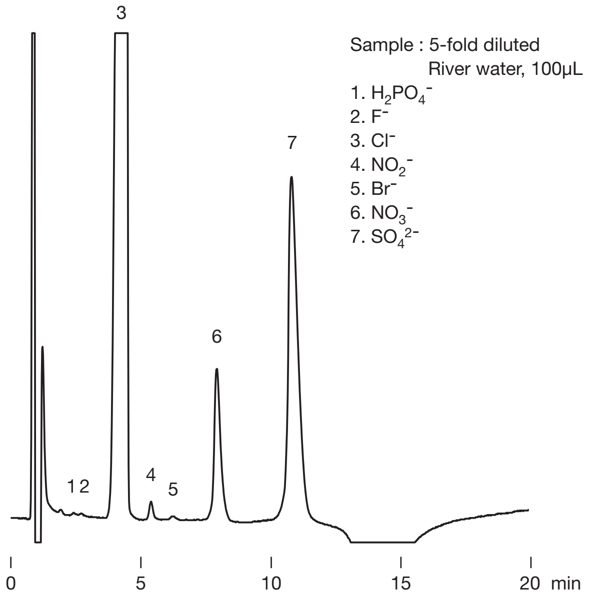
Tap water

2. Na^+	
3. NH_4^+	
4. K^+	
5. Mg^{2+}	
6. Ca^{2+}	
7. Ethylenediamine	50mg/L

* 1mL of ethylendiamine solution (50mg/mL) was added to 1L of sample.

Column : Shodex IC YS-50 (4.6mmI.D. x 125mm)
Eluent : 4mM Nitric acid + 1.5mM 18-Crown 6-ether aq. /CH_3CN=90/10
Flow rate : 1.0mL/min
Detector : Non-suppressed conductivity
Column temp. : 40˚C

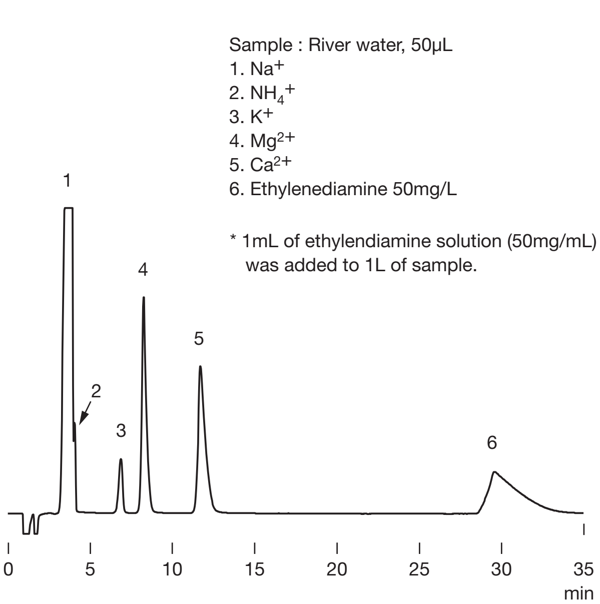
Fig. 5-2 Analysis of cations in tap water using IC YS-50



Column : **Shodex IC NI-424 (4.6mmI.D. x 100mm)**
Eluent : 8mM 4-Hydroxybenzoic acid + 2.8mM Bis-Tris + 2mM Phenylboronic acid + 5μM *CyDTA aq.
Flow rate : 1.0mL/min
Detector : Non-suppressed conductivity
Column temp. : 40°C

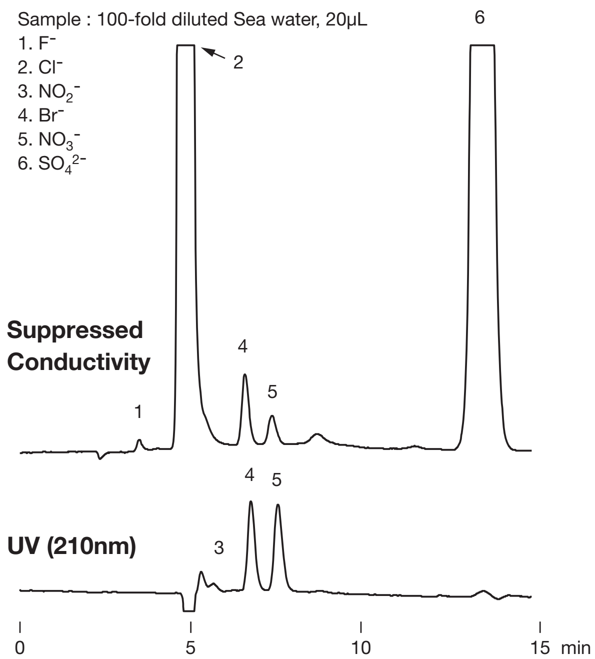
* CyDTA : trans-1,2-Diaminocyclohexane-N,N,N',N'-tetraacetic acid

