Chemistry 110
The Cycle of Copper

Purpose

To observe a sequence of reactions of copper that form a cycle and to observe the color and physical property changes that indicate those reactions. Also, to practice quantitative laboratory techniques by determining the percent recovery of the initial copper mass.

Discussion

Most chemical syntheses involve….to be continued☺

$Cu\ (s)\ +\ 4\ HNO_3\ (aq)\ \rightarrow\ Cu(NO_3)_2\ (aq)\ +\ 2\ NO_2\ (g)\ +\ 2\ H_2O\ (l)$

$Cu(NO_3)_2\ (aq)\ +\ 2\ NaOH\ (aq)\ \rightarrow\ Cu(OH)_2\ (s)\ +\ 2\ NaNO_3\ (aq)$

$Cu(OH)_2\ (s)\ \rightarrow\ CuO\ (s)\ +\ H_2O\ (g)$

$CuO\ (s)\ +\ H_2SO_4\ (aq)\ \rightarrow\ CuSO_4\ (aq)\ +\ H_2O\ (l)$

$CuSO_4\ (aq)\ +\ Zn\ (s)\ \rightarrow\ ZnSO_4\ (aq)\ +\ Cu\ (s)$

Safety Precautions

Concentrated nitric acid, HNO_3, is a hazardous liquid producing severe burns and the vapor is a lung irritant. The dissolution of the copper wire in concentrated nitric acid **must be carried out in the fume hood** to avoid the toxic brown nitrogen dioxide gas, NO_2.

Sodium hydroxide, NaOH, solutions are corrosive to the skin and especially dangerous if splashed into the eyes—ALWAYS WEAR YOUR SAFETY GOGGLES!

Methanol is flammable and the vapors are toxic. **Use it in or near the fume hood**.

Pre-Lab Questions

1. Give one example of a Redox reaction and one example of a Precipitation reaction. Write the complete balanced, molecular equation for each reaction, including all phases.

2. Define percent yield in general terms, including the formula.

3. Name the two methods of separation that you have used in lab this semester and describe each method.

4. Compare and contrast endothermic and exothermic reactions.

5. Write the complete balanced, molecular equation and calculate the percent yield of the reaction if 1.7024 grams of copper (II) nitrate are produced from 1.0563 grams of solid copper and excess aqueous nitric acid.

6. What is the maximum percent yield in any reaction?

7. What might be the cause of a percent yield higher than the maximum?

8. Write the complete balanced, molecular equation for the reaction of aqueous copper (II) nitrate with aqueous sodium hydroxide. Type of reaction is:

9. Write the complete balanced, molecular equation for the reaction of solid copper (II) hydroxide with heat producing solid copper (II) oxide and liquid water. Type of reaction is:

10. Write the complete balanced, molecular equation for the reaction of solid copper (II) oxide with aqueous sulfuric acid. Type of reaction is:

11. Write the complete balanced, molecular equation for the reaction of aqueous copper (II) sulfate with solid zinc. Type of reaction is:

Procedure

Weigh a piece of previously cut copper wire and record the mass. It should weigh ~0.5 grams. Coil the copper wire into a flat spiral and place it into a 250-mL beaker.
Next, **in the fume hood**, add ~4-5 mL of concentrated nitric acid.
If any acid splashes on to your skin wash the area with copious (LOT'S!!) of tap water.
Record a description of what you see. (6)

Allow the reaction to run to completion. How long will this take? Don't ask! When what you recorded as a description of what you see stops, then wait 5 more minutes. There should be no visual evidence of the initial copper wire.

Add ~100 mL of deionized water to the beaker, then return to your lab bench.
Add ~30 mL of 3.0 M NaOH to the solution in your beaker, with continuous stirring.
Record a description of what you see. (7)

Next, add two boiling beads and place the beaker on a hot plate. Gently heat the mixture, with stirring, for ~20-30 minutes or until the reaction is <u>complete</u>. Don't let this solution boil.
Record a description of what you see. (8)

Remove the beaker from the hot plate and allow the solution to cool and the solid to settle to the bottom of the beaker. This will take time…be patient. When the liquid above the solid appears clear decant the supernatant liquid and dispose of it in the appropriate waste container. There may be some liquid left in the beaker, don't risk losing your product to get rid of it!

