Thermo Scientific Dionex Reagent-Free Ion Chromatography (RFIC) System Capabilities

The power to
increase productivity

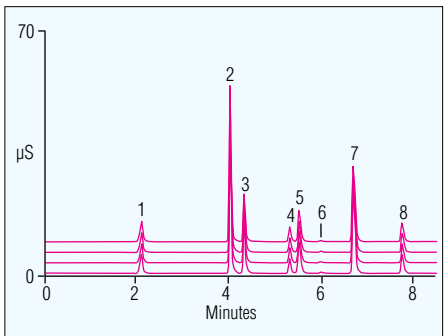
Thermo SCIENTIFIC

RFIC System Technology

Since the introduction of eluent generation in 1998, Thermo Fisher Scientific has continued to simplify ion chromatography (IC) while expanding the capabilities and power of ion analysis. Advances in eluent generation and electrolytic suppression technologies are enabling a wider variety of applications and increased productivity.

Reagent-Free™ IC (RFIC™) systems are available with eluent generation (RFIC-EG) or with eluent regeneration (RFIC-ER), such as the Thermo Scientific™ Dionex™ ICS-2100, ICS-4000, and ICS-5000$^+$ systems. These systems combine automated eluent generators and electrolytically regenerated suppressors to electrolytically create the required eluents and regenerants used for IC applications. Plumb in a clean source of deionized water, and the RFIC-EG system takes care of the rest.

RFIC-ER systems (available option Thermo Scientific Dionex ICS-1100, ICS-1600, ICS-2100, and ICS-5000$^+$ systems) are designed for routine isocratic separations. The systems use the electrolytically regenerated suppressor and patented trap and purification columns to electrolytically regenerate suppressed eluent. A single 4 L bottle of eluent can be recirculated for up to four weeks. When left on, the system remains equilibrated and calibrated between eluent changes. Time that would have been used maintaining the system can now be used for running additional samples, and increasing productivity.



Column: Dionex IonPac AG17, AS17
Eluent: KOH gradient, 1 mM for 1.5 min,
1 mM to 20 mM from 1.5 to 5 min.
20 mM to 40 mM from 5 min to 7 min
Eluent Source: Thermo Scientific Dionex EGC-KOH cartridge
Peaks:

1. Fluoride	2 mg/L	5. Nitrate	10
2. Chloride	20	6. Carbonate	—
3. Nitrite	10	7. Sulfate	20
4. Bromide	5	8. Phosphate	10

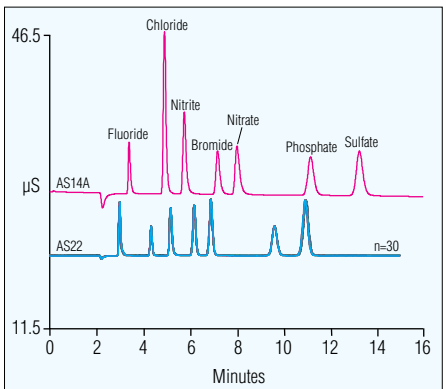
RFIC-EG systems produce consistent run-to-run eluent concentrations for highly reproducible retention times and peak areas.

Reagent-Free System Advantages

In addition to saving time, labor, and operating costs, RFIC systems eliminate errors associated with daily manual eluent preparation. This effectively improves method reproducibility, day to day, week to week, operator to operator. Laboratories using RFIC systems spend less time on equilibration, calibration, method verification, troubleshooting, and consistency checks because the systems minimize unintentional variations in the preparation of eluents and regenerants. RFIC systems not only reduce the manual labor of IC, they make it easy to learn and easy-to-use.

Eluent Generation Advantages

Eluent generators allow automatic production of high purity IC eluents. The precise control of eluent concentration allowed by electrolytic eluent generation prevents baseline shifts, increases sensitivity, improves resolution, and ensures consistent peak integration. By eliminating trace contamination in eluents, these instruments provide outstanding run-to-run reproducibility. The power of RFIC-EG systems extends beyond your laboratory, so your methods and results are reproducible in other laboratories as well. Eluent generation produces highly reproducible retention times with the generation of isocratic carbonate/bicarbonate or gradient hydroxide eluents, as demonstrated in the figures below.



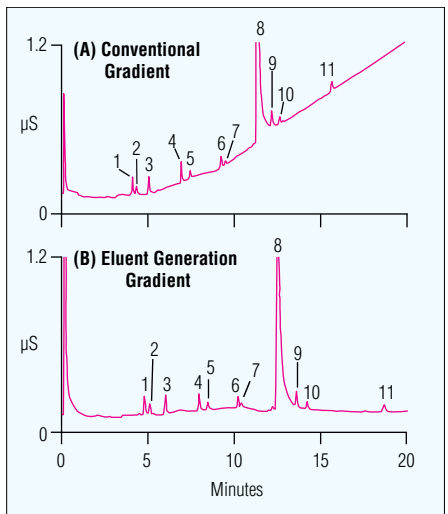
RFIC-EG System Reproducibility with the Dionex IonPac AS22

	Fl	Cl	NO_2	Br	NO_3	PO_4	SO_4
RT % RSD	0.08	0.76	0.05	0.04	0.04	0.05	0.13
Area % RSD	1.4	0.2	0.4	0.09	0.15	0.14	0.11

Separation of seven anions on 4-mm Dionex IonPac AS14A and AS22 columns using a Thermo Scientific Dionex ICS-3000 RFIC-EG system and carbonate eluent generation.

The state-of-the-art Dionex ICS-2100, ICS-4000, and ICS-5000$^+$ RFIC-EG systems provide unprecedented flexibility with the generation of methanesulfonic acid (MSA), carbonate-only, and carbonate/bicarbonate eluents as well as hydroxide eluents. Carbonate eluent generation offers ease-of-use for isocratic IC separations, while hydroxide eluents make both gradient and isocratic IC separations easy and reliable, for the ultimate in chromatographic flexibility and selectivity. MSA generation brings the power of RFIC to cation analysis. Only Thermo Fisher Scientific gives you this choice and offers a full line of Thermo Scientific™ Dionex™ IonPac™ columns designed for all three chemistries.

Eluent generators eliminate the need to handle acids and bases traditionally required for the preparation of IC eluents. An IC system that pumps only deionized water also increases the lifetime of pump seals and pistons, requiring less maintenance than a traditional IC system. The eluent generator has no moving parts and offers precise eluent concentration control, resulting in positive peak identification and excellent reproducibility.



Column: Dionex IonPac AG11, AS11, 2 mm
Eluent Source: A) Manually prepared eluent
B) Dionex EGC-KOH cartridge
Peaks: 0.27 to 1.1 µg/L (ppb)

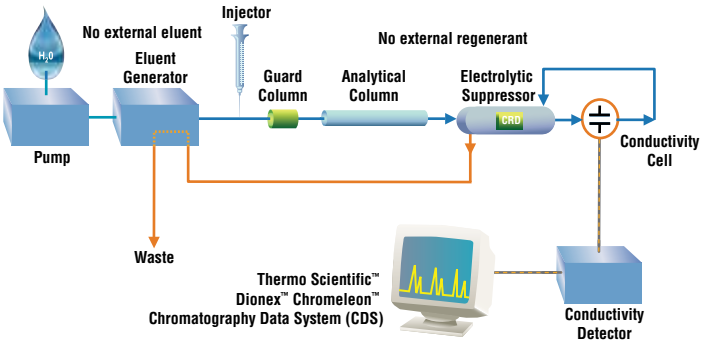
1. Fluoride	7. Nitrate
2. Acetate	8. Carbonate
3. Formate	9. Sulfate
4. Chloride	10. Oxalate
5. Nitrite	11. Phosphate
6. Bromide	

Gradient separation of trace level anions using a hydroxide gradient. The carbonate-free KOH generated by the eluent generator dramatically reduces baseline shifts during the gradient, improving signal-to-noise ratios.