Fig. 5-3 Analysis of anions in river water



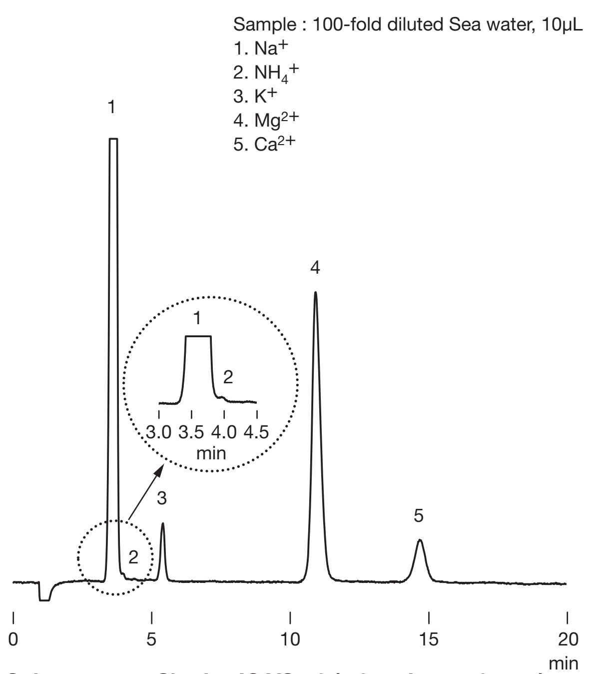
Column : **Shodex IC YS-50 (4.6mmI.D. x 125mm)**
Eluent : 4mM Nitric acid + 1.5mM 18-Crown 6-ether aq. /CH_3CN=90/10
Flow rate : 1.0mL/min
Detector : Non-suppressed conductivity
Column temp. : 40°C

Fig. 5-4 Analysis of cations in river water



Column : **Shodex IC SI-90 4E (4.0mmI.D. x 250mm)**
Eluent : 1.8mM Na_2CO_3 + 1.7mM $NaHCO_3$ aq.
Flow rate : 1.0mL/min
Detector : Suppressed conductivity, UV (210nm)
Column temp. : 25°C

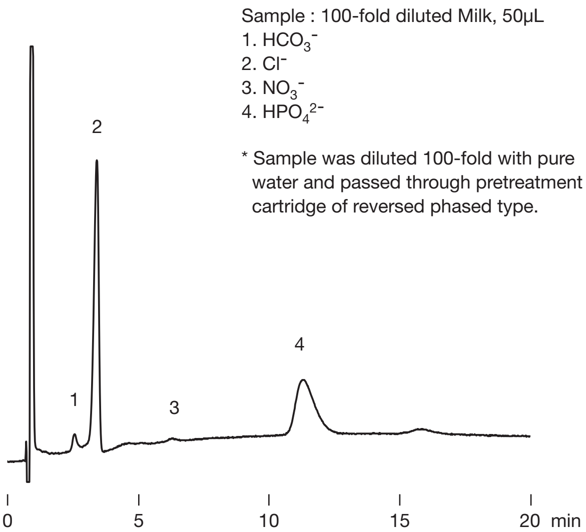
Fig. 5-5 Analysis of anions in sea water



Column : **Shodex IC YS-50 (4.6mmI.D. x 125mm)**
Eluent : 4mM Methanesulfonic acid aq.
Flow rate : 1.0mL/min
Detector : Non-suppressed conductivity
Column temp. : 40°C

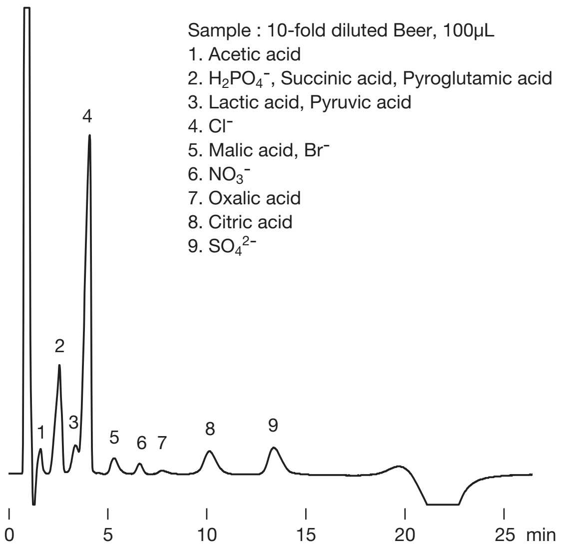
Fig. 5-6 Analysis of cations in sea water

