



Van London Co.

"When Accuracy Matters"



Cadmium Ion Selective Electrode

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GENERAL INSTRUCTIONS

Introduction

The Van London Co. Cadmium Ion Electrode is used to measure Cadmium ions in aqueous solutions.

Required Equipment

1. An ion meter
2. Cadmium Ion Sensing Electrode
3. Polishing Paper to polish dirty or etched Cadmium electrode crystals.
4. Plastic syringe, pipets, volumetric flasks, 150 ml beakers

Required Solutions

1. Deionized or distilled water for solution preparation.
2. Van London Co. Ionic Strength Adjuster (ISA), Cat. No. CD2IS01.
3. Cadmium Standard Solution, 1000 ppm Cd^{+2} . To prepare this solution from your own laboratory stock, half fill a one liter volumetric flask with distilled water and add 2.74 grams of reagent-grade $\text{Cd}(\text{NO}_3)_2 \cdot 4\text{H}_2\text{O}$. Swirl the flask gently to dissolve the solid. Fill to the mark with distilled water, cap, and upend several times to mix the solution.

Remove the rubber cap covering the electrode tip and the rubber insert covering the filling hole of the Electrode Reference Fill Solution Cat.# R001015. Fill the combination electrode with the filling solution shipped with the electrode to a level just below the fill hole. No preparation is required with a sealed reference electrode. Connect the electrode to the proper terminals of the meter as recommended by the meter manufacturer. Store the black shipping cap for later use.

Electrode Slope Check (for Ion meters which display mV)

1. To a clean, dry, 150 ml beaker, add 100 ml of distilled water and 2 ml of ISA. After assuring that the meter is in the millivolt mode, lower the electrode tip into the solution. Stir moderately. Remove air bubbles on the dark gray membrane by redipping probe.
2. Using a pipet, add 1 ml of 1000 ppm Cadmium standard into the solution. Stir moderately. After 1 minute, record the mV reading.
3. Using a pipet, add 10 ml of the 1000 ppm Cadmium standard to the beaker. Stir moderately. After 1 minute, record the mV reading.
4. Determine the difference between the two readings. The electrode is operating correctly if a slope difference of 26 ± 3 mV is found, assuming the solution temperature is 25°C . Slope is defined as the change in mV observed when the concentration changes by a factor of 10.

Measurement using an Ion Meter (in the Concentration Mode)

1. By serial dilution of the 1000 ppm Cadmium standard, prepare two Cadmium standards whose concentration is near the expected sample concentration. (e.g 10 ppm and 100 ppm) For example, to make a 100 ppm standard, pipet 10 ml of the 1000 ppm standard into a 100 ml volumetric flask and dilute to volume with deionized water. Next to make a 10 ppm standard, pipet 10 ml of the newly-made 100 ppm standard into a 100 ml volumetric flask and dilute to volume with deionized water. A 1 ppm standard is made by further dilution of the 10 ppm standard. Measure out 100 ml of each standard into individual 150 ml beakers.
2. Assure that the meter is in the concentration mode and set for a 2-point calibration.
3. Lower the electrode tip into the least concentrated solution. Begin stirring at a constant rate. Add 2 ml of ISA to the solution and continue stirring.
4. After 1 minute, adjust the meter to the concentration of the more dilute Cadmium standard and fix the value in the memory according to the meter manufacturer's instructions.
5. Rinse the electrode tip with distilled water and blot dry.
6. Lower the electrode tip into the more concentrated solution. Begin stirring at a constant rate. Add 2 ml of ISA to the solution and continue stirring.

7. After 1 minute, adjust the meter to the concentration of the more concentrated Cadmium standard and fix the value in the memory according to the meter manufacturer's instructions.
8. Add 100 ml of the sample and 2 ml of ISA in a 150 ml beaker. Lower the electrode tip into the solution. Begin stirring at a constant rate. Ensure that the meter is in sample mode.
9. After 1 minute, read the concentration directly from the meter display.
10. The electrode should be re-calibrated every 2-3 hours. Simply repeat Steps 2-7 above.

Measuring Hints

As Cadmium electrodes are used or stored for long periods, they will experience some deterioration in performance and slope errors will increase. By using the meter's calibration controls this error can be corrected. If an electrode is able to be calibrated and is stable and responsive, it is still a functional electrode and may be used in service even though it no longer meets "new" electrode specifications.

All samples and standards should be at the same temperature for precise measurement. A difference of 1°C in temperature will result in approximately a 4% error.

Always rinse the electrode with distilled water and blot dry between measurements. Use a clean, dry tissue to prevent cross-contamination.

