

Finding the Charge of an Electron

Lab 8

Text reference: Chapter 3

Introduction

An electron is too small to see or to have its mass measured in a school laboratory, but a flow of electrons (an electric current) can produce large-scale changes in matter. An electric current in the form of a lightning bolt, for example, can incinerate a tree. On a smaller scale, you probably know from experience that the electric current in a toaster can easily make your breakfast waffle too hot to touch.

In this investigation, you will monitor a chemical change, called an electroplating reaction, produced by an electric current. In an electroplating reaction, a source of electric current is connected to two metal electrodes immersed in a solution that can conduct electricity. The solution is composed of water and a compound that dissolves into charged particles, called ions. The current causes metal atoms to leave one electrode and dissolve into the solution. At the same time, metal atoms plate out, or attach, onto the other electrode.

You will use zinc metal (Zn) for the electrodes in this investigation. At the positive electrode, zinc atoms lose two electrons each and dissolve as Zn^{2+} ions. These ions travel freely in the solution. At the negative electrode, Zn^{2+} ions from the solution gain two electrons and plate out as neutral zinc atoms. You will be able to measure the change in mass at each electrode and from these data derive the number of zinc atoms gained or lost. Since changes in each zinc atom involve two electrons, the number of electrons involved is double the number of atoms.

The electroplating reaction is driven by an external battery, which causes electrons to move through a wire toward the negative electrode and away from the positive electrode through another wire. You will measure the flow of electrons through the external wire using an ammeter. With the data you have, you can use a series of calculations to find the charge on one electron.

Pre-Lab Discussion

Read the entire laboratory investigation and the relevant pages of your textbook. Then answer the questions that follow.

1. What quantities do you need to know in order to determine the charge of the electron?

Name _____

2. How is each quantity in Question 1 obtained?
3. What quantity is measured by the ammeter?
4. How is the total charge calculated?
5. Why must the number of zinc atoms be doubled to find the number of electrons that flowed through the circuit?
6. What hazards are present in this investigation, and what safety precautions should you follow?

Problem

How can the charge of an electron be determined?

Materials

chemical splash goggles	3 wire leads with alligator clips
laboratory apron	ammeter
2 zinc (Zn) electrodes	stopwatch or clock with a second hand
steel wool	beaker containing tap water
marking pen or pencil	beaker containing denatured alcohol
beaker, 250-mL	laboratory balance
zinc sulfate solution, (ZnSO ₄) 1.0 M	
4 D batteries	

Safety



Wear your goggles and lab apron at all times during the investigation. The denatured alcohol bath contains methyl alcohol, which is poisonous and highly flammable. Wash any spills and splashes immediately with plenty of water and make sure there are no open flames in the laboratory. Use the alcohol bath only under your teacher's supervision.

Note the caution alert symbols here and with certain steps of the Procedure. Refer to page xi for the specific precautions associated with each symbol.

Procedure

1. Put on your goggles and lab apron.
2. Rub both sides of the two zinc electrodes with steel wool to remove any dirt or grease. Use the marking pen to draw a + (positive sign) on one electrode and a - (negative sign) on the other electrode. Measure the masses of the electrodes, and record these values in Data Table 1.
3. Assemble the apparatus shown in Figure 8-1 as follows. Bend one end of each electrode so that it can rest on the rim of the 250-mL beaker. Then place the electrodes on opposite sides of the beaker and add (200* mL) of the zinc sulfate solution to the beaker. ** ≈ 125 ml* CAUTION: Be sure that the electrodes do not touch each other. Connect one of the wire leads to the positive zinc electrode and the other end of that lead to the negative terminal of your ammeter. Connect a second lead to the negative zinc electrode and the other end of that lead to the negative terminal of the batteries. Do not connect the third wire yet.

