CHEM1001 Worksheet 5: Yields

Model 1: Limiting reagents – The Ice Cream Sundae Case

A perfect ice cream sundae requires exactly:

- 3 scoops of ice cream
- 2 squirts of chocolate sauce
- 1 spoon of peanuts
- 1 cherry

If you have 7 scoops of ice cream, 3 spoons of peanuts, 5 cherries and 11 squirts of sauce, you can only make 2 complete sundaes. In this case, the icecream is the *limiting reagent*.

If you have a truckload of icecream, a bucket of sauce, a box of peanuts but only 1 cherry, you can only make 1 complete sundae. In this case the cherry is the *limiting reagent*.

The *limiting reagent* is the term given to the ingredient (read: *reactant*) that has the (stoichiometrically) least amount. The other reactants are said to be *in excess*. In a reaction the limiting reagent will be totally consumed, and some of the reactant in excess will be leftover.

Critical thinking questions

1. If you have 20 scoops of ice cream, 14 squirts of chocolate sauce, 5 spoons of peanuts and 7 cherries, how many sundaes can you make and which ingredient is the limiting reagent?

2. For the reaction, $FeCl_2(s) + 2AgNO_3(s) \rightarrow 2AgCl(s) + Fe(NO_3)_2(s)$

   (a) What is the required molar ratio between $FeCl_2$ and $AgNO_3$? (Hint: how do these numbers relate to the stoichiometric coefficients?)

   Next, for the same reaction, identify the *limiting reagent* and calculate the *number of moles* of AgCl(s) and $Fe(NO_3)_2(s)$ that will be obtained when the following are reacted:

   (b) 3 mol of $FeCl_2(s)$ and 4 mol of $AgNO_3(s)$.

   (c) 0.50 mol of $FeCl_2(s)$ and 1.5 mol of $AgNO_3(s)$.

   (d) 0.078 mol of $FeCl_2(s)$ and 0.155 mol of $AgNO_3(s)$.

   For the same reaction, identify the *limiting reagent* and calculate the *mass* of AgCl(s) and $Fe(NO_3)_2(s)$ that will be obtained when the following are reacted. (*Hint*: you need to convert mass to moles at the start and moles to mass at the end of these longer calculations and may find it easier to use a table)

   (e) 17.5 g of $FeCl_2(s)$ and 35.7 g of $AgNO_3(s)$.

	$FeCl_2(s)$	$AgNO_3(s)$	AgCl(s)	$Fe(NO_3)_2(s)$
mass (g)				
number of moles (mol)				
limiting reagent				

   (f) 72.0 mg of $FeCl_2(s)$ and 300. mg of $AgNO_3(s)$ are present

	$FeCl_2(s)$	$AgNO_3(s)$	AgCl(s)	$Fe(NO_3)_2(s)$
mass (g)				
number of moles (mol)				
limiting reagent				

Model 2: Theoretical and percentage yields

Before performing a reaction, chemists want to know how much product (by mass) can theoretically be made from the reactants. This amount is called the *theoretical yield*.

Critical thinking questions

1. The chemical equation for the combustion of methane is $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$.

   (a) If the reaction is carried out in a kitchen where there is plenty of air, which species is the limiting reagent?

   (b) How many moles of $CH_4(g)$ are there in 4.0 g?

   (c) How many moles of $CO_2(g)$ will be obtained if 4.0 g of CH_4 are burnt?

   (d) What is the theoretical yield of $CO_2(g)$ in grams?

   (e) If 12 g of $CO_2(g)$ is required, how much $CH_4(g)$ must be burnt?

2. For most reactions in the laboratory (or in nature), the final yield of product is less than the theoretical yield. Why do you think this might be the case?

Chemists generally calculate the *percentage yield* of a reaction:

$$\text{Percentage yield} = \frac{\text{Actual Yield (g)}}{\text{Theoretical Yield (g)}} \times 100\ \%$$

The *actual yield* is the weighed amount of dried product.

3. The combustion of $CH_4(g)$ is carried out with a portable burner which is suspected of leaking fuel.. When 4.0 g of $CH_4(g)$ is used, only 9.5 g of $CO_2(g)$ is obtained.

   (a) What is the percentage yield? (*Hint:* use the theoretical yield you calculated in Q1(c) above).

   (b) How much $CH_4(g)$ did not burn?

Challenge question:

With the percentage yield you calculated in Q3(a), how much of each of the reactants is required to produce an actual yield of 17 g of $CO_2(g)$?