OMEGA ENGINEERING
ISE-8800 AND ISE-8802
INSTRUCTION MANUAL

General Instructions

Introduction:

The Omega Cupric Ion Electrodes are used to quickly, simply, accurately, and economically measure cupric ion in aqueous solutions.

Required Equipment

1. A pH/mV meter or an ion meter, either line operated or poratable.
2. Semi-logarithmic 4-cycle graph paper for preparing calibration curves when using the meter in the mv mode.
3. Magnetic stirrer
4. The ISE-8800 Cupric Ion Electrode or ISE-8802 Cupric Ion Combination Glass Electrode
5. Double Junction Reference Electrode, PHFS-A250 filling solution in the inner junction and With the PHFS-B250 filling solution in the outer junction.
6. Polishing paper to polish dirty or etched electrode membranes.

Required Solutions:

1. Deionized or distilled water for solution and standard preparation
2. ISE-8800-R1 Ionic strength adjuster
3. ISE-8800-S1 Cupric Nitrate Standard Solution, 0.1M
4. ISE-8800-S2 Cupric Nitrate Standard Solution, 1000 ppm Cu^{+2}
5. EDTA Titrant (1M) for Cupric Titrations. To prepare this solution from your own laboratory stock, add 37.2 grams of reagent-grade $Na_2EDTA * 2H_20$ to a 100 ml volumetric flask about three-fourths full of distilled water. Swirl the flask to dissolve the solid. Add distilled water to the mark, cap the flask, and upend it several times to thoroughly mix the solution.

GENERAL PREPARATION

Electrode Preparation

Remove the rubber cap(s) covering the electrode tip(s) and the rubber insert covering the filling hole of the cupric combination ion electrode or the reference electrode. Fill the reference electrode or 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(s) to the proper terminal(s) as recommended by the meter manufacturer.

Electrode Slope Check (with standard pH/mV meter)
(check electrodes each day)

1. To a 150 ml beaker, add 100 ml of distilled water and 2 ml of ISA. Place the beaker on the magnetic stirrer and begin stirring at a constant rate. After assuring that the meter is in the mV mode, lower the electrode tip(s) into the solution.

2. Using a pipet, add 1 ml of either the 0.1M or 1000 ppm cupric standard to the beaker. When the reading is stable, record the millivolt reading.

3. Using a pipet, add 10 ml of the standard used above to the beaker. When the reading is stable, record the

millivolt reading.

4. Determine the difference between the two readings. A difference of 27±2 mV indicates correct electrode operation, assuming the temperature is between 20° and 25°C. See the **TROUBLESHOOTING GUIDE** and **TROUBLESHOOTING HINTS** sections if the potential change is not within this range.

Slope is defined as the change in potential observed when the concentration changes by a factor of 10.

Electrode Slope Check (with ion meter)
(check electrodes each day)

1. Prepare standard cupric solutions whose concentrations vary be tenfold. Use either the 0.1M or 1000 ppm stock solutions and the serial dilution method for this preparation.

2. To a 150 ml beaker, add 100 ml of the lower value standard and 2 ml of ISA. Place the beaker on a magnetic stirrer and begin stirring at a constant rate. After assuring that the meter is in the concentration mode, lower the electrode tip(s) into the solution.

3. After the reading has stabilized, adjust the meter to the concentration of the standard and fix the value in the memory according to the meter manufacturer's instructions.

4. Rinse the electrode(s) with distilled water and blot dry.

5. To a 150 ml beaker, add 100 ml of the higher value standard and 2 ml of ISA. Place the beaker on the magnetic stirrer and begin stirring at a constant rate. Lower the electrode tip(s) into the solution.

6. After the reading has stabilized, adjust the meter to the concentration of the standard and fix the value in the memory.

7. Read the electrode slope according to the meter manufacturer's instructions. Correct electrode operation is indicated by a slope of 90-100%. If the slope is not within this range, see the **TROUBLESHOOTING GUIDE** and **TROUBLESHOOTING HINTS** sections.

MEASUREMENT

Measuring Hints

All samples and standards should be at the same temperature for precise measurement.

Constant, but not violent, stirring is necessary for accurate measurements. Magnetic stirrers can generate sufficient heat to change the solution temperature. To counteract this effect, place a piece of insulating material, such as styrofoam sheet, between the stirrer and beaker.

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

For samples with high ionic strength, prepare standards whose composition is similar to the sample. Dilute concentrated samples (>0.1M) before measurement.

Use fresh standards for calibration.

Use 2 ml of ISA for each 100 ml of sample or standard.

Always check to see that the membrane is free from air bubbles after immersion into the standard or sample.

Sample Requirements

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, benzene, or acetonitrile are permitted. Highly polar solvents slowly attack the electrode. Please check with pHoenix Electrode Company before using these electrodes in other organic solvents.

The temperature of the standard and of the sample solution should be the same and below 80 degrees C. About a 4% error in the slope will occur for each 1°C difference in temperature.

