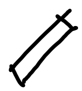
CONCEPT OF LIMITING REACTANT

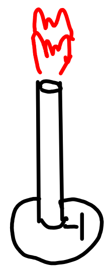
- When does a chemical reaction STOP?

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



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:

$$\underset{56.08}{CaO(s)} + 3\,\underset{12.01}{C(s)} \xrightarrow{\Delta} \underset{64.10}{CaC_2(s)} + CO(g)$$

64.10 <- Formula weights

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

(1) $56.08\,g\,CaO = mol\,CaO$ (2) $mol\,CaO = mol\,CaC_2$ (3) $64.10\,g\,CaC_2 = mol\,CaC_2$

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

(1) $12.01\,g\,C = mol\,C$ (2) $3\,mol\,C = mol\,CaC_2$ (3) $64.10\,g\,CaC_2 = mol\,CaC_2$

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

The reaction will stop when we make 114 grams calcium carbide, since at that point all of the CaO will be gone. We can say that calcium oxide is LIMITING, and carbon is present IN EXCESS (since there will be unreacted carbon left over at the end of the reaction!)

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

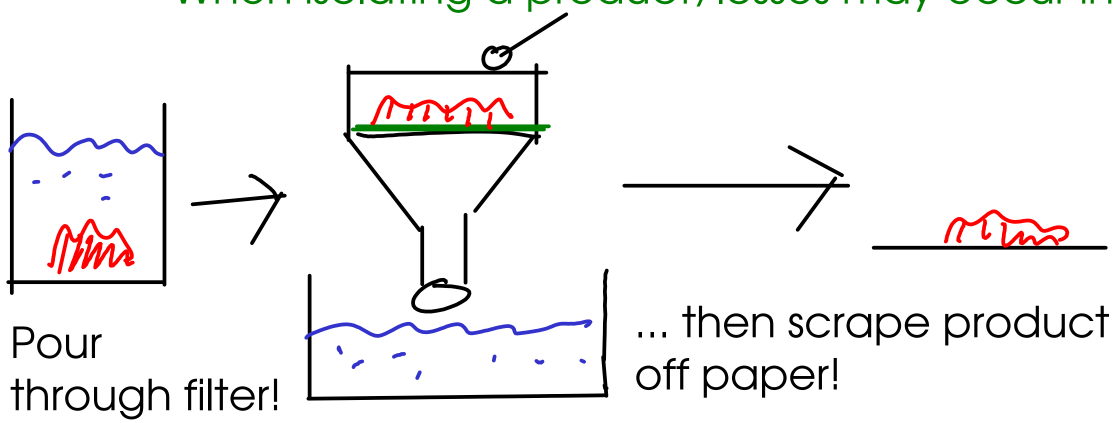
$$2C + O_2 \longrightarrow 2CO$$

... 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?

We were already given the ACTUAL yield of nitrobenzene (31.6 g). We need to calculate the THEORETICAL YIELD of nitrobenzene, starting from the reactant (benzene, 22.4 g)...

(1) $78.114\,g\ C_6H_6 = mol\ C_6H_6$ (2) $mol\ C_6H_6 = mol\ C_6H_5NO_2$

(3) $123.111\,g\ C_6H_5NO_2 = mol\ C_6H_5NO_2$

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

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

Electrolytes and Ionic Theory

- electrolytes: substances that dissolve in water to form charge-carrying solutions

* Electrolytes form ions in solution - (ions that are mobile are able to carry charge!). These IONS can interact with one another and undergo certain kinds of chemistry!

IONIC THEORY

- the idea that certain compounds DISSOCIATE in water to form free IONS

Strong vs weak?

- If an electrolyte COMPLETELY IONIZES in water, it's said to be STRONG

- If an electrolyte only PARTIALLY IONIZES in water, it's said to be WEAK

- Both kinds of electrolyte undergo similar kinds of chemistry.

What kinds of compounds are electrolytes?

$\boxed{\text{MOLECULAR COMPOUNDS}}$

- Most molecular compounds are NONELECTROLYTES - they don't ionize in water

-ACIDS and BASES will ionize in water. Most of these are WEAK ELECTROLYTES, but there are a few STRONG ACIDS and STRONG BASES.

$C_{12}H_{22}O_{11}(s) \xrightarrow{H_2O} C_{12}H_{22}O_{11}(aq)$ ... nonelectroiyte

$HC_2H_3O_2(l) \xrightarrow{H_2O} H^+(aq) + C_2H_3O_2^-(aq)$

... acetic acid (electrolyte)

$\boxed{\text{IONIC COMPOUNDS}}$

- SOLUBLE ionic compounds are STRONG ELECTROLYTES - they completely ionize in water.

- Not all ionic compounds are water soluble, however!

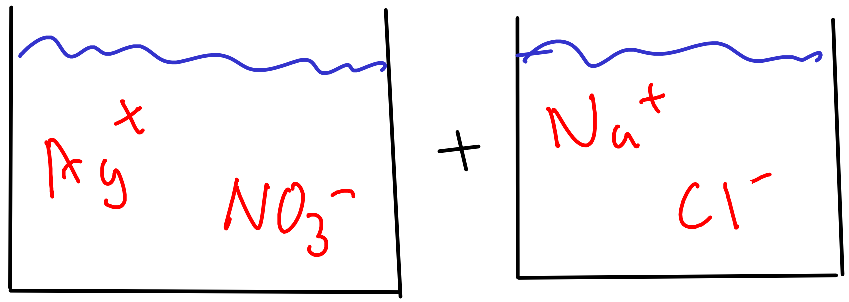
$NaCl(s) \xrightarrow{H_2O} Na^+(aq) + Cl^-(aq)$

- What good is ionic theory?

