

ION SELECTIVE ELECTRODES

(FOR AMMONIUM, CALCIUM, CHLORIDE, NITRATE)

DESCRIPTION D039xx



Figure 1. Ion-Selective Electrode

Short description

The family of ion-selective electrodes can be used to measure the concentration of a specific ion in aqueous samples. The following electrodes are available:

Ammonium ion-selective electrode (039NH₄)

Calcium Ion-Selective Electrode (039Ca)

Chloride Ion-Selective Electrode (039Cl)

Nitrate Ion-Selective Electrode (039NO₃).

The Ion-Selective Electrodes (ISEs) are delivered with BT-plugs and can be connected to the following interfaces:

- UIA/UIB through Measuring console (via 0520 adapter)
- CoachLab
- CoachLab II
- SMI (via 0520 adapter)
- Texas Instruments CBL™ and CBL2™ dataloggers
- Vernier LabPro datalogger

There is an adapter (art. 0520) to connect sensors with BT-plugs to 4-mm inputs.

Suggestion for experiments

The electrodes can be used to perform a wide variety of experiments, including the following:

- *Water hardness (Calcium ISE):* Calcium is very useful as an indicator of hardness of water in freshwater samples. Even though water hardness is also due to other ions (Mg²⁺ and Fe³⁺), because Ca²⁺ is normally the predominate hardness ion, hardness as Ca²⁺ is reliable indicator of water hardness.
- *Nitrate monitoring (Nitrate ISE):* This ISE can be used to qualitatively determine the concentration of the nitrate ion NO₃⁻ in freshwater samples. This ion may appear in samples due to waste or fertilizer runoff. Increased levels of nitrate may also be present in water sample in waste from plants animal decay.
- *Salinity and Chloride monitoring in sea water (Chloride ISE):* This ISE can be used to determine the concentration of chloride ion Cl⁻ or salinity levels in saltwater samples. The wide range of this electrode allows you to measure salinity (as sodium chloride) or chloride concentration or seawater or brackish water samples.
- *Monitoring streams for Ammonium (Ammonium ISE):* Ammonium (NH₄⁺) is often present as a result of water runoff from fertilized fields. This ISE gives you an easy way to check for this environmental important ion.
- *Calcium in milk (Calcium ISE):* This ISE can be used to determine calcium levels in skim milk.
- *NH₃/NH₄⁺ equilibrium (Ammonium ISE):* This ISE, in conjunction with the pH system, allows studying the equilibrium that occurs between aqueous NH₃ and NH₄⁺ at different pH levels.

- *Chloride monitoring in freshwater sample (Chloride ISE):* This ISE can be used to determine the concentration of chloride ion in fresh water samples. Chloride ions are often present due to natural salinity from sodium, potassium and calcium chloride in mineral deposits.

How an ion-selective electrode works

Ion-selective electrodes are membrane-based electrodes that measure a specific ion (e.g., Ca^{2+}) in aqueous solutions.

When the membrane of the electrode is in contact with a solution containing the specific ion, a voltage, dependent on the level of that ion in solution, develops at the membrane. All of ISEs are combination style; that is the voltage develops in relation to an internal Ag/AgCl reference code. The ISEs measure for the specific ion concentration directly. Samples need to be aqueous to avoid contaminating or dissolving the membrane.