Constant, but not violent, stirring is necessary for accurate measurement.

Check the electrode for air bubbles adhering to the membrane surface after immersion in solution. Agitate the electrode gently to remove the air bubbles.

A slow or sluggish electrode response may indicate surface contamination of the membrane. Use a moistened polishing strip to lightly scrub the membrane surface, then soak in deionized water for five minutes to restore proper performance.

Use fresh standards for calibration. Re-calibrate every few hours for routine measurement.

All samples must be aqueous and not contain organics which can dissolve the epoxy electrode body and/or the cement bonding the sensing crystal to the electrode body. Infrequent measurements in solutions containing methanol, ethanol, benzene, and acetonitrile are permitted. Highly polar solvents slowly attack the electrode. Please check with Van London Co. before using the electrode in other organic solvents.

Interferences should be absent. If they are present, use the procedure found in the **Interference and Electrode Response** sections to remove them.

Adjust sample pH with 1M HNO₃ to below pH 7 to avoid precipitation of cadmium hydroxide, Cd(OH)₂.

ELECTRODE CHARACTERISTICS

Reproducibility

Electrode measurements reproducible to ±2% can be obtained if the electrode is calibrated every hour. Factors such as temperature fluctuation, drift, and noise limit reproducibility.

Interferences

A surface layer of silver metal may be formed by strongly reducing solutions. A layer of silver salt may be deposited on the membrane if high levels of ions forming very insoluble salts are present in the sample. Proper performance can be restored by polishing. See the section entitled **Electrode Response** for proper polishing procedure.

The cadmium ion electrodes do not respond to anions or most cations. The electrode membrane is poisoned by solutions containing copper, mercury, and silver. These ions must be absent from the solution.

If the level of ferric ion or lead ion exceeds the level of cadmium ion in the sample, the measurement will be affected. Sodium fluoride added to the sample will eliminate ferric ion.

Precipitation and Complexation

Sulfide, carbonate, oxalate, phosphate, hydroxide, and other ions precipitate insoluble cadmium salts. The level of cadmium ion, the level of the precipitating ion, and the pH of the sample determine formation of a precipitate.

A wide variety of species, including acetate, ammonia, bromide, chloride, citrate, cyanide, and EDTA, form complexes with cadmium. The total cadmium concentration, the concentration of the complexing species, the solution pH, and the ionic strength all determine the extent of complexation. Complexation reduces the free cadmium ion concentration and, since the electrode responds only to free cadmium ions, a false reading results.

Temperature Influences

The electrode response will shift and change slope with change in temperature. Standards and samples should be at the same temperature. A 4% error results with a 1°C temperature change for a 10 ppm solution.

The electrode can be used at temperatures from 0° - 80°C. Room temperature measurements are recommended, since measurements at temperatures quite different from room temperature may require equilibrium times up to one hour.

Electrode Response

Plotting the electrode mV potential against the Cadmium concentration results in a straight line with a slope of 26 ± 3 mV between 10 ppm and 100 ppm at 25°C.

For concentrations above 10 ppm Cd^{+2} , the electrode exhibits good time response (95% of total mV reading in 30 seconds or less). Response times are longer below this value.

A drifting potential reading or a decrease in electrode slope may mean that the electrode membrane needs polishing.

To polish the membrane:

1. If using polishing paper, cut off a 1-2" piece and place it face up on the lab bench.
2. Put a few drops of distilled or deionized water in the center of the paper.
3. Holding the paper (cotton) steady with one hand, bring the membrane of the electrode down perpendicular to the paper and, with a slight swirling motion, gently polish the tip of the electrode against the surface of the polishing paper (cotton) for a few seconds.
4. Rinse the electrode surface with distilled or deionized water and soak the electrode tip in standard solution for about five minutes before use.

Limits of Detection

Cadmium levels from 10 ppb to 11,200 ppm can be measured with the Cadmium electrode.

The electrodes respond to Cadmium in the sample as well as to ions dissolved from the membrane at low levels. The electrode membrane shows a very slight water solubility. The detection limit of the electrode is determined by this factor. Plastic lab-ware must be used and the beakers must be covered with Parafilm for low level Cadmium or determinations or Cadmium will be lost. Allow a longer stabilization time before taking the meter reading for best results.

pH Effects

At a high pH, free cadmium ion precipitates with hydroxide ion, thereby reducing the cadmium ion concentration. By keeping all solutions slightly acidic, this can be avoided. Adjust the pH of Cadmium solutions below 8, if necessary, with 1M HNO_3 .

