Survey of General, Organic and Biochemistry
Laboratory No 4
CHM 108L-01
Spring 2020

# If you are not part of the solution, you are part of the ______________?

A teaching experiment produced by

Zulma Jiménez Ph.D.
Department of Chemistry
Notre Dame of Maryland University

**Concepts to explore in this lab:**

- Chemical reactions: precipitation, redox and acid-base reactions
- Writing and balancing chemical equations
- Stoichiometry
- Reaction yields
- Limiting and excess reactant

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# If you are not part of the solution, you are part of the ______________?

A chemical reaction is a process where one or multiple substances (the reactants) interact to produce a new set of substances (the products). Substances are either chemical elements or compounds. During the chemical reaction, different transformations occur simultaneously like for example breaking and forming chemical bonds; the nature of the elements remains the same because there is no change in the nuclei, only the position of electrons.

A chemical reaction may be represented by a chemical equation, which indicates the number and type of each atom, as well as their organization into molecules or ions. A chemical equation uses the element symbols as shorthand notation for the elements, with arrows to indicate the direction of the reaction. There is different type of chemical reactions:

1. **Neutralization reactions:** these are the reactions which occur in between and acid and base. These reactions result in formation of water and salt in general.
$$Mg(OH)_{2(aq)} + 2\,HCl_{(aq)} \rightarrow MgCl_{2(aq)} + 2\,H_2O_{(l)}$$

2. **Redox reactions:** these reactions are also called as oxidation-reduction reactions. The redox reactions mostly involve oxidation of one substance while other substance is reduced.
$$4\,Fe_{(s)} + 3\,O_{2(g)} \rightarrow 2\,Fe_2O_{3(s)}$$

3. **Precipitation reactions:** these reactions occur when cations and anions in aqueous solution combine to form an insoluble ionic solid called a precipitate.
$$Pb(NO_3)_{2(aq)} + 2\,NaI_{(aq)} \rightarrow PbI_{2(s)} + 2\,NaNO_{3(aq)}$$

4. **Combustion reactions:** these reactions occur when an organic compound is oxidized in an exothermic reaction that produces carbon dioxide and water.
$$C_4H_{10(g)} + 5\,O_{2(aq)} \rightarrow 4\,CO_{2(g)} + 2\,H_2O_{(g)}$$

5. **Decomposition reactions**: these reactions occur when a compound breaks down into simpler components.
$$2\,HgO_{(s)} \xrightarrow{heat} 2\,Hg_{(l)} + O_{2(g)}$$

Chemical reactions are not always carried out in their stoichiometric ratios. Typically, one of the reactants is added in excess; for instance, in the redox reaction shown above, oxygen is usually in excess. So, more than 3 moles of oxygen will be used for every 4 moles of iron. For this reason, iron is called the limiting reagent and oxygen is called the excess reagent. The number of products produced depend only on the amount of limiting reactant used in the reaction. Therefore, if four moles of iron are used in a reaction with excess of oxygen, we expect to obtain two moles of iron (III) oxide; however, not all reactions work 100%. Some reactions have a yield that is less than 100%.

Percent yield of the reaction is calculated to be the experimental yield divided by theoretical yield then multiplied by 100. The theoretical yield is the amount predicted by a stoichiometric calculation based on the number of moles of the limiting reactant present, assuming that the limiting reactant reacts completely. The actual yield is the quantity of a product that is obtained from a chemical reaction.

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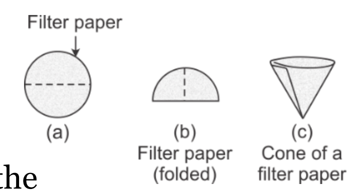
## PART ONE

**Pre-experiment Questions (**write answers on the notebook**)**

1. Write down and balance the chemical equation for the following reactions:
   a. Silver nitrate in aqueous solution reacts with metallic copper to produce metallic silver and copper (II) nitrate which remains in aqueous solution.
   b. Calcium chloride reacts with sodium carbonate, both in aqueous solution, to produce a calcium carbonate precipitate and sodium chloride which remains in solution.
   c. Hydrochloric acid reacts with sodium hydroxide, both in aqueous solution, to produce water and sodium chloride which remains in aqueous solution.
2. Write down the type of reaction for the three reactions you represented in numeral 1.
3. Find on the web or in a chemistry textbook, what is phenolphthalein? What is the working pH for this indicator, and which are the colors of the phenolphthalein at different solution-pH?
4. Find on the web or in a chemistry textbook, the definition of limiting reactant and excess reactant.

**General Protocol** (Read entire protocol before starting the experiment)




Filtration by gravity:

- Using a marker, write your team's name on the edge of a watch glass.
- **Weight together the labeled watch glass and a piece of filter paper.**
- Fold the paper in half twice and make a cone as shown in the figure to the right.
- Place the filter paper in the funnel and then place the funnel in the ring that is attached to the stand.
- Place an Erlenmeyer below the funnel to collect the liquid as shown in the figure to the right.

