Limiting Reactant

Lab 3

Page 67 to 74 : Lab Notebook

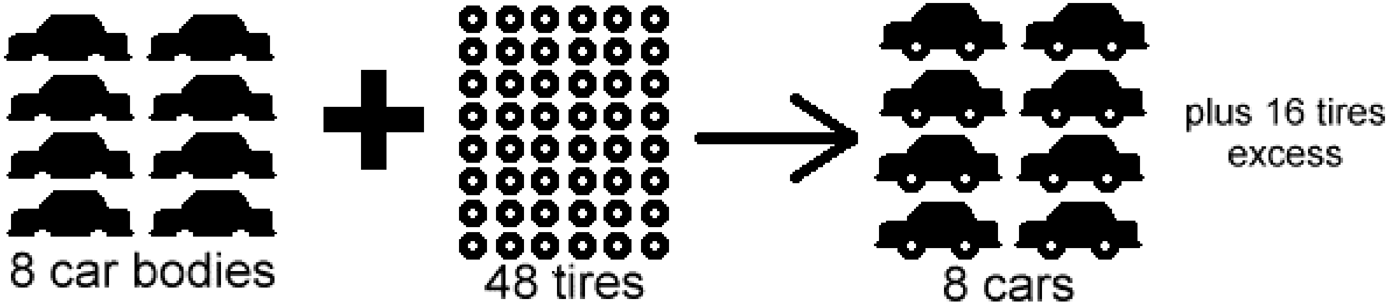
Pre-Lab = Page 71 – All questions

Lab Questions: 1, 2, 3, 5

Page 140: Brady

What is a limiting reactant?

- It is the reactant that limits the product that can be formed.
- Stoichiometry allows us to compare the amounts of various species involved in a reaction.



- If you have the balanced chemical equation and the quantity of one of the reactants or a product produced, the quantities of the other species produced or required can be evaluated
- In order to determine which of the reactants is the limiting reactant, both amounts present must be considered and how they relate stoichiometrically to the balanced equation.

Method for determining limiting reactant

1. The equation must be balanced.
2. The amount of two (or more) of the reactants involved, must be known.
3. Treat each as a separate stoichiometry problem.

4. Evaluate the amount of product made or reagent required of each unknown species based on the known quantities. This is determined by comparing the number of moles of product formed for each mole of the reactant used. Do this for each of the known reactants.
5. Compare the amount of product made by each reagent.
6. The limiting reagent is the one that produces the least amount and is the one that any subsequent calculations should be based on.

Why have limiting reactants?

If you produce no more product, then it just does not make economic sense to use an excess of one reagent.

- Not all reactions go 100% to completion, in fact the majority of really interesting ones do not.
- However one trick employed to make them go to completion is to start with an excess of one of the reactants.
- This essentially makes the other the limiting reagents. For economical reasons it makes sense to choose the less expensive reagent as one to use in excess.

Lab Objectives

- To determine the limiting reactant in a mixture of insoluble salts
- Determine the % composition of each substance in a salt mixture

Background Information for Lab

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

Barium Phosphate is the insoluble product

Sodium Chloride remains in solution

The ionic equation can be written:

$$3Na^+ + 2PO_4^{3-} + 3Ba^{2+} + 2Cl^- \rightarrow Ba_3(PO_4)_{2\ (s)} + 6Na^+ + Cl^- + 30H_2O$$

The ‘spectator’ ions can be cancelled out, leaving the net ionic eqn.

$$2PO_4^{3-}\ (aq) + 3Ba^{2+}\ (aq) \rightarrow Ba_3(PO_4)_{2\ (s)}$$

Recap

- A **spectator ion** is an ion that exists as a reactant and a product in a chemical equation. Spectator ions can be observed in the reaction of aqueous solutions of sodium chloride and copper (II) sulfate:
- $2Na^{+}_{(aq)} + 2Cl^{-}_{(aq)} + Cu^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)} \rightarrow 2Na^{+}_{(aq)} + SO_4^{2-}{}_{(aq)} + CuCl_{2\,(s)}$
- The Na^{+} and SO_4^{2-} ions are spectator ions since they remain unchanged on both sides of the equation. They simply "watch" the other ions react, hence the name. In reaction stoichiometry, spectator ions are removed from a complete ionic equation to form a net ionic equation. For the above example this yields:
- $2Cl^{-}_{(aq)} + Cu^{2+}_{(aq)} \rightarrow CuCl_{2\,(s)}$
- Common spectator ions include Na^{+}, K^{+}, and NO_3^{-}.