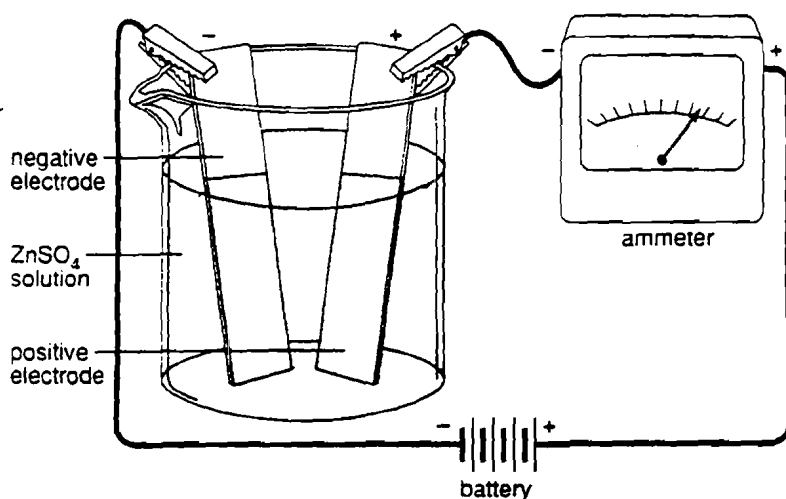







Figure 8-1

4. After your teacher has checked your apparatus, connect the third lead between the positive terminal of the ammeter and the positive terminal of the batteries. Watch the ammeter for a few moments until the current remains unchanging, and then adjust the current to between 0.70 and 0.80 amperes by moving the electrodes closer together or further apart. Do not allow the electrodes to touch.
5. In Data Table 2, record the current indicated by the ammeter. Take a reading at the beginning of each minute for 20-25 minutes. If the current varies beyond the 0.70-0.80 ampere range, readjust the positions of the electrodes. Be sure to wait until the end of a 1-minute interval to make any adjustments.

Name _____

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 6. Disconnect the wire leads from the electrodes when you have finished taking readings. Carry your beaker containing the electrodes to the washing area set up by your teacher. Holding each electrode by its dry end, rinse it very carefully by dipping it first in a large beaker of water and then in a beaker of denatured alcohol. Do not shake or swirl the electrodes in the rinse liquids, or you may dislodge pieces of zinc. **CAUTION:** *The alcohol is toxic, and its vapors are flammable. Use only under your teacher's supervision. Be sure there are no flames in the laboratory. Avoid touching the alcohol. Wash spills or splashes on your skin with plenty of water.*
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 7. Set the electrodes gently on a paper towel, and place them in a protected area to dry. Return the zinc sulfate solution to a container provided by your teacher.
8. Measure the mass of each electrode when it is completely dry, and record these values in Data Table 1.
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 9. Clean up your work area and wash your hands before leaving the laboratory.

Observations

DATA TABLE 1

	Negative Electrode	Positive Electrode
initial mass (g)		
final mass (g)		
change in mass (g)		

DATA TABLE 2

Time (min)	Current (amp)	Time (min)	Current (amp)
1		11	
2		12	
3		13	
4		14	
5		15	
6		16	
7		17	
8		18	
9		19	
10		20	



Calculations

1. Find the change in mass for each electrode and write this value in Data Table 1.
2. The mass of a zinc atom is 1.09×10^{-22} g. Find the total number of zinc atoms involved at each electrode by dividing the change in mass by the mass of one atom.
3. Calculate the average current flowing through the ammeter. Then find the total charge in ampere-seconds by multiplying the average current by the time elapsed in seconds. (Remember to convert minutes to seconds.)
4. In SI units, charge is measured in coulombs. One coulomb is equal to one ampere-second. Convert your value for total charge to coulombs and calculate the charge per zinc atom involved at each electrode.
5. Find the charge per electron. (Note: Remember that for every zinc atom in the reaction, two electrons are involved.)

Critical Thinking: Analysis and Conclusions

1. How closely do your two values for the charge of an electron match the accepted value given in your textbook? ('

Lab 8


Name _____

2. Are the charge values you calculated for the two electrodes the same? If not, how might the discrepancy be explained?
3. What source of energy caused the change in masses of the electrodes?
4. Are the changes in mass measured at each electrode consistent with the reactions taking place? Explain.

Critical Thinking: Applications

1. If you were to try this experiment using a different metal for the electrodes (and an appropriate conducting solution), predict whether or not you would find similar values for the charge on the electron. Explain.
2. How do you think the number of zinc ions in solution at the start of the reaction compares to the number at the end? Explain your reasoning.

Going Further

1. Under your teacher's supervision, redo this experiment using a different metal (lead or copper are recommended). See if you arrive at the same value for the charge on an electron.
2.  Look in your textbook to find the mass of an electron as calculated by Robert Millikan. Using this value and the value you found for the charge on the electron at the negative electrode, calculate the charge-to-mass ratio of an electron. Compare your answer to the charge-to-mass ratio determined by J.J. Thomson.