5-2. Food



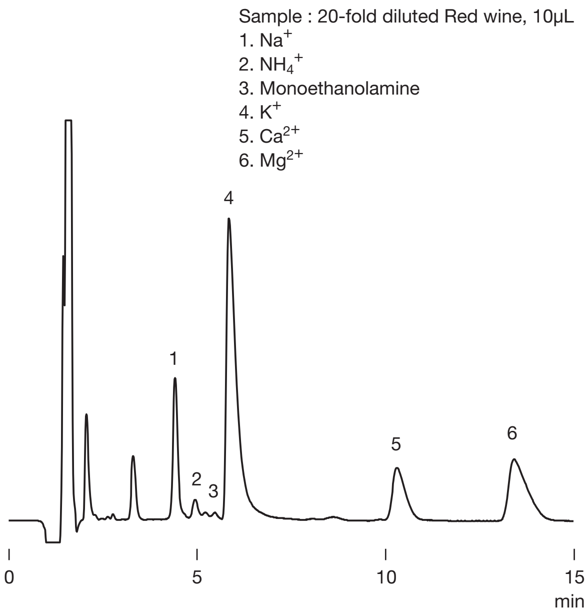
Column : **Shodex IC I-524A (4.6mmI.D. x 100mm)**
Eluent : 1.5mM p-Hydoxybenzoic acid
+ 1.7mM N,N-Diethylethanolamine
+ 10% CH_3OH
Flow rate : 1.2mL/min
Detector : Non-suppressed conductivity
Column temp. : 40°C

Fig. 5-7 Analysis of anions in milk



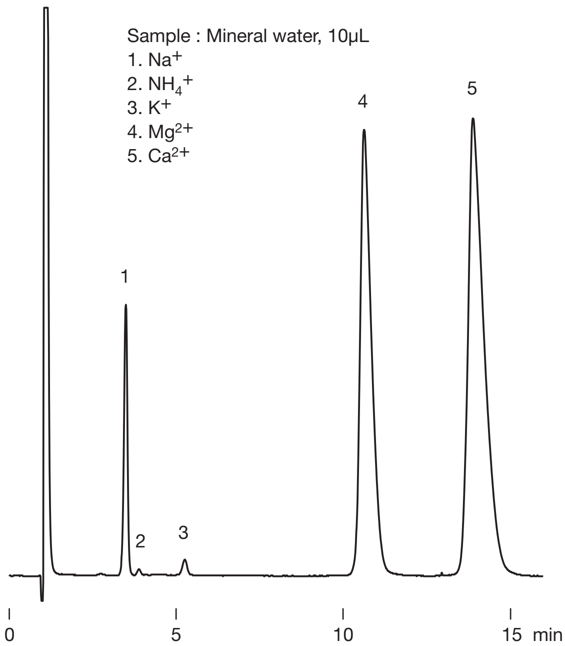
Column : **Shodex IC I-524A (4.6mmI.D. x 100mm)**
Eluent : 1.5mM Phthalic acid
+ 1.38mM Tris(hydroxymethyl)aminomethane
+ 300mM Boric acid aq.
Flow rate : 1.2mL/min
Detector : Non-suppressed conductivity
Column temp. : 40°C

Fig. 5-8 Analysis of cations in beer



Column : **Shodex IC YK-421 (4.6mmI.D. x 125mm)**
Eluent : 5mM Tartaric acid + 1mM Dipicolinic acid
+ 1.5g/L Boric acid aq.
Flow rate : 1.0mL/min
Detector : Non-suppressed Conductivity
Column temp. : 40°C

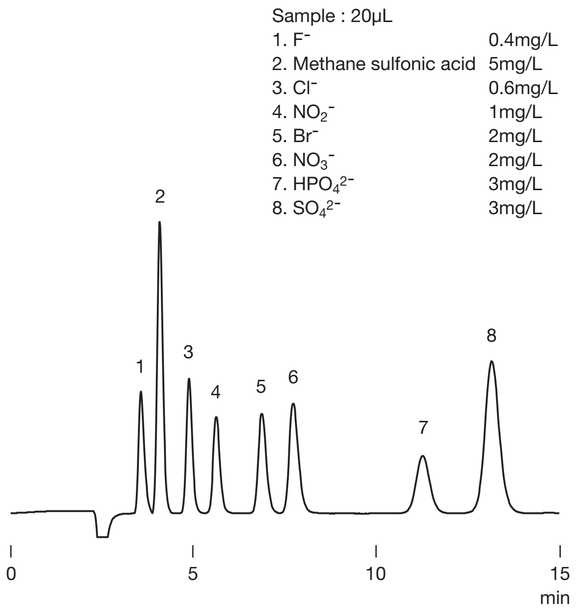
Fig. 5-9 Analysis of cations in red wine



Column : **Shodex IC YS-50 (4.6mmI.D. x 125mm)**
Eluent : 4mM Methanesulfonic acid aq.
Flow rate : 1.0mL/min
Detector : Non-suppressed conductivity
Column temp. : 40°C

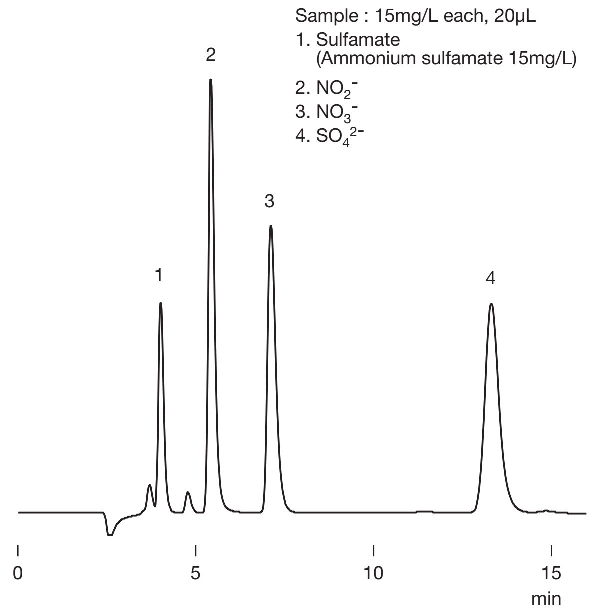
Fig. 5-10 Analysis of cations in mineral water

