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]**
<table>
<thead>
<tr>
<th>Product Code</th>
<th>Product Name</th>
<th>Functional Group</th>
<th>Base Material</th>
<th>Plate Number (TP/column)</th>
<th>Particle Size (μm)</th>
<th>Column Size (mm) I.D. x L</th>
</tr>
</thead>
<tbody>
<tr>
<td>F69595244</td>
<td>IC SI-90 4E</td>
<td>Quaternary ammonium</td>
<td>Polyvinyl alcohol</td>
<td>&gt; 5,000 guard column</td>
<td>9</td>
<td>4.0 x 250 4.6 x 10</td>
</tr>
<tr>
<td>F69595245</td>
<td>IC SI-90G</td>
<td>Quaternary ammonium</td>
<td>Polyvinyl alcohol</td>
<td>&gt; 10,000 guard column</td>
<td>5</td>
<td>4.0 x 250 4.6 x 10</td>
</tr>
<tr>
<td>F69596200</td>
<td>IC SI-52 4E</td>
<td>Quaternary ammonium</td>
<td>Polyvinyl alcohol</td>
<td>&gt; 14,000 guard column</td>
<td>5</td>
<td>4.0 x 250 4.6 x 10</td>
</tr>
<tr>
<td>F69596216</td>
<td>IC SI-52G</td>
<td>Quaternary ammonium</td>
<td>Polyvinyl alcohol</td>
<td>&gt; 13,000 guard column</td>
<td>3.5</td>
<td>4.0 x 150 4.6 x 10</td>
</tr>
<tr>
<td>F6959627</td>
<td>IC SI-35 4D</td>
<td>Quaternary ammonium</td>
<td>Polyvinyl alcohol</td>
<td>&gt; 2,500 guard column</td>
<td>9</td>
<td>4.0 x 100 4.6 x 10</td>
</tr>
<tr>
<td>F6959628</td>
<td>IC SI-91 4C</td>
<td>Quaternary ammonium</td>
<td>Polyvinyl alcohol</td>
<td>&gt; 7,000 guard column</td>
<td>9</td>
<td>4.0 x 150 4.6 x 10</td>
</tr>
<tr>
<td>F6959623</td>
<td>WINE VH-anion 4D</td>
<td>Quaternary ammonium</td>
<td>Polyvinyl alcohol</td>
<td>&gt; 7,000 guard column</td>
<td>5</td>
<td>4.0 x 100 4.6 x 10</td>
</tr>
<tr>
<td>F6959629</td>
<td>WINE VH-anionG 4A</td>
<td>Quaternary ammonium</td>
<td>Polyvinyl alcohol</td>
<td>&gt; 7,000 guard column</td>
<td>5</td>
<td>4.0 x 150 4.6 x 10</td>
</tr>
</tbody>
</table>

  **[Non-suppressor method]**
<table>
<thead>
<tr>
<th>Product Code</th>
<th>Product Name</th>
<th>Functional Group</th>
<th>Base Material</th>
<th>Plate Number (TP/column)</th>
<th>Particle Size (μm)</th>
<th>Column Size (mm) I.D. x L</th>
</tr>
</thead>
<tbody>
<tr>
<td>F69595243</td>
<td>IC NI-424</td>
<td>Quaternary ammonium</td>
<td>Polyhydroxyethylacrylate</td>
<td>&gt; 5,000 guard column</td>
<td>5</td>
<td>4.6 x 100 4.6 x 10</td>
</tr>
<tr>
<td>F69595240</td>
<td>IC I-524A</td>
<td>Quaternary ammonium</td>
<td>Polyhydroxyethylacrylate</td>
<td>&gt; 2,000 guard column</td>
<td>12</td>
<td>4.6 x 100 4.6 x 10</td>
</tr>
</tbody>
</table>

