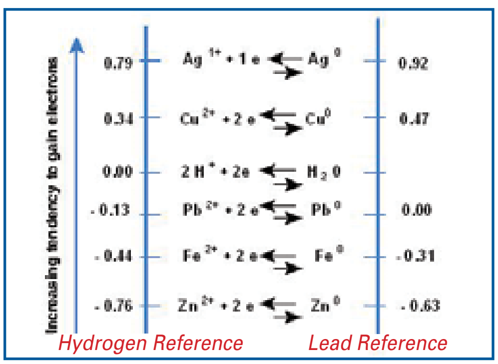
Spontaneous Electrochemical Reactions

Several concepts concerning spontaneous electrochemical reactions can be easily developed or demonstrated in the laboratory.

- Oxidation and Reduction
- The Electrochemical Series
- The effect of ion concentration on cell potential (The Nernst Equation).
- The effect of the number of electrons transferred on the slope of Nernst Equation data.

These experiments involve only a MicroLab 528, its voltage test lead, and MicroLab's **Model 152 Multi-EChem Half Cell Module.**

This module provides space for eight user-designated electrochemical metal/ion half-cells. These cells are coupled by small channels to a central aqueous potassium nitrate salt bridge surrounded by a polyethylene barrier with 20-60 micron pores. This barrier prevents mixing of the half-cell solutions and provides adequate motion of ions to maintain an extremely stable cell potential.



The Electrochemical Series orders ions and elements in terms of increasing tendency to gain electrons. Any half reaction can take electrons from any half reaction below it. Left scale numbers use hydrogen as a reference electrode (convention), right scale numbers are from a MicroLab experiment using lead ion/ lead as a reference. The order of the series is the same regardless of choice of reference.

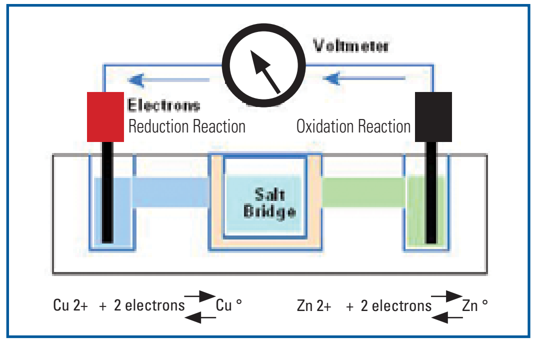
The Multi-EChem design provides three advantages:

(1) Connection of half-cell pairs is easily implemented and clearly visualized.

These may be different metal/ion pairs to develop the electrochemical series, or different concentrations of the same metal/ion pair to create concentration cells.

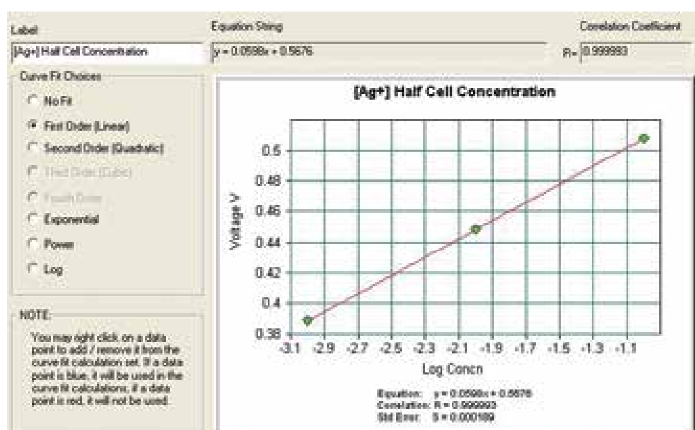
(2) The salt bridge does not dry out and electrochemical cell voltages are extremely stable for long periods of time.

(3) The polypropylene body of the module is rugged and chemically resistant. Its non-skid feet keep it securely in place on the lab bench. It will have a long service lifetime.



One can experimentally develop the electrochemical series by comparing a series of metal/ion pair half cells against one "reference" metal/ion half cell.

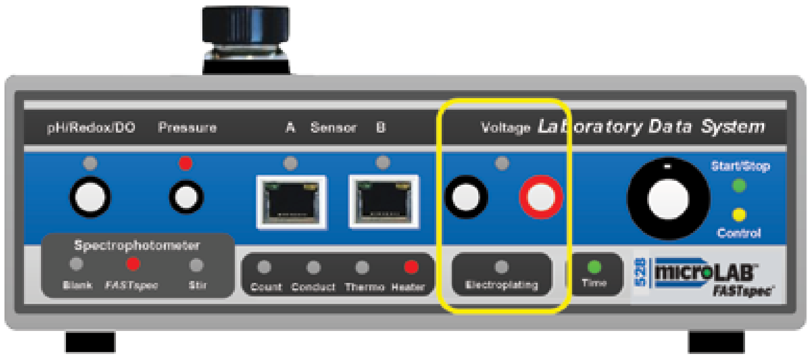
*The **Model 152** Multi-EChem Half Cell Module has space for eight half-cells, each equally accessing a central salt bridge through a porous cylinder. A milled "overflow" area prevents spills and mixing of solutions. A positive voltage reading indicates that electrons are running into the black lead from the oxidation reaction and out of the red clip to the reduction reaction.*