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 HNO_3 to below pH 7 to avoid precipitation of cupric hydroxide, $Cu(OH)_2$.

Units of Measurement

Cupric ion concentrations are measured in units of parts per million, moles per liter, equivalents per liter, or any other convenient concentration unit. Table 1 indicates some of these concentration units.

TABLE 1: Concentration Unit Conversion Factors

ppm Cu^{+2}	moles/liter
6354.0	$1.0X10^{-1}$
635.0	$1.0X10^{-2}$
63.5	$1.0X10^{-3}$
6.4	$1.0X10^{-4}$

MEASUREMENT PROCEDURES

Direct Measurement

A simple procedure for measuring a large number of samples. A single meter reading is all that is required for each sample. The ionic strength of samples and standards should be made the same by adjustment with ISA. The temperature of both sample solutions and standard solutions should be the same.

Direct Measurement of Cupric Ion (using a standard pH/mV meter)

1. By serial dilution of the 0.1M or 1000 ppm standards, prepare 10^{-2}, 10^{-3}, and 10^{-4}M or 100 and 10 ppm standards for the cupric ion. To 100 ml of each standard, add 2 ml of ISA. Prepare standards with a composition similar to the samples if the samples have an ionic strength above 0.1M.

2. Place 100 ml of the 10^{-4}M or 10 ppm standard in a 150 ml beaker, place the beaker on the magnetic stirrer and begin stirring at a constant rate.

3. Lower the electrode tip(s) into the solution. Make sure that the meter is in the mV mode. When the reading has stabilized, record the mV reading.

4. Place 100 ml of the 10^{-3}M or 100 ppm standard in a 150 ml beaker, place the beaker on the magnetic stirrer and begin stirring at a constant rate.

5. After rinsing the electrode(s) with distilled water and blotting dry, immerse the electrode tip(s) in the solution. When the reading has stabilized, record the mV reading.

6. Place 100 ml of the 10^{-2}M or 1000 ppm standard in a 150 ml beaker, place the beaker on the magnetic stirrer and begin stirring at a constant rate.

7. After rinsing the electrode(s) with distilled water and blotting dry, immerse the electrode tip(s) in the solution. When the reading has stabilized, record the mV reading.

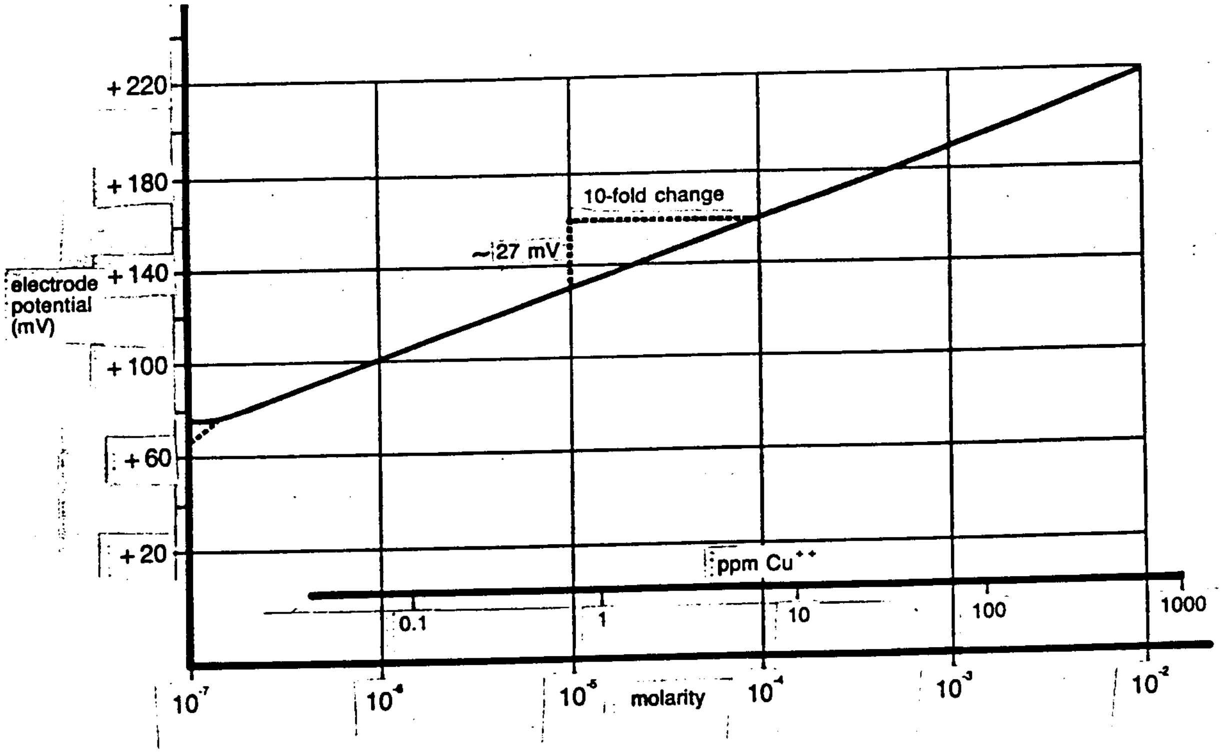
8. Using the semi-logarithmic graph paper, plot the mV reading (linear axis) against concentration (log axis). A typical calibration curve can be found in Figure 1.