The Power
to Increase Productivity

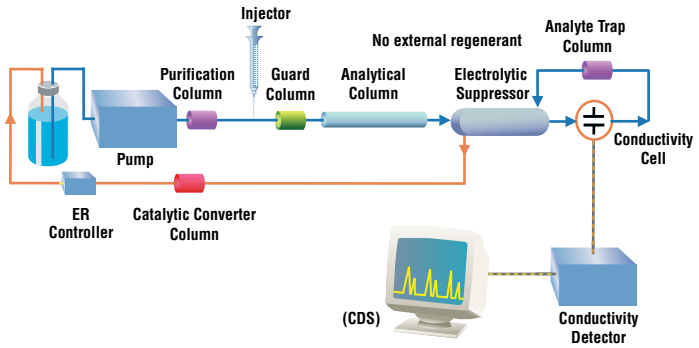
Eluent Regeneration Advantages

Eluent regeneration uses an electrolytic suppressor in combination with trap and purification columns to reconstitute the starting eluent. This approach uses patented technologies to allow use of a single eluent preparation for up to four weeks. The system is a self-contained loop, it is always on, always ready—able to operate continuously without any operator intervention other than loading samples. After the initial setup, the system does not need to be recalibrated or reequilibrated, and waste is reduced from approximately 48 L to just 4 L per month for continuous use.



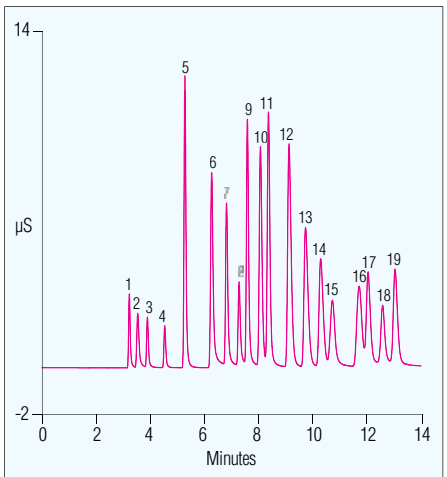
RFIC-EG System

Eluent generators increase accuracy and reproducibility and simplify operation. Eluent generation is an important reason why RFIC-EG systems are superseding traditional IC systems.



RFIC-ER System

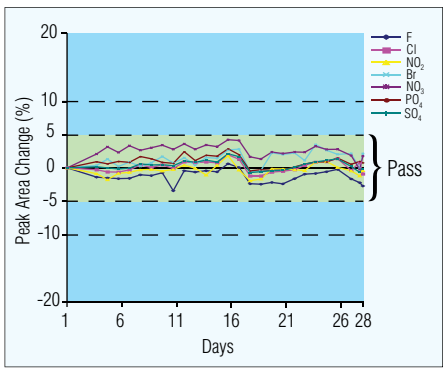
Eluent regeneration saves time and reduces cost for frequent-use isocratic analyses. The always on, always ready RFIC-ER system is ideal for municipalities and contract labs that monitor drinking water quality.



Column:	Dionex IonPac AS18, 4 mm
Eluent:	Potassium hydroxide: 12–44 mM from 0–5 min and 44–52 mM from 8–10 min
Eluent Source:	Dionex EGC-KOH cartridge with CR-ATC Thermo Scientific™ Dionex™ CR-ATC Continuously Regenerated Anion Trap Column
Temperature:	30 °C
Flow Rate:	1.0 mL/min
Inj. Volume:	25 µL
Detection:	Suppressed conductivity, Thermo Scientific™ Dionex™ ASRS™ ULTRA II Anion Self-Regenerating Suppressor™ 4 mm, 150 mA, Thermo Scientific™ Dionex™ AutoSuppression™ device, recycle mode

Peaks:				
1. Fluoride	0.5 mg/L (ppm)			
2. Acetate	0.5	12. Nitrate	10.0	
3. Formate	1.0	13. Chlorate	0.0	
4. Chlorite	5.0	14. Phosphate	10.0	
5. Chloride	3.0	15. Molybdate	10.0	
6. Nitrite	6.0	16. Tungstate	10.0	
7. Selenite	10.0	17. Arsenate	10.0	
8. Sulfite	10.0	18. Thiosulfate	10.0	
9. Sulfate	10.0	19. Chromate	10.0	
10. Bromide	10.0			
11. Selenate	10.0 mg/L (ppm)			

Anion separation including inorganic anions, organic acids, oxyanions, and oxyhalides on a Dionex IonPac AS18 column using a potassium hydroxide eluent delivered by a potassium hydroxide eluent generator using the Dionex EGC II KOH cartridge.



Percent peak area changes over 28 days for a seven-anion calibration check standard separated using a 4-mm Dionex IonPac AS22 column on a Dionex ICS-1500 RFIC-ER system with regenerated carbonate/bicarbonate eluent. The system passed the daily calibration check for an entire month, requiring only one 4 L bottle of eluent.

Eluent regeneration is available as an option for Dionex ICS-1100, -1600, -2100, and 5000^{+} systems. Designed for systems dedicated to high-throughput analyses of samples with low concentration matrices, eluent regeneration can be used for isocratic separations with carbonate, carbonate/bicarbonate, or MSA eluents.

Eluent Generation

Just Add Water

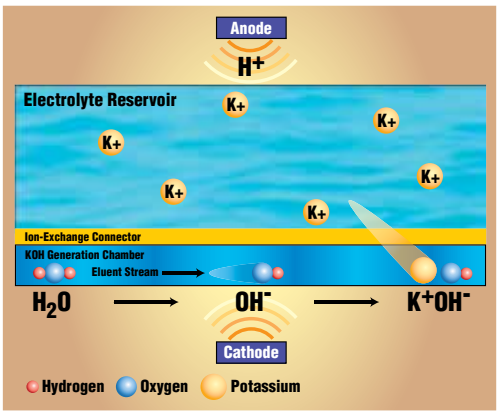
Flexibility to Fit Your Applications

The Eluent Generator Cartridge (EGC) is the heart of the patented eluent generation technology used in RFIC-EG systems. For cation-exchange applications, the Dionex EGC III MSA, EGC MSA (Capillary) and EGC 500 MSA cartridges produce methanesulfonic acid eluents. For anion-exchange applications, the Dionex EGC III KOH, NaOH, or LiOH, EGC KOH (Capillary) and EGC 500 KOH cartridges produce potassium, sodium, or lithium hydroxide eluents. The Dionex EGC III K_2CO_3 cartridge produces carbonate-only eluent, and the Electrolytic pH Modifier (EPM III) can be added for generating carbonate/bicarbonate eluents.

KOH, NaOH, and LiOH Eluent Generation

The Dionex EGC III KOH, EGC KOH (Capillary) and EGC 500 KOH cartridges are the cartridges of choice for use with hydroxide-selective Dionex IonPac columns. The Dionex EGC III NaOH cartridge is ideal for applications using the Dionex IonPac Cryptand A1 analytical or C1 concentrator column. The Dionex EGC III LiOH cartridge is designed for applications using the Dionex IonPac Cryptand A1 column. The Dionex EGC KOH (Capillary) cartridge is designed for generating KOH eluents at capillary flow rates. Both the Dionex EGC KOH (Capillary) and the EGC 500 KOH cartridges are designed for high-pressure IC applications and are rated for operation up to 5000 psi. The Dionex EGC III cartridges are rated to 3000 psi.

The Dionex EGC KOH cartridges consist of a high-pressure KOH generation chamber and a low-pressure K^+ ion electrolyte reservoir. The generation chamber contains a cathode where hydroxide ions are generated. The electrolyte reservoir contains an anode and an electrolyte solution of K^+ ions. A cation-exchange connector permits the passage of K^+ ions from the electrolyte reservoir into the high-pressure generation chamber, and also serves the critical role of a high-pressure physical barrier between the two chambers.



A Dionex EGC KOH generator cartridge consists of a KOH generation chamber and a K^+ electrolyte reservoir, connected by a cation exchange connector. A high-pressure connector permits the passage of K^+ ions from the K^+ electrolyte reservoir into the electrolytic chamber.

