Example:

How many milliliters of 6.00M hydrochloric acid is needed to completely react with 25.0 g of sodium carbonate?

$$2HCl(aq) + Na_2CO_3(s) \longrightarrow H_2O(l) + CO_2(g) + 2NaCl(aq)$$

1 - Convert 25.0 g of sodium carbonate to MOLES using the FORMULA WEIGHT of sodium carbonate
2 - Convert moles sodium carbonate to moles HCl using the CHEMICAL EQUATION
3 - Convert moles HCl to volume of solution using the MOLAR CONCENTRATION (6.00 M)

1 Na_2CO_3: Na : 2 x 22.99
C : 1 x 12.01
O : 3 x 16.00

Formula weight of sodium carbonate

105.99 g Na_2CO_3 = mol Na_2CO_3

$$25.0\,g\,Na_2CO_3 \times \frac{mol\,Na_2CO_3}{105.99\,g\,Na_2CO_3} = 0.235871\,mol\,Na_2CO_3$$

2 2 mol HCl = mol Na_2CO_3

This relationship comes from the COEFFICIENTS of these substances in the chemical equation

$$0.235871\,mol\,Na_2CO_3 \times \frac{2\,mol\,HCl}{mol\,Na_2CO_3} = 0.471743\,mol\,HCl$$

99 Example:

How many milliliters of 6.00M hydrochloric acid is needed to completely react with 25.0 g of sodium carbonate?

$$2HCl(aq) + Na_2CO_3(s) \longrightarrow H_2O(l) + CO_2(g) + 2NaCl(aq)$$

③ 6.00 mol HCl = L   mL = 10^{-3} L

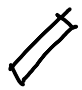
$$0.471743 \text{ mol HCl} \times \frac{L}{6.00 \text{ mol HCl}} \times \underbrace{\frac{mL}{10^{-3} L}} = \boxed{78.6 \text{ mL of } 6.00M \text{ HCl}}$$

This "extra" step converts liters to milliliters as requested by the problem statement.

CONCEPT OF LIMITING REACTANT

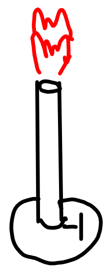
- When does a chemical reaction STOP?

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



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 the reaction has produced 114 g of the carbide, so no further product can be made.

We would call calcium oxide "limiting" in this reaction, and we'd say that 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

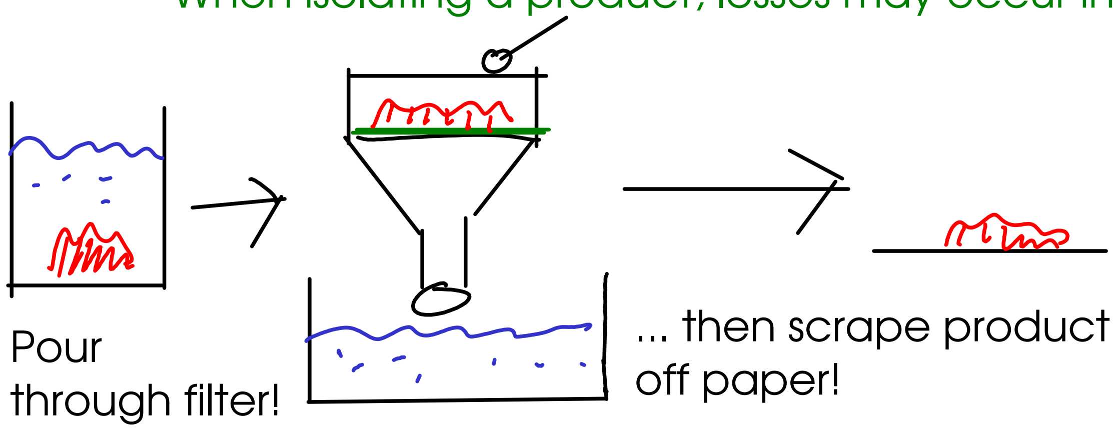
$$2C + O_2 \longrightarrow 2CO$$

... 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 find the PERCENT YIELD, we first need to calcuate the THEORETICAL YIELD; in other words, the amount of nitrobenzene we would make under ideal conditions. We have already been told the actual yield.

78.114 g C_6H_6 = mol C_6H_6 mol C_6H_6 = mol $C_6H_5NO_2$ 123.11 g $C_6H_5NO_2$ = mol $C_6H_5NO_2$

$$22.4\text{ g } C_6H_6 \times \frac{\text{mol } C_6H_6}{78.114\text{ g } C_6H_6} \times \frac{\text{mol } C_6H_5NO_2}{\text{mol } C_6H_6} \times \frac{123.11\text{ g } C_6H_5NO_2}{\text{mol } C_6H_5NO_2} = \underbrace{35.3\text{ g } C_6H_5NO_2}_{\text{THEORETICAL YIELD}}$$

$$\%\text{ yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100\%$$

$$= \frac{31.6\text{ g}}{35.3\text{ g}} \times 100\% \approx \boxed{89.5\%}$$