A calibration curve is constructed on semi-logarithmic paper when using a pH/mV meter in the millivolt mode. The measured electrode potential in mV (linear axis) is plotted against the standard concentration (log axis). In the linear region of the curve, only three standards are necessary to determine a calibration curve. In the non-linear region, additional points must be measured. The direct measurement procedures given are for the linear portion of the curve. The non-linear portion of the curve requires the use of low level procedures.

9. To a clean, dry 150 ml beaker, add 100 ml of the sample and 2 ml of ISA. Place the beaker on the magnetic stirrer and begin stirring at a constant rate.

10. After rinsing the electrode tip(s) in distilled water and blotting dry, lower the electrode tip(s) into the solution. When the reading has stabilized, record the mV

Figure 1
Typical cupric electrode calibration curve



A calibration curve is constructed on semi-logarithmic paper when using a pH/mV meter in the direct measurement procedure. The measured electrode potential in mV (linear axis) is plotted against the standard concentration (log axis). In the linear region of the curve, only three standards are necessary to determine a calibration curve. In the non-linear region, additional points must be measured. The direct measurement procedures given are for the linear portion of the curve. The non-linear portion of the curve requires the use of low level procedures.

9. To a clean, dry 150 ml beaker, add 100 ml of the sample and 2 ml of ISA. Place the beaker on the magnetic stirrer and begin stirring at a constant rate.

10. After rinsing the electrode tip(s) in distilled water and blotting dry, lower the electrode

Assuming no change in ambient temperature, immerse the electrode tip(s) in the more dilute standard. After the reading has stabilized, compare it to the original reading recorded in step 4 above. If the reading differs by more than ±0.5 units, or the temperature has changed from ambient, recalibrate the electrode.

Low Level Cupric Determination (using a standard pH/mV meter)

This procedure is recommended for solutions with cupric concentrations of less than 10^{-5}M (0.6 ppm). If the solution is high in ionic strength, but low in cupric ion, use the same procedure, but prepare a calibration solution with a composition similar to the sample.

1. Using 20 ml of standard ISA, dilute to 100 ml with distilled water. This low level ISA (1.0M $NaNO_3$) is added at the rate of 1 ml low level ISA to each 100 ml of solution. The background ionic strength will be $1.0X10^{-2}$M.

2. Dilute 1 ml of 0.1M standard to 100 ml to prepare a $1.0X10^{-3}$M solution. Dilute 1 ml of this solution to prepare a 10^{-5}M standard for measurements in moles per liter. Prepare a 1 ppm standard solution by diluting 1 ml of the 1000 ppm standard to 1 liter of solution for measurements in ppm. Standards should be prepared fresh daily.

3. Add 100 ml of distilled water and 1 ml of low level ISA to a 150 ml beaker. Place the beaker on the magnetic stirrer and begin stirring at a constant rate.

4. Place the electrode tip(s) in the solution. Assure that the meter is in the mV mode.

5. Add increments of the $1.0X10^{-5}$M or 1 ppm standard as given in Table 2 below.

6. After the reading has stabilized, record the mV reading.

TABLE 2: Stepwise Calibration for Low Level Cupric Measurements

Step	Pipet	Added Volume (ml)	Concentration ppm	Concentration M
1	A	0.1	$1.0X10^{-3}$	$1.0X10^{-8}$
2	A	0.1	$2.0X10^{-3}$	$2.0X10^{-8}$
3	A	0.2	$4.0X10^{-3}$	$4.0X10^{-8}$
4	A	0.2	$6.0X10^{-3}$	$6.0X10^{-8}$
5	A	0.4	$1.0X10^{-2}$	$9.9X10^{-8}$
6	B	2.0	$2.9X10^{-2}$	$2.9X10^{-7}$
7	B	2.0	$4.8X10^{-2}$	$4.8X10^{-7}$

Pipet A = 1 ml graduated pipet
Pipet B = 2 ml pipet
Solutions: additions of 1 ppm or $1.0\text{X}10^{-5}$M
standard to 100 ml of solution
prepared in Step 3 above.

7. On semi-logarithmic graph paper, plot the mV reading (linear axis) against the concentration (log axis) as in Figure 1.

8. Rinse the electrode(s) and blot dry.

9. Measure out 100 ml of the sample into a 150 ml beaker. Add 1 ml of low level ISA. Place the beaker on the magnetic stirrer and begin stirring at a constant rate. Lower the electrode tip(s) into the solution. After the reading has stabilized, record the mV reading and determine the concentration from the low level calibration curve.