To generate a KOH eluent, deionized water is pumped through the KOH generation chamber and a DC current is applied between the anode and cathode of the Dionex EGC cartridge. At the anode, water is oxidized to form H^+ ions and oxygen gas:

$$H_2O \rightarrow 2H^+ + \tfrac{1}{2}O_2 + 2e^-$$

At the cathode, water is reduced to form OH^- ions and hydrogen gas:

$$2H_2O + 2e^- \rightarrow 2OH^- + H_2$$

H^+ ions generated at the anode displace K^+ ions in the electrolyte reservoir. The K^+ ions migrate across the cation-exchange connector into the KOH generation chamber. These K^+ ions combine with OH^- ions generated at the cathode to produce the KOH solution used as eluent for anion-exchange chromatography. The concentration of generated KOH is determined by the current applied to the KOH generator and the flow rate through the KOH generation chamber:

$$[KOH] \propto \frac{I_{applied}}{\text{flow rate}}$$

The same process is used for the generation of potassium, sodium or lithium hydroxide when using the Dionex EGC KOH (Capillary), EGC 500 KOH, or EGC III NaOH or LiOH cartridges, or MSA when using the Dionex EGC III MSA, EGC MSA (Capillary), or EGC 500 MSA cartridges.

Both the Dionex EGC 500 and EGC KOH (Capillary) cartridges can operate at pressures up to 5000 psi, making them suitable for use with high pressure IC systems. We offer a full system qualification that includes pump flow rate, EG current, and EGC reproducibility, you can have confidence in the accuracy of the eluent generated. All concentration commands are automatically logged to Chromeleon CDS's audit trail, making the EG fully GLP compliant.

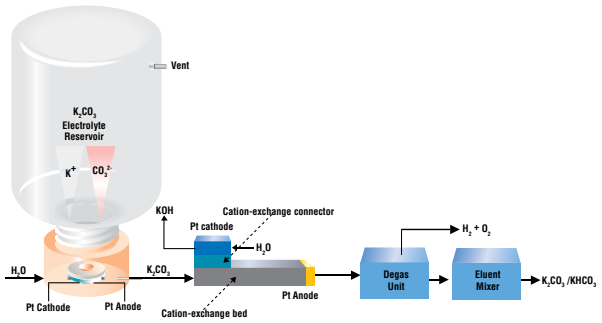
Potassium Carbonate (K_2CO_3) and Bicarbonate ($KHCO_3$) Eluents

Exclusive to the Dionex ICS-2100 and Dionex ICS-5000+ RFIC-EG systems, the Dionex EGC III K_2CO_3 cartridge produces carbonate-only eluent. The Dionex EGC III K_2CO_3 cartridge consists of an electrolyte reservoir filled with a potassium carbonate solution and a high-pressure eluent generation chamber containing both the anode and cathode of the device. The ion-exchange connector of this device consists of two regions: a cation-exchange region and an anion-exchange region.

Under an applied electric field, potassium ions in the electrolyte reservoir migrate across the cation-exchange connector and combine with hydroxide ions formed at the cathode to form potassium hydroxiden. Carbonate ions migrate across the anion-exchange connector and combine with hydronium ions formed at the anode to form carbonic acid. The potassium hydroxide reacts with the carbonic acid to form potassium carbonate. The concentration of potassium carbonate formed is directly proportional to the applied current and inversely proportional to the deionized water flow rate.

The optional EPM III is used for generating carbonate/bicarbonate eluents. Potassium carbonate, generated using the Dionex EGC III K_2CO_3, cartridge is passed through the EPM III. Potassium ions are exchanged with electrolytically generated hydronium ions, thus converting carbonate into bicarbonate. By selecting the current applied to the EPM III, a prespecified concentration of potassium carbonate is converted to bicarbonate.

A degas unit is used to remove the electrolysis gases (hydrogen and oxygen) generated. A mixer is also used to provide sufficient mixing of potassium hydroxide and carbonic acid or potassium carbonate and bicarbonate to obtain a homogeneous eluent solution.



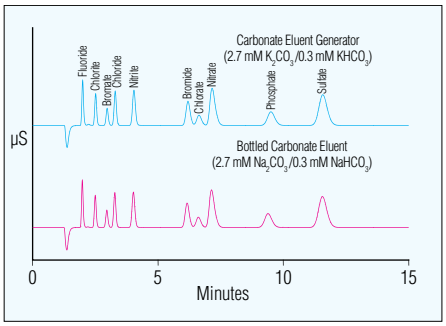
Electrolytic generation of mixed carbonate/bicarbonate eluent using a Dionex EGC III K_2CO_3 cartridge EPM III.

Eluent Regeneration

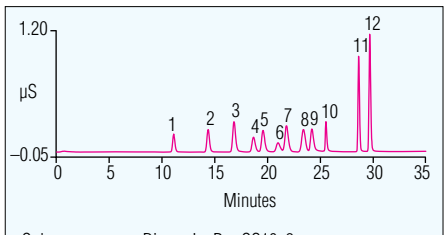
Always on, Always Ready

Cost-Effective Time and Labor Savings

Advances in IC automation have simplified operation while increasing precision and accuracy. However, eluent preparation, calibration, and equilibration still take operator and instrument time away from analysis. To save time and labor, eluent regeneration was developed for systems dedicated to high-throughput analyses of samples with low to moderate concentration matrices. RFIC-ER systems are designed to use carbonate, carbonate/bicarbonate, or MSA eluents for isocratic separations. Eluent regeneration is available as an optional configuration or upgrade for Dionex ICS-1100, -1600, -2100, and -5000$^+$ systems.



Anion separation using the Dionex IonPac AS14 column. As shown, the carbonate eluent generator cartridge in combination with an EPM compares favorably to an existing method using manually prepared eluent.



Column: Dionex IonPac CS18, 2 mm
Eluent: MSA gradient
Eluent Source: Dionex EGC II MSA cartridge

Peaks:

1. Lithium	0.1	7. Potassium	1.0	mg/L
2. Sodium	0.4	8. Dimethylamine	0.8	
3. Ammonium	0.5	9. Triethanolamine	9.0	
4. Ethanolamine	1.0	10. Trimethylamine	3.0	
5. Methylamine	1.0	11. Magnesium	0.5	
6. Diethanolamine	2.0	12. Calcium	1.0	

Cation separation of ethanolamines, methylamines, and the six common cations using a methaneslfonic acid (MSA) eluent delivered by an MSA eluent generator (Dionex EGC II MSA).

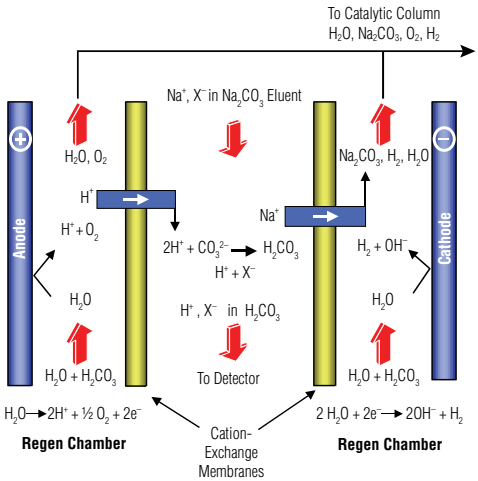
Eluent regeneration uses the suppressor to reconstitute the starting eluent, allowing use of a single 4 L bottle of eluent for up to four weeks. Because the system is a closed loop, it can run continuously, eliminating the need for recalibration or reequilibration during the 28 days of eluent regeneration. Eluent preparation and waste disposal are both reduced from approximately 48 L to 4 L per month, reducing not only labor but also costs for materials and hazardous waste disposal.

Regenerating Eluent

The same electrolytic process that suppresses eluent for detection is used to regenerate eluent for reuse. After detection, suppressed eluent is passed through an analyte trap column to remove the analyte ions. The suppressed eluent is then returned to the suppressor to provide the water for electrolytic suppression. The effluent from the suppressor contains the eluent ions and H_2 and O_2 gases. A catalytic column recombines the oxygen and hydrogen to form water. The suppressor effluent is then returned to the eluent reservoir for reuse. Because the electrolysis gases are recombined stoichiometrically, no water is lost in the system and eluent concentration remains constant. A purification column is plumbed after the pump to further assure eluent purity.

