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Galvanic Cell

Preparer's Version

Introduction

Electrochemical reactions are a cornerstone of chemistry, particularly evident in galvanic cells where chemical energy is converted into electrical energy. A classic demonstration of this concept involves constructing a galvanic/voltaic cell using zinc(II) sulfate ($ZnSO_4$) and copper(II) sulfate ($CuSO_4$) solutions, with a salt bridge containing sodium sulfate (Na_2SO_4) to complete the circuit. In chemistry, reduction is the gain of electrons by a molecule, atom, or ion, while oxidation is the loss of electrons. These processes often occur simultaneously in redox reactions, where one species is reduced and another is oxidized. This setup showcases the fundamental principles of redox reactions, where oxidation and reduction processes occur at different electrodes.

The voltage produced by a galvanic cell results from the difference in potential energy between the electrons in the two metals. Zinc has a higher tendency to lose electrons (a more negative electrode potential) compared to copper. This difference in electrode potential drives the electrons from zinc to copper, creating a potential difference measured as voltage. The salt bridge, usually a U-shaped tube filled with an electrolyte like sodium sulfate, maintains electrical neutrality by allowing ions to flow between the two solutions, preventing charge buildup that would otherwise stop the reaction.

Safety Hazards

- Personal Protective Equipment
  - Safety glasses/goggles
  - Nitrile gloves
  - Chemical & flame retardant lab coat
- Chemical Hazards
  - Copper(II) sulfate is harmful if swallowed and causes serious skin irritation; very toxic to aquatic life with long lasting effects.
  - Zinc sulfate is harmful if swallowed and causes serious eye damage; very toxic to aquatic life with long lasting effects.
  - Sodium sulfate may cause skin, eye, and respiratory tract irritation.

Materials

- 75 mL 0.5M Copper(II) sulfate solution
- 75 mL 0.5M Zinc(II) sulfate solution
- 150 mL 0.5M Sodium sulfate solution
- Salt bridge
- 2x 150 mL glass beakers
- Zinc electrode
- Copper electrode
- Voltmeter/Multimeter
- Pipette and pipette tips
- Polypad (blue absorbent paper)

Safety Data Sheet(s)

- Copper(II) sulfate
- Zinc(II) sulfate
- Sodium sulfate

Procedure

1. Weigh out 5.9854 g of copper(II) sulfate and add it to 75 mL of deionized water. Stir until fully dissolved.
2. Weigh out 6.0551 g of zinc(II) sulfate and add it to 75 mL of deionized water. Stir until fully dissolved.
3. Weigh out 10.653 g of sodium sulfate and add it to 150 mL of deionized water. Stir until fully dissolved.
4. Ensure that both electrodes are clean. If not, acid wash the electrodes thoroughly and then rinse completely before use.
5. To maximize visibility, use a document camera for this demonstration.
6. Place the polypad over the surface on which the galvanic cell will be set.
7. Place the salt bridge standing in the empty beakers, with one end in each beaker, or standing on the polypad. Using the pipette set to 5.00 mL, slowly add 0.5M Sodium sulfate to the salt bridge via the opening stem. Make sure it is entirely full (as depicted on the diagram)!
8. Pour 0.5M Copper(II) sulfate solution into one beaker.
9. Pour 0.5M Zinc sulfate solution to the other beaker.
10. Make sure the red wire is plugged into the middle plug of the multimeter, directly above the black one. Make sure the black wire is plugged into the bottom plug (black).
11. Turn the multimeter to the left until it's set to 2000 m. The arrow should be in the quadrant labeled 'V' – meaning that it will be measuring voltage. There shouldn't be any voltage initially, since the clips aren't attached to anything.
12. Carefully place the copper strip/electrode into the copper sulfate solution. Carefully place the zinc strip/electrode into the zinc sulfate solution.
13. Clip the red wire onto the top of the copper strip, and the black wire onto the top of the zinc strip. The multimeter should read a voltage ~1000 (Divide by 1000 to get actual voltage; should be roughly 1 V produced).

Tips & Tricks

- Do not fill the salt bridge until you are ready to perform the demonstration. It may leak! If it is not completely filled, it will not ‘close the circuit’ and voltage will not be read from the multimeter.

Clean-Up Procedures

1. Pour each solution into a waste bottle. Keep the salt bridge and electrodes sitting in the beakers until you're back in the lab.
2. Using a larger beaker, thoroughly rinse all glassware with DI water. This runoff water should also go into the waste bottle.
3. The salt bridge may be difficult to empty. Gently tapped it to try getting the liquid to come out. If you cannot get all of the solution out, wait until the bridge completely drains to refill it with deionized water for several rounds of rinsing.
4. Clean glassware thoroughly with lab soap and water.

5. Acid wash the electrodes. Rinse off well with DI water first (into the waste bottle). Using 0.5M acetic acid, gently and carefully clean off the end of the electrode that was in solution. You don't need more than ~10-15 mL to do this per electrode, and it can be done in a large crystallization dish to catch the acid running off of the electrode. Once you're finished, thoroughly rinse with DI water again and pat dry with a paper towel.

Set-Up References & Diagrams