10. Prepare a new low level calibration curve daily. Check the calibration curve every two hours by repeating Steps 3-7 above.

Low Level Cupric Determination (using an ion meter)

1. Using 20 ml of standard ISA, dilute to 100 ml with distilled water. This low level ISA (1.0M $NaNO_3$) is added at the rate of 1 ml low level ISA to each 100 ml of solution. The background ionic strength will be $1.0\text{X}10^{-2}$M.

2. Follow the steps given in **Direct Measurement of Cupric Ion (using an ion meter)** to the end of Step 7.

3. Add 100 ml of distilled water and 1 ml of low level ISA to a 150 ml beaker. Place the beaker on the magnetic stirrer and begin stirring at a constant rate.

4. Lower the electrode tip(s) into the solution. When the reading has stabilized, fix the blank value in the meter according to the meter manufacturer's instructions.

5. Continue with Steps 8-10 in **Direct Measurement of Cupric Ion (using an ion meter)**, remembering to use the low level ISA described in Step 1 above.

Titration

A very accurate determination of total cupric ion concentration. This method makes use of the electrode as an endpoint detector when EDTA is used as a titrant.

Titration of Cupric Ion

The method outlined in this section makes use of the cupric ion electrode as a highly sensitive endpoint detector for cupric-containing samples. The titrant used is EDTA.

EDTA complexes cupric as well as other cations. The sample pH can be adjusted to a low pH by adding HNO_3 to eliminate unwanted ion complexes. Masking agents may be added in some cases.

1. Prepare the stock EDTA titrant as given in the section **Required Solutions**. Dilute the EDTA to 10 to 20 times as concentrated as the suspected sample concentration. The sample should contain at least $1.0X10^{-3}M$ cupric ion for a good detection of the end point.

2. Fill a 50 ml buret with the EDTA solution. Pipet 100 ml of the sample into a 150 ml beaker, place the beaker on the magnetic stirrer and begin stirring at a constant rate. Adjust the sample to a low pH by adding HNO_3.

3. Position the buret tip in the beaker, slightly above the liquid level in the beaker and slightly off center. Position the electrode tip(s) in the solution about halfway between the center of the beaker and the beaker wall.

4. Begin adding the EDTA in 0.5 ml to 1.0 ml increments, followed by smaller increments down to about 0.1 ml to 0.2 ml increments as the potential change increases. Record the mV potential after each addition. Continue the additions several milliliters past the endpoint until little change is noted in the mV reading even when adding 0.5-1.0 ml increments.

5. Plot the milliliters of EDTA added against the mV potential on standard coordinate graph paper. See Figure 2. The point of greatest potential change is the endpoint.

6. The cupric ion concentration from the unknown is calculated as follows:

$$M_{Cu^{+2}} = \frac{V_t M_t}{V_{Cu^{+2}}}$$

where:

$M_{Cu^{+2}}$ = concentration of cupric ion in the sample (moles/liter)
V_t = volume of EDTA added at endpoint
M_t = EDTA concentration (moles/liter)
$V_{Cu^{+2}}$ = volume of unknown sample (100 ml)

ELECTRODE CHARACTERISTICS

Reproducibility

Electrode measurements reproducible to ±2% can be obtained if the electrode is calibrated every hour. Factors such as temperature fluctuations, drift, and noise limit reproducibility. Reproducibility is independent of concentration within the electrode's operating range.

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

If the level of ferric ion is greater then one-tenth the level of cupric ion in the sample, the measurement will be affected. Sodium fluoride added to the sample will eliminate ferric ion.