Care-Free Consistency

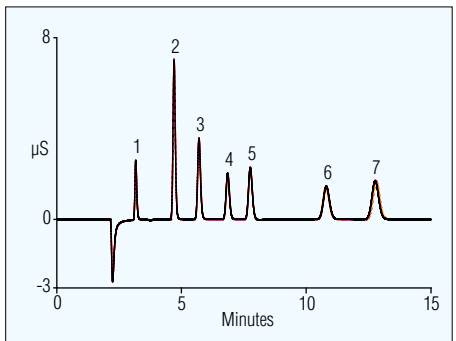
Eluent regeneration not only reduces labor, it also increases consistency over manual eluent preparation. Because the same eluent is used for up to four weeks, variations in preparation procedures are eliminated. Stable eluent concentration yields reproducible results, with little variability in peak retention times or areas. The system does not need to be recalibrated as it would if eluent were prepared manually. A daily calibration check standard is sufficient to assure accuracy.



Carbonate eluent regenerated using a Dionex ASRS 300 Anion Self-Regenerating Suppressor.

Because the system forms a closed loop, it can be left running without the need to empty waste or prepare eluent for up to four weeks. Continuous operation eliminates the need to reequilibrate, and with no need to prepare eluent, all the operator has to do is load samples. This means higher sample throughput and more time for operators to pursue other tasks. Pump maintenance is also reduced, since the flowing eluent has no chance to crystallize on pump surfaces.

Eluent can be regenerated for up to four weeks for analysis of samples with low-concentration matrices, such as drinking water. Higher injection volumes or heavy workloads may require more frequent replacement or regeneration of trap and purification columns and eluent. Chromeleon CDS software wellness features monitor eluent, trap, and column usage, and alert operators when replacement or regeneration is necessary.



Column: Dionex IonPac AS22, 4 mm
Eluent: 4.5 mM carbonate/ 1.4 mM bicarbonate
Eluent Source: Eluent regeneration

Peaks:

1. Fluoride	0.5 mg/L
2. Chloride	2.5
3. Nitrite	2.5
4. Bromide	2.5
5. Nitrate	2.5
6. Phosphate	5.0
7. Sulfate	2.5

Overlay of seven daily calibration check standards separated on a Dionex ICS-1500 RFIC-ER system using regenerated carbonate/bicarbonate eluent. RFIC-ER systems can run for up to a month using a single eluent preparation without requiring recalibration or reequilibration.

RFIC System Tools

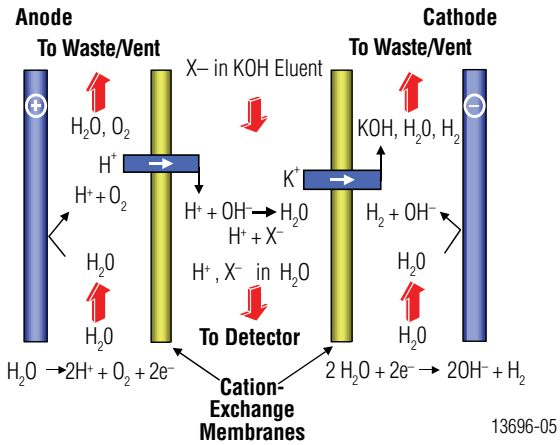
Electrolytically Regenerated Suppressors

The Thermo Scientific™ Dionex™ ERS™ 500 Electrolytically Regenerated Suppressor and the Thermo Scientific™ Dionex™ Atlas™ Suppressor electrolytically generate the ions necessary for eluent suppression through the electrolysis of water. To the analyst, this patented process means no regenerant solutions to make and no need for off-line regeneration of the suppressor to achieve low background and high signal-to-noise levels. Dionex IC systems with electrolytic suppressors are easy to start up, and once the system is started it runs without operator intervention—with superior results. In both isocratic and gradient separations, RFIC suppressors deliver low background signals, low noise levels, and stable baselines through the selective electrochemical migration of ions. These advantages result in dramatic improvements in analyte detection limits.

When used for anion analysis, the Thermo Scientific Dionex AERS 500 Anion Electrolytically Regenerated Suppressor converts highly conductive hydroxide-based eluents into pure water and carbonate-based eluents into carbonic acid. The Dionex AERS 500 suppressor achieves this by completely exchanging eluent cations (e.g., potassium or sodium) with hydronium ions. The schematic below shows the suppression of KOH eluent inside a Dionex AERS 500 suppressor. Analyte anions elute from the column with potassium counter ions. Two electrodes, one beside each membrane (on the side opposite the eluent), electrolyze water to hydronium and hydroxide ions. Hydronium ions diffuse across the membrane next to the anode, neutralizing the hydroxide eluent to water, while potassium ions from the eluent diffuse across the other membrane, providing counter ions to the hydroxide being generated at the cathode. In effect, potassium hydroxide from the eluent is transferred across the membrane and does not reach the detector. The suppressor functions to lower background conductivity (and thus baseline noise and drift) and increase the signal. The resulting eluent background conductivity is near zero, many orders of magnitude lower than before suppression.

Likewise, when used for cation analysis, the Thermo Scientific Dionex CERS 500 Cation Electrolytically Regenerated Suppressor converts highly conductive MSA eluents into pure water. This simplification of IC methodology has led to wider use of cation-exchange applications due to the elimination of expensive suppressor regeneration solutions.

The Dionex ERS 500 suppressor is also a key component of RFIC-ER systems. When the Dionex ERS 500 suppressor is used in recycle mode, suppressed eluent is returned to the suppressor after detection to serve as the water source for electrolysis. The effluent from the suppressor contains the eluent ions, analyte ions, and H_2 and O_2 gases. A RFIC-ER system uses patented trap and catalytic column technologies to purify this effluent for reuse.



Chemistry and ion movement in a Dionex AERS 500 suppressor.

Continuously Regenerated Trap Columns (CR-TC)

Thermo Scientific Dionex CR-TC Continuously Regenerated Trap Columns are high-pressure electrolytically regenerated devices designed for use with hydroxide and MSA eluent generators exclusively. These trap columns operate continuously, without the need for off-line chemical regeneration, to remove trace levels of contaminants introduced by the feed water. Dionex CR-TC's allow operation with very low baseline drift during gradient operation and improve day-to-day and lab-to-lab reproducibility. The Thermo Scientific Dionex CR-ATC Continuously Regenerated Anion Trap Column (Dionex CR-ATC 500 or CR-ATC Capillary) when plumbed after a Dionex EGC 500 KOH, EGC KOH (Capillary), EGC III KOH, NaOH or LiOH, NaOH, or LiOH cartridge, removes all anionic contaminants (including carbonate) for anion-exchange applications. Trace level cationic contaminants (including ammonia) are removed by the Thermo Scientific Dionex CR-CTC Continuously Regenerated Cation Trap Column (Dionex CR-CTC 500 or CR-CTC Capillary) when plumbed after a Dionex EGC 500 MSA, EGC MSA (Capillary) or EGC III MSA cartridge. The Dionex CR-TC column is available in two size formats, the Dionex CR-TC 500 column for standard and microbore systems, and the Dionex CR-TC (Capillary) column for capillary systems. Both the Dionex CR-TC 500 and CR-TC (Capillary) columns can operate at pressures up to 5000 psi making them suitable for use with high-pressure IC systems.

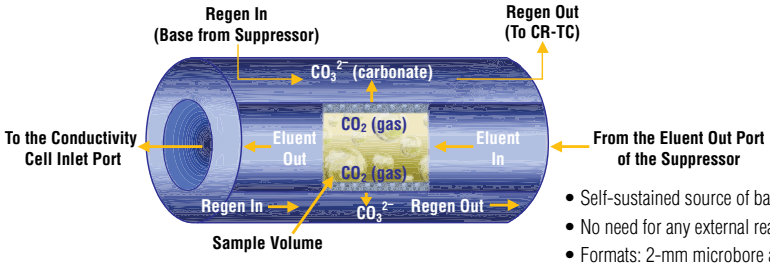
Thermo Scientific Dionex CRD 180 and 200 Carbonate Removal Device: an Optional Analytical Tool for Hydroxide Eluents

Absorption of carbon dioxide from air into a sample will often introduce carbonate contamination. In hydroxide eluent chemistries, the presence of high levels of carbonate can interfere with the accurate determination of analytes of interest, such as sulfate and nitrite. Under the above conditions minimizing the carbonate interference leads to improved quantitation.