This plot of log [Ag+] concentration vs cell voltage confirms the Nernst equation prediction that cell potential will be directly proportional to log [Ag+]. The slope is 0.0598 volts/decade.

Multi-EChem Half Cell Module.	
Solution volume for each half cell:	3.2 mL
Overflow volume for each half cell:	2.5 mL
Salt bridge well volume:	3.2 mL
Mass:	196 g
Dimensions:	10.1 cm diameter x 3.1 cm high
Stability over time:	Better than 1 mV over 30 minutes

Forced Electrochemical Reactions



Electrochemistry is somewhat of a step-child in the general chemistry curriculum.

Often left for quick treatment at the end of the semester, "hands-on" electrochemistry labs are thought difficult and expensive.

This need not be true. Here are some new tools that use small samples and will make electrochemistry understandable, affordable, easy and fun to teach – and to learn!

MicroLab 528's black and red "Voltage" banana jacks play double duty. For **spontaneous electrochemical experiments** such as the electrochemical series and the Nernst equation, they measure DC voltage ± 2500 mV with a resolution of ± 0.076 mV.

For **forced electrochemical experiments** such as electroplating, these banana jacks provide an adjustable regulated 0-5 volt DC power supply delivering up to 750 mA.

The **Model 272 Electrochemistry Module** provides a controlled voltage and integrates instantaneous current for electroplating (electrogravimetric) experiments, or for coulometric titrations that generate the titrant through electrochemical oxidation or reduction in a solution.

"Microlab software is not just easy to use. It is also the kind of software, with it's logic and graphical interface, that prepares students to make the transition to PC-based software in high-end stand-alone instruments like HPLC, NMR, and UV-Vis in research and advanced courses as well as on the job."

Dr. Mike Collins, Viterbo University

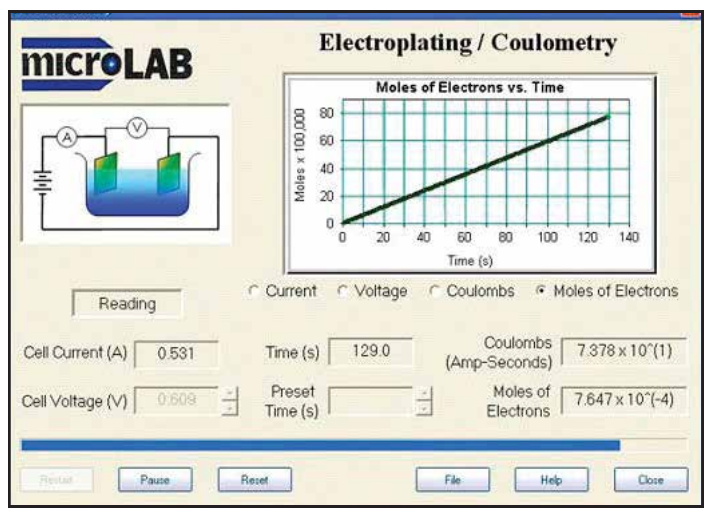
Experiments include:

- Electroplating - qualitative demonstration of electrochemical reduction and its industrial applications.
- Electro-gravimetric experiments - measurement of mass and charge transfer. Given experimental data for mass, coulombs of charge transferred, and any two of the three following parameters, calculate the third: (a) Avogadro's number, (b) Ionic charge, and (c) atomic mass.

Determination of Atomic Mass

MicroLab's Electroplating / Coulometry software permits the student to set the voltage applied to the electrochemical cell and to monitor time, cell current in amps, and coulombs of charge and moles of electrons delivered during the experiment. Data from an electroplating experiment to determine the atomic mass of copper is illustrated in the box below. This data shows an experimental atomic mass for copper of 61.3 grams/mole.

–Data from Dr. Tim Sorey, Central Washington University.