5-3. Others



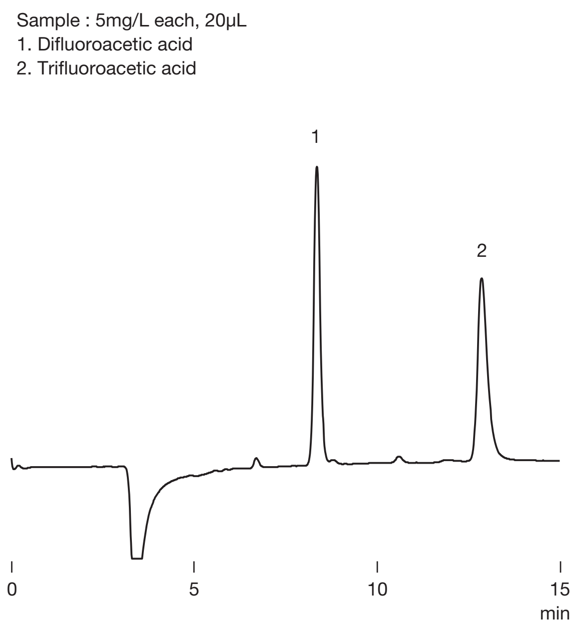
Column : Shodex IC SI-90 4E (4.0mmI.D. x 250mm)
Eluent : 1.8mM Na_2CO_3 + 1.7mM $NaHCO_3$ aq.
Flow rate : 1.0mL/min
Detector : Suppressed conductivity
Column temp. : 25˚C

Fig. 5-11 Analysis of methane sulfonic acid using IC SI-90 4E



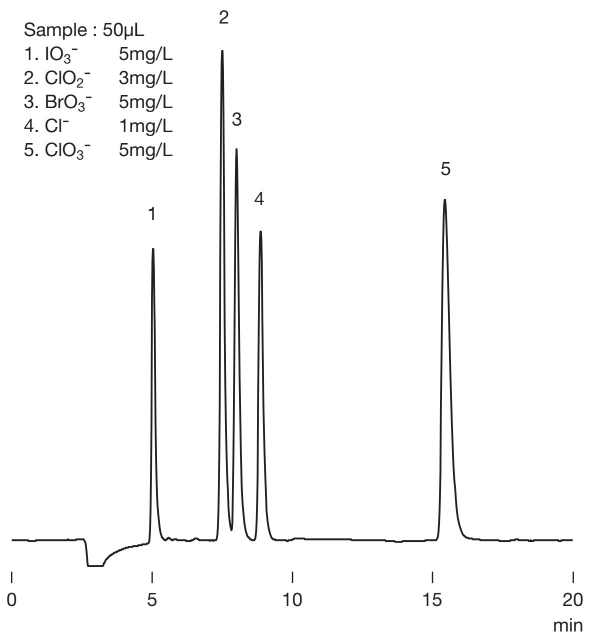
Column : Shodex IC SI-90 4E (4.0mmI.D. x 250mm)
Eluent : 1.8mM Na_2CO_3 + 1.7mM $NaHCO_3$ aq.
Flow rate : 1.0mL/min
Detector : Suppressed conductivity
Column temp. : 30˚C

Fig. 5-12 Analysis of sulfamate using IC SI-90 4E



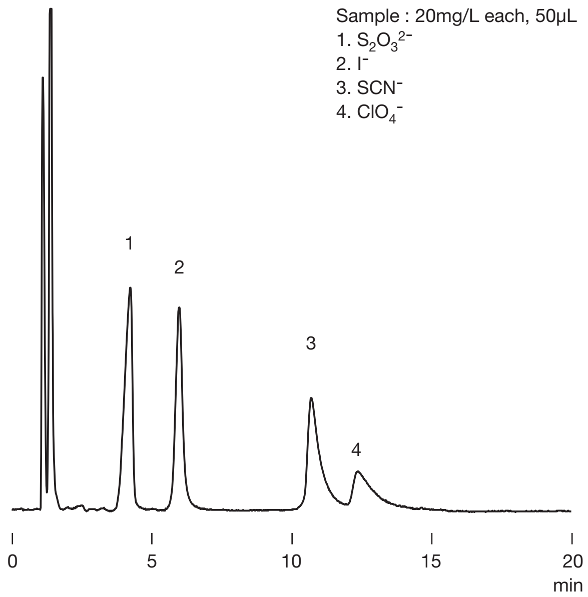
Column : Shodex IC SI-50 4E (4.0mmI.D. x 250mm)
Eluent : 3.2mM Na_2CO_3 + 1mM $NaHCO_3$ aq.
Flow rate : 0.7mL/min
Detector : Suppressed conductivity
Column temp. : 25˚C