The Thermo Scientific Dionex CRD 200 Carbonate Removal Device minimizes interference from sample-introduced carbonate in hydroxide-based eluents. The Dionex CRD 200 reduces the carbonate peak after the chromatographic separation, thereby improving peak integration and quantitation for analytes such as sulfate and nitrite.

The Dionex CRD 200 is installed into a RFIC-EG system flow path after the suppressor. The device consists of a thin film of carbon dioxide-permeable coating on the exterior surface of a narrow-bore capillary membrane tube, surrounded by a regenerant

Better Results with Electrolytic Suppressors, Trap Columns, and Carbonate Removal Devices.



- Self-sustained source of base
- No need for any external reagents
- Formats: 2-mm microbore and 4-mm standard bore available

The Dionex CRD 200 requires no reagents or software control and is particularly useful for analyzing drinking water, groundwater, wastewater, ultrapure water, and caustic solutions where carbonate is a major component in the samples, especially when pursuing large-volume injections or preconcentration techniques. The Dionex CRD 200 is available in two formats for 2 mm microbore and 4 mm standard bore applications.

chamber. Suppressed eluent is routed inside the coated capillary membrane tube. Carbonate, carbonic acid, and carbon dioxide are in equilibrium in the eluent. As carbon dioxide diffuses through the coated capillary membrane, the carbonic acid/carbon dioxide equilibrium

$$CO_2 + H_2O \leftrightarrows H_2CO_3$$

is driven to the left, releasing and removing more carbon dioxide. A self-sustained source of base originating from the suppressor sweeps the exterior of the capillary tube, removing the carbon dioxide. In normal operation, the Dionex CRD 200 removes the peak comprised of carbonic acid from the sample. The removed carbon dioxide is quickly converted to carbonate—due to the presence of base in the exterior chamber—and then swept to waste.

The Dionex CRD 180 (Capillary) is a low-volume version of the Dionex CRD 200 (Capillary). It is designed for use with columns utilizing 4 µm resin beads. It is not recommended for use with columns utilizing resin beads 5 µm and above.

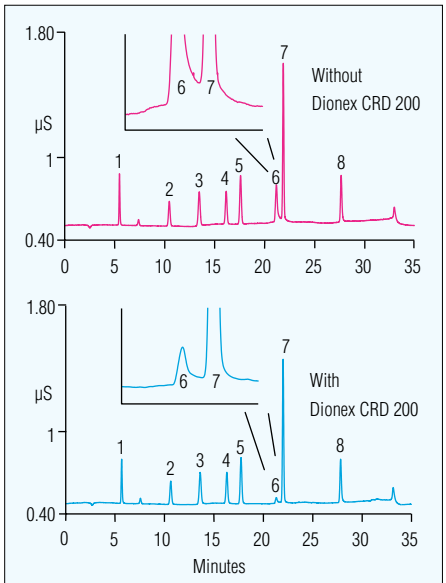
Dionex CRD 300 Carbonate Removal Device: an Optional Analytical Tool for Carbonate Eluents

The carbonate suppression reaction converts highly conductive sodium carbonate species into far less conductive carbonic acid species. The residual conductivity of the carbonic acid does not interfere with most analyses. However, this residual conductivity can reduce the detection limit and linearity range of the system, making certain applications difficult with carbonate eluents.

The Dionex CRD 300 removes carbonic acid from the suppressed eluent before detection, thus eliminating most of the residual conductivity. The Dionex CRD 300 can reduce the background conductivity of electrolytically generated or manually prepared eluents consisting of up to 15 mM carbonate (not for use with RFIC-ER systems). Background noise can be reduced to less than 1.0 µS; levels typically only seen with hydroxide eluents for anion separations. The Dionex CRD 300 has a higher capacity than the Dionex CRD 200, and cannot maintain a self-sustained source of base from the suppressor. Either an external source of base (external regenerant mode) or a vacuum (vacuum mode) must be used to regenerate the Dionex CRD 300.

In external regenerant mode, a peristaltic pump delivers a sodium hydroxide solution to the regenerant chamber of the Dionex CRD 300. As the carbonic acid eluent passes through the eluent chamber, carbon dioxide crosses the carbonate selective barrier, is converted to sodium carbonate, and is swept away. Only a tiny fraction of the sodium hydroxide is converted to sodium carbonate, so the regenerant waste can be returned to the regenerant container in a closed loop. The same regenerant can be circulated for up to one month of constant operation.

In vacuum mode, a vacuum pump evacuates the regenerant chamber, thus drawing carbonic acid across the carbonate-selective barrier where it is converted to carbon dioxide gas. Carbon dioxide is swept away by bleeding fresh air into the regenerant chamber inlet. This mode offers the main advantage that corrosive regenerant solutions are not required for operation.



Column:	Dionex IonPac AS19, 4 mm
Eluent:	Dionex EGC-KOH cartridge
Time:	Gradient (mM)
0	10
10	10
25	45
30	45
30.1	10
35	10
Flow Rate	1.0 mL/min
Inj. Volume:	200 µL
Temperature:	30 °C
Detection:	Suppressed conductivity

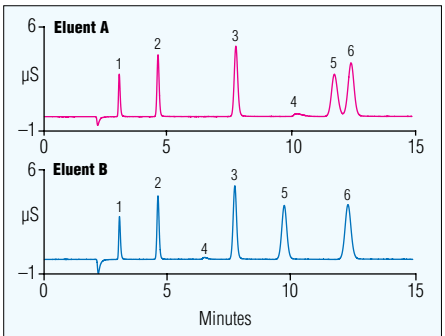
Peaks:	
1. Fluoride	10 µg/L (ppb)
2. Chloride	15
3. Nitrite	50
4. Bromide	50
5. Nitrate	50
6. Carbonate	n/a
7. Sulfate	75
8. Phosphate	75

Anion separation showing the expected reduction of the interfering carbonate after the Dionex CRD 200 is installed, facilitating improved sulfate quantitation.

Drinking Water

RFIC Systems Deliver Improvements for Your Applications

RFIC systems are the culmination of more than 30 years of innovative Thermo Scientific technology development, covering electrolytic eluent generation, continuously regenerated trap columns, Dionex IonPac anion- and cation-exchange columns, and electrolytically regenerated eluent suppressors. These state-of-the-art components combine to increase productivity and capability in your laboratory.



Column: Dionex IonPac AG22, AS22, 4 mm
Eluent Source: Dionex EGC II K_2CO_3 / electrolytic pH modifier (EPM)
Eluents: (A). 4.5 mM Sodium carbonate/ 0.5 mM sodium bicarbonate
(B). 4.5 mM Sodium carbonate/ 3.5 mM sodium bicarbonate
Flow Rate: 1.2 mL/min
Temperature: 30 °C
Sample Volume: 25 µL

Peaks:		mg/L (ppm)
1.	Fluoride	1
2.	Chloride	3
3.	Nitrate	10
4.	Carbonate	300
5.	Phosphate	20
6.	Sulfate	10

The Dionex IonPac AS22 and AS23 columns allow carbonate peak placement anywhere between nitrate and sulfate, depending on the pH of the eluent. The Dionex EGC II K_2CO_3 cartridge combined with the EPM allows precise control of the eluent pH.

Water Analysis

RFIC systems are ideal for a wide range of water analyses. With proven accuracy and precision, RFIC systems are acceptable in virtually all regulatory environments.

RFIC-EG systems provide the most flexibility for drinking, waste-, and ground water analyses for regulatory compliance, as well as the accuracy and reproducibility required for the analysis of high-purity water for the semiconductor and power industries. Electrolytically generated carbonate/bicarbonate eluents can be tailored to fit your existing procedures. Electrolytically generated gradients provide the flexibility needed for the analysis of water samples with a wide variety of matrices.

