

Determining Avogadro's Number

The basic counting unit in chemistry, the mole, has a special name, *Avogadro's number*, in honor of the Italian scientist Amadeo Avogadro (1776-1856). The commonly accepted definition of Avogadro's number is the number of atoms in exactly 12 g of the isotope ^{12}C , and the quantity itself is $6.02214199 \times 10^{23}$.¹

Avogadro was a teacher of physics and math at the University of Turin, where he was later promoted to the chair of physical chemistry. In 1811, Avogadro published a paper in the *Journal de Physique*, entitled "Essay on a Manner of Determining the Relative Masses of the Elementary Molecules of Bodies, and the Proportions in Which They Enter into These Compounds". This paper includes the statement that has come to be regarded as Avogadro's Hypothesis:

The first hypothesis to present itself in this connection, and apparently even the only admissible one, is the supposition that the number of integral molecules in any gases is always the same for equal volumes, or always proportional to the volumes. Indeed, if we were to suppose that the number of molecules contained in a given volume were different for different gases, it would scarcely be possible to conceive that the law regulating the distance of molecules could give in all cases relations as simple as those which the facts just detailed compel us to acknowledge between the volumes and the number of molecules.

In this experiment, you will confirm Avogadro's number by conducting an electrochemical process called *electrolysis*. In electrolysis, an external power supply is used to drive an otherwise nonspontaneous reaction. You will use a copper strip and a zinc strip as the electrodes, placed in a beaker of sulfuric acid. By determining the average current used in the reaction, along with the knowledge that all of the copper ions formed are the 2^+ cations, you will calculate the number of atoms in one mole of copper and compare this value with Avogadro's number.

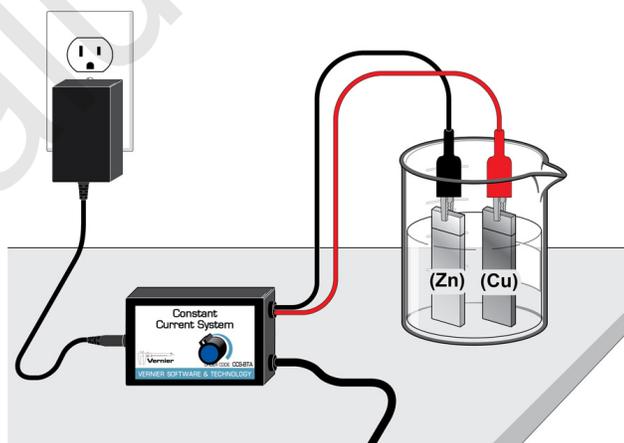


Figure 1 Electrochemical cell using the Constant Current System

¹ *CRC Handbook of Chemistry and Physics*, 82nd edition, pp. 1-7.

OBJECTIVES

In this experiment, you will

- Prepare an electrochemical cell to oxidize a copper electrode.
- Measure the amount of copper that was deposited in the electroplating process and determine the average current used.
- Calculate a value for Avogadro's number and compare it to the accepted value.

MATERIALS

Vernier computer interface
computer
Logger *Pro* (version 3.8.5 or newer)
Vernier Constant Current System
or 1.5 volt DC power source and
Vernier Current Probe
4 connecting wires with alligator clips
(for use with the Current Probe only)

1 M sulfuric acid, H₂SO₄, solution
copper strip
zinc strip
distilled water
two 250 mL beakers
analytical balance
steel wool

PROCEDURE

Both Constant Current System and Generic Power Supply Users

1. Obtain and wear goggles.
2. Use steel wool to clean a strip of copper. Obtain a strip of zinc metal and clean it with steel wool if needed.
3. Use an analytical balance to measure the mass of the copper strip. Record the mass in your data table.
4. Fill a 250 mL beaker about $\frac{3}{4}$ full with 1 M H₂SO₄ solution. **CAUTION:** *Handle the sulfuric acid with care. It can cause painful burns if it comes in contact with the skin.*

Constant Current System Users (Others see Generic Power Supply Users below)

5. Gently turn the dial of the Constant Current System counterclockwise to confirm that it is in the minimum current position.
6. Clip the zinc to the black lead and the copper strip to the red lead. See Figure 1 for the setup. Do not place the electrodes in the beaker until Step 9. **Important:** Be careful when handling the electrodes. Do not allow the electrodes to touch each other.
7. Plug the Constant Current System into a powered electrical outlet. Connect the sensor cable to Channel 1 of the Vernier computer interface. Connect the interface to your computer with the proper cable.
8. Start the Logger *Pro* program on your computer. The default mode of data collection is suitable for this experiment.

Generic Power Supply Users

- Obtain a DC power supply and a Vernier Current Probe. **Important:** Make sure the power supply is turned off.