Fig. 5-13 Analysis of fluoroacetic acid using IC SI-90 4E



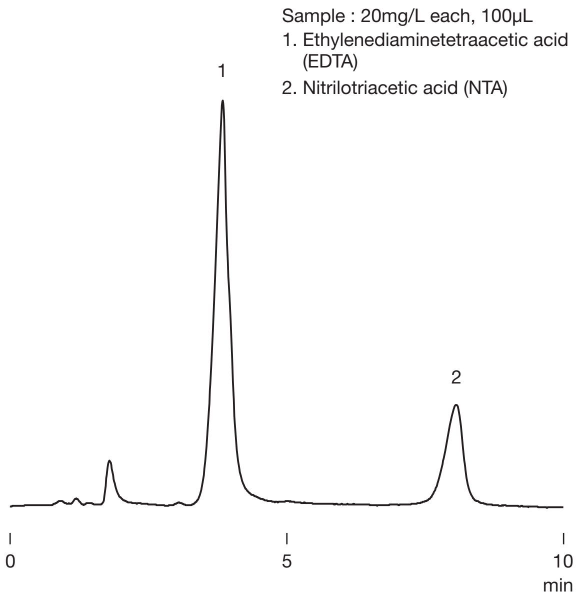
Column : Shodex IC SI-52 4E (4.0mmI.D. x 250mm)
Eluent : 3.6mM Na_2CO_3 aq.
Flow rate : 0.8mL/min
Detector : Suppressed conductivity
Column temp. : 45˚C

Fig. 5-14 Analysis of Iodate using IC SI-90 4E



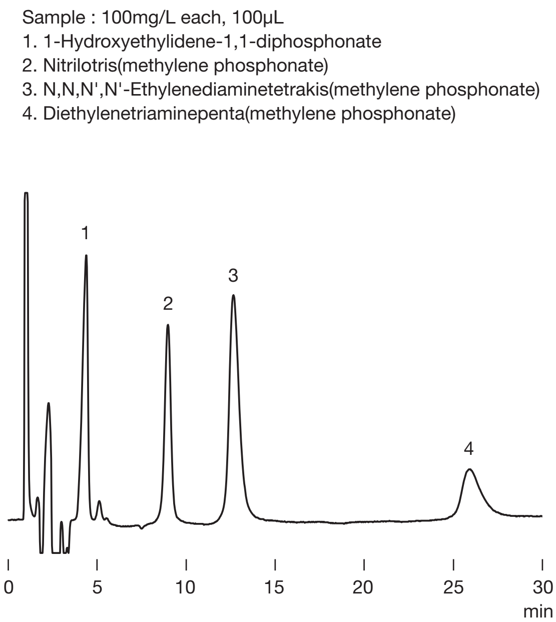
Column : **Shodex IC NI-424 (4.6mmI.D. x 100mm)**
Eluent : 0.9mM Sodium 1-octanesulufonate
+ 20mM Boric acid aq.
Flow rate : 1.0mL/min
Detector : Non-suppressed conductivity
Column temp. : 40°C

Fig. 5-15 Analysis of hydrophobic anions using IC NI-424



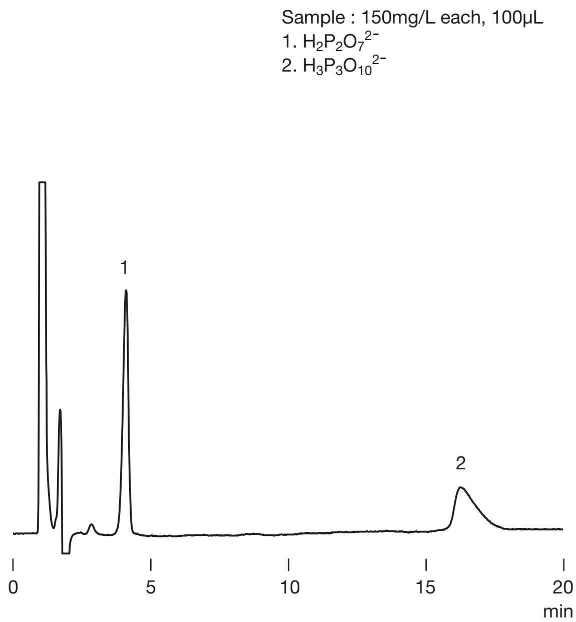
Column : **Shodex IC NI-424 (4.6mmI.D. x 100mm)**
Eluent : 2mM H_2SO_4 aq.
Flow rate : 1.0mL/min
Detector : UV (210nm)
Column temp. : 40°C