- **Cation analysis**
<table>
<thead>
<tr>
<th>Product Code</th>
<th>Product Name</th>
<th>Functional Group</th>
<th>Base Material</th>
<th>Plate Number (TP/column)</th>
<th>Particle Size (μm)</th>
<th>Column Size (mm) I.D. x L</th>
</tr>
</thead>
<tbody>
<tr>
<td>F7122000</td>
<td>IC YS-50</td>
<td>Carboxyl</td>
<td>Polyvinyl alcohol</td>
<td>&gt; 5,000 guard column</td>
<td>5</td>
<td>4.6 x 125 4.6 x 10</td>
</tr>
<tr>
<td>F7122012</td>
<td>IC YK-421</td>
<td>Carboxyl</td>
<td>Silica</td>
<td>&gt; 2,800 guard column</td>
<td>5</td>
<td>4.6 x 125 4.6 x 10</td>
</tr>
<tr>
<td>F69595210</td>
<td>IC Y-521</td>
<td>Sulfo</td>
<td>Styrene divinylibenzene copolymer</td>
<td>&gt; 3,000 guard column</td>
<td>12</td>
<td>4.0 x 150 4.6 x 10</td>
</tr>
</tbody>
</table>
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.

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 litter range.

![System configuration of suppressor method](image1)

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.

![System configuration of non-suppressor method](image2)

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 10 minutes. The IC SI-90 4E fulfills U.S. EPA Methods 300.0 (A) requirements.

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

<table>
<thead>
<tr>
<th>Anion</th>
<th>Column: Shodex IC SI-90 4E (4.0mmI.D. x 250mm)</th>
<th>Flow rate: 1.0mL/min</th>
<th>Flow rate: 1.5mL/min</th>
</tr>
</thead>
<tbody>
<tr>
<td>F⁻</td>
<td>3.5</td>
<td>3.9</td>
<td>4.7</td>
</tr>
<tr>
<td>Cl⁻</td>
<td>3.7</td>
<td>4.2</td>
<td>5.1</td>
</tr>
<tr>
<td>formic acid</td>
<td>4.0</td>
<td>4.5</td>
<td>5.6</td>
</tr>
<tr>
<td>ClO₂⁻</td>
<td>4.2</td>
<td>4.8</td>
<td>6.3</td>
</tr>
<tr>
<td>methacrylic acid</td>
<td>4.3</td>
<td>4.9</td>
<td>6.4</td>
</tr>
<tr>
<td>BrO₃⁻</td>
<td>4.4</td>
<td>5.1</td>
<td>6.7</td>
</tr>
<tr>
<td>Cl⁻</td>
<td>4.7</td>
<td>5.5</td>
<td>7.2</td>
</tr>
</tbody>
</table>

Column: Shodex IC SI-90 4E (4.0mmI.D. x 250mm)
Eluent: (1) 1.8mM Na₂CO₃ + 1.7mM NaHCO₃ aq,
(2) 1.0mM Na₂CO₃ + 4.0mM NaHCO₃ aq,
(3) 12mM NaHCO₃ aq.
Flow rate: 1.0mL/min
Detector: Suppressed conductivity
Column temp.: 25°C
Phosphate \((\text{HPO}_4^{2-})\), phosphite \((\text{HPO}_3^{2-})\), and hypophosphite \((\text{HPO}_2^{2-})\) ions were simultaneously analyzed with seven common anions. An aqueous solution of 12mM sodium hydrogen carbonate \((\text{NaHCO}_3)\) 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.

![Fig. 3-2 Phosphate, phosphite and hypophosphite ions](image)

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.

![Fig. 3-3 High-sensitivity analysis using IC SI-90 4E](image)
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:

![UV (210nm)](image)

**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.
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.

**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°C is recommended to achieve separation of chlorate (ClO$_3^-$) from bromide (Br$^-$).

**Fig. 3-7** Temperature-dependent properties of IC SI-52 4E
IC SI-35 4D provides rapid analysis of oxyhalides and inorganic anions; about a half the time of existing column IC SI-52 4E. This IC SI-35 4D fulfills U.S. EPA Methods 300.0 (A) and (B) requirements.

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 15 minutes using IC SI-35 4D.