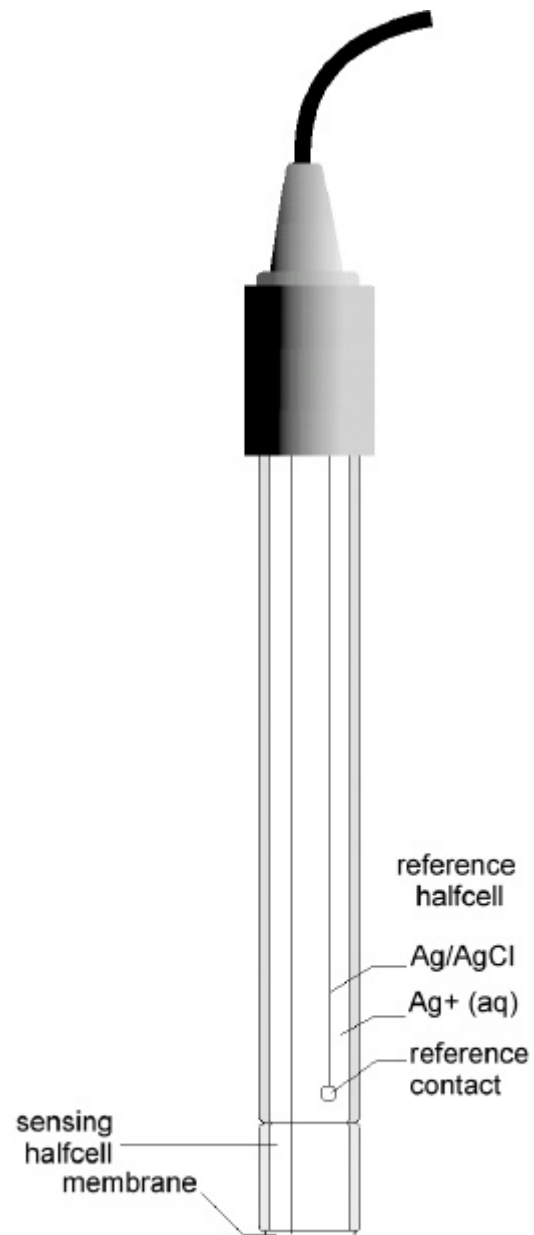
Electrodes have two types of membrane:

- **Solid Polymer Membrane:**

this type of PCV membrane is used in the Nitrate, Calcium, and Ammonium ISEs. The membrane is a porous plastic disk, permeable to the ion exchanger but impermeable to the water. It allows the sensing cell to contact the sample solution and separates the internal filling solution from the sample. The PCV membrane electrodes have a replaceable membrane module.

- **Solid State Membrane:**

This thin crystal, used in the Chloride ISE, is an ionic conductor. It separates the internal reference solution from the sample solution. The Chloride ISE does not have a replaceable membrane module.



The voltage developed between the sensing and the reference electrodes is a measure of the concentration of the reactive ion being measured. As the concentration of the ion reacting at the sensing electrodes varies, so does the voltage measured between two electrodes.

As described in the Nernst equation, ISE response is a linear equation:

$$E = E_0 + m * \ln(a).$$

E = the measured voltage

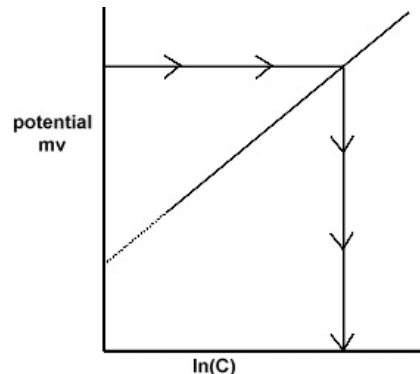
E₀ = the standard potential for the combination of the two half cells

m = a constant (slope)

ln(a) = natural logarithm of the activity (a) of the measured ion species.

Assuming the ionic strength is fairly constant, the Nernst equation may be rewritten to describe the electrode response to the concentration, C, of the measured ionic species:

$$E = E_0 + m * \ln(C),$$



A graph of the natural log of concentration (lnC) vs. potential (V) can be plotted:

The method for determining the concentration ions using one of the ISEs is based on the following:

- The interface reads a voltage that is related to ion concentration.
- Using the voltage reading and the principle described in the graph above, the natural log of concentration of the specific ion can be determined.
- The ion concentration can be determined from the natural log of concentration.

Gel-sealed combination feature of Ion-Selective Electrodes

Combination ion-selective electrodes offer added convenience for ISE measurements. This feature eliminates the need to refill electrodes before each use. They house both Ag/AgCl reference half-cell and the ion-selective sensing element in the same body.

Items included with the ion-selective electrodes

An ISE package consists of:

- One Ion-Selective Electrode (Nitrate, Calcium, Chloride or Ammonium¹).
- One bottle of High Standard Calibration Standard with MSDS sheet (1000 mg/l (ppm) calcium, 1000 mg/l (ppm) chloride, 100 mg/l (ppm) nitrate or 100 mg/l (ppm) ammonium).

¹ If the Ion-Selective Electrode has a BNC connector on it, there should also be an ISE Amplifier box included. If the ISE has a BTA or 5-pin DIN connector, the amplifier is built into the handle of the ISE and will not be a separate item.

