

Name: _____

Chemistry 117 Laboratory
University of Massachusetts Boston

REACTIONS OF COPPER

PRELAB ASSIGNMENT

How many millimoles of $\text{HNO}_3(aq)$ are needed to react completely with a 0.2800 gram piece of copper wire according to reaction (1) below?

IN THE LABORATORY

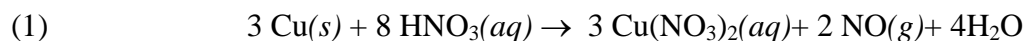
In this experiment we will carry out several reactions of the element copper (symbol Cu). These are summarized as a Schematic Diagram at the end of the manual. In the process we will learn new laboratory techniques as well as practice mole calculations involving chemical equations.

Reaction of Metallic Copper with Nitric Acid Solution

1. Obtain a piece of copper wire and measure its mass on an analytical balance. Record the mass on the proper line on page 6.
2. Roll the wire into a flat coil and place it in a clean 150-mL beaker labeled with your initials.
3. Use a 10 mL graduated cylinder to measure 3 mL of deionized water into the beaker.
4. In the fume hood dispense 3.0 mL of HNO_3 solution into the beaker. Move to a fume hood with a hot plate. Warm the beaker to get the reaction started and then leave it in the hood.

WARNING! NITRIC ACID IS CORROSIVE. IF ANY ACID CONTACTS YOUR SKIN OR SPILLS ANYWHERE, WASH IT UP IMMEDIATELY.
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The reaction going on in the beaker is described by the following balanced equation:



The brown gas is NO_2 (nitrogen dioxide), which is formed by reaction of $\text{NO}(g)$ (nitric oxide) with

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$O_2(g)$ (oxygen gas) in the air. These nitrogen oxide gases are toxic. Keep the beaker in the fume hood until the gas evolution stops. Notice that the solution is blue. The aqueous $Cu(NO_3)_2$ (copper nitrate) is dissociated into Cu^{2+} (copper) ions and NO_3^- (nitrate) ions and the Cu^{2+} ions are blue.

Wait until the copper wire disappears. What does the disappearance of the copper wire mean? Consider the following possibilities:

- Copper was the limiting reagent and HNO_3 was in excess.
- HNO_3 was the limiting reagent and Cu was in excess.
- Neither Cu nor HNO_3 was added in excess.

Which of these is possible?	a.	b.	c.
Which is impossible?	a.	b.	c.

- Add about 25 mL of deionized water measured by graduated cylinder to the baker and bring it back to your bench.

Precipitation of Copper Hydroxide

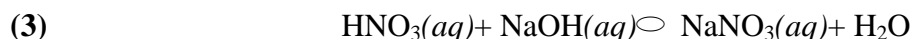
- Gather up the following:
 - a glass stirring rod
 - a 10-mL graduate cylinder
 - two strips of red litmus paper
 - a 50-ml beaker
 - a medicine dropper
 - a wash bottle filled with deionized water
- Measure out about 6 mL of NaOH (sodium hydroxide) solution using the 10-mL graduated cylinder. Transfer this to the 50-mL beaker.
- Dip the stirring rod into the copper nitrate/nitric acid solution and then touch it to the red litmus paper. Notice the color remains red which indicates that the solution is acidic.
- Rinse off the stirring rod, dip it into the NaOH and then touch the litmus paper. Notice the color turns blue which indicates that the sodium hydroxide solution is alkaline.
- Slowly add NaOH solution dropwise and with continuous stirring just until the solution turns alkaline. Notice that a blue precipitate forms, but redissolves at first when the solution is still very acidic. Eventually when enough NaOH is added, the precipitate remains. **STOP ADDING NaOH WHEN THE SOLUTION IS ALKALINE** as indicated by a blue litmus test.

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There are two reactions going on when NaOH is added. Reaction 2 describes the precipitation of the blue solid $\text{Cu}(\text{OH})_2$ (copper hydroxide).



and Reaction 3 describes the neutralization of the excess nitric acid by the base NaOH.