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

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 fluoride ions, which is difficult by IC I-524A.

Phthalate eluent improves the peak height to twice that achieved with hydroxybenzoate eluents, but six anions, from $\text{H}_2\text{PO}_4^{-}$ to $\text{NO}_3^{-}$, elutes closely. (No.1-6 peaks in Figure 3-11).
IC NI-424 is not only capable of separating phosphate and fluoride ions but also capable of separating carbonate ion from phosphate.

![Analysis of carbonate ion using IC NI-424](image)

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

![Analysis of organic acids using IC NI-424](image)
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.

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.
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.

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

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

**Standards**

- 1. F⁻  2mg/L
- 2. HCO₃⁻  20mg/L
- 3. Cl⁻  3mg/L
- 4. NO₂⁻  5mg/L
- 5. Br⁻  10mg/L
- 6. NO₃⁻  10mg/L
- 7. PO₄³⁻  15mg/L
- 8. SO₄²⁻  15mg/L

**Sample**: 100µL each

**Anion standards**

<table>
<thead>
<tr>
<th>Anion</th>
<th>Concentration (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F⁻</td>
<td>2</td>
</tr>
<tr>
<td>HCO₃⁻</td>
<td>20</td>
</tr>
<tr>
<td>Cl⁻</td>
<td>3</td>
</tr>
<tr>
<td>NO₂⁻</td>
<td>5</td>
</tr>
<tr>
<td>Br⁻</td>
<td>10</td>
</tr>
<tr>
<td>NO₃⁻</td>
<td>10</td>
</tr>
<tr>
<td>PO₄³⁻</td>
<td>15</td>
</tr>
<tr>
<td>SO₄²⁻</td>
<td>15</td>
</tr>
</tbody>
</table>

**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.
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-fold 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.

---

**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\(_4^+\))

---

**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.

![Fig. 4-3 Analysis of transition metal ions using IC YS-50](image)

Sample: 20µL
1. Zn²⁺ 10mg/L
2. Co²⁺ 10mg/L
3. Fe²⁺ 10mg/L
4. Mn²⁺ 10mg/L
5. Cd²⁺ 10mg/L
6. Pb²⁺ 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°C

![Fig. 4-4 Analysis of cations and alkyl amines using IC YS-50](image)

Sample: 10µL
1. Li⁺ 2mg/L
2. Na⁺ 10mg/L
3. NH₄⁺ 10mg/L
4. Methylamine 10mg/L
5. K⁺ 20mg/L
6. Trimethylamine 20mg/L
7. Triethylamine 20mg/L
8. Mg²⁺ 10mg/L
9. Ca²⁺ 10mg/L
10. Sr²⁺ 10mg/L
11. Ba²⁺ 10mg/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°C

![Fig. 4-5 Analysis of ten cations using IC YK-421](image)

Sample: 10µL
1. Li⁺ 1mg/L
2. Na⁺ 5mg/L
3. NH₄⁺ 5mg/L
4. K⁺ 10mg/L
5. Rb⁺ 30mg/L
6. Cs⁺ 30mg/L
7. Ca²⁺ 10mg/L
8. Mg²⁺ 5mg/L
9. Sr²⁺ 10mg/L
10. Ba²⁺ 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-suppressed conductivity
Column temp.: 50°C
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. HCO₃⁻
4. ClO₃⁻
5. NO₃⁻
6. SO₄²⁻

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

Column : Shodex IC SI-35 4D (4.0mm.I.D. x 150mm)
Eluent : 3.6mM Na₂CO₃ 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. NH₄⁺ 10mg/L
4. K⁺ 20mg/L
5. Mg²⁺ 10mg/L
6. Ca²⁺ 20mg/L
7. Ethylenediamine 50mg/L

Tap water
2. Na⁺
3. NH₄⁺
4. K⁺
5. Mg²⁺
6. Ca²⁺
7. Ethylenediamine 50mg/L

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

Column : Shodex IC YS-50 (4.6mm.I.D. x 125mm)
Eluent : 4mM Nitric acid + 1.5mM 18-Crown-6-ether aq. /CH₃CN=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