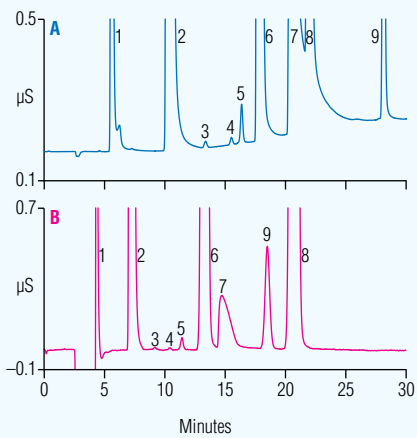
Carbonate/Bicarbonate Generation for EPA Method 300.0 Part A and Method 300.1 Part A

The Dionex IonPac AS22 is a high-capacity carbonate-selective anion-exchange column designed for compliance with EPA Methods 300.0 Part A and 300.1 Part A. The Dionex IonPac AS23 column is ideal for the determination of oxyhalides formed during the disinfection of drinking water, and is recommended for the determination of low-µg/L concentrations of bromate, a carcinogenic by-product of ozone disinfection. These two columns offer the unique advantage of allowing the carbonate peak's relative retention time to be adjusted by changing the eluent pH. The carbonate peak can be placed anywhere between the nitrate and sulfate peaks, allowing the operator to minimize interference with peaks of interest.

Hydroxide Generation for EPA Method 300.0 Part A and Method 300.1 Part A

The EPA's Statistics and Analytical Support Branch and the Office of Ground Water and Drinking Water's Technical Support Center have concluded that the use of hydroxide eluents falls within the method flexibility allowed in EPA Methods 300.0 Part A and 300.1 Part A for determining inorganic anions. These methods are critical for compliance monitoring under the Clean Water Act and Safe Drinking Water Act.

The Dionex IonPac AS18 is a hydroxide-selective anion-exchange column designed for the fast separation of common inorganic anions, including fluoride, acetate, chloride, nitrite, bromide, nitrate, carbonate, sulfate, and phosphate. The Dionex IonPac AS19 high-capacity, hydroxide-selective, anion-exchange column is designed for the analysis of oxyhalides and the common inorganic anions including fluoride, chlorite, bromate, chloride, nitrite, bromide, chlorate, nitrate, phosphate, and sulfate in drinking water, groundwater, wastewater, and other diverse sample matrices. The selectivity of the Dionex IonPac AS19 column ensures that bromate can be quantified at low-µg/L concentrations using suppressed conductivity detection, even in the presence of very high concentrations of chloride, sulfate, and carbonate.



Column: A)Dionex IonPac AG19, AS19, 4 mm
B)Dionex IonPac AG23, AS23, 4 mm
Eluent: A)10 mM KOH 0-10 min,
10-45 mM 10-25 min,
45 mM 25-30 min
B)4.5 mM potassium carbonate/
0.8 mM potassium bicarbonate
Eluent Source: A)Dionex EGC II KOH cartridge with Dionex CR-ATC Continuously Regenerated Anion Trap Column
B)EGC II K_2CO_3 / EPM
Temperature: 30 °C
Flow Rate: 1.0 mL/min
Inj. Volume: 250 µL
Detection: Suppressed conductivity,
A) Recycle mode
B) External mode

Peaks:		A	B	
1.	Fluoride			
2.	Chloride			
3.	Nitrite			
4.	Chlorate	4.4	4.6	µg/L
5.	Bromide			
6.	Nitrate			
7.	Carbonate			
8.	Sulfate			
9.	Phosphate			

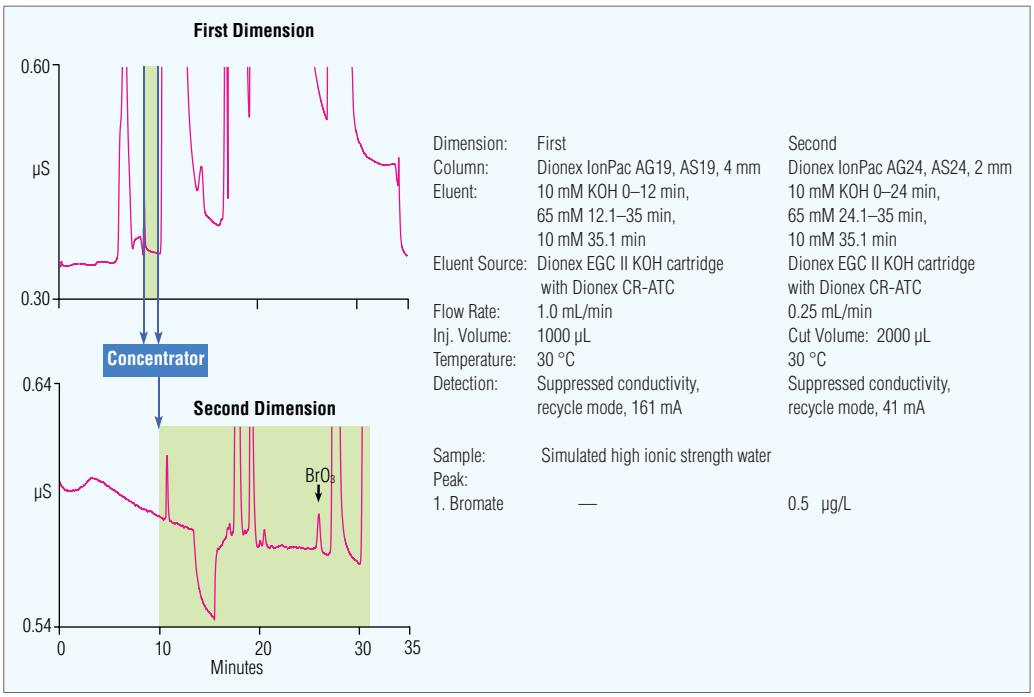
Comparison of Dionex IonPac AS19 and AS22 column performances. Both columns meet the performance requirements specified in EPA Method 300.0 and Method 300.1 for the determination of oxyhalides produced as by-products during disinfection of drinking water.

Hydroxide Generation for Determination of Bromate in Drinking Water Using Two-Dimensional Ion Chromatography

Ozone is a powerful drinking water disinfectant, effective in treating chlorine-resistant organisms. However, ozonation of water containing bromide can result in the formation of bromate, a carcinogen. The U.S. EPA and European Commission have established a regulatory maximum contaminant level of 10 µg/L of bromate in drinking waters, and the U.S. FDA has established the same limit for bottled drinking waters. The European Commission has set a lower limit of 3 µg/L for bottled natural spring waters and mineral waters treated by ozonation. Low levels of bromate can be difficult to determine using conductivity detection because matrix anion signals can interfere with bromate, and high-concentration matrices can overload the column, broadening or obscuring the bromate peak. Postcolumn reaction methods using UV detection do not suffer from interference, but can still lose sensitivity due to column overloading.

Two-dimensional IC (2D-IC) for bromate analysis uses an electrolytically generated hydroxide eluent and a high-capacity Dionex IonPac AS19 4-mm anion-exchange column to separate the bromate-containing fraction (cut volume) of a sample from the bulk of the matrix ions. The cut volume is focused on a concentrator column, then eluted onto a Dionex IonPac AS24 2-mm anion-exchange column. The smaller-diameter column resolves the bromate, allowing a detection limit of 0.036 µg/L regardless of matrix ionic strength.

The purity and precision of eluent produced by a RFIC-EG system facilitates trace detection, and the automation of the eluent gradients makes this complicated procedure easy. The electrolytic suppression of the eluent to water allows the cut volume to be concentrated before analysis in the second dimension, reducing detection limits.

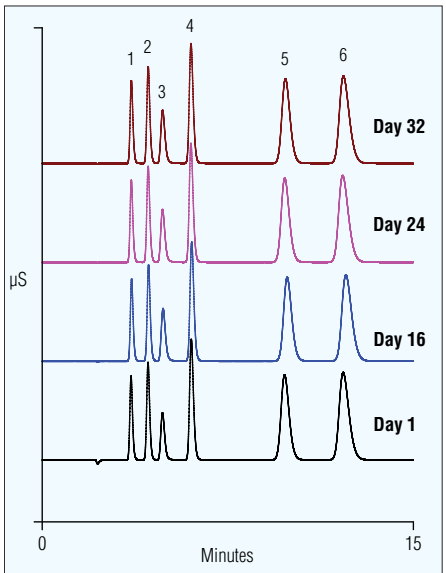


Dimension:	First	Second
Column:	Dionex IonPac AG19, AS19, 4 mm	Dionex IonPac AG24, AS24, 2 mm
Eluent:	10 mM KOH 0–12 min, 65 mM 12.1–35 min, 10 mM 35.1 min	10 mM KOH 0–24 min, 65 mM 24.1–35 min, 10 mM 35.1 min
Eluent Source:	Dionex EGC II KOH cartridge with Dionex CR-ATC	Dionex EGC II KOH cartridge with Dionex CR-ATC
Flow Rate:	1.0 mL/min	0.25 mL/min
Inj. Volume:	1000 µL	Cut Volume: 2000 µL
Temperature:	30 °C	30 °C
Detection:	Suppressed conductivity, recycle mode, 161 mA	Suppressed conductivity, recycle mode, 41 mA
Sample:	Simulated high ionic strength water	
Peak:		
1. Bromate	—	0.5 µg/L

High concentration matrices containing common anions such as Cl^- and SO_4^{2-} can overload IC columns, making low concentrations of bromate undetectable. Two-dimensional IC uses a high-capacity Dionex IonPac AS19 4-mm column to separate bromate from the matrix, and a Dionex IonPac AS24 2-mm column to determine trace bromate.