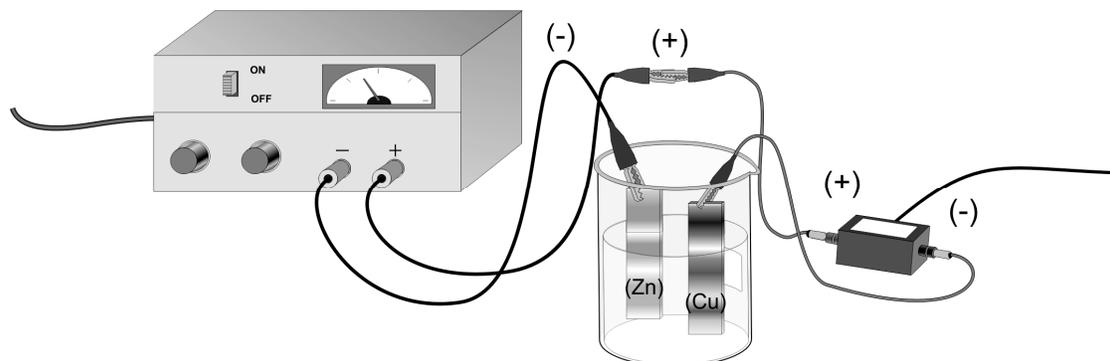


Figure 2: Electrochemical cell using a power supply and Current Probe

- Use connecting wires, with alligator clips, to connect the DC power supply, Current Probe, and the two metal electrodes to be used in the electrochemical cell (see Figure 2). Do not place the electrodes in the cell until Step 9. **Important:** Be careful when handling the electrodes. Do not allow the electrodes to touch each other.
- Connect the Current Probe to Channel 1 of the Vernier computer interface. Connect the interface to your computer with the proper cable.
- Start the *Logger Pro* program on your computer. Open the file “31 Avogadro” from the *Advanced Chemistry with Vernier* folder.

Both Constant Current System and Generic Power Supply Users

- Place the electrodes into the 1 M H_2SO_4 solution in the cell. Make sure that the electrodes are immersed in the solution to equal depths and as far apart as possible.
- Click to begin the data collection. Check the readings of current from the power supply. The initial current should be in the 0.2 – 0.4 A range. If the current is not in this range, adjust the settings on the power supply.
- Data will be collected for 3 minutes. Observe the reaction carefully. **Note:** Be ready to turn off or unplug the power as soon as the data collection stops.
- When data collection is complete, turn off or unplug the power supply and carefully remove the electrodes from the H_2SO_4 solution. Carefully rinse the copper electrode with distilled water. Dry the copper electrode very carefully.
- Measure and record the mass of the dry copper electrode, in your data table, for Trial 1.
- To analyze the graph of your data and determine the average current that was applied during the electrolysis, click the Statistics button, . Record the mean in your data table as the average current for Trial 1.
- To store your data, open the Experiment menu and choose Store Latest Run.

16. Clean the electrodes, or obtain new electrodes. Measure and record the mass of the copper electrode in preparation for a second run. Reconnect the electrodes and repeat Steps 9–15 to conduct a second trial. At the direction of your instructor, conduct a third trial.

DATA TABLE

	Trial 1	Trial 2	Trial 3
Initial mass of copper electrode (g)			
Final mass of copper electrode (g)			
Average current (A)			
Time of current application (s)			

DATA ANALYSIS

1. Calculate the total charge, in coulombs (C), that passed through the electrolytic cell for each trial.
2. Use your answers from 1 above to calculate the number of electrons in the electrolysis for each trial. Recall from the famous Millikan oil-drop experiment that the charge of an electron is 1.602×10^{-19} coulombs per electron.
3. Determine the number of atoms lost from the copper electrode in each trial. Remember that the electrolysis process uses two electrons to produce one copper ion (Cu^{2+}).
4. Calculate the number of copper atoms per gram of copper lost at the electrode for each trial. The mass lost at the copper electrode is equal to both the mass of copper atoms lost and the mass of copper ions produced (the mass of the electrons is negligible).
5. Calculate the number of copper atoms in a mole of copper for each trial. Compare this value to Avogadro's number.

Vernier Lab Safety Instructions Disclaimer

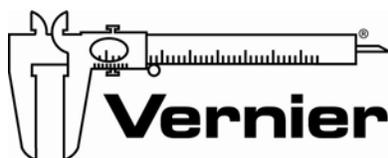
THIS IS AN EVALUATION COPY OF THE VERNIER STUDENT LAB.

This copy does not include:

- Safety information
- Essential instructor background information
- Directions for preparing solutions
- Important tips for successfully doing these labs

The complete *Advanced Chemistry with Vernier* lab manual includes 35 labs and essential teacher information. The full lab book is available for purchase at:

<http://www.vernier.com/cmat/chema.html>



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