Electrode Life

The Cadmium electrode will last one year in normal laboratory use. On-line measurements might shorten operational lifetime to several months. In time, the response time will increase and the calibration slope will decrease to the point calibration is difficult and electrode replacement is required.

Since Cadmium electrodes have a limited shelf life, it is important to have a backup electrode which is in working condition when required.

Electrode Storage

The Cadmium electrode may be stored for short periods of time in 10 ppm Cadmium solution with ISA added. For longer storage (longer than two weeks), rinse and dry the sensing pellet and cover the membrane tip with any protective cap shipped with the electrode. The reference portion of the combination electrode (or the outer chamber of the reference electrode) should be drained of filling solution, if refillable, and the rubber insert placed over the filling hole.

TROUBLESHOOTING HINTS

*Remember to remove the black protective shipping cap on the bottom of the electrode and expose the fill hole underneath the electrode cap. Fill the electrode with the Reference Filling Solution shipped with the electrode to a level just below the fill hole.

<u>Symptom</u>	<u>Possible Causes</u>	<u>Next Step</u>
Out of Range Reading	defective meter	check meter with shorting strap (see meter instruction manual)
	defective electrode	check electrode operation
	electrode not plugged in properly	unplug electrode from meter and reseat
	electrode reference chamber not filled	fill reference chamber as instructed in <u>Electrode Preparation</u>
	air bubble on membrane	remove air bubble by re-dipping electrode
	electrode not in solution	put electrode in solution
Noisy or Unstable Reading (readings continuously or randomly changing.)	insufficient reference filling solution	fill outer body of electrode with proper amount of reference filling solution
	defective meter	check meter with shorting strap (see meter instruction manual)
	defective electrode	check electrode operation
	air bubble on membrane	remove air bubble by re-dipping electrode
Drift (reading slowly changing in one direction)	meter or stirrer improperly grounded	check meter and stirrer for grounding
	electrode exposed to interferences	soak electrode in Cadmium stand with ISA
	incorrect reference filling solution	refill outer body of electrode using filling solution shipped with electrode

	total sample level of dissolved species above 1M	dilute sample
	membrane failure (wet, perforation, discoloration)	replace electrode
	samples and standards at different temperatures	allow samples and standards to come to same temperature before measurement
Low Slope or No Slope	standards contaminated or incorrectly made	prepare fresh standards
	ISA not used	use recommended ISA
	standard used as ISA	use ISA
	membrane failure (wet, perforation, discoloration)	replace electrode
"Incorrect Answer" but calibration curve is good)	incorrect standards	prepare fresh standards
	wrong units used	apply correct conversion factor: $10^{-3}\text{M} = 112 \text{ ppm as Cd}^{+2}$
	ISA added to standards and not samples	add same proportions of ISA to standards and samples
	sample carryover	rinse electrodes thoroughly between samples

SPECIFICATIONS

Concentration Range:	11,200 to 0.01 ppm
pH Range:	2 to 12
Slope:	26 ± 3 mV between 10 ppm and 100 ppm at 25°C
Temperature Range:	0° to 80°C
Interferences:	Ag^{+1} , Hg^{+2} , Cu^{+2} , Pb^{+2} , Fe^{+2}
Reproducibility:	$\pm 2\%$
Size:	110 mm length 12 mm diameter 1 m cable length
Storage:	store electrode in Cadmium standard with ISA added

ELECTRODE THEORY

Electrode Operation

The Cadmium Ion Electrode is composed of a Cadmium crystal membrane bonded into an epoxy or glass body. When an electrode potential develops across the membrane, the membrane is in contact with a solution containing Cadmium ions and is capable of measuring free Cadmium ions. This electrode potential is measured against a constant reference potential, using a pH/mV meter or an ion meter. The level of Cadmium ions, corresponding to the measured potential, is described by the Nernst equation:

$$E = E_o + S \log X$$

where: E = measured electrode potential
E_o = reference potential (a constant)
S = electrode slope (-26 mV for Cadmium)
X = level of Cadmium in solution

The activity, X, represents the effective concentration of the ions in solution. The activity is related to the free ion concentration, C_f, by the activity coefficient, γ, by:

$$X = \gamma C_f$$

Activity coefficients vary, depending on total ionic strength, I, defined as:

$$I = 1/2 \sum C_x Z_x^2$$

where: C_x = concentration of ion X
Z_x = charge of ion X
Σ = sum of all of the types of ions in the solution.

In the case of high and constant ionic strength relative to the sensed ion concentration, the activity coefficient, γ, is constant and the activity, X, is directly proportional to the concentration.