Column: Shodex IC SI-90 4E (4.0mmI.D. x 250mm)
Eluent: 1.8mM Na2CO3 + 1.7mM NaHCO3 aq.
Flow rate: 1.0mL/min
Detector: Suppressed conductivity, UV (210nm)
Column temp.: 25˚C

Column: Shodex IC YS-50 (4.6mmI.D. x 125mm)
Eluent: 4mM Nitric acid + 1.5mM 18-Crown 6-ether aq. /CH3CN=90/10
Flow rate: 1.0mL/min
Detector: Non-suppressed conductivity
Column temp.: 40˚C

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

Fig. 5-3 Analysis of anions in river water

Fig. 5-4 Analysis of cations in river water

Sample: 5-fold diluted River water, 100µL
1. H2PO4-
2. F-
3. Cl-
4. NO2-
5. Br-
6. NO3-
7. SO42-

Sample: 100-fold diluted Sea water, 20µL
1. F-
2. Cl-
3. NO2-
4. Br-
5. NO3-
6. SO42-

Sample: River water, 50µL
1. Na+
2. NH4+
3. K+
4. Mg2+
5. Ca2+
6. Ethylenediamine 50mg/L

* Sample: 100-fold diluted Sea water, 10µL
1. Na+
2. NH4+
3. K+
4. Mg2+
5. Ca2+

Fig. 5-5 Analysis of anions in sea water

Fig. 5-6 Analysis of cations in sea water
5-2. Food

**Fig. 5-7** Analysis of anions in milk

- Sample: 100-fold diluted Milk, 50µL
- 1. HCO₃⁻
- 2. Cl⁻
- 3. NO₃⁻
- 4. HPO₄²⁻

* Sample was diluted 100-fold with pure water and passed through pretreatment cartridge of reversed phased type.

**Fig. 5-8** Analysis of cations in beer

- Sample: 10-fold diluted Beer, 100µL
- 1. Acetic acid
- 2. H₂PO₄⁻, Succinic acid, Pyroglutamic acid
- 3. Lactic acid, Pyruvic acid
- 4. Cr⁶⁺
- 5. Malic acid, Br⁻
- 6. NO₃⁻
- 7. Oxalic acid
- 8. Citric acid
- 9. SO₄²⁻

**Fig. 5-9** Analysis of cations in red wine

- Sample: 20-fold diluted Red wine, 10µL
- 1. Na⁺
- 2. NH₄⁺
- 3. Monoethanolamine
- 4. K⁺
- 5. Ca²⁺
- 6. Mg²⁺

**Fig. 5-10** Analysis of cations in mineral water

- Sample: Mineral water, 10µL
- 1. Na⁺
- 2. NH₄⁺
- 3. K⁺
- 4. Mg²⁺
- 5. Ca²⁺

---

Column: Shodex IC I-524A (4.6mm I.D. x 100mm)
Eluent: 1.5mM p-Hydroxybenzoic acid
+ 1.7mM N,N-Diethylethanolamine
+ 10% CH₃OH
Flow rate: 1.2mL/min
Detector: Non-suppressed conductivity
Column temp.: 40°C

Column: Shodex IC I-524A (4.6mm I.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

Column: Shodex IC YK-421 (4.6mm I.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

Column: Shodex IC YS-50 (4.6mm I.D. x 125mm)
Eluent: 4mM Methanesulfonic acid aq.
Flow rate: 1.0mL/min
Detector: Non-suppressed conductivity
Column temp.: 40°C
5-3. Others

**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 Na₂CO₃ + 1.7mM NaHCO₃ aq.
- **Flow rate**: 1.0mL/min
- **Detector**: Suppressed conductivity
- **Column temp.**: 25°C