11. Add another 25 mL of deionized water to the beaker containing the precipitate.
12. Set up a suction filtration apparatus with a piece of wet filter paper in the funnel. Your instructor will demonstrate how to use this apparatus.
13. Filter the solid from the solution. Use a stream of water from the wash bottle to transfer all the solid $\text{Cu}(\text{OH})_2$ from the beaker. Continue the suction until the cake of solid on the filter paper looks dry.
14. Clean up
 - Discard the litmus papers.
 - Rinse out the graduated cylinder, both beakers and the dropper.
 - Wash off the stirring rod.
 - Discard the liquid in the filter flask. Rinse out the flask.

Dissolving Solid $\text{Cu}(\text{OH})_2$ by Reaction with Hydrochloric Acid

15. Gather up clean glassware:
 - a 250 mL beaker.
 - a medicine dropper.
 - a 50 mL beaker.
16. Label the 250-mL beaker with your initials. Set the filtration funnel with the cake of solid $\text{Cu}(\text{OH})_2$ into the beaker.
17. Dispense 10 mL of HCl (hydrochloric acid) solution into the 50-mL beaker. Use the dropper to place drops of HCl solution directly on to the blue solid.

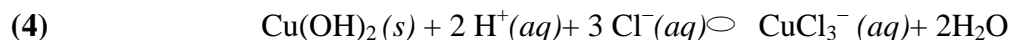
Notice that the solid gradually dissolves and the liquid runs through the filter paper into the beaker.

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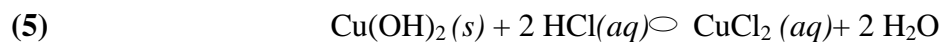
Notice also that HCl solution first turns yellow and then appears blue-green in the beaker.

18. Continue dropping HCl solution into the funnel until all the solid is dissolved. If the filter paper has any color at all, add drops of deionized water until all colored solution is washed through.

When the HCl solution first contacts solid $\text{Cu}(\text{OH})_2$, the H^+ (hydrogen ions) and the Cl^- (chloride ions) in the HCl react with $\text{Cu}(\text{OH})_2(s)$ according to



The yellow color is caused by the complex ion CuCl_3^- . As the solution becomes diluted, the CuCl_3^- ions tend to lose Cl^- and their color shifts towards green (indicating a mixture of different copper/chloride species) and eventually to blue (indicating Cu^{2+} ions). When the solution is blue, the overall change is



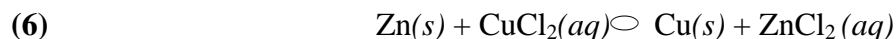
19. Discard the filter paper and rinse out the filter funnel.

Conversion of Copper Ion to Copper Metal

20. Use a triple-beam balance to weigh out about 1 gram of Zn (zinc) metal onto a weighing dish.

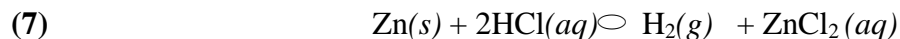
21. Bring this weighing dish and your 250 mL beaker containing the copper solution to a fume hood and add the zinc to the beaker.

Notice the change in appearance of the metal and the evolution of gas. There are two reactions occurring here. One is the reaction of copper ion in CuCl_2 with metallic zinc according to



The change in appearance of the solid is the coating of copper metal on the zinc. Notice that as the reaction proceeds the blue color of the solution gradually disappears as the colorless Zn^{2+} (ions) replace the blue Cu^{2+} ions in the solution.

The second reaction is the reaction of the excess hydrogen ions in the hydrochloric acid with zinc metal according to



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The gas bubbles are H_2 (hydrogen gas).