- One bottle of Low Standard Calibration Standard with MSDS sheet (10 mg/l (ppm) calcium, 10 mg/l (ppm) chloride, 1 mg/l (ppm) nitrate or 1 mg/l (ppm) ammonium).
- One ISE Soaking Bottle (empty bottle with insertion cap).

Using ISE for use and making measurements

I. Preparing the ISE for use

- The Ion-Selective Electrode (ISE) must be soaked in the High Standard solution (included with the ISE) for approximately 30 minutes.
Important: Make sure the ISE is not resting on the bottom of the container, and that the small white reference contacts are immersed. Make sure no air bubbles are trapped below the ISE. If the ISE needs to be transported to the field during the soaking process, use the short-term ISE Soaking Bottle. Remove the cap from the bottle and fill it 3/4-full with High Standard. Slide the bottle's cap onto the ISE, insert it into the bottle, and tighten.
Important: Do not leave the ISE soaking for more than 24 hours. Long-term storage should be in the long-term ISE Storage Bottle.
- Connect the ISE to the appropriate input on the interface.

II. Calibrating the ISE

Calibration of an ISE is easy enough that we recommend that you perform a calibration whenever you use the probe. As an alternative you can use the standard calibration that is included in Coach 5 program.

- **High Standard Calibration Point**
 The ISE should still be soaking in the High Standard. Read an output voltage and enter the value of natural logarithm of the concentration.
- **Low Standard Calibration Point**
 Remove the ISE from the High Standard, rinse well with distilled water from a wash bottle, and gently blot dry with a paper towel or lab wipe. Place the electrode into the Low Standard (included with your ISE).
Important: Make sure the ISE is not resting on the bottom of the container, and that the small white reference contacts are immersed. Make sure no air bubbles are trapped below the ISE.
 Hold the ISE still and wait for the voltage reading displayed on the computer to stabilize. Read an output voltage and enter the value of natural logarithm of the concentration.

The names of the ion-selective electrodes in the sensor library of Coach 5 program are:

- **Ammonium sensor (039NH4) (CMA)**
- **Calcium sensor (039Ca) (CMA)**
- **Chloride sensor (039Cl) (CMA)**
- **Nitrate sensor (039NO3) (CMA).**

III Collecting data

- After calibration, rinse off the end of the electrode, and blot it dry with a paper towel or lab wipe.
- Insert the tip of the probe into the sample to be tested.
Important: Make sure the ISE is not resting on the bottom of the container, and that the small white reference contacts are immersed. Make sure no air bubbles are trapped below the ISE.
- Hold the ISE still and wait for the reading displayed on the computer to stabilize.

Storing ion-selective electrodes

Proper care and storage of your ISE are important considerations for optimal longevity, especially with the PVC membrane ISEs (Ammonium, Calcium, and Nitrate).

- Long-term storage of ISEs (longer than 24 hours) should be done in the long-term ISE Storage Bottle, which is included. The sponge in the bottom of the bottle should be kept moist with distilled water. When you finish using the ISE, simply rinse it off with distilled water and blot it dry using a paper towel or lab wipe. Loosen the lid of the bottle and insert the ISE.

NOTE: The tip of the ISE should NOT be touching the sponge. Check to be sure the white ceramic junctions are inside, rather than outside the bottle or under the grommet. Tighten the lid. This storage system keeps the electrode in a humid environment, which prevents the reference functions from completely drying out.

- Short-term, wet storage (less than 24 hours) can be done by using the short-term ISE Soaking Bottle included with the electrode. Fill the bottle 3/4 full with High Standard. Loosen the cap, insert the electrode into the bottle, and tighten.

Maintaining and replacing the ISE Standard Calibration Solutions

Having accurate standard solutions is essential for performing good calibrations. The two standard solutions that were included with the ISE can last a long time if you take care not to contaminate them with a wet or dirty probe.

You should perform and save calibration with a probe while it is new and uncontaminated. At some point, you will need to replenish your supply of standard solutions. To prepare your own standard solutions, use the amounts of solid reagent prescribed in table shown on the next page.

Note: Use glassware designed for accurate volume measurements, such as volumetric flasks or graduated cylinders. All glassware must be very clean.