**Sample**: 20µL

1. F⁻ 0.4mg/L
2. Methane sulfonic acid 5mg/L
3. Cl⁻ 0.6mg/L
4. NO₂⁻ 1mg/L
5. Br⁻ 2mg/L
6. NO₃⁻ 3mg/L
7. HPO₄²⁻ 3mL/L
8. SO₄²⁻ 3mL/L

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

- **Column**: Shodex IC SI-90 4E (4.0mmI.D. x 250mm)
- **Eluent**: 1.8mM Na₂CO₃ + 1.7mM NaHCO₃ aq.
- **Flow rate**: 1.0mL/min
- **Detector**: Suppressed conductivity
- **Column temp.**: 30°C

**Sample**: 15mg/L each, 20µL

1. Sulfamate (Ammonium sulfamate 15mg/L)
2. NO₂⁻
3. NO₃⁻
4. SO₄²⁻

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

- **Column**: Shodex IC SI-50 4E (4.0mmI.D. x 250mm)
- **Eluent**: 3.2mM Na₂CO₃ + 1mM NaHCO₃ aq.
- **Flow rate**: 0.7mL/min
- **Detector**: Suppressed conductivity
- **Column temp.**: 25°C

**Sample**: 5mg/L each, 20µL

1. Difluoroacetic acid
2. Trifluoroacetic acid

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

- **Column**: Shodex IC SI-52 4E (4.0mmI.D. x 250mm)
- **Eluent**: 3.6mM Na₂CO₃ aq.
- **Flow rate**: 0.8mL/min
- **Detector**: Suppressed conductivity
- **Column temp.**: 45°C

**Sample**: 50µL

1. IO₃⁻ 5mg/L
2. ClO₂⁻ 3mg/L
3. BrO₃⁻ 5mg/L
4. Cl⁻ 1mg/L
5. ClO₃⁻ 5mg/L

**Sample**: 20µL

1. F⁻ 0.4mg/L
2. Methane sulfonic acid 5mg/L
3. Cl⁻ 0.6mg/L
4. NO₂⁻ 1mg/L
5. Br⁻ 2mg/L
6. NO₃⁻ 2mg/L
7. HPO₄²⁻ 3mg/L
8. SO₄²⁻ 3mg/L
Column : Shodex IC NI-424 (4.6mmI.D. x 100mm)
Eluent : 0.9mM Sodium 1-octanesulfonate
+ 20mM Boric acid aq.
Flow rate : 1.0mL/min
Detector : Non-suppressed conductivity
Column temp. : 40°C

Column : Shodex IC NI-424 (4.6mmI.D. x 100mm)
Eluent : 2mM H2SO4 aq.
Flow rate : 1.0mL/min
Detector : UV (210nm)
Column temp. : 40°C

Sample : 20mg/L each, 50µL
1. S2O32-
2. I\(^{-}\)
3. SCN\(^{-}\)
4. ClO4\(^{-}\)

Sample : 100mg/L each, 100µL
1. 1-Hydroxyethylidene-1,1-diphosphonate
2. Nitrilotris(methylene phosphonate)
3. N,N,N',N'-Ethylenediaminetetraakis(methylene phosphonate)
4. Diethylenetriaminepentamethylene phosphonate

Sample : 100mg/L each, 100µL
1. 1-Hydroxyethylidene-1,1-diphosphonate
2. Nitrilotris(methylene phosphonate)
3. N,N,N',N'-Ethylenediaminetetraakis(methylene phosphonate)
4. Diethylenetriaminepentamethylene phosphonate

Sample : 20mg/L each, 100µL
1. Ethylenediaminetetraacetic acid (EDTA)
2. Nitrilotriacetic acid (NTA)

Fig. 5-15 Analysis of hydrophobic anions using IC NI-424
Fig. 5-16 Analysis of chelating agents using IC NI-424
Fig. 5-17 Analysis of phosphonic acids using IC NI-424
Fig. 5-18 Analysis of pyrophosphoric acid and tripolyphosphate using IC NI-424
Phthalic acid