Using the balanced equation:

- Molar mass of $Na_3PO_4 \cdot 12H_2O$ = 380.12
- The water is included in the formula mass
- To calculate the % of each ion present we can use the molar mass
- % of H_2O present in formula –
  - H_2O Molar mass = 18.01
  - 12 are present in the formula = 12 x 18.01 = 216.12
  - % of H_2O present = 216.12 / 380.12 x 100 = 56.86%

$2PO_4^{3-}$ (aq) + $3Ba^{2+}$ (aq) $\rightarrow Ba_3(PO_4)_2$ (s)

- Ratio of reactants is 2:3 (1 : 1.5)
- In this experiment, known masses of sodium phosphate and barium chloride will be reacted.
- For example:
  - If you have 1g of sodium phosphate and need to calculate the moles of Barium required
  - Calculate the no. of moles of Sodium phosphate
  - # of moles = mass / Molar mass= 1 / 380.12 = 0.00263 moles Sodium phosphate

$2PO_4^{3-}$ (aq) + $3Ba^{2+}$ (aq) $\rightarrow Ba_3(PO_4)_2$ (s))

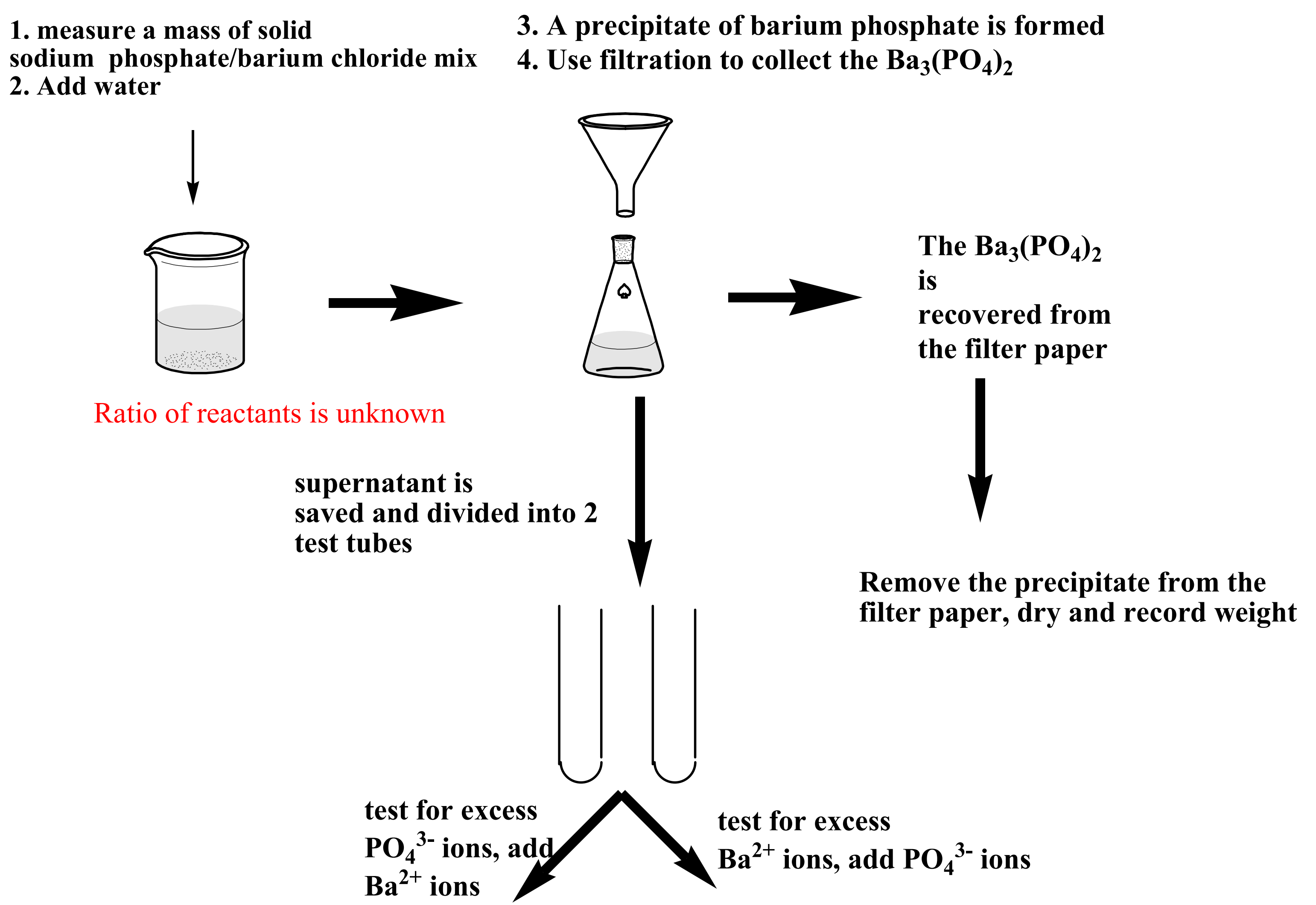
– From the balanced equation, we know that every 2 moles of sodium phosphate required 3 moles of barium chloride we need 0.00263 x 1.5 moles = 0.00395

