

Chemistry 20: Five Day Copper Recovery Lab

Teacher NOTES

A prelab quiz each day keeps the students up to date. Although this is a 5 day lab, some days will only take 15 minutes or so. It is also possible to do more than one step per day if time is an issue.

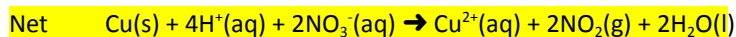
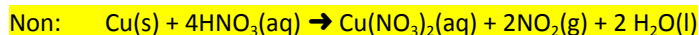
The number of significant digits that a student can measure will determine what the rounding should be for all calculations. I have assumed students have access to scales measuring to the nearest hundredth → so three significant digits

Objective: Recover 1.50 g of $\text{Cu}_{(s)}$ after making 5 chemical conversions

Materials: Copper wire
Assorted beakers
Dilute nitric acid
Watch glass
pH paper
 $\text{NaOH}_{(aq)}$
Ice/snow bath
Distilled Water
Dilute sulfuric acid
Zinc metal

Conversion 1 Change $\text{Cu}_{(s)}$ to $\text{Cu}(\text{NO}_3)_2(aq)$

- Take approximately $1.50 \pm 0.03\text{g}$ of copper wire. Clean off any corrosion using steel wool
- You may find it useful to cut the copper into small pieces as this will facilitate a quicker reaction.
- Find the exact mass and record this value _____
- Place the copper into a clean 400 mL beaker. Carefully add 20 mL of dilute nitric acid
- Place a watch glass on top and observe the reaction that is taking place. Record your observations.
- Be patient as this is a SLOW reaction. Do not expect immediate changes.
- Then place the beaker in the fume hood until the copper has completely dissolved
 - The $\text{NO}_2(g)$ is NOT healthy ... so use some caution here. Overnight the fumes will dissipate ... but don't let the students breathe in much of this stuff!
- The brownish-orange gas produced by the reaction is $\text{NO}_{2(g)}$. The blue colour of the solution is characteristic of many copper compounds dissolved in water.
- Write the non, total and net ionic equations for this conversion.
Copper + nitric acid → copper (II) nitrate + nitrogen dioxide + water



Calculate the volume of $\text{NO}_{2(g)}$ produced at SATP

Moles of Cu x 2/1 x 22.4 L/mol = 1.06 L

Calculate the mass of $\text{Cu}(\text{NO}_3)_2(aq)$ that will be dissolved in the solution.

Moles of Cu x 1/1 x 187.57 g/mol = 4.43 g

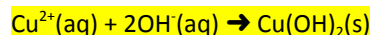
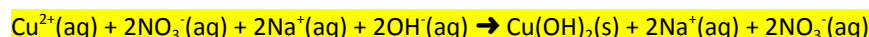
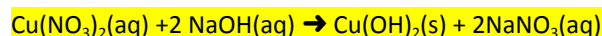
What has caused the solution to be blue in color?

$\text{Cu}^{2+}(aq)$ ions are blue in colour.

Conversion 2: Change $\text{Cu}(\text{NO}_3)_2(\text{aq})$ to $\text{Cu}(\text{OH})_2(\text{s})$

- Test the solution from conversion 1 with pH paper. Record the pH value
 - o Should be low as acid was in excess in conversion 1
- Now obtain 20 mL of $\text{NaOH}_{(\text{aq})}$. Test this solution with pH paper. Record the pH value
 - o Should test high as this is a concentrated base
- Fill a large beaker one third full of ice/snow and water. Carefully place the beaker containing conversion 1 inside. (like a double boiler)
- Cautiously and carefully add the 20 mL of $\text{NaOH}_{(\text{aq})}$ to conversion 1.
- Mix the solutions with a gentle swirling motion. The $\text{NaOH}_{(\text{aq})}$ neutralizes the excess acid from conversion 1.
 - o This is an exothermic reaction and the beakers may become hot. BE CAREFUL.
- Test the pH of the mixture again and record _____
- If the pH is not as high as the pH of the $\text{NaOH}_{(\text{aq})}$, keep adding more $\text{NaOH}_{(\text{aq})}$ until it does match.
 - o You want the $\text{NaOH}_{(\text{aq})}$ to become the EXCESS reagent
- A pale blue solid precipitate should have formed.
- Write the non, total and net ionic equations for this conversion.

Copper(II) nitrate + sodium hydroxide → copper (II) hydroxide + sodium nitrate



Calculate the mass of $\text{Cu}(\text{OH})_2(\text{s})$ that is produced in this conversion

$$\frac{4.43 \text{ g}}{187.57 \frac{\text{g}}{\text{mol}}} \times \frac{1}{1} \times \frac{1}{97.57 \frac{\text{g}}{\text{mol}}} = 2.32 \text{ g}$$

What is a precipitate?

A precipitate is an ionic compound that is low in solubility. It will remain as an undissolved solid in the solution. Remember that dissolving is temperature dependent.

Why did you continue to add the $\text{NaOH}_{(\text{aq})}$ until the pH became high?

To ensure that all the copper (II) nitrate is actually converted to copper (II) hydroxide, the excess acid must be completely used up and the sodium hydroxide must be in excess.

