# 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

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

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

CaO: 56.08 g CaO = mol CaO | 1 mol CaO = 1 mol $CaC_2$ | 64.10 g $CaC_2$ = mol $CaC_2$

$$100.\,g\,CaO \times \frac{mol\,CaO}{56.08\,g\,CaO} \times \frac{1\,mol\,CaC_2}{1\,mol\,CaO} \times \frac{64.10\,g\,CaC_2}{mol\,CaC_2} = \boxed{114\,g\,CaC_2}$$

C: 12.01 g C = mol C | 3 mol C = 1 mol $CaC_2$ | 64.10 g $CaC_2$ = mol $CaC_2$

$$100.\,g\,C \times \frac{mol\,C}{12.01\,g\,C} \times \frac{1\,mol\,CaC_2}{3\,mol\,C} \times \frac{64.10\,g\,CaC_2}{mol\,CaC_2} = 178\,g\,CaC_2$$

114g of calcium carbide should be produced. Calcium oxide runs out when we make 114g of carbide, so the reaction stops there. We say 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

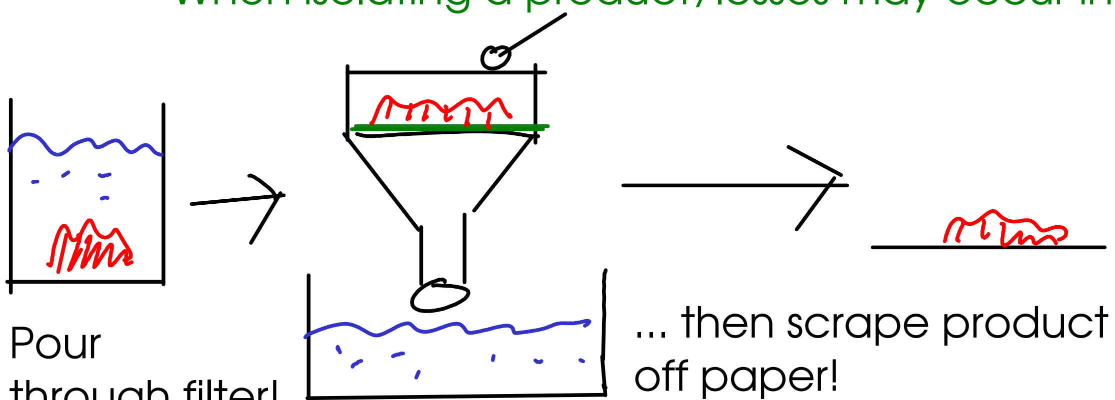
$$2C + O_2 \longrightarrow 2CO$$

... 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



Pour through filter!

... then scrape product off paper!

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 find the percent yield, we need to know both the ACTUAL YIELD (31.6g of nitrobenzene) and the THEORETICAL YIELD. We CALCULATE the theoretical yield based on the starting amount of benzene (22.4g).

$78.114\,g\ C_6H_6 = mol\ C_6H_6 \;|\; 1\ mol\ C_6H_6 = 1\ mol\ C_6H_5NO_2 \;/\; 123.111\,g\ C_6H_5NO_2 = mol\ C_6H_5NO_2$

$$22.4\,g\ C_6H_6 \times \frac{mol\ C_6H_6}{78.114\,g\ C_6H_6} \times \frac{1\ mol\ C_6H_5NO_2}{1\ mol\ C_6H_6} \times \frac{123.111\,g\ C_6H_5NO_2}{mol\ C_6H_5NO_2} = 35.3\,g\ C_6H_5NO_2$$

THEORETICAL YIELD

$$\%\ yield = \frac{actual}{theor.} \times 100\% \quad \Big| \quad \frac{31.6\,g}{35.3\,g} \times 100\% = \boxed{89.5\%}$$

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?

$$\hookrightarrow \frac{mol\ HC_2H_3O_2}{L\ solution \leftarrow 25.0\ mL\ (0.0250\ L)}$$

Since we know the volume of the acetic acid solution, we merely need to calculate the number of moles of acetic acid reacted.

$0.150\ mol\ NaOH = L \quad | \quad 1\ mol\ NaOH = 1\ mol\ HC_2H_3O_2$

$37.3\ mL \rightarrow 0.0373\ L$

$$0.0373\ L \times \frac{0.150\ mol\ NaOH}{L} \times \frac{1\ mol\ HC_2H_3O_2}{1\ mol\ NaOH} = 0.005595\ mol\ HC_2H_3O_2$$

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

Shortcut: Use millimoles!

$$37.3\ mL \times \frac{0.150\ mol\ NaOH}{L} \times \frac{1\ mol\ HC_2H_3O_2}{1\ mol\ NaOH} = 5.595\ mmol\ HC_2H_3O_2$$

$$M = \frac{mol}{L} = \frac{mmol}{mL} = \frac{5.595\ mmol\ HC_2H_3O_2}{25.0\ mL} = 0.224\ M\ HC_2H_3O_2$$

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

propylene acrylonitrile

Calculate how many grams of acrylonitrile could be obtained from 651 kg of propylene, assuming there is excess NO present. (651000 g)

1- Change the mass of propylene to moles using formula weight of propylene.
2- Change moles propylene to moles acrylonitrile using the chemical equation
3 - Change moles of acrylonitrile to grams using formula weight of acrylonitrile

$42.081\,g\ C_3H_6 = mol\ C_3H_6$ | $4\,mol\ C_3H_6 = 4\,mol\ C_3H_3N$ | $53.064\,g\ C_3H_3N = mol\ C_3H_3N$

$$651000\,g\ C_3H_6 \times \underset{1}{\frac{mol\ C_3H_6}{42.081\,g\ C_3H_6}} \times \underset{2}{\frac{4\,mol\ C_3H_3N}{4\,mol\ C_3H_6}} \times \underset{3}{\frac{53.064\,g\ C_3H_3N}{mol\ C_3H_3N}} =$$

$$= \boxed{821000\,g\ C_3H_3N}$$

(821 kg)