- Wet the paper with a little bit of DI water and make sure it sticks to the glass.
- Start pouring the solution (over the filter paper) slowly and stop when the liquid gets too close to the edge of the paper, wait until the volume goes down to add more.
- As you pour the solution the precipitate will start accumulating on the filter paper. Transfer all the precipitate using a spatula.
- Rinse the beaker with small portions of DI water making sure you transfer all the solid.
- Rinse the solid two to three times by pouring small amounts of water over the solid and letting the water fully drained before rinsing again.
- When no more liquid is coming off the funnel's stem, remove the paper carefully and transfer it to the watch glass you previously weighted.

Drying:

- After filtration, spread the solid evenly over the paper so it dries evenly.
- Place the watch glass that contains your sample to dry in the oven.
- After few days, remove the watch glass from the oven and take it to the lab bench. (note: walk slowly so the dry solid does not fly around)
- Let the watch glass/ solid cool down on the bench, and then weight the dry the solid with the paper and the watch glass.

## Experiment

5. Compare the chemical equations with a couple of groups and come to an agreement on the equations; make sure the equations are balanced and they have the correct states of matter for each compound. If you have any doubts, ask your professor.
6. Measure the pH of your five solutions using a strip of pH paper, write your observations.

Reaction#1

7. Find a piece of copper metal, weight it and write the exact mass number in your notebook. Shape the copper wire as a spiral or any shape you would like, shape the end of the wire as a hook so you can hold the wire on a 150 mL beaker as shown in the drawing on the right side. Then, add very carefully the silver nitrate solution to this beaker. (note remember silver nitrate will leave black spots in your skin!)
8. Observe the reaction for 10 minutes; then, gently shake the copper wire inside the solution and write your observations in detail. Cover the beaker with two pieces of paraffin paper and leave the beaker on your lab bench for a week.

Reaction #2

9. Take a 400 mL beaker and carefully pour all the calcium chloride solution into it, then carefully pour slowly into the same beaker the sodium carbonate solution. Write your observations.
10. Filtrate the solution by gravity, recover the solid and dry it for a week. (note: check the general protocol)
11. Dispose the solution left from the filtration in the waste container labeled sodium chloride solution.

Reaction #3

12. For the next reaction, take to the bench the beaker containing the sodium hydroxide formed from the reaction between metallic sodium and water. Add to the beaker a few drops of phenolphthalein solution (the indicator) and write your observations.
13. Transfer about 30 mL of the hydrochloric acid solution into a 50 mL beaker and then from the beaker into a dropper bottle (label as HCl 0.30 M). Drop by drop, add hydrochloric acid into the beaker that contains the sodium hydroxide, **count the drops** and mix the solution with a glass rod after the addition of every drop. During the addition of hydrochloric acid solution drops, if the solution is not fuchsia, it will turn fuchsia; keep adding acid until the fuchsia color disappears. When this happens stop adding acid immediately and **write down the number of drops** of the acid solution that you used to make that color disappeared. Measure the pH of the final solution and write down your observations.
14. After the neutralization, dispose the solution in the waste container labeled sodium chloride solution.

## Thinking About the Data

15. In lab #2, you prepared the solutions that you used today, write down the mass in grams for each compound that you used to prepare the solutions and calculate the number of moles; also, based on the mass of the copper wire, calculate the moles of copper.

| | Compound | Molar mass (g/mol) | Mass in grams | Moles | Limiting or Excess reactant |
|---|---|---|---|---|---|
| Reaction #1 | Silver nitrate | | | | |
| | Copper | | | | |
| Reaction #2 | Calcium chloride | | | | |
| | Sodium carbonate | | | | |

Looking at the moles of the initial reactants and the chemical equation for reactions #1 and #2 (numeral 1), find the limiting and excess reactants for each reaction. Write a statement on how you figure this out (give details).

16. Calculate the moles and mass of the products you expect to obtain from the first two reactions (note: keep in mind you must use the limiting reactant):

| | Compound | Molar mass (g/mol) | Moles | Mass expected in grams |
|---|---|---|---|---|
| Reaction #1 | Silver | | | |
| | Copper (II) nitrate | | | |
| Reaction #2 | Calcium carbonate | | | |
| | Sodium chloride | | | |

17. Convert the number of drops used in the reaction (from numeral 13) into mL, knowing that 20 drops are approximately 1.0 mL. Using this volume and the molarity of the diluted hydrochloric acid solution you prepared, calculate the number of moles of HCl used to neutralize the sodium hydroxide solution.