Eluent Regeneration for Water Analysis

RFIC-ER systems are best suited for the analysis of anions and cations in low-concentration matrices, such as drinking, surface, or groundwater. RFIC-ER systems are compatible with methods using isocratic elution with carbonate, carbonate/bicarbonate, or MSA. The ability to regenerate the eluent automatically, combined with robust analysis, is ideal for labs performing dedicated drinking water analysis.



Column:	Dionex IonPac CG12A, CS12A, 4 mm
Eluent:	20 mM MSA
Eluent Source:	Regenerated MSA
Flow Rate:	1.0 mL/min
Inj. Volume:	25 µL
Temperature:	30 °C
Detection:	Suppressed conductivity, Thermo Scientific Dionex AutoSuppression™ device, recycle mode, 59 mA
Peaks:	1. Lithium 2. Sodium 3. Ammonium 4. Potassium 5. Magnesium 6. Calcium

Overlay of representative chromatograms of a six cation standard determined using an RFIC-ER system and a single preparation of 20 mM MSA. Peak retention times are highly reproducible, even after the eluent has been recycled for 32 days.

Foods and Pharmaceuticals

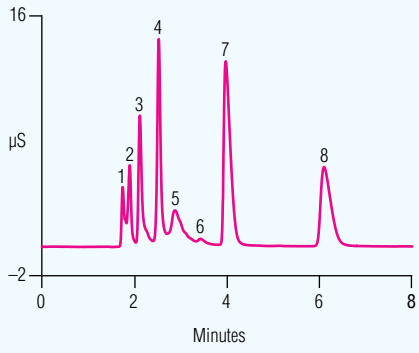
The Versatility of RFIC Systems

Phosphate and Citrate in Soda

Phosphoric and citric acids in cola soft drinks can be analyzed in less than seven minutes using an isocratic potassium hydroxide eluent delivered by an eluent generator in combination with suppressed conductivity detection. The hydroxide-selective Dionex IonPac Fast Anion IIIA column is rugged and reliable for this application.

Analyzing Trace Anions and Cations

Eluent generation makes trace level analysis of anions and cations routine. The ultrapure hydroxide produced by the Dionex EGC III KOH cartridge results in a low, stable baseline, which makes integration easier. Using the eluent generator with the Dionex CR-TC trap columns minimizes baseline shift during the step changes or gradients. For cation determinations the Dionex EGC III MSA cartridge delivers ultrapure MSA for a low, stable baseline and reproducible retention times.



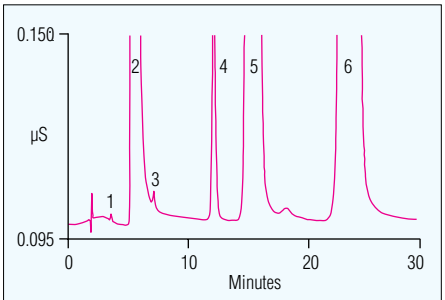
Column:	Dionex IonPac Fast Anion IIIA Guard and Analytical, 3 mm		
Eluent:	22 mM potassium hydroxide		
Eluent Source:	Dionex EGC II KOH cartridge with Dionex CR-ATC column		
Temperature:	30 °C		
Flow Rate:	1.0 mL/min		
Inj. Volume:	1.3 µL		
Detection:	Suppressed conductivity, Dionex AutoSuppression, device, recycle mode		
Peaks:	1. Unknown	—	mg/L (ppm)
	2. Unknown	—	
	3. Unknown	—	
	4. Unknown	—	
	5. Unknown	—	
	6. Unknown	—	
	7. Phosphate	228	
	8. Citrate	175	

Phosphate, citrate, and other important anions are separated in less than seven minutes using 22 mM potassium eluent delivered isocratically with a Dionex IonPac Fast Anion IIIA column.

The soft drink industry is the largest user of the anion benzoate as a preservative to prevent bacteria from breaking down the high fructose corn syrup in many carbonated beverages. Soft drinks contribute the largest proportion of benzoate to human consumption.

The U.S. Food and Drug Administration (FDA) regulates the uses of benzoate as a preservative in the USA. The FDA lists benzoate as a substance that is generally recognized as safe (GRAS) with a maximum permitted concentration of 0.1% in accordance with good manufacturing or feeding practices. Similarly, benzoate is regulated in Europe by the European Union Legislation (Directive 95/2/EC) with a limit of 0.015% in soft drinks and up to 0.2% in other food products.

The chromatogram below demonstrates a simple and reliable RFIC-EG system method for the determination of benzoate in food products using a high-capacity, hydroxide selective, anion-exchange column. The method can also determine other anions that are often present in food products, such as chloride, phosphate, and citrate. In comparison to previously reported methods for benzoate, the RFIC-EG system provides added convenience and simplicity for the user by enabling full control of the hydroxide eluent concentration through Chromeleon CDS software. Samples require only a simple dilution prior to injection, and the precision is significantly improved by avoiding manual preparation of eluents.

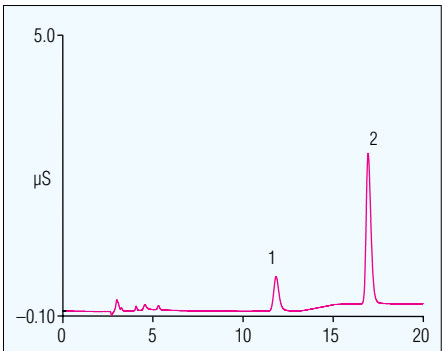


Column:	Dionex IonPac CG16, CS16, 5 mm		
Eluent:	26 mM Methanesulfonic acid		
Eluent Source:	Dionex EGC-MSA cartridge with Dionex CR-CTC column		
Temperature:	30 °C		
Flow Rate:	1.5 mL/min		
Inj. Volume:	10 µL		
Detection:	Suppressed conductivity Dionex AutoSuppression, device, recycle mode		
Sample Prep:	Filtration		
Peaks:	1. Lithium	<0.2 mg/L (ppm)	
	2. Sodium	200	
	3. Ammonium	0.03	
	4. Potassium	0.5	
	5. Magnesium	8.0	
	6. Calcium	20	

Group I and II cations and trace level ammonium are optimally resolved using the Dionex IonPac CS16 column with 26 mM MSA and suppressed conductivity detection.

Determination of Cations in High Sodium Matrices

Cation-exchange IC methods are similarly streamlined using RFIC-EG systems with cation-exchange columns. The MSA eluent used with the Dionex IonPac CS16 column in this application is easy to program into the application method and allows isocratic separation of Group I and Group II cations and ammonium.

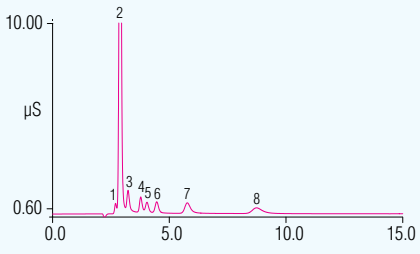


Column:	Dionex IonPac AG18, AS18, 4 mm		
Eluent:	35 mM KOH 0–10 min, 35–40 mM, 10–12 min		
Eluent Source:	Dionex EGC II KOH cartridge with Dionex CR-ATC column		
Temperature:	30 °C		
Flow Rate:	1.0 mL/min		
Inj. Volume:	25 µL		
Detection:	Suppressed conductivity, Dionex AutoSuppression, device, recycle mode		
Sample Prep:	1:1000 dilution		
Peaks:	1. Benzoate	0.04 %	
	2. Citrate	–	

RFIC systems are ideal for the determination of benzoate in food products, using the high-capacity, hydroxide selective Dionex IonPac AS18 column.