= 0.00395 moles of barium chloride

Using the no of moles equation and the molar mass of $BaCl_2$, (244.27) it can be calculated how much is required:

- 0.0395 = mass / 244.27
- 0.0395 x 244.27 = 0.96g

- You will be provided with a sample of unknown composition of $Na_3PO_4 \bullet 12H_2O$/ $BaCl_2 \bullet 2H_2O$
- This will be added to water
- A precipitate of barium phosphate will form
- This will be collected by filtration, dried and weighed
- The supernatant (the liquid left after the solid is removed) will be analyzed to see what ions are left in solution



Formation of a precipitate indicates the presence of that ion. Therefore that ion is present in excess and is not the L.R

Analyzing the supernatant

- Analyzing the supernatant aims to determine which is the limiting reactant.
- Possible ions in solution are Ba^{2+} or PO_4^{3-}
- Excess Ba^{2+} is tested by the addition of a phosphate ion, if a precipitate forms, excess Ba^{2+} ions are present, no precipitate means no Ba^{2+} , therefore Ba^{2+} is the Limiting Reactant
- Likewise, PO_4^{3-} excess is tested by addition of Ba^{2+} ions, if a precipitate forms, excess PO_4^{3-} ions are present

Using the data to calculate composition of the salt

- Use what you know:
  - Weight of initial sample (e.g., 0.942g)
  - Formula of precipitate: $Ba_3(PO_4)_2$
  - Molar mass of $Ba_3(PO_4)_2$ =601.93
  - Amount of $Ba_3(PO_4)_2$ formed, this is the solid collected by filtration (e.g. 0.118g)
  - What was left in solution (excess Barium or phosphate ions), therefore know the limiting reactant.

Using the mass collected of $Ba_3(PO_4)_2$, the no of moles can be calculated:

# of moles of $Ba_3(PO_4)_2$ = 0.188 / 601.093

# of moles of $Ba_3(PO_4)_2$ = 0.00031 (3.12×10^{-4})

Going back to the balanced ionic equation:

$$2PO_4^{3-} (aq) + 3Ba^{2+} (aq) \rightarrow Ba_3(PO_4)_2$$

it can be seen that every 1 mole of product (precipitate) is formed from 3 moles of Ba^{2+} and 2 moles of PO_4^{3-}

- Therefore, if we have 3.12 $x10^{-4}$ moles of $Ba_3(PO_4)_2$ and Ba is the limiting reactant.
- No of moles of Ba^{2+} in the sample = 3.12 $x10^{-4}$ x 3 = 9.36 x 10^{-4}
- Using the molar mass of $BaCl_2{\bullet}2H_2O$, and the equation n = m / M, the mass of barium chloride can be calculated.
- 9.36 x 10^{-4} = mass / 244.27
- Mass = 9.36 x 10^{-4} x 244.27 = 0.23g