Sample: 10µL each, 10µL

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

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

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

Sample: 10mg/L each, 100µL
1. SO₄²⁻  2. SO₃²⁻  3. S₂O₃²⁻  4. SCN⁻

Column: Shodex IC I-524A (4.6mmI.D. x 100mm)
Eluent: 0.25mM p-Hydroxybenzoic acid + 1.2mM N,N-Diethylethanolamine + 10% CH₃OH
Flow rate: 1.5mL/min
Detector: Non-suppressed conductivity
Column temp.: 50°C
Fig. 5-22  Analysis of amino acids using IC YS-50

Column : Shodex IC YS-50 (4.6mmI.D. x 125mm)
Eluent : 6mM H₃PO₄ aq.
Flow rate : 1.0mL/min
Detector : RI
Column temp. : 40˚C

Sample : 5µL
1. Aspartic acid 0.8mg/mL
2. Glutamic acid 0.8mg/mL
3. Glycine 0.8mg/mL
4. Valine 1.0mg/mL
5. Methionine 1.0mg/mL
6. Isoleucine 1.0mg/mL
7. γ-Aminobutyric acid (GABA)
8. Phenylalanine 1.0mg/mL
9. Ornithine 1.0mg/mL
10. Histidine 1.0mg/mL
11. 1-Methylhistidine 1.0mg/mL
12. Arginine 1.0mg/mL

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

Column : Shodex IC YS-50 (4.6mmI.D. x 125mm)
Eluent : 10mM H₃PO₄ aq.
Flow rate : 1.0mL/min
Detector : UV (210nm)
Column temp. : 40˚C

Sample : 10µL
1. Urea 0.06%
2. Creatine 0.001%
3. Creatinine 0.001%

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

Column : Shodex IC YK-421 (4.6mmI.D. x 125mm)
Eluent : 4mM HNO₃ aq./CH₃CN=70/30
Flow rate : 1.0mL/min
Detector : Non-suppressed conductivity
Column temp. : 40˚C

Sample : 100mg/L each, 20µL
1. Trimethylamine
2. Triethylamine
3. Tripropylamine
4. Tributylamine
5. Trihexylamine

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

Column : Shodex IC YK-421 (4.6mmI.D. x 125mm)
Eluent : 4mM H₂PO₄ aq./CH₃CN=95/5
Flow rate : 1.0mL/min
Detector : Non-suppressed conductivity
Column temp. : 25˚C

Sample : 10mg/L each, 50µL
1. Monoethanolamine
2. Diethanolamine
3. Triethanolamine
Welcome to
http://www.shodex.com/

If you have any question regarding this technical notebook, we welcome your questions.
Please contact your local office listed below.

Manufactured by

SHOWA DENKO K.K.

Shodex offices:

(HEAD QUARTERS)
SHOWA DENKO K.K.
Shodex Separation & HPLC Group
Tel: +81-46-525-8900 Fax: +81-46-525-1989 E-mail: info@shodex.co.jp Web: www.shodex.com

(NORTH & LATIN AMERICA)
SHOWA DENKO America, Inc.
Tel: +1-212-370-0633 Fax: +1-212-370-4566 E-mail: support@shodex.net Web: www.shodex.net

(EUROPE & AFRICA)
SHOWA DENKO Europe GmbH
Tel: +49-089-9394217 Fax: +49-089-9394259 E-mail: info@shodex.de Web: www.shodex.de

(CHINA)
SHOWA DENKO China Co., Ltd.
Tel: +86-021-6217-6111 Fax: +86-021-6217-9879 E-mail: support@shodexchina.com Web: www.shodex.com/index_ch.html

(JAPAN)
SHOWA DENKO Co., Ltd.
Tel: +81-3-3459-5100 Fax: +81-3-3459-5081 E-mail: shodex.tokyo@shokoc.co.jp Web: www.shodex.com

(KOREA)
SHOWA DENKO Korea Co., Ltd.
Tel: +82-02-784-5111 Fax: +82-02-784-5125 E-mail: shoko.korea@shokoc.com Web: www.shodex.com/index_kr.html