AP CHEMISTRY LAB
LIMITING REACTANT

Objective:

- To determine the limiting reactant in a salt mixture.
- To determine the percent composition of each substance in a salt mixture.

Introduction

Two factors limit the yield of products in a chemical reaction: (1) the amounts of starting materials (reactants) and (2) the percent yield of the reaction. Many experimental conditions, for example, temperature and pressure, can be adjusted to increase the yield, especially of a desired product, but because chemicals react according to fixed mole ratios (stoichiometrically), only a limited amount of product forms from given amounts of starting materials. The reactant determining the amount of product generated in a chemical reaction is called the **limiting reactant** in the chemical system.

To better understand the concept of the limiting reactant, lets look at the reaction that is under investigation in this experiment: The reaction of sodium dodecahydrate, $Na_3PO_4 \cdot 12H_2O$ and barium chloride dihydrate, $BaCl_2 \cdot 2H_2O$.

The molecular equation is:

$$2\ Na_3PO_4 \cdot 12H_2O_{(aq)} + 3\ BaCl_2 \cdot 2H_2O_{(aq)} \rightarrow Ba_3(PO_4)_{2(s)} + 6\ NaCl_{(aq)} + 30\ H_2O_{(l)}$$

In this experiment an unknown salt mixture of $Na_3PO_4 \cdot 12H_2O$ and $BaCl_2 \cdot 2H_2O$ is added to water producing insoluble $Ba_3(PO_4)_2$. The mass of the initial salt mixture and the mass of the final product, $Ba_3(PO_4)_2$, are measured. A series of tests is also used to determine the limiting reactant. Finally, the percent composition of the original salt mixture is calculated.

Pre-laboratory Questions:

1. When 0.844 grams of $Na_3PO_4 \cdot 12H_2O$ reacts with excess $BaCl_2 \cdot 2H_2O$, how many grams of $Ba_3(PO_4)_2$ are produced?
2. When 0.629 grams of $Na_3PO_4 \cdot 12H_2O$ and 0.527 grams of $BaCl_2 \cdot 2H_2O$, are mixed with water forming 500 ml of solution, how many grams of $Ba_3(PO_4)_2$ precipitate?
3. The solubility of $Ba_3(PO_4)_2$ is 0.519 mg/L. How many milligrams and moles of $Ba_3(PO_4)_2$ dissolve in 200. ml of solution?
4. Describe how the mass of $Ba_3(PO_4)_2$ precipitate is determined in Part A.
5. Describe how to test your unknown salt mixture for the presence of excess $Na_3PO_4 \cdot 12H_2O$.
6. Why is fine porosity paper required for use in the filtering of the $Ba_3(PO_4)_2$ precipitate?

Procedure:

Two trials are recommended for this experiment. To hasten the analysis, weigh duplicate unknown salt mixtures and simultaneously follow the procedure for each. Label the beakers accordingly for trial 1 and trial 2 to avoid the intermixing of samples and solutions. Obtain about 2-3 grams of an unknown $Na_3PO_4 \cdot 12\,H_2O$ – $BaCl_2 \cdot 2\,H_2O$ mixture.