Table: Replacing standard and ISA solutions

| STANDARD SOLUTION | CONCENTRATION (MG/L OR PPM) | PREPARATION METHOD USING HIGH QUALITY DISTILLED WATER |
|----------------------------|--|---|
| Ammonium ISE High Standard | 100 mg/l NH ₄ ⁺ as N | 0.382 g NH ₄ Cl per 1 l solution |
| Ammonium ISE Low Standard | 1 mg/l NH ₄ ⁺ as N | Dilute the High Standard by a factor of 100 (from 100 mg/l to 1 mg/l)* |
| Calcium ISE High Standard | 1000 mg/l as Ca | 2.771 CaCl ₂ per 1 l solution or 3.669 CaCl ₂ •2H ₂ O per 1 l solution |
| Calcium ISE Low Standard | 10 mg/l as Ca | Dilute the High Standard by a factor of 100 (from 1000 mg/l to 10 mg/l)* |
| Chloride ISE High Standard | 1000 mg/l as Cl | 1.648 g NaCl per 1 l solution |
| Chloride ISE Low Standard | 10 mg/l as Cl | Dilute the High Standard by a factor of 100 (from 1000 mg/l to 10 mg/l)* |
| Nitrate ISE High Standard | 100 mg/l NO ₃ ⁻ as N | 0.607 g NaNO ₃ per 1 l solution |
| Nitrate ISE Low Standard | 1 mg/l NO ₃ ⁻ as N | Dilute the High Standard by a factor of 100 (from 100 mg/l to 1 mg/l)* |

* Perform two serial dilutions as described below. Use glassware designed for accurate volume measurements such as volumetric flasks or graduated cylinders. All glassware must be very clean.

- a) Combine 100 ml of the High Standard with 900 ml of distilled water. Mix well.
- b) Combine 100 ml of the solution made in Step (a) with 900 ml of distilled water. Mix well.

Replacement membrane modules (Ammonium, Nitrate, and Calcium only)

The Nitrate, Calcium, and Ammonium ISEs each have a PVC membrane with a limited life expectancy. They are warranted to be free from defects for a period of twelve (12) months from the date of purchase; it is possible, however, that you may get somewhat longer use than the warranty period. If you start to notice a reduced response. (e.g., distinctly different voltages or voltage ranges during calibration), it is probably time to replace the membrane module.

Important: Do not order membrane modules far in advance of the time you will be using them: the process of degradation takes place even when they are stored dry on the shelf. Note that the Chloride ISE has a solid-state membrane, with a longer membrane life, and does not need a replacement module.

To replace a membrane module, hold the base of the electrode with one hand, and unscrew the membrane module with counter-clockwise turns (you will see the seam of the module about 1/2 inch from the tip of the electrode). Insert the stem of the new

membrane module up into the base of the electrode, then carefully thread the module snugly onto the base with several clockwise turns. Do not over tighten.

Using ISA (Ionic Strength Adjuster) solutions to improve accuracy of results

- For optimal results at low concentration of calcium, chloride, and nitrate ions, a standard method for making measurements with ion-selective electrodes is to add ionic strength adjuster (ISA) solutions to each of your standard solutions and samples. **Note:** Do not use an ISA for low concentrations of ammonium.
- Adding an ISA ensures that the total ion activity in each solution being measured is nearly equal, regardless of the specific ion concentration. This is especially important when measuring very low concentrations of specific ions. The ISA contains no ions common to the ion-selective electrode itself.

Note: The additions of ISA to samples or standards described below do not need to have a high level of accuracy - combining the ISA solution and sample solution counting drops using disposable Beral pipette works fine. Here are the directions for using ISA solutions.

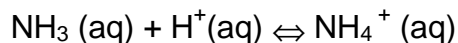
Calcium ISA: Add 1.0 M KCl ISA solution (7.46 KCl/100 ml solution) to the Ca^{2+} standard or to the solution being measured, in a ratio of 1 part of ISA (by volume) to 50 parts of total solution (e.g., 1 ml of ISA to 50 ml of total solution, or 2 drops of ISA to 5 ml of total solution).

Chloride ISA: Add 5.0 M NaNO_3 ISA solution (42.5 g NaNO_3 / 100 ml solution) to the Cl^- standard or to the solution being measured, in a ratio of 1 part of ISA (by volume) to 50 parts of total solution (e.g., 1 ml of ISA solution to 50 ml of total solution, or 2 drops of ISA to 5 ml of total solution).

Nitrate ISA: Add 2.0 M $(\text{NH}_4)_2\text{SO}_4$ ISA solution (26.42 g $(\text{NH}_4)_2\text{SO}_4$ / 100 ml solution) to the NO_3^- standard or to the solution being measured, in a ratio of 1 part of ISA (by volume) to 50 parts of total solution (e.g., 1 ml of ISA solution to 50 ml of total solution, or 2 drops of ISA to 5 ml of total solution).