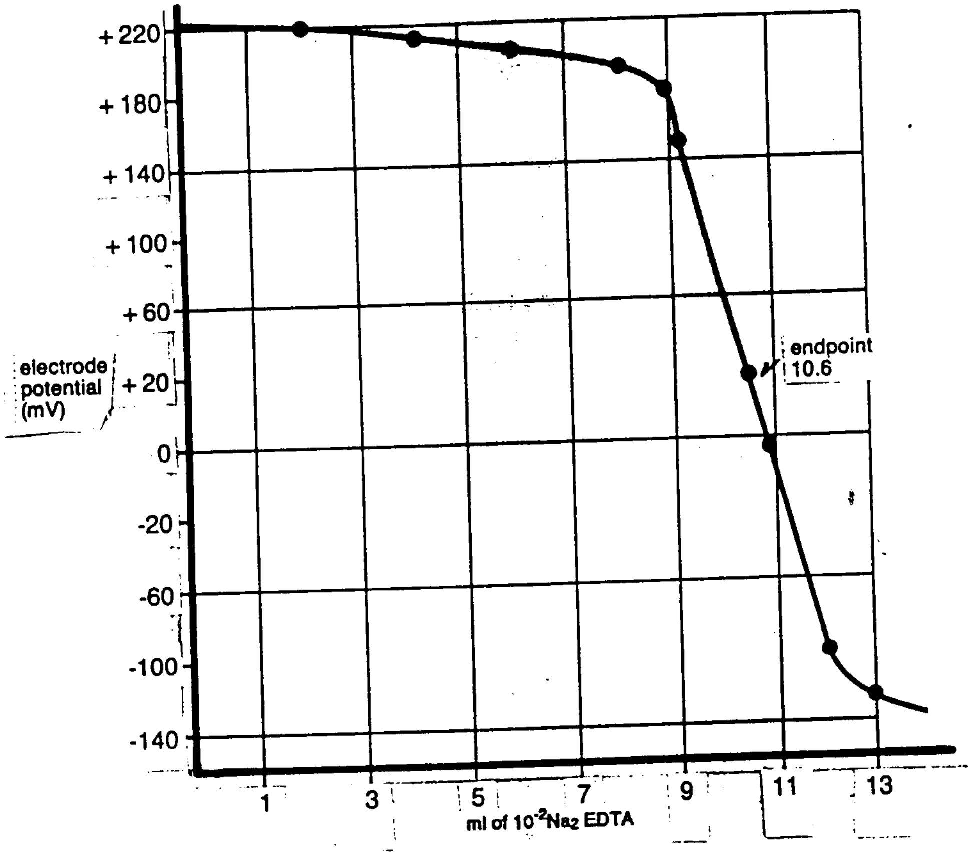
Occassionally, chloride and bromide ions interfere with the electrode's operation. The level of chloride or bromide ion relative to the level of cupric ion in the sample is the determining factor for interference. Interference will occur if the concentrations are outside the following limits (mole/liter).

$$(Cu^{+2})(Cl^{-1})^2 > 1.6X10^{-6}$$
$$(Cu^{+2})(Br^{-1})^2 > 1.3X10^{-12}$$

the endpoint.

5. Plot the milliliters of EDTA added against the mV potential on standard coordinate graph paper. See Figure 2. The point of greatest potential change is the endpoint.

Figure 2
Typical titration of 10^{-3}M $CuCl_2$ with 10^{-2}M Na_2EDTA



6. The cupric ion concentration from the unknown is calculated as follows:

$$M_{Cu^{+2}} = \frac{V_t M_t}{V_{Cu^{+2}}}$$

where:

$M_{Cu^{+2}}$ = concentration of cupric ion in the unknown (moles/liter)
V_t = volume of EDTA added at end point
M_t = EDTA concentration (moles/liter)
$V_{Cu^{+2}}$ = volume of unknown sample

TABLE 3: Temperature vs. Values for the Electrode Slope.

Temp. (°C)	**S**
0	27.10
10	28.10
20	29.08
25	29.58
30	30.07
40	31.07
50	32.06

If changes in temperature occur, the electrode(s) should be recalibrated.

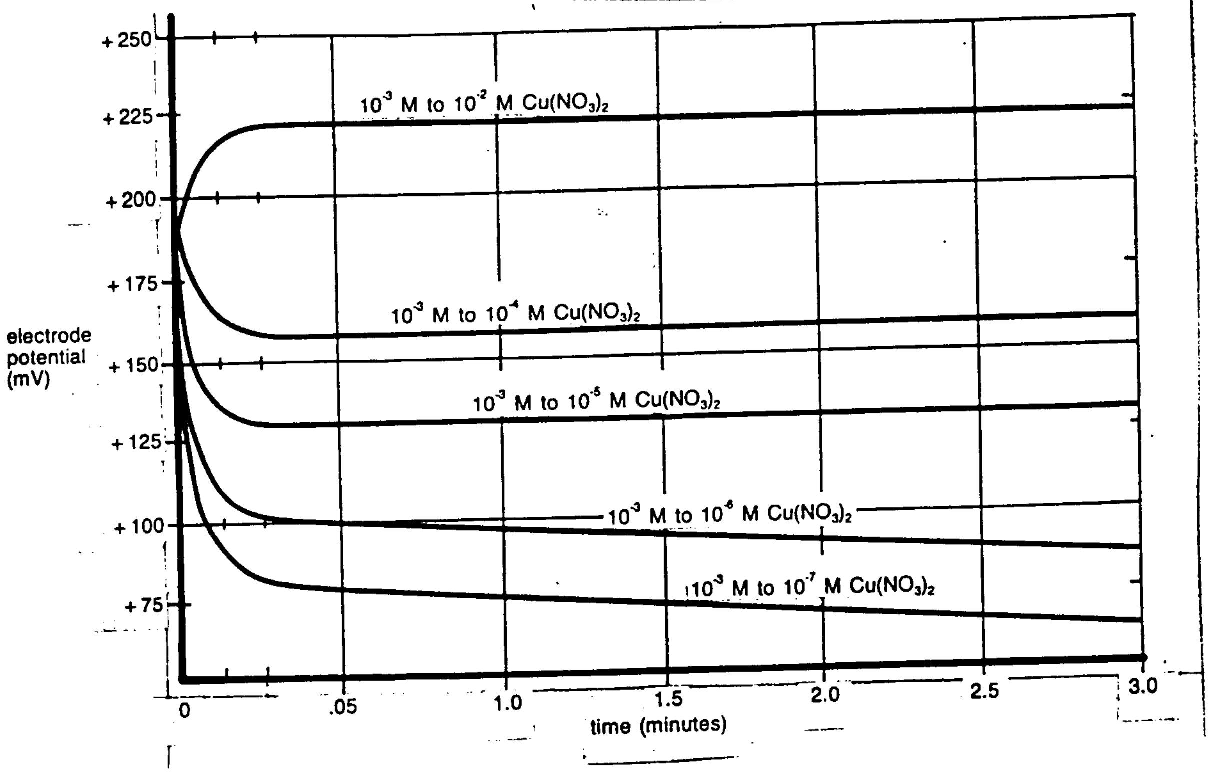
The temperature range for the pHoenix Cupric Ion Electrode is 0°-80°C, provided that temperature equilibrium has occurred. If the temperature varies substantially from room temperature, equilibrium times up to one hour are recommended.