<u>**Determining the Atomic Mass of Copper**</u> Ionic charge = +2. Reduction equation: $Cu^{2+} + 2\ e \rightarrow Cu^{0}$

Duration of experiment: 912 seconds Voltage: Held constant at 0.65 volts. Average Current: 0.52 amps (current sensitive to electrode size and spacing)

Mass of copper deposited: 0.155 g (carefully dry and weigh electrode after experiment is complete)

Number of coulombs delivered: 474.2 coulombs (from display)

Number of moles of electrons delivered: 4.92×10^{-3} moles (from display)

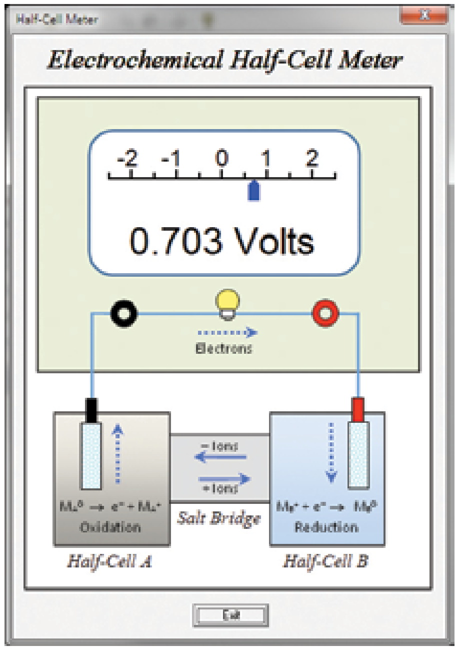
Each atom of Cu^{2+} requires two electrons:

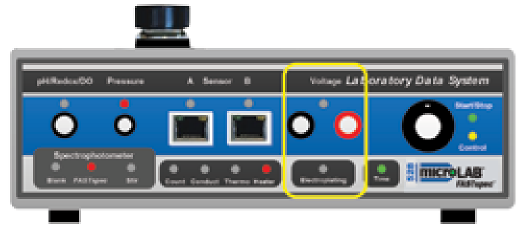
Number of moles of Cu atoms: (4.92×10^{-3} moles electrons) * (1 mole Cu atoms / 2 moles of electrons)

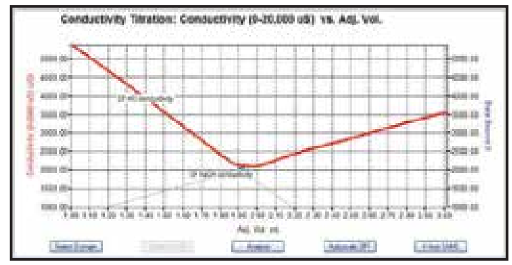
Atomic mass = (0.155g Cu) / (2.46×10^{-3} mole Cu) = 61.3 g/mole. Accepted value 63.5 g/mole

Which Way Do Electrons Go?

For a beginner, probably the most difficult part of an electron-transfer experiment is figuring out which way the electrons are moving. In the old days we had center-zero moving needle galvanometers, and you could see which way the needle leaned. Today we have digital voltmeters that protest if the electrons are going the "wrong" way by putting a negative sign in front of the voltage number. The convention is that electrons running into the black (negative) lead of a voltmeter produce a positive voltage display.







This graph shows conductivity change during a titration of silver nitrate with sodium chloride. Minimum conductivity occurs when all of the silver ion is converted into insoluble silver chloride.

MicroLab's electrochemistry software display can help with this. It gives three types of display:

- If electrons go in the black FS-528 voltage jack, the meter reads to the right and the voltage sign in the digital display is positive.
- Blue arrows show the direction of electron motion, and a light bulb lights up to show the motion of electrons though a load.

Generic oxidation and reduction reactions are written in the correct direction.

If the position of the cells is reversed placing the oxidation reaction on the right, the meter reverses, the voltage sign turns negative, the electron motion arrows turn red and reverse, and the reactions reverse.

Conductance Sensor

Use the **MicroLab Model 160** Conductance Sensor to measure accurately the conductance of solutions. The sensor is very useful for measuring the salinity of environmental samples, for measuring total dissolved solids (TDS), or for tracking titrations which consume or produce ions.

Chemical concepts such as solubility, weak and strong electrolytes, acids/bases can be explored easily.

Conductance Ranges: 0-2,000 uS, resolution 0.03 uS

0-20,000 uS, resolution 0.3 uS

Cell Constant: 1.0

Electrochemistry Module
Coulometry / Voltammetry / Isolated Sensors

MicroLab's Model 292 Coulometric Titration Module connects coulometry and voltammetry experiments to MicroLab's Port A general purpose input.

Because the cell current in a coulometric experiment will interfere with other electrochemical measurements in the same solution, the Model 292 module includes circuits used in medical electronics to provide 2 kV electrical isolation for the sensor amplifiers. pH, REDOX, ISE, and amperometric end points may be tracked with no interference between the coulometric titration and the monitoring electrode.

A manual control permits the operator to set the voltage applied to the amperometric detector.