Conversion 3: Change $\text{Cu}(\text{OH})_2(\text{s})$ to $\text{CuO}_{(\text{s})}$

- Add 100 mL of distilled water to the beaker containing conversion 2
- Using a hotplate and eye protection, carefully heat the beaker until the solution begins to boil. STIR!
 - o This is the step that students tend to have trouble with. If they get the heat too high, the solution will “spit” chunks out and they will lose some of their copper.
it goes without saying that EYE protection is a MUST until all the students are done heating glassware!
- A brown-black precipitate will form
- Be careful that the solution does not spit out of the beaker or you will lose part of your copper for recovery!
- Remove from the heat and let the solution cool for at least 5 minutes
- Use a wash bottle to rinse the stir rod back into the beaker
- Decant the extra liquid. Ensure that no solid is lost.
- Wash the precipitate by adding an additional 100 mL of distilled water. STIR

- Let the precipitate settle again and decant off the extra liquid.
- Write the non, total and net ionic reactions for this conversion.

Copper(II) hydroxide → copper (II) oxide + water



Name the black solid produced in this step **copper (II) oxide**

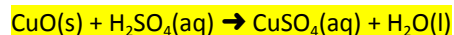
Calculate the mass of copper (II) oxide produced in this conversion

$$\frac{2.33\text{g}}{97.57 \frac{\text{g}}{\text{mol}}} \times \frac{1}{1} \times 79.55 \frac{\text{g}}{\text{mol}} = 1.90 \text{ g}$$

Conversion 4: Change $\text{CuO}_{(\text{s})}$ to $\text{CuSO}_{4(\text{aq})}$

- Add 50 mL of dilute sulfuric acid to the black copper (II) oxide.
- Stir gently. The copper (II) oxide will dissolve and the solution will turn blue again.
- Write the non, total and net ionic equations for this conversion.

Copper(II) oxide + sulfuric acid → copper (II) sulfate + water



Determine the mass of copper (II) sulfate formed in this conversion

$$\frac{1.90\text{g}}{79.55 \frac{\text{g}}{\text{mol}}} \times \frac{1}{1} \times 159.62 \frac{\text{g}}{\text{mol}} = 3.79 \text{ g}$$

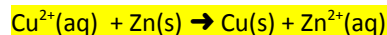
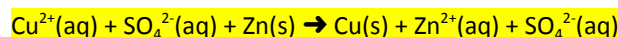
Conversion 5: Change $\text{CuSO}_{4(\text{aq})}$ to $\text{Cu}_{(\text{s})}$

- Weigh about 7.0 g of $\text{Zn}_{(\text{s})}$ and record _____
 - o $\text{Zn}_{(\text{s})}$ must be in excess. This will work better if the pieces of $\text{Zn}_{(\text{s})}$ are not too big. It may give trouble later on if the pieces are really large.
- Add this $\text{Zn}_{(\text{s})}$ to the copper (II) sulfate solution
- Immediately cover the beaker with a watch glass and allow it to stand until the **blue colour disappears**. You will have to swirl the beaker. (Be patient – this make take 10 – 15 minutes)
- If the reaction appears to slow or stop, add an additional 20 mL of acid.
- Let the beaker stand until the solid zinc metal disappears as well. Since the reaction involves the evolution of hydrogen gas, the **absence of bubbles** forming will be an indication that the zinc metal is all consumed

o Sometimes I have had the students let this sit overnight Depending on the size of the zinc chunks, this can be a SLOW process.

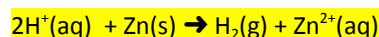
- You should now have the solid copper returning.!!
- There are actually two reactions that have happened!
- **The first explains the formation of the copper**
- Write a non, total and net ionic equation for this process.

Copper(II) sulfate + Zinc → copper + Zinc sulfate



- **The second reaction explains how you get rid of the excess zinc**
- Write a non, total and net ionic equation for this process.

Sulfuric Acid + Zinc → hydrogen gas + zinc sulfate



- Now you need to collect and find the mass of the copper you have recovered.
 - o Allow the solid copper to settle to the bottom.
 - o Decant and discard the clear liquid
 - o Wash the solid copper a **minimum of three times**. Use 50 mL portions of hot (almost boiling) distilled water
 This is important because if there are impurities left in the sample, it will darken and possibly turn black again as it dries. A good sample should be the 'coppery' colour of pure copper.
 - o Each time, stir, and then decant the liquid
 - o Accurately weigh an evaporating dish _____
 - o Transfer the copper metal to the dish. Decant off as much excess water as possible.
 Have them spread the copper sample out so it will dry faster. Remember that clothes in a 'heap' do not dry well. Neither will the sample!
 - o Allow the dish to sit and dry overnight (or several nights!).
 - o Find the mass of the dish + the copper _____
 - o If the copper metal gets too hot, it will go back to copper (II) oxide!. This is a bad thing you have already done this step!

Observations:

Conversion I	
Conversion II	
Conversion III	
Conversion IV	
Conversion V	

Analysis of data

Initial mass of copper _____
 Final mass of copper and evaporating dish _____
 Mass of evaporating dish _____
 Mass of recovered copper _____

Use the mass of copper recovered to calculate the % recovery for this lab

Be sure to allow for sufficient time for the sample to dry or the students will all be OVER by a great amount.

Remember that there may be impurities trapped in their final sample

But in the same breath, the copper they started with may not have been pure either

Justify why you recover is

- ☐ Less than 100%
- ☐ More than 100%
- ☐ Exactly 100%

Choose only one of the above!!

This is a really cool lab Teaches lots of good techniques and reinforces that the limiting reagent is in charge of the reaction
It also gives them practice at 'removing' the excess reagents!