Electrode Response

Plotting the mV potential against the cupric ion concentration on semi-logarithmic graph paper results in a straight line with a slope of about 27 mV per decade. Refer to Figure 1.

The time needed to reach 99% of the stable electrode potential reading, the electrode response time, varies from several seconds in highly concentrated solutions to several minutes near concentrations of $1.0X10^{-5}M$ cupric ion. Below $10^{-5}M$, considerably longer response time can be expected. See Figure 3.

Figure 3
Typical electrode response to step changes in $Cu(NO_3)_2$



Detection Limit

Neutral solutions containing free cupric ions can be measured down to $1.0X10^{-8}M$ ($6X10^{-4}$ ppm). Extreme care must be taken with measurements below $1.0X10^{-5}M$ (0.6 ppm) to avoid contamination of samples.

Interferences

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

If the level of ferric ion is greater then one-tenth the level of cupric ion in the sample, the measurement will be affected. Sodium fluoride added to the sample will eliminate ferric ion.

Accidental poisoning of the membrane by exposure to mercury or silver results in sluggish electrode response. The precipitate coating on the membrane can be removed by following the procedures given in the section entitled **Measuring Hints** through treatment with polishing paper or jeweller's rouge.

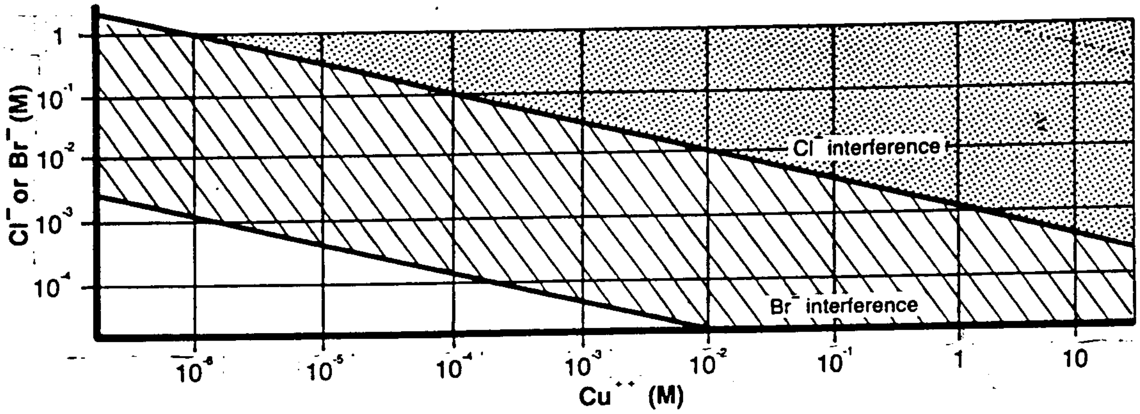
Occassionally, chloride and bromide ions interfer with the electrode's operation. The level of chloride or bromide ion relative to the level of cupric ion in the sample is the determining factor for interference. Interference will occur if the concentrations are outside the following limits (mole/liter).

$$(Cu^{+2})(Cl^{-1})^2 > 1.6X10^{-6}$$

$$(Cu^{+2})(Br^{-1})^2 > 1.3X10^{-12}$$

Figure 4 indicates the regions in which curpic ion and chloride or bromide ion levels are high enough to cause electrode interference.