Using the Ammonium ISE

The Ammonium ISE can be used to determine concentration of NH_4 ions in aqueous solutions, in units of mg/l, ppm or mol/l. Concentration of aqueous ammonium ions should not be mistaken for concentration of aqueous ammonia, or $\text{NH}_3(\text{aq})$. The concentration of these two species, though different, are often involved in the same equilibrium reaction:



In a more acidic environment, higher concentrations of H^+ ions will cause this reaction to shift toward the right, resulting in higher concentration of $\text{NH}_4^+(\text{aq})$. In a more basic (alkaline) environment the concentration of $\text{H}^+(\text{aq})$ will be lower, causing the reaction to shift to left, producing higher concentration of $\text{NH}_3(\text{aq})$. At pH value greater than 10 most of the ammonium ions will be converted to ammonia. At pH value

less than 7.5 most of aqueous ammonia will be converted to ammonium ions.

Sampling freshwater sample for ammonium concentration

While permissible level of ammonium in drinking water should not exceed 0.5 mg/l, streams or ponds nearby heavily fertilized fields may have higher concentrations of this ion. Fertilizers containing ammonium sulfate $(\text{NH}_4)_2\text{SO}_4$ or ammonium nitrate NH_4NO_3 , may result in runoff from fields containing higher levels of ammonium ion NH_4^+ . Monitoring ammonium levels on a stream that borders fertilized fields may show significant seasonal differences in NH_4^+ concentrations. In this kind of study, you may also take pH measurements in water samples; as indicated in the previous paragraph, higher or lower pH value can greatly affect the ratio of $\text{NH}_4^+/\text{NH}_3$ in the sample. Since the Ammonium ISE measures only NH_4^+ levels, you may want to adjust your samples to the same pH value each time you make measurements; this may not be necessary if you have relatively "hard" water. Hard water is naturally buffered against changes in pH.

Using the Ammonium ISE at Low Concentration Levels (0.1-0.5 mg/L NH_4^+-N)

If the concentration of your sample is less than 0.5 mg/l $\text{NH}_4^+ - \text{N}$, you will obtain better results if you calibrate the electrode with 0.1 mg/l and 1.0 mg/l $\text{NH}_4^+ - \text{N}$. This is because the slope of the calibration changes at these low levels. You can make up the 0.1 mg/l Ammonium Standard by following the directions in Table 1 to make the 1.0 mg/l $\text{NH}_4^+ - \text{N}$ Standard, then diluting one more time using 100 ml of the 1.0 mg/l with 900 ml of high quality distilled water.

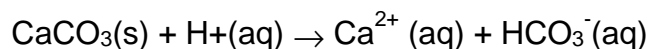
Expressing ammonium concentration

Concentrations of ammonium are often expressed in units of mg/l NH_4^+ as N. Here is a calculation for a 100 mg/l NH_4^+ as N standard solution that is prepared by adding solid NH_4Cl to distilled water:

$$(100 \text{ mg } \text{NH}_4^+/\text{l}) \times (1 \text{ g } \text{NH}_4^+ / 100 \text{ mg } \text{NH}_4^+) \times (53.5 \text{ g } \text{NH}_4\text{Cl} / 14.0 \text{ NH}_4^+ - \text{N}) \\ = 0.382 \text{ g } \text{NH}_4\text{Cl} / \text{l solution.}$$

Using the Calcium ISE

The Calcium ISE can be used to determine the concentration of aqueous Ca^{2+} ions, in the range of 1.8 mg/l to 40 100 mg/l. It can be especially useful in determining "hardness of water". Calcium ions are often found in freshwater samples as a result of water flowing over soil and mineral deposits containing limestone, chalk, magnesite, or dolomite. In one common reaction, limestone is dissolved according to the reaction:



This reaction and others similar to it produce water with a relatively high concentration of Ca^{2+} ions, and lesser concentrations of Mg^{2+} and Fe^{3+} ions known as *hard water*.

Using the Calcium ISE to determine water hardness as Ca²⁺

Many methods of determining water hardness use "total" hardness, or the sum of hardness due to Ca²⁺ and Mg²⁺. Since the Ca²⁺ concentration of freshwater usually exceeds that of Mg²⁺ determining the Ca²⁺ concentration alone can be a good indicator of water hardness - we will refer to this measurement as "calcium hardness".