22. As the evolution of gas slows down, use a glass stirring rod to agitate the mixture breaking up clumps of copper metal that tend to coat the remaining zinc metal. Continue occasional stirring until the gas bubbles stop.
23. Add about 5 mL of HCl solution from the 50-mL beaker. If gas bubbles form again, continue stirring and occasionally adding a few mL of HCl until no more gas bubbles form. This will take some time. In the meantime work on the problems starting on page 6.
24. Wash the copper metal two or three times by adding deionized water (roughly to the 50 mL line on the beaker), stirring, allowing the metal to settle and decanting (carefully pouring off) the wash water.
25. Pour off as much liquid as possible and set your beaker on a warm (not hot) hotplate to dry it out.

Examine the dry metal powder in the beaker. This is the same copper that was in your original wire. If you did not lose any along the way and if the copper powder is pure, the mass of this powder would be the same as your wire.

26. Discard the powder into the WASTE COPPER beaker and return all equipment to the proper places.
27. Clean up.

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Name _____ Lab Section _____

Partner(s) _____

Reactions of Copper Data and Calculations

Remember to always provide units and the correct # of sig. figs.

Mass of your copper wire _____ (4 decimal places)

<p>Problem 1. Considering that the atomic mass of Cu is 63.54 g/mol, calculate the moles of copper and the millimoles of copper in your wire.</p>	<p>moles of Cu</p>	<p>mmol Cu</p>
<p>Problem 2. The nitric acid has a concentration of 16 moles per liter (or 16 mmol per mL). If you added 3.0 mL of this acid to your beaker, calculate the moles and millimoles HNO₃ in this 3.0 mL.</p>	<p>mol HNO₃</p>	<p>mmol HNO₃</p>
<p>Problem 3. This problem refers to Reaction 1. The observed disappearance of the copper wire might indicate that Cu was the limiting reagent. We now check this by a calculation.</p>	<p>a. How much HNO₃ (in millimoles) reacted with your wire?</p>	
	<p>b. Compare this with your answer to Problem 2. The limiting reagent is:</p>	
	<p>c. How much HNO₃ (in millimoles) remains unreacted with Cu(s)?</p>	
	<p>d. How much Cu(NO₃)₂ is produced?</p>	
<p>Problem 4. Suppose you add just enough NaOH so that all the Cu(NO₃)₂ is converted to solid Cu(OH)₂ by Reaction 2 and all</p>	<p>a. How much NaOH is needed in Reaction 2?</p>	
	<p>b. How much NaOH is needed in Reaction 3?</p>	

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the remaining HNO_3 is neutralized in Reaction 3.	c. The total NaOH needed is:	
	d. How much $\text{Cu}(\text{OH})_2$ is produced?	
PROBLEM 5. The NaOH solution contains 10.0 moles per liter or 10.0 mmol/mL.	a. What volume is needed to provide the total quantity calculated in Problem 4c?	
	b. Suppose that the average size of your drop was 0.050 mL. How many drops would be needed to supply the total NaOH requirement?	drops
PROBLEM 6. Refer to Reaction 5.	a. How much HCl (in millimoles) is needed to dissolve all the solid $\text{Cu}(\text{OH})_2$?	
	b. The HCl solution concentration is 6.0 moles per liter (or 6.0 mmol per mL). What volume is required?	
	c. How much CuCl_2 is produced?	
PROBLEM 7. Suppose that you weighed out 1.1 grams of zinc metal (65.4 g/mol). Calculate the moles and millimoles of this metal.	mol Zn	mmol Zn
PROBLEM 8. Refer to Reaction 6.	a. Assuming that the zinc is in excess, how much copper metal is produced (in moles and millimoles)?	
	b. What mass of Cu metal is produced?	
	c. How much zinc (in moles and millimoles) remains after Reaction 6 is completed?	
PROBLEM 9. Refer to Reaction 6.	a. How many moles or millimoles of HCl reacts with all the remaining metallic zinc calculated in Problem 8c?	
	b. The HCl solution contains 6.0 mol/L (or 6.0 mmol/mL). What volume is needed?	mL HCl

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Schematic Diagram of the Reactions of Copper

Chemical Equations

