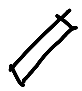
CONCEPT OF LIMITING REACTANT

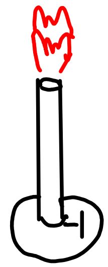
- When does a chemical reaction STOP?

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



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

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

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

CaO: 56.08 g CaO = mol CaO | 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

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

This reaction will stop when 114 grams of calcium carbide is produced, At that point, there will be no more CaO remaining. We say that the CaO is limiting, and C is present in excess (since there will still be some unreacted C at the end)

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

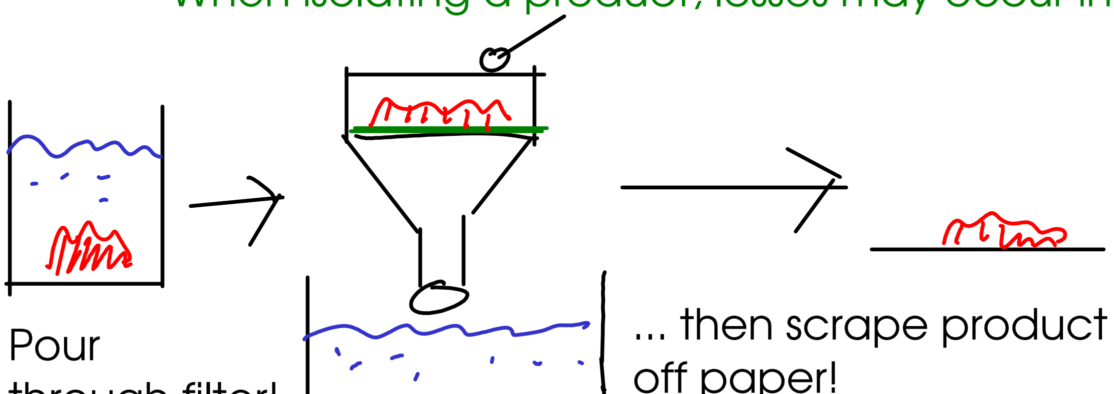
$$2C + O_2 \longrightarrow 2CO$$

... 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 $\qquad\qquad$ 123.111 g/mol <- Formula weights

22.4 g $\qquad\qquad$ 31.6 g ACTUAL

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

benzene $\qquad$ nitric acid $\qquad$ 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 already know our actual yield (31.6 g nitrobenzene). We just need to calculate our theoretical yield. Start with the 22.4 g benzene (our reactant!)...

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 $C_6H_5NO_2$

$$22.4\,g\,C_6H_6 \times \frac{mol\ C_6H_6}{78.114\,g\ C_6H_6} \times \frac{mol\ C_6H_5NO_2}{mol\ C_6H_6} \times \frac{123.111\,g\ C_6H_5NO_2}{mol\ C_6H_5NO_2} = 35.3033566 3\,g\ C_6H_5NO_2\ (\text{theor.})$$

Now that we know the theoretical yield, calculate the percent yield:

$$\%\,yield = \frac{actual}{theor} \times 100\%$$

$$= \frac{31.6\,g}{35.3033566 3\,g} \times 100\% = \boxed{89.5\,\%}$$

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?

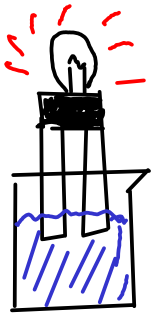
- If an electrolyte COMPLETELY IONIZES in water, it's said to be STRONG

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

- Both kinds of electrolyte undergo similar kinds of chemistry.

111

Ionic theory experiment



Simple conductivity tester: The stronger the electrolyte, the brighter the light.

SOME PURE COMPOUNDS (MOLECULAR AND IONIC)

DISTILLED WATER

Nonconductor. (Typical for molecules!)

SOLID SODIUM CHLORIDE

Nonconductor in solid state. (Ions unable to move)

SOLID SUCROSE $C_{12}H_{22}O_{11}$

Nonconductor. It's a molecule like water.

MOLECULAR AND IONIC SOLUTIONS

SODIUM CHLORIDE + WATER

Bright light! Sodium chloride is an electrolyte!

SUCROSE + WATER

No light. Sucrose is a NONELECTROLYTE. This is typical behavior for molecules.

ACIDS

PURE (GLACIAL) ACETIC ACID

No light. It's a nonconductor like water. This suggests that acetic acid is a molecular substance, as we'd expect any ions in the liquid state to be able to move and carry a current.

ACETIC ACID + WATER

Dim light, Even so, we