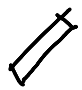
CONCEPT OF LIMITING REACTANT

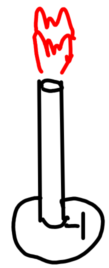
- When does a chemical reaction STOP?

$$2Mg(s) + O_2(g) \xrightarrow{\Delta} 2MgO(s)$$



Magnesium strip

+



Flame, oxygen from air

Magnesium oxide powder

- When does this reaction stop? When burned in open air, this reaction stops when all the MAGNESIUM STRIP is gone. We say that the magnesium is LIMITING.

- This reaction is controlled by the amount of available magnesium

- At the end of a chemical reaction, the LIMITING REACTANT will be completely consumed, but there may be amount of OTHER reactants remaining. We do chemical calculations in part to minimize these "leftovers".

These are often called "excess" reactants, or reactants present "in excess"

LIMITING REACTANT CALCULATIONS

- To find the limiting reactant, calculate how much product would be produced from ALL given reactants. Whichever produces the SMALLEST amouht of product is the limiting reactant, and the smallest anount of product is the actual amount of product produced.

Example: 56.08 12.01 64.10 <- Formula weights

$$CaO(s) + 3C(s) \xrightarrow{\Delta} CaC_2(s) + CO(g)$$

If you start with 100. g of each reactant, how much calcium carbide would be produced?

CaO: 56.08 g CaO = mol CaO | mol CaO = mol CaC_2 | 64.10 g CaC_2 = mol CaC_2

$$100.\,g\ CaO \times \frac{mol\ CaO}{56.08\,g\ CaO} \times \frac{mol\ CaC_2}{mol\ CaO} \times \frac{64.10\,g\ CaC_2}{mol\ CaC_2} = \boxed{114\,g\ CaC_2}$$

C: 12.01 g C = mol C | 3 mol C = mol CaC_2 | 64.10 g CaC_2 = mol CaC_2

$$100.\,g\ C \times \frac{mol\ C}{12.01\,g\ C} \times \frac{mol\ CaC_2}{3\,mol\ C} \times \frac{64.10\,g\ CaC_2}{mol\ CaC_2} = 178\,g\ CaC_2$$

114 g of calcium carbide should be produced. Calcium oxide runs out when this amount of carbide is made, and there's nothing left for the remaining carbon to react with! No further product can be made,

We say that calcium oxide is "limiting" and carbon is present "in excess".

PERCENT YIELD

- Chemical reactions do not always go to completion! Things may happen that prevent the conversion of reactants to the desired/expected product!

1. SIDE REACTIONS:

$$C + O_2 \longrightarrow CO_2$$

This reaction occurs when there is a large amount of oxygen available

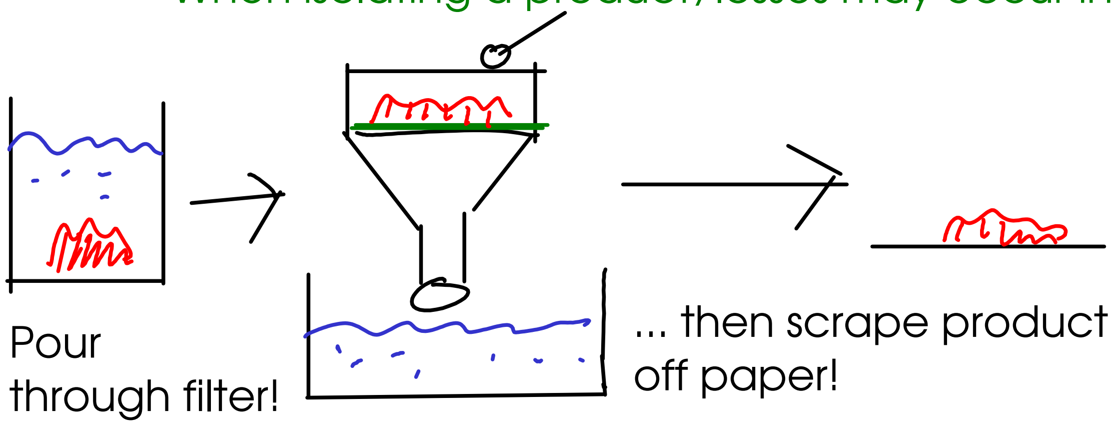
$$2C + O_2 \longrightarrow 2CO$$

... while this reaction is more favorable in low-oxygen environments!

... so in a low-oxygen environment, you may produce less carbon dioxide than expected!

2. TRANSFER AND OTHER LOSSES

- When isolating a product, losses may occur in the process. Example: filtering



During each step of this process, some amount of product loss will occur!

3 EQUILIBRIUM

- Reactions may reach an equilbrium between prodcuts and reactants. We'll talk more about this in CHM 111. The net results is that the reaction will appear to stop before all reactants have been consumed!

- All of these factors cause a chemical reaction to produce LESS product than calculated. For many reactions, this difference isn't significant. But for others, we need to report the PERCENT YIELD.

Determined EXPERIMENTALLY!

$$\text{PERCENT YIELD} = \frac{\text{ACTUAL YIELD}}{\text{THEORETICAL YIELD}} \times 100\%$$

Calculated based on the limiting reactant. (The chemical calculations you've done up to now have been theoretical yields!)

... the percent yield of a reaction can never be greater than 100% due to conservation of mass! If you determine that a percent yield is greater than 100%, then you've made a mistake somewhere - either in a calculation or in the experiment itself!