Figure 4
Interference from chloride and bromide ion

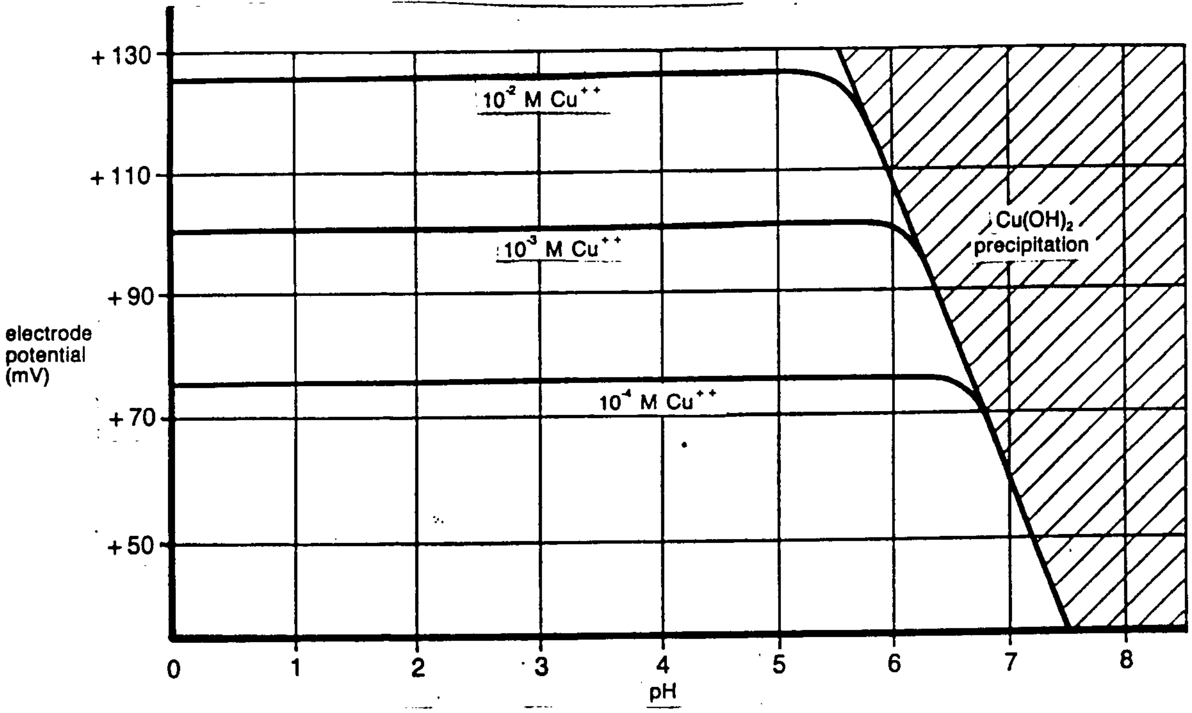


pH Effects

Figure 5 shows how the electrode responds to cupric ion in solution at various pH levels.

At a high pH, free cupric ion precipitates with hydroxide ion, thereby reducing the cupric ion concentration. The maximum pH at which cupric concentration can be measured without interference from hydroxide is given by a solid line to the left of the lined area on Figure 5. Within this lined area, cupric ion combines with hydroxide to form $Cu(OH)_2$. Since only free cupric concentration can be measured with the cupric ion electrodes, a false reading results.

Figure 5
Precipitation of cupric ion by hydroxide ion



Electrode Storage

The ISF-8800 is stored dry after rinsing well and blotting dry. Replace the protective cap.

For short term storage, the reference electrode and the CU01502 combination electrode may be stored in the salt bridge filling solution or in distilled water. The reference cell should never be allowed to dry and crystallize. For long periods of time, drain the reference completely, rinse with distilled water, and store dry.

Precipitation and Complexation

Sulfide, phosphate, hydroxide, and other ions precipitate insoluble cupric salts. The level of cupric ion, the level of the precipitated ion, and the pH of the sample determine formation of a precipitate.

A wide variety of species, including acetate, ammonia, amino acids, citrate, cyanide, and EDTA, form complexes with cupric ion. The total cupric concentration, the concentration of the nitrate, $NaNO_3$. Solutions other than this may be used as ionic strength adjusters as long as ions that they contain do not interfere with the electrode's response to cupric ions.

The reference electrode must also be considered. When two solutions of different composition are brought into contact with one another, liquid junction potentials arise. Millivolt potentials occur from the interdiffusion of ions in the two solutions. Electrode charge will be carried unequally across the solution boundary resulting in a potential difference between the two solutions, since ions diffuse at different rates. When making measurements, it is important to remember that this potential be the same when the reference is in the standardizing solution as well as in the sample solution or the change in liquid junction potential will appear as an error in the measured electrode potential.

The composition of the liquid junction filling solution in the reference electrode is most important. The speed with which the positive and negative ions in the filling solution diffuse into the sample should be as nearly equal as possible, that is, the filling solution should be equitransferent. No junction potential can result if the rate at which positive and negative charge carried into the sample is equal.

Strongly acidic (pH = 0 - 2) and strongly basic (pH = 12 - 14) solutions are particularly troublesome to measure. The high mobility of hydrogen and hydroxide ions in samples make it impossible to mask their effect on the junction potential with any concentration of an equitransferent salt. One must either calibrate the electrode(s) in the same pH range as the sample or use a known increment method for ion measurement.