- Mass of sodium phosphate can be determined from the initial mass weighed.
- 0.942g was weighed of the mixture
- Mass of Barium Chloride = 0.229g
- Mass of $Na_3PO_4 \cdot 12H_2O$ = 0.942 – 0.229
- Mass of $Na_3PO_4 \cdot 12H_2O$ = 0.713g
- % of $Na_3PO_4 \cdot 12H_2O$ in sample = 0.713 / 0.942 x 100
- % of $Na_3PO_4 \cdot 12H_2O$ in sample = 75.7%

Lab Techniques

- Gravity Filtration
- Filtration is a technique used either to remove impurities from an organic solution or to isolate an organic solid. The two types of filtration commonly used in organic chemistry laboratories are gravity filtration and vacuum or suction filtration.

Digesting the precipitate

- Before filtering the precipitate and supernatant are heated gently.
- This is to form larger particles of the precipitate, in order to minimize the loss through the filter paper.
- If the precipitate is not digested, some particles may be lost in the filtration. Less product would infer less limiting reactant.

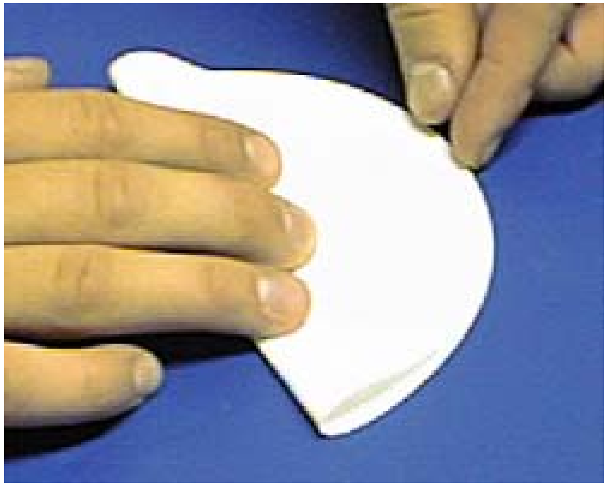
Note

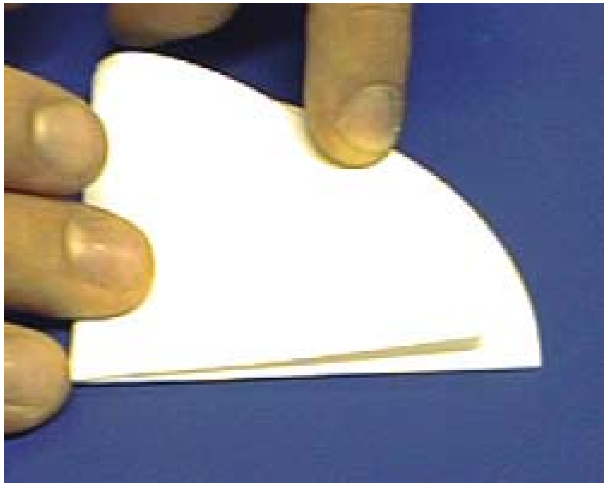
- Before performing your filtration, write your name on the filter paper IN PENCIL.

- This is so when the samples are dried in the oven, you can identify your sample.

Procedure for standard gravity filtration

Select and fold the filter paper
Select the size of filter paper that, when folded,
will be a few millimeters below the rim of your glass funnel.
Fold the paper into a cone by first folding it in half,
and then in half again, as shown.





Filter the solution

Support the glass funnel in a ring or place it in the neck of an Erlenmeyer flask. Wet the filter paper with a few milliliters of the solvent to be used in the following procedure. Wetting the paper holds it in place against the glass funnel. Pour the mixture to be filtered through the funnel, in portions if necessary.

- When you have collected your precipitate, place it on a watch glass.
- Place the watch glass and filter paper in the oven to dry the sample.
- The sample is dry when it is powdery.
- A wet sample will affect your results.

- Two runs on the same sample need to be performed.
- You should expect to see similar results for both runs.
- If you do not, explain why or carry out another experimental run.
- The two trials can be run simultaneously