For best results, calibrate the calcium ISE, using 10 mg/l and 1000 mg/l standards. Using the standard solutions described here, your results will be in units of mg/l of Ca²⁺. Units of water hardness are usually expressed as "hardness as CaCO₃". To convert from units of mg/l of Ca²⁺ (150 mg/l is used in this example) to units of hardness as CaCO₃, in mg/l, you would use this expression:

$$(150 \text{ mg Ca}^{2+} / 1\text{l}) \times (100 \text{ g CaCO}_3 / 40 \text{ g Ca}^{2+}) = 374 \text{ mg/l (hardness as CaCO}_3\text{)}$$

It is important to remember that total hardness, taking into account both the Ca and Mg levels, will be about 1.5 times higher than your calcium hardness value. Water hardness can vary considerably. Water with hardness as CaCO₃ level greater than 120 mg/l is considered to be "hard", while levels exceeding 180 mg/l are referred to as "very hard".

Using the Calcium ISE for Equivalence Point Detection

This electrode can also be used to detect the equivalence point in the titration of water hardness (total Ca²⁺ & Mg²⁺ hardness as CaCO₃). EDTA is used as the titrant. The Ca²⁺ and Mg²⁺ ions are complexed by the EDTA as it is added to the sample. The Ca²⁺ equivalence point occurs first, with the Mg²⁺ equivalence point following; therefore Ca²⁺ can be determined as well as total hardness (as Ca²⁺ and Mg²⁺). A plot of ln[Ca²⁺] (natural log of calcium ion concentration) vs. volume is used to determine the equivalence point. The second derivative can be used to calculate the point of maximum inflection at the equivalence point of the titration.

Using the Chloride ISE

Chloride ions are found in freshwater samples as a result of water flowing over salt-containing minerals. These salts might include either sodium chloride (NaCl) or potassium chloride (KCl). The EPA maximum contamination level of chloride concentration in drinking water is 250 mg/l. The chloride ion concentration in seawater is approximately 19 400 mg/l, well below the upper limit of the Chloride ISE of 35 500 mg/l.

Sampling freshwater samples for chloride concentration

For best results calibrate the Chloride ISE, using the 10 mg/l and 1000 mg/l standards.

Measuring the chloride concentration of saltwater or brackish water

When measuring chloride concentration in seawater or brackish water, calibrate the Chloride ISE, using 1000 mg/l standard included with your Chloride ISE for one

calibration point (or 1.806 parts per thousand or ppt). For the second calibration point, prepare a standard that is 20000 mg/l Cl⁻ by adding 32.96 g of solid NaCl to enough distilled water to prepare 1 l of solution:

$$(20000 \text{ mg Cl}^- / 1 \text{ l}) \times (1 \text{ g Cl}^- / 1000 \text{ mg Cl}^-) \times (58.5 \text{ g NaCl} / 35.5 \text{ g Cl}^-) = 32.96 \text{ g NaCl} / 1 \text{ solution}$$

If you are calibrating in ppt, call this solution 36.13 ppt.

Determining salinity of saltwater or brackish water

Salinity is the total of all salts dissolved in water, expressed either as mg/l (equal to parts per million, ppm) or in parts per thousand (ppt). Seawater contains a fairly constant quantity of chloride ions. From your measurement of chloride ion concentration (in the previous section), salinity can be calculated using the following formula:

$$\text{Salinity (mg/l or ppm)} = 1.8066 \times [\text{Cl}^- \text{ concentration in n mg/l}]$$

Using this formula, the salinity of saltwater is calculated to be:

$$\text{Salinity (mg/l or ppm)} = 1.8066 \times (19400 \text{ mg/l}) = 35\,000 \text{ mg/l}$$

The level of salinity of seawater in parts per thousand, or ppt, would be:

$$\text{Salinity (ppt)} = 35000 / 1000 = 35 \text{ ppt}$$

Using the Nitrate ISE

Nitrate ions NO₃⁻, may be found in freshwater samples from a variety of sources. Sewage is often the primary source. Sometimes nitrates are present due to runoff from fertilized fields. Nitrates can also result from the runoff from cattle feedlots and barnyards. In all of these cases, as plants and animal organisms die, bacterial action breaks down the protein into ammonia, NH₃. Some ammonia is converted into ammonium ions NH₄⁺. Other bacterial action converts some of the ammonia and ammonium ions into nitrite ions NO₂⁻, and then into nitrate ions NO₃⁻.