Fig. 5-16 Analysis of chelating agents using IC NI-424



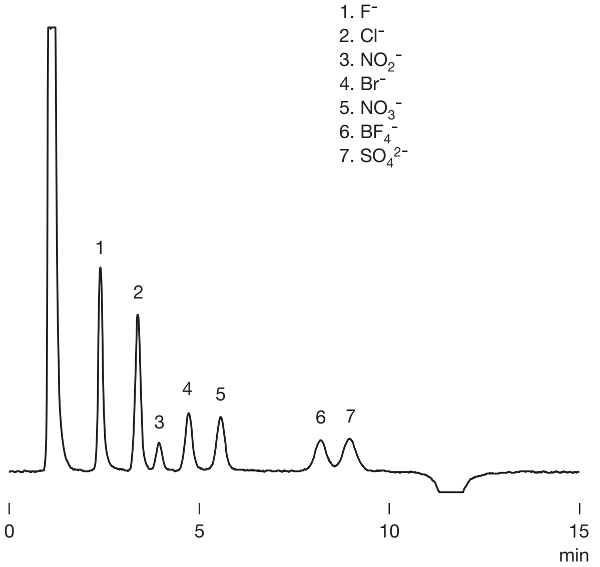
Column : **Shodex IC NI-424 (4.6mmI.D. x 100mm)**
Eluent : 3mM H_2SO_4 aq.
Flow rate : 1.0mL/min
Detector : RI
Column temp. : 40°C

Fig. 5-17 Analysis of phosphonic acids using IC NI-424



Column : **Shodex IC NI-424 (4.6mmI.D. x 100mm)**
Eluent : 8mM H_2SO_4 + 0.04mM EDTA·2Na aq.
Flow rate : 1.0mL/min
Detector : RI
Column temp. : 40°C

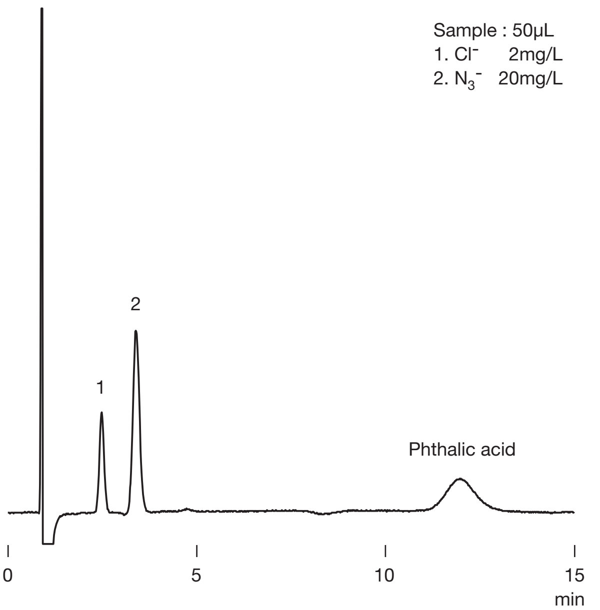
Fig. 5-18 Analysis of pyrophosphoric acid and tripolyphosphate using IC NI-424



Sample : 10mg/L each, 10μL
1. F^-
2. Cl^-
3. NO_2^-
4. Br^-
5. NO_3^-
6. BF_4^-
7. SO_4^{2-}

Column : **Shodex IC I-524A (4.6mmI.D. x 100mm)**
Eluent : 2.5mM Phthalic acid
+ 2.29mM Tris(hydroxymethyl)aminomethane) aq.
Flow rate : 1.0mL/min
Detector : Non-suppressed conductivity
Column temp. : 40˚C

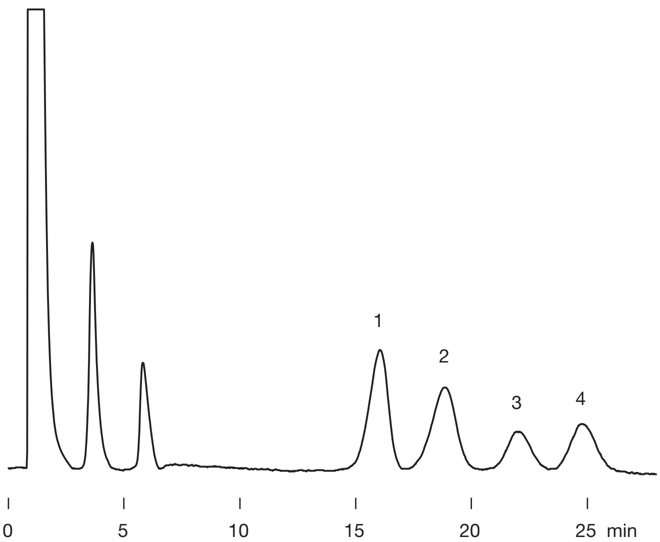
Fig. 5-19 Analysis of tetrafluoroborate using IC I-524A



Sample : 50μL
1. Cl^- 2mg/L
2. N_3^- 20mg/L

Column : **Shodex IC I-524A (4.6mmI.D. x 100mm)**
Eluent : 2.5mM Phthalic acid
+ 2.9mM Tris(hydroxymethyl)aminomethane aq.
Flow rate : 1.2mL/min
Detector : Non-supprssed conductivity
Column temp. : 40˚C