A. Precipitation of $Ba_3(PO_4)_2$ from the salt mixture

1. Weigh and Dissolve the Salt Mixture. Weigh (±0.001 g) on weighing paper about 1.0 gram of the unknown salt mixture. Record the mass for trial 1 in your laboratory notebook. Repeat for trial 2. Transfer the salt mixture to a labeled 400-ml beaker and add 200-ml of deionized water. Stir the mixture with a stirring rod for about 1 minute and then allow the precipitate to settle. Leave the stirring rod in the beaker.
2. Digest the Precipitate. Cover the beaker with a watchglass and maintain the solution hot (80-90ºC) on a steam bath or with a low flame for 30 minutes. While the precipitate is being warmed, proceed to part A.3. Periodically check on the progress of heating.
   After 30 minutes, allow the precipitate to settle; it does not need to be cooled to room temperature. While the precipitate is settling, heat in a 150-ml beaker, about 30 ml of deionized water for use as wash in Part A.5.
3. Filter the Precipitate. Set up a gravity filtering apparatus. Weigh (±0.001g) a piece of Whatman No.42 or Fisherbrand Q2 filter paper fine porosity filter paper. Fold it properly and seal it into the filter funnel with a small amount of deionized water. Discard the water in the receiving flask. Return to Part A.2.
4. Separation of Supernatant in Part A.2. Once the supernatant has cleared in Part A.2, decant two 50-ml volumes into separate 100-ml beakers, labeled Beaker I and Beaker II. Save for part B.
5. Filter the Precipitate Salt. While the solution is still warm from Part A.4, quantitatively transfer the precipitate to the filter funnel. Remove any precipitate on the wall of the beaker with a rubber policeman, and hot (80-90ºC) water*, wash the precipitate onto the filter. Rinse the $Ba_3(PO_4)_2$ precipitate with two 5-ml portions of hot water (see Part A.2).
   **I'll keep a hot water bath up front for this purpose*.
6. Dry and Weigh the Salt Precipitate: Remove the filter paper holding the precipitate from the filter funnel. Air-dry the precipitate on the filter paper until the next laboratory period or in a 110 ºC constant-temperature drying oven overnight. Weigh (±0.001 g) the precipitate and filter paper. Record in notebook.

B. Determination of the Limiting Reactant

From the following two tests we can determine the limiting reactant in the original salt mixture. Some cloudiness may appear in both tests, but one will show definite precipitation formation.

A. Test for excess PO_4^{3-}. Add 2 drops of 0.5 *M* Ba^{2+} (from 0,5 *M* $BaCl_2$) to the 50 ml of supernatant liquid in beaker I. If a precipitate forms, the PO_4^{3-} is in excess and Ba^{2+} is the limiting reactant in the original salt mixture.

B. Test for excess Ba^{2+}. Add 2 drops of 0.50 *M* PO_4^{3-} (from 0.5 *M* Na_3PO_4) to the 50 ml supernatant liquid in Beaker II. If a precipitate forms, the Ba^{2+} is in excess and PO_4^{3-} is the limiting reactant in the original salt mixture.

Analysis:

Data:

A. Precipitation of $Ba_3(PO_4)_2$ from the salt mixture

	Trial 1	**Trial 2**
Mass of salt mixture		
Mass of filter paper		
Mass of filter paper and $Ba_3(PO_4)_2$		
Mass of $Ba_3(PO_4)_2$		

B. Determination of Limiting Reactant

1. Limiting Reactant in a salt mixture (write complete formula): _____
2. Excess reactant in salt mixture: (write complete formula) _____

Calculations:

1. Moles of $Ba_3(PO_4)_2$ precipitated.
2. Moles of limiting reactant. Include formula of limiting hydrate.
3. Mass of limiting reactant. Include formula of limiting hydrate.
4. Moles of excess reactant *that reacted*. Include formula of excess hydrate.
5. Mass of excess reactant *that reacted*. Include formula of excess hydrate.
6. Mass of original salt mixture.
7. Mass of unreacted excess reactant. Include formula of excess hydrate.
8. Percent of limiting reactant in mixture. Include formula of limiting hydrate.
9. Percent of excess reactant in mixture. Include formula of excess hydrate.

Class Data:

Group	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
% Limiting Reactant in Mixture								

10. Determine the standard deviation of the percent limiting reactant in the salt mixtures.

Conclusion:

1. Since $Ba_3(PO_4)_2$ is a finely divided precipitate, some is lost in the filtering process. If a coarse filter paper had been used instead of one with fine porosity, would the reported percent of limiting reactant been high or low? Explain.
2. Explain the purpose of washing the precipitate in Part A.5
3. If Na_2SO_4 is an unknown contaminant of $Na_3PO_4 \cdot 12H_2O$, how does its presence affect the yield of $Ba_3(PO_4)_2$ in the experiment? $BaSO_4$ is also insoluble. *Hint: Prove by writing a balanced equation of "1" g of $BaCl_2$ reacting with excess Na_2SO_4 to make x grams of $BaSO_4$. Then compare this with the reaction of "1" gram of $BaCl_2$ reacting with excess Na_3PO_4 to make y grams of $Ba_3(PO_4)_2$.*