18. In lab #1 part two, we carried out the reaction between sodium and water, this reaction produced sodium hydroxide and hydrogen gas.

$$2Na_{(s)} + 2\,H_2O_{(l)} \rightarrow 2\,NaOH_{(aq)} + H_{2(g)}$$

Since we do not know how much sodium we put in the water, we are going to find this amount by figuring out the amount of hydrochloric acid that was needed **to neutralize** the sodium hydroxide solution. Neutralization means that all the sodium hydroxide reacted, and that the pH of the solution goes from basic ~12 to pH ~7 (neutral pH).

Since you calculated the moles of hydrochloric acid used in the neutralization (numeral 16), you can use the stoichiometric ratio between hydrochloric acid and sodium hydroxide to find the number of moles of sodium hydroxide formed in the reaction of metallic sodium and water. Write this number in the table below and calculate the amount of water and sodium chloride formed. The first step is to check the balanced chemical equation for the reaction between $HCl_{(aq)}$ and $NaOH_{(aq)}$ (numeral 1). Then figure out the stoichiometric ratio between hydrochloric acid and sodium hydroxide. Using this ratio, calculate the amount of $NaOH_{(aq)}$ that you had at the beginning of the reaction and the amount of products generated.

Then, using the initial amount of NaOH (in moles) and using the chemical equation for the reaction between sodium and water, calculate the number of moles of sodium that we used in LabNo1. Collect your information in the table below.

| | Compound | Molar mass (g/mol) | Moles | Mass expected in grams |
|---|---|---|---|---|
| Reaction #3 | Hydrochloric acid | | | ----------------------- |
| | Sodium hydroxide | | | ----------------------- |
| | Water | | | |
| | Sodium chloride | | | |

19. Since you found the moles of sodium hydroxide, calculate the grams of sodium metallic we initially dropped in the water.
20. Back in numeral 6, what is the pH of the salts ($Na_2CO_3$, $AgNO_3$, $CaCl_2$) in water? What is the pH of HCl in water? And what is the pH of NaOH in water? Do you see any significant differences between the salts and the other two solutions? Explain.
21. After the neutralization the pH of the solution is closer to the pH of a salt, and acid or a base? Explain.
22. Compare your answers for numerals 15-21 with a couple of groups and discuss any differences.

**PART TWO**

**Pre-experiment Questions**

23. Find on your ebook or on the web, the equation for the percent yield of chemical reaction.
24. Find on the web the solubility of calcium carbonate in water at $20^oC$.
25. Find on the web the solubility of silver chloride in water at $20^oC$.
26. What is the law of conservation of mass?

**Experiment**

Reaction#2 continuation:
27. Find the calcium carbonate solid that you filtrated last week and measure the mass of the watch glass with the solid on it.
28. Dispose the solid in the waste container labeled calcium carbonate.

Reaction#1 continuation:
29. Back in your bench, find the beaker with the copper wire, observe and write your observations.
30. Shake the wire such that the solid formed on it goes to the bottom of the beaker. Using a spatula, carefully remove the rest of the solid deposited on the copper wire into the solution. Take out whatever is left of the copper wire, rinse it with a small amount of water (over the solution), let it dry over a paper towel, and weight it by itself. Write the mass on your notebook.
31. Filtrate the solution by gravity, rinse the solid with DI water and dry the silver obtained for a week in the oven.
32. Transfer ~ 1 mL of the solution that remains after filtration into a test tube by using a transfer pipet; and add few drops of the hydrochloric acid solution. Write your observations.

33. Dispose the bluish/greenish solution in the waste container labeled copper nitrate solution.
34. After drying for a week, let the solid silver cool down and then weight it. Don't forget to write the mass of silver on your notebook.
35. Dispose the solid silver in the container labeled metallic silver.

## Thinking About the Data

36. Calculate the percent yield for reactions #1 and #2 using equation from numeral 23 and the mass expected from numeral 16:

| | Compound | Mass expected in grams (Theoretical) | Mass in grams obtained in the lab (actual) | %yield |
|---|---|---|---|---|
| Reaction #1 | Silver | | | |
| Reaction #2 | Calcium carbonate | | | |

37. Did you expect the theoretical mass be equal of different to the actual mass? Explain.
38. How does the percent yield relate to the law conservation of mass?
39. Why is the percent yield not exactly 100.0%?
40. Check the solubility of calcium carbonate from numeral 24, how does this value relate to the results and observations of reaction#2?
41. In reaction #1, which element is being oxidized (lose electrons) and which element is being reduced (gain electrons)? Explain.
42. Write one important experimental observation that indicated the formation of copper (II) nitrate in solution?
43. How much copper metallic reacted? Why did you have copper metallic left after the reaction?
44. Do the results from numeral 32 show that you have or that you do not have silver ions ($Ag^+$) left in solution? (hint: check the solubility of AgCl from numeral 25)
45. Write three conclusions of what you learn in this lab and based on your experimental results. (around 250 words. Base your conclusions on the concepts we explored in this lab and your observations)