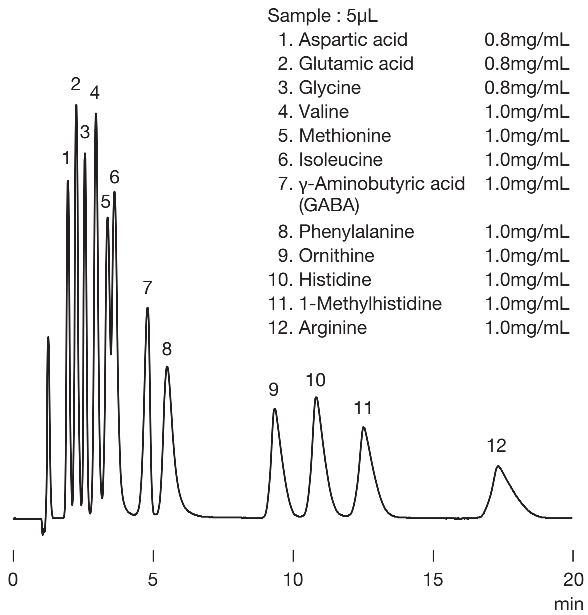
Fig. 5-20 Analysis of azide using IC I-524A



Sample : 10mg/L each, 100μL
1. SO_4^{2-}
2. SO_3^{2-}
3. $S_2O_3^{2-}$
4. SCN^-

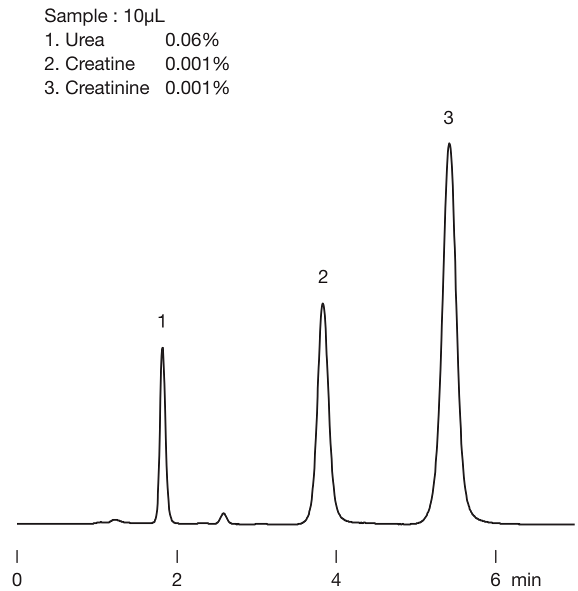
Column : **Shodex IC I-524A (4.6mmI.D. x 100mm)**
Eluent : 0.25mM p-Hydroxybenzoic acid
+ 1.2mM N,N-Diethylethanolamine
+ 10% CH_3OH
Flow rate : 1.5mL/min
Detector : Non-suppressed conductivity
Column temp. : 50˚C

Fig. 5-21 Analysis of sulfate, sulfite, thiosulfate and thiocyanate using IC I-524A



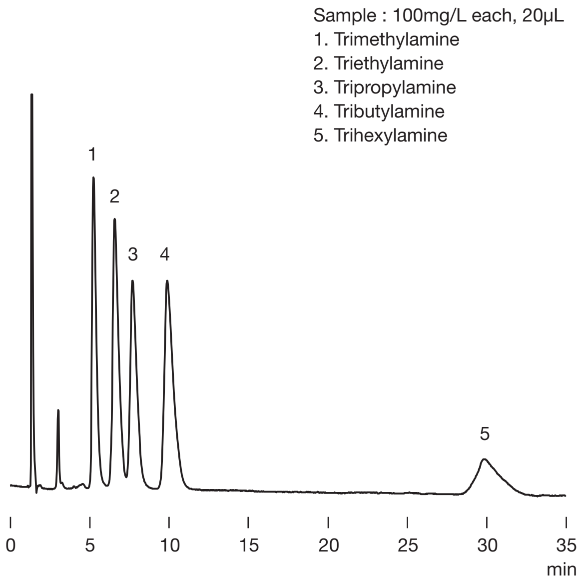
Column : Shodex IC YS-50 (4.6mmI.D. x 125mm)
Eluent : 6mM H_3PO_4 aq.
Flow rate : 1.0mL/min
Detector : RI
Column temp. : 40˚C