78.114 g/mol 123.111 g/mol <- Formula weights

22.4 g 31.6 g ACTUAL

$$C_6H_6 + HNO_3 \longrightarrow C_6H_5NO_2 + H_2O$$

benzene nitric acid nitrobenzene

22.4 grams of benzene are reacted with excess nitric acid. If 31.6 grams of nitrobenzene are collected from the reaction, what is the percent yield?

To determine the percent yield, we need to first calculate the THEORETICAL YIELD - the amount of nitrobenzene that could be produced if all 22.4 grams of benzene reacted.

78.114 g C_6H_6 = mol C_6H_6 | mol C_6H_6 = mol $C_6H_5NO_2$

123.111 g $C_6H_5NO_2$ = mol $C_6H_5NO_2$

$$22.4\,g\,C_6H_6 \times \frac{mol\,C_6H_6}{78.114\,g\,C_6H_6} \times \frac{mol\,C_6H_5NO_2}{mol\,C_6H_6} \times \frac{123.111\,g\,C_6H_5NO_2}{mol\,C_6H_5NO_2} =$$

$= 35.3\,g\,C_6H_5NO_2$ (theoretical yield)

$$\text{Percent yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100\% = \frac{31.6\,g}{35.3\,g} \times 100\% = \boxed{89.5\%}$$

25.0 mL of acetic acid solution requires 37.3 mL of 0.150 M sodium hydroxide for complete reaction. The equation for this reaction is:

$$NaOH + HC_2H_3O_2 \rightarrow NaC_2H_3O_2 + H_2O$$

What is the molar concentration of the acetic acid?

$$\frac{mol\ HC_2H_3O_2}{L\ solution} \leftarrow = 25.0\ mL\ \text{or}\ 0.0250\ L$$

Since we already know the volume of solution, what we're really being asked to find is the moles of acetic acid. (Once we know that, we can divide and find concentration!)

$mL = 10^{-3}\ L$ $\quad 0.150\ mol\ NaOH = L$ $\quad mol\ NaOH = mol\ HC_2H_3O_2$

$$37.3\ mL \times \frac{10^{-3}\ L}{mL} \times \frac{0.150\ mol\ NaOH}{L} \times \frac{mol\ HC_2H_3O_2}{mol\ NaOH} = 0.005595\ mol\ HC_2H_3O_2$$

To get molarity, divide by the volume OF ACETIC ACID.

$$M = \frac{mol\ HC_2H_3O_2}{L\ solution} = \frac{0.005595\ mol\ HC_2H_3O_2}{0.0250\ L} = \boxed{0.224\ \underline{M}\ HC_2H_3O_2}$$

$$\overset{42.081\ g/mol}{4\,C_3H_6} + 6\,NO \longrightarrow \overset{53.064\ g/mol}{4\,C_3H_3N} + 6\,H_2O + N_2$$

propylene acrylonitrile

Calculate how many grams of acrylonitrile could be obtained from 651 kg of propylene, assuming there is excess NO present.

1 - Convert mass propylene to moles using formula weight.
2 - Convert moles propylene to moles acrylonitrile using chemical equation.
3 - Convert moles acrylonitrile to mass using formula weight.

$42.081\,g\ C_3H_6 = mol\ C_3H_6$ | $4\,mol\ C_3H_6 = 4\,mol\ C_3H_3N$

$53.064\,g\ C_3H_3N = mol\ C_3H_3N$ | $kg = 10^3\,g$

$$651\,kg\ C_3H_6 \times \underbrace{\frac{10^3\,g}{kg} \times \frac{mol\ C_3H_6}{42.081\,g\ C_3H_6}}_{1} \times \underbrace{\frac{4\,mol\ C_3H_3N}{4\,mol\ C_3H_6}}_{2} \times \underbrace{\frac{53.064\,g\ C_3H_3N}{mol\ C_3H_3N}}_{3} =$$

$$= \boxed{821000\,g\ C_3H_3N}\ (821\,kg)$$

151.90 g/mol

$$10\,FeSO_4 + 2\,KMnO_4 + 8\,H_2SO_4 \rightarrow 5\,Fe_2(SO_4)_3 + 2\,MnSO_4 + K_2SO_4 + 8\,H_2O$$

How many mL of 0.250M potassium permangenate are needed to react with 3.36 g of iron(II) sulfate?

1 - Convert mass of iron(II) sulfate to moles using formula weight.
2 - Convert moles iron(II) sulfate to moles potassium permangenate using chemical equation
3 - Convert moles potassium permangenate to volume solution using molar concentration.

$151.90\,g\ FeSO_4 = mol\ FeSO_4$	$10\ mol\ FeSO_4 = 2\ mol\ KMnO_4$	$0.250\ mol\ KMnO_4 = L$

$mL = 10^{-3}\,L$

$$3.36\,g\ FeSO_4 \times \underbrace{\frac{mol\ FeSO_4}{151.90\,g\ FeSO_4}}_{1} \times \underbrace{\frac{2\ mol\ KMnO_4}{10\ mol\ FeSO_4}}_{2} \times \underbrace{\frac{L}{0.250\ mol\ KMnO_4} \times \frac{mL}{10^{-3}\,L}}_{3} =$$

$$= \boxed{17.7\ mL\ of\ 0.250\ \underline{M}\ KMnO_4}$$