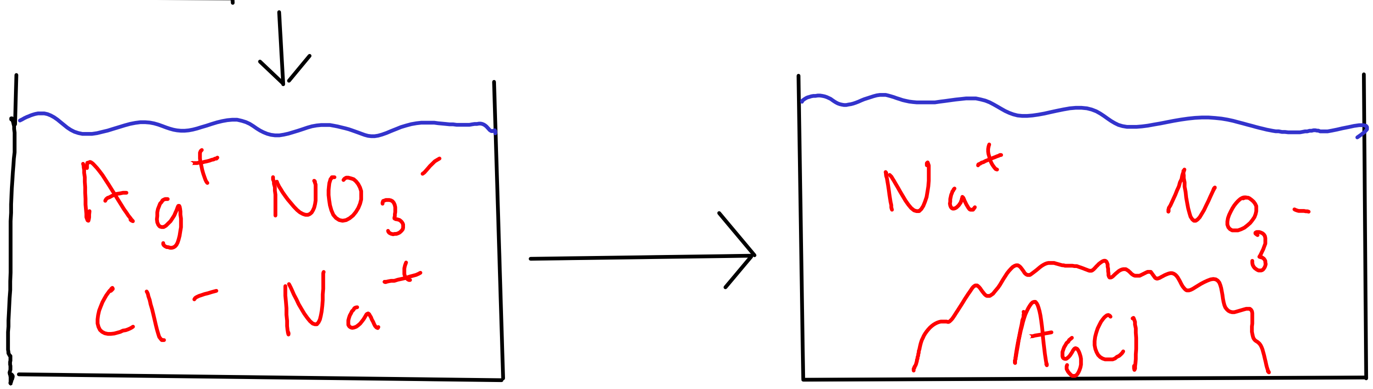
  - provides an easy-to-understand MECHANISM for certain kinds of chemical reactions.

    - "Exchange" reactions. (a.k.a "double replacement" reactions)

$$AgNO_3(aq) + NaCl(aq) \longrightarrow AgCl(s) + NaNO_3(aq)$$



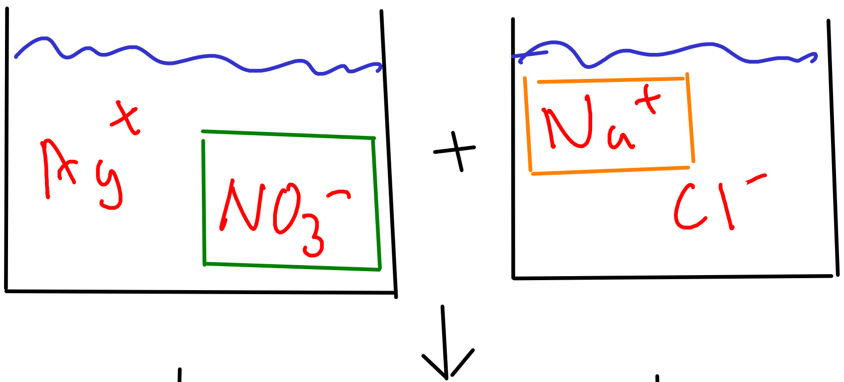
These free ions mix and can interact with each other!



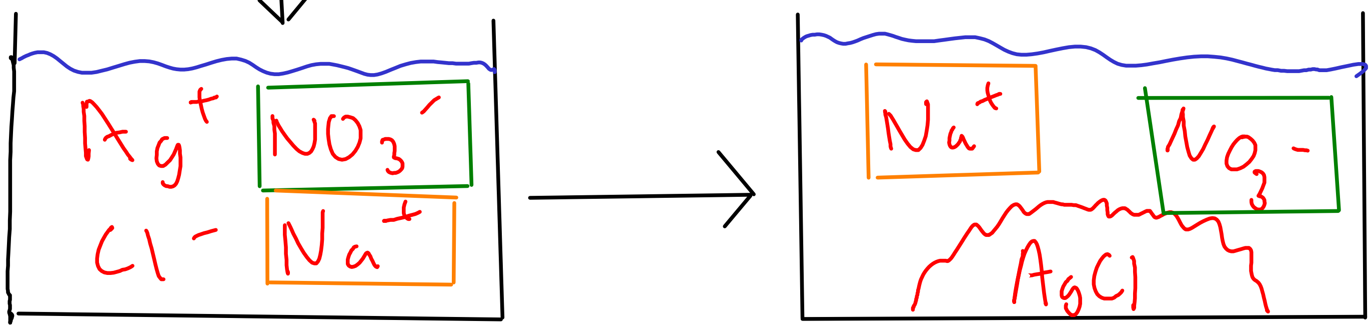
"ion soup"!

Insoluble AgCl falls out of solution as it is formed - "precipitation"

Looking a bit more closely...



The nitrate and sodium ions do not really participate in this reaction. They start and end in exactly the same state. We call them "SPECTATOR IONS".



$$AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$$ "Molecular equation"

$$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$$ "Net ionic equation"

(The net ionic equation shows only ions and substances that change during the course of the reaction!)

- The net ionic equation tells us that any source of aqueous silver and chloride ions will exhibit this same chemistry, not just silver nitrate and sodium chloride!