Fig. 5-22 Analysis of amino acids using IC YS-50



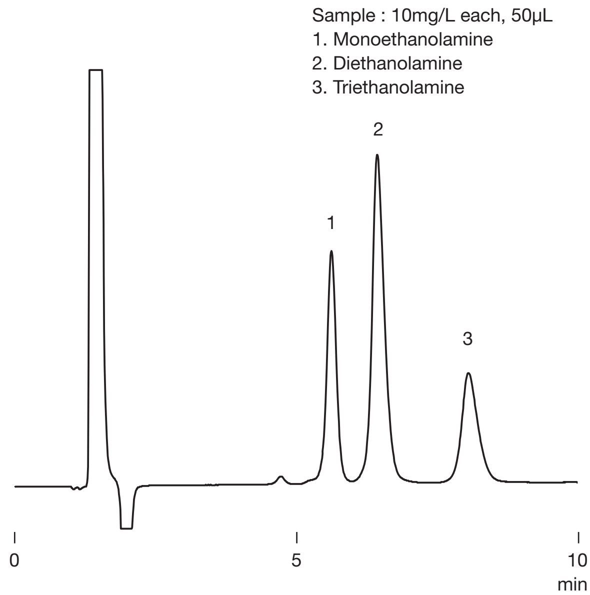
Column : Shodex IC YS-50 (4.6mmI.D. x 125mm)
Eluent : 10mM H_3PO_4 aq.
Flow rate : 1.0mL/min
Detector : UV (210nm)
Column temp. : 40˚C

Fig. 5-23 Analysis of metabolite of nitrogenous substances using IC YS-50



Column : Shodex IC YK-421 (4.6mmI.D. x 125mm)
Eluent : 4mM HNO_3 aq./CH_3CN=70/30
Flow rate : 1.0mL/min
Detector : Non-suppressed conductivity
Column temp. : 40˚C

Fig. 5-24 Analysis of trialkylamines using IC YK-421



Column : Shodex IC YK-421 (4.6mmI.D. x 125mm)
Eluent : 4mM H_3PO_4 aq./CH_3CN=95/5
Flow rate : 1.0mL/min
Detector : Non-suppressed conductivity
Column temp. : 25˚C

Fig. 5-25 Analysis of ethanolamines using IC YK-421

Notice

1. Thoroughly read the instruction manuals included in your Shodex product prior to use.
2. Product specifications may be changed without notice to improve product performance.
3. The numerical data in this technical notebook are reference values and not guaranteed.
4. Exercise appropriate caution when using any reagent or chemical with Shodex products, even if safety or hazard warnings about these substances are not included in the product instruction manual.
5. Use of any these products for medical diagnostics, medical procedures, or any other medical applications is strictly prohibited.

European website
www.shodex.de

Shodex provides information of new products and new analysis technologies by e-mail.

If you are interested in receiving these newsletters by email please join our newsletter list on our website.

Shodex™

Shodex Europe Office in Munich, Germany

If you have any questions regarding this technical notebook please don't hesitate to contact us via our website or send us an e-mail directly.

www.shodex.de or info@shodex.de

Manufactured by

SHOWA DENKO K.K.

MZ ANALYSENTECHNIK

AUTHORIZED DISTRIBUTOR

MZ-Analysentechnik GmbH
Wöhlerstraße 2-6 • D-55120 Mainz
Tel +49 6131 68 66 19
Fax +49 6131 68 66 20
e-mail: info@mz-at.de
www.mz-at.de

Shodex offices

(HEAD QUARTERS) **Showa Denko K.K** Shodex (Separation & HPLC) Group	23F Muza Kawasaki Central Tower, 1310, Omiya-cho, Saiwai-ku, Kawasaki, Kanagawa 212-0014 JAPAN Tel : +81-(0)44-520-1380 Fax : +81-(0)44-520-1383 Email : sdk_shodex@sdk.co.jp **Web : www.shodex.com**
(NORTH & LATIN AMERICA) **Showa Denko America, Inc.**	420 Lexington Avenue, Suite 2850, New York, NY 10170 USA Tel : +1-212-370-0033 Fax : +1-212-370-4566 E-mail : support@shodex.net **Web : www.shodex.net**
(EUROPE, Middle East & AFRICA) **Showa Denko Europe GmbH**	Konrad-Zuse-Platz 4, 81829 Munich, GERMANY Tel : +49-(0)89-93996234 Fax : +49-(0)89-9399627734 E-mail : info@shodex.de **Web : www.shodex.de**
(CHINA) **Shodex China Co., Ltd.**	18F, Wang Wang Building, No.211 Shi Men Yi Road, Jing An, Shanghai, 200041, CHINA Tel : +86-(0)21-6217-6111 Fax : +86-(0)21-6217-9879 E-mail : support@shodexchina.com **Web : www.shodex.com/index_ch.html**
(JAPAN) **Shoko Co., Ltd.**	4-1, Shibakohen 2-chome, Minato-ku, Tokyo, 105-8432, JAPAN Tel : +81-(0)3-3459-5104 Fax : +81-(0)3-3459-5081 E-mail : shodex.tokyo@shoko.co.jp **Web : www.shodex.com**
(KOREA) **Shoko Korea Co., Ltd.**	322, Chungjeong Rizion, 465, Chungjeongno 3-ga, Seodaemun-gu, Seoul 120-013, KOREA Tel : +82-(0)2-784-5111 Fax : +82-(0)2-784-5125 Email : shoko.korea@shokokorea.com **Web : www.shodex.com/index_kr.html**

TNE.No.08E.(1)11.1000.JAN.TR