Ammonium salts and amines are widely used in various industries, such as the chemical, manufacturing, power, and pharmaceutical industries. In pharmaceuticals, amines are used in the production of some emulsifying agents and medications. Bethanechol chloride is a quaternary ammonium compound that is administered either as an injection or tablet for the treatment of urinary retention. A method in the U.S. Pharmacopeia (USP-29 NF 24, page 278) specifies the use of a Dionex IonPac CS14 cation-exchange column using a MSA eluent and suppressed conductivity detection for the assay of bethanechol chloride. Electrolytically generated MSA may also be used. The RFIC-EG system optimizes reproducibility, convenience, and method transfer between laboratories.

The separation and detection of bethanechol and 2-hydroxypropyltrimethylammonium (2-HPTA) using the Dionex IonPac CS14 column with electrolytically generated 20 mM MSA and suppressed conductivity detection is shown below. These pharmaceutically important amines were shown to be well resolved from the common inorganic cations that may be present as inactive ingredients. Optimal reproducibility of the retention times of these analytes was achieved with the continuous on-line generation of MSA using a RFIC-EG system.



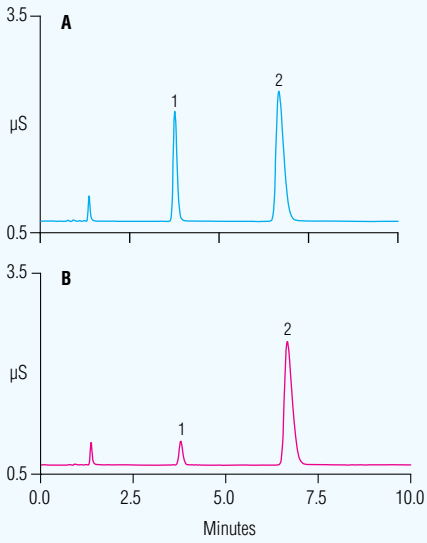
Retention Times	
1. Lithium	2.697 min
2. Sodium	2.893
3. Ammonium	3.233
4. Potassium	3.777
5. Magnesium	4.043
6. Calcium	4.463
7. 2-hydroxypropyltrimethyl ammonium	5.770
8. Bethanechol	8.737

Chromatogram showing the separation and detection of bethanechol and 2-hydroxypropyltrimethylammonium (2-HPTA) using the Dionex IonPac CS14 column with electrolytically generated 20 mM MSA and suppressed conductivity detection.

Determination of Phosphate and Citrate in Pharmaceutical Formulations

IC with suppressed conductivity detection is the chromatographic technique of choice for citrate determination. IC can simultaneously determine phosphate and other anions that are present in some pharmaceutical formulations and uses eluents that do not require expensive reagents or pH adjustments.

An IC method using a low-capacity, hydroxide selective, anion-exchange Dionex IonPac AS11 column with suppressed conductivity detection provides an efficient and rapid separation of phosphate and citrate in different pharmaceutical formulations. This method meets USP performance requirements in terms of specificity, linearity, precision, and recovery of samples spiked with phosphate and citrate. Laboratories that currently support multiple USP citrate assays for different pharmaceutical formulations may be able to standardize on this single IC assay. This assay can incorporate electrolytic generation of the potassium hydroxide eluent to enhance the consistency of the results between analysts and laboratories.



Column:	Dionex IonPac AG11, AS11, 4 mm		
Eluent:	20 mM KOH		
Eluent Source:	Dionex EG II KOH cartridge with Dionex CR-ATC column		
Flow Rate:	2.0 mL/min		
Inj. Volume:	10 µL		
Temperature:	30 °C		
Detection:	Suppressed conductivity, Dionex AutoSuppression, device, recycle mode, 130 mA		
Sample:	A) Standard B) Anticoagulant citrate, phosphate, dextrose, and adenine dosage form		
		A	B
Peaks:	1. Phosphate	12	2.6 mg/L
	2. Citrate	20	21

Chromatogram showing the separation and detection of phosphate and citrate in an anticoagulant formulation, using the Dionex IonPac AS11 column with electrolytically generated 20 mM KOH and suppressed conductivity detection.

The Software Behind RFIC Systems

Effortless Control of Your RFIC System

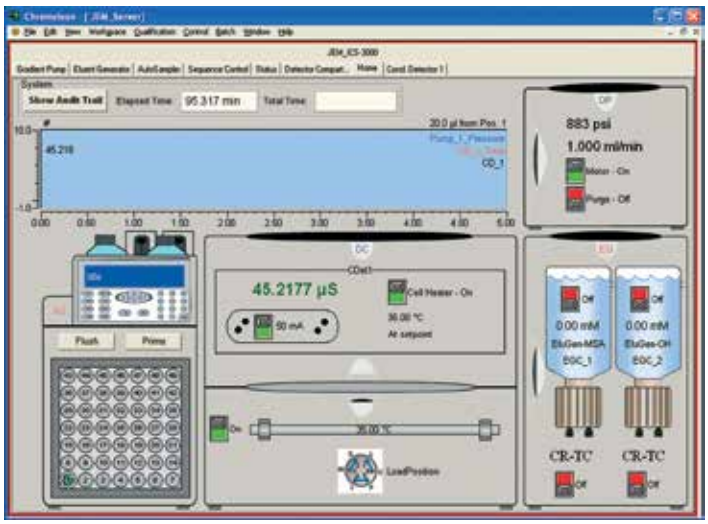
Gain immediate access to the power of RFIC systems with the Chromeleon CDS software. Simply set your desired conditions through the friendly user interface, and let Chromeleon CDS do all the work preparing and running your system and collecting your data.

With the graphical editing tools available in Chromeleon CDS, even complex concentration gradients can be performed accurately and easily. Seamless digital control between Chromeleon CDS and your instrument ensures that your commands are executed perfectly. Wellness functions monitor usage of instrument parts and consumables, and can be programmed to warn you when replacement or regeneration is necessary. When you combine Chromeleon CDS with RFIC systems, you get the fastest, easiest, and most precise IC possible today.

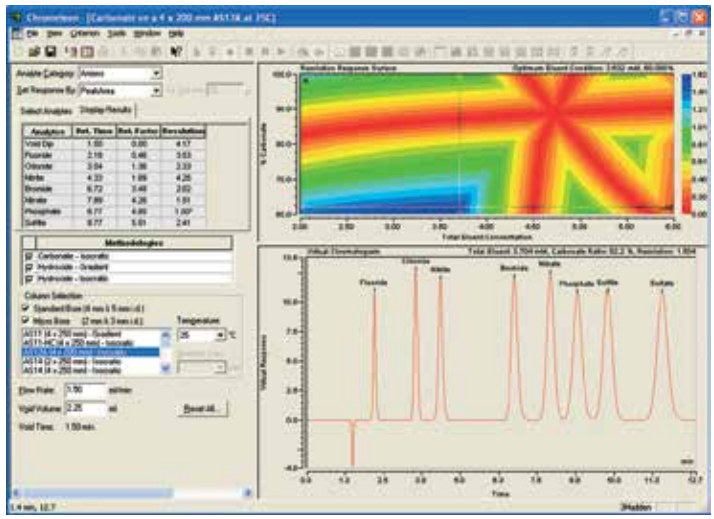
Virtual Column Separation Simulator

Optimizing your IC separations now takes just a few seconds. The Virtual Column™ Separation Simulator is the easiest, fastest, and most economical way to determine your ideal operating conditions. Simply select your analytes and choose a column, and Virtual Column will prepare the control program and quantitation method needed to perform the analysis on your specific instrument.

Method development used to take days of hands-on eluent preparation and data processing. Combine Virtual Column with powerful RFIC systems and you will be running your optimized separations in no time at all.



RFIC systems are easily controlled through Chromeleon control panels such as this (RFIC-EG system pictured).



Virtual Column models the separation of anions on a carbonate selective column.

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