Units of nitrate concentration

Nitrate ion concentration is usually expressed in units of mg/l of NO₃⁻, as N, also known as "nitrate-nitrogen". This means that the concentration of nitrate is expressed as if the nitrate were only in the form of nitrogen itself. The standards that are included with your Nitrate ISE have concentrations of 1 and 100 mg/l of NO₃⁻, as N. Here is the calculation for making a 100 mg/l of NO₃⁻ as N standard starting with solid NaNO₃ (as shown in Table). Notice that the atomic weight of N 14 is used instead of the atomic weight of NO₃⁻, 62.

$$(100 \text{ mg N} / 1 \text{ l}) \times (1 \text{ g N} / 1000 \text{ mg N}) \times (85 \text{ g NaNO}_3 / 14 \text{ g N}) = 0.607 \text{ g NaNO}_3 / 1 \text{ solution}$$

Unpolluted water usually have nitrate-nitrogen (NO₃⁻, as N) levels below 1 mg/l. Nitrate-nitrogen levels above 10 mg/l are considered unsafe for drinking water. Test results are sometimes publish in units of mg/l NO₃⁻ instead of NO₃⁻ as N. To convert


100 mg/l NO₃⁻ as N to mg/l NO₃⁻, you would perform this conversion.

$$(100 \text{ mg N} / 1 \text{ l}) \times (62 \text{ g NO}_3^- / 14 \text{ g N}) = 443 \text{ mg} / 1 \text{ l NO}_3^-$$

Sampling freshwater samples for nitrate concentration

For best results calibrate the Nitrate ISE, using the 1 mg/l and 100 mg/l standards.

Technical data

| | AMMONIUM | CALCIUM | CHLORIDE | NITRATE |
|--|---|---|--|--|
| Voltage range indication | 2.05 V (100 ppm) 1.20 V (1 ppm) | 1.65 V 1000ppm) 1.23 V (10 ppm) | 1.17 V 1000ppm) 1.62 V (10 ppm) | 1.36 V (100 ppm) 1.66 V (1 ppm) |
| Range (mg/l, ppm) | 0.1 to 18000 (5.5x10 ⁻⁶ M to 1 M) | 0.2 to 40000 (5x10 ⁻⁶ M to 1 M) | 1.8 to 35 500 (5x10 ⁻⁶ M to 1 M) | 0.1 to 14000 (7x10 ⁻⁶ M to 1 M) |
| Resolution with 12-bits ADC % of reading, low scale reading high scale reading | 0.7% of reading (0.10 ± 0.0007 or 18000 ± 130 mg/l) | 1.4 % of reading (0.20 ± 0.0028 or 40000 ± 560 mg/l) | 0.7% of reading (1.8 ± 0.013 or 35500 ± 250 mg/l) | 0.7% of reading (0.10 ± 0.0007 or 14000 ± 98 mg/l) |
| PH range | 4 to 10 | 3 to 10 | 2 to 12 | 2.5 to 11 |
| Interfering ions | K ⁺ | Pb ²⁺ , Hg ²⁺ , Sr ²⁺ , Cu ²⁺ , Ni ²⁺ | CN ⁻ , Br ⁻ , I ⁻ , S ²⁻ | ClO ₄ ⁻ , I ⁻ , ClO ₃ ⁻ , CN ⁻ , BF ₄ ⁻ |
| Electrode resistance: 1 to 4 MΩ Temperature range (can be placed) in 0 to 50°C (no temperature compensation) | | | | |
| Minimum immersion: 1 inch Electrode Length: 155 mm; Body Diameter: 12 mm; Cap Diameter: 16 mm; Cable Length: 100 cm | | | | |
| Connections |  BT (British Telecom) plug | | | |

This product is to be used for educational purposes only. It is not appropriate for industrial, medical, research, or commercial applications.

Warranty

All CMA ion-selective electrodes are warranted to be free from defects in material and workmanship for a period of twelve (12) months from purchase provided the electrode has been used on accordance with this instruction manual and used under normal laboratory conditions. The warranty does not apply when the electrode has been subjected to accident, alternate use, misuse, or abuse in any manner.

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