TROUBLESHOOTING GUIDE

The goal of troubleshooting is the isolation of a problem through checking each of the system components in turn: the meter, the glassware, the electrode(s), the reagents, the sample, and the technique.

Meter

The meter may be checked by following the checkout procedure in the instrument instruction manual.

Glassware

Clean glassware is essential for good measurement. Be sure to wash the glassware well with a mild detergent and rinse very well with distilled or deionized water. Clean glassware will drain without leaving water droplets behind.

Electrodes

The electrodes may be checked by using the procedure found in the sections entitled **Electrode Slope Check**.

1. Be sure to use distilled or deionized water when following the procedures given in **Electrode Slope Check**.

2. If the electrode fails to respond as expected, see the sections **Measuring Hints** and **Electrode Response**. Repeat the slope check.

3. If the electrode(s) still fail to respond as expected, substitute another cupric ion electrode that is known to be in good working order for the questionable electrode. If the problem persists and you are using an electrode pair, try the same routine with a working reference electrode.

4. If the problem persists, the reagent may be of poor quality, interferences in the sample may be present or the technique may be faulty. See **Reagents**, **Sample**, and **Technique** sections below.

5. If another electrode is not available for test purposes, or if the electrode in use is suspect, review the instruction manual and be sure to:

   - Clean and rinse the electrode(s) thoroughly.
   - Prepare the electrode(s) properly.
   - Use the proper filling solution.
   - Adjust the pH and the ionic strength of the solution by the use of the proper ISA.
   - Measure correctly and accurately.
   - Review <u>TROUBLESHOOTING</u> <u>HINTS</u>.

Reagents

Whenever problems arise with the measuring procedure that has been used successfully in the past, be sure to check the reagent solutions. If in doubt about the credibility of any of the reagents, prepare them again. Errors may result from contamination of the ISA, incorrect dilution, poor quality distilled/deionized water, or a simple mathematical miscalculation.

Sample

Look for possible interferences, complexing agents, or substances which could affect the response or physically damage the sensing electrode (or the reference electrode) if the electrode(s) work perfectly in the standard, but not in the sample.

Try to determine the composition of the samples prior to testing to eliminate a problem before it starts. See **Measuring Hints**, **Sample Requirements**, and **Interferences**.

Technique

Be sure that the electrode's limit of detection has not been exceeded.

Be sure that the analysis method is clearly understood and that Good Laboratory Practice has been followed.

Refer to the instruction manual again. Reread <u>GENERAL PREPARATION</u> and <u>ELECTRODE</u> <u>CHARACTERISTICS</u>.

TROUBLESHOOTING HINTS

Symptom	**Possible Causes**	**Next Step**
Out of Range Reading	defective meter	check meter with shorting strap (see meter instruction manual)
	defective electrode	check electrode operation
	electrode(s) not plugged in properly	unplug electrode(s) and reseat
	reference electrode not filled	be sure reference electrode is filled
	air bubble on membrane	remove bubble by redipping electrode
	electrode(s) not in solution	put electrode(s) in solution
Noisy or Unstable Readings (readings continuously or rapidly changing)	defective meter	check meter with shorting strap
	air bubble on membrane	remove bubble by redipping electrode
	electrode exposed to interferences	soak electrode in cupric standard
	defective electrode	replace electrode
	ISA not used	use recommended ISA
	meter or stirrer not grounded	ground meter or stirrer
Drift (reading slowly changing in one direction)	samples and standards at different temperatures	allow solutions to come to room temperature before measurement
	electrode exposed to complexing agents	check section entitled **Precipitation and Complexation**

	incorrect reference filling solution	use recommended filling solution
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
	electrode exposed to complexing agents	check section entitled **Precipitation and Complexation**
	air bubble on membrane	remove bubble by redipping probe
"Incorrect Answer" (but calibration curve is good)	incorrect scaling of semi-log paper	plot millivolts on the linear axis. On the log axis, be sure concentration numbers within each decade are increasing with increasing concentration.
	incorrect sign	be sure to note sign of millivolt number correctly
	incorrect standards	prepare fresh standards
	wrong units used	apply correct conversion factor: $10^{-3}M = 63.5$ ppm Cu^{+2}
	complexing agents in sample	check section entitled **Precipitation and Complexation;** use titration

SPECIFICATIONS

Concentration Range:	$1X10^{-1}$ to $10^{-8}M$ Cu^{+2} (6354 to $6.4X10^{-4}$ ppm)
pH Range:	2 to 12
Temperature Range:	0° - 80°C
Resistance:	< 1 Mohm
Reproducibility:	+/-2%
Samples:	aqueous solutions only: no organic solvents
Size:	110 mm length 12 mm diameter 1 m cable length
Storage:	store in cupric solution

M-3545