Add ~200 mL of hot deionized water to the beaker, stir and allow the precipitate to settle again (patience), then decant once more. Again, don't risk any of your product!
What is being removed by this washing and decantation process? (9)

Add ~15 mL of 6.0 M H_2SO_4, with stirring.
Now, what copper compound is present in this solution? (10)

Place your beaker next to the lab bench vent, then add ~2.0 grams of zinc metal (all at once) with stirring. Continue stirring at the vent until the liquid becomes colorless.
Record a description of what you see. (11)

What is being produced in the solution? (12)

What gas is being formed in this reaction? (13)

When the evolution of a gas becomes very slow look for silvery grains of unreacted zinc in the beaker. If there are any present add ~10 mL of 6.0 M HCl and warm very gently, the evolution of gas should begin again. If there is no evidence of unreacted zinc go to the next step. When the evolution of a gas becomes very slow and there is no evidence of unreacted zinc on the bottom of the beaker remove the heat and let the beaker and its contents cool.

Decant the solution and transfer the precipitate to a pre-weighed evaporating dish.
This liquid must go into a waste container labeled "Zinc's" not the waste container used previously.

Add to the solid in the dish, ~5 mL of DI water and stir. Let the mixture settle and decant the liquid into the "Zinc's" waste container. Repeat this water wash once more.
What is being removed by this washing and decantation process? (14)

Next wash the precipitate with ~5 mL of methanol, and repeat once more.
This liquid must go into a waste container labeled "Organic's" not the containers used previously.
Decant off as much of the methanol possible without losing any product!

Carefully, dry the product by placing the evaporating dish on the hot plate. After a while the product might begin to splatter, consider a watch glass 'lid' and/or turn the heat down.

When the product is dry, remove it from the heat, and allow it to cool. Carefully, remove the boiling beads and scrape any product back into the dish if necessary. Weigh the dish with the product on the same balance that you weigh your empty dish earlier.

What is the product? (15)

What color is the product and how does this color compare to the initial reactant? (16)

Calculate the final mass of copper and the percent yield

Report Sheet

1. Initial mass of copper _____
2. Mass of recovered copper and evaporating dish _____
3. Mass of empty evaporating dish _____
4. Mass of recovered copper _____
5. Percent yield, show calculation _____

6. Describe the reaction: $Cu\ (s)\ +\ HNO_3\ (aq)\ \rightarrow$

7. Describe the reaction: $Cu(NO_3)_2\ (aq)\ +\ \ NaOH\ (aq)\ \rightarrow$

8. Describe the reaction: $Cu(OH)_2\ (s)\ \rightarrow$

9. What is being removed by this washing? _____
10. What copper compound is present in the beaker? _____
11. Describe the reaction: $Cu(SO_4)\ (aq)\ +\ Zn\ (s)\ \rightarrow$

12. What is present in the solution? _____
13. What is the gas being produced? _____
14. What is being removed by this washing? _____
15. What is the product? _____

What color is the product and how does it compare to the initial reactant?

_____

Questions and Calculations

1. Now that you have completed the experiment, if your percent yield is greater than 100%, at what step(s) in the procedure did this occur? Or, if your percent yield is less than 100%, at what step(s) in the procedure did this occur?

2. Write the complete balanced, molecular equation for the combustion of methane gas, CH_4:

   a) If 2.55 moles of methane react with 4.50 moles of oxygen, what is the limiting reagent?
   b) From this mixture of reactants, how many grams of carbon dioxide and how many grams of water can be produced?
   c) If the percent yield for this reaction is 95.0%, what actual yield can you expect?
   d) How many grams of the excess reactant (if there is one) will remain unreacted?

3. How many milliliters (mL) of 3.84 M sulfuric acid are required to react completely with 0.878 grams of copper (II) oxide?

4. If 3.00 grams of zinc are reacted with 1.75 grams of copper (II) sulfate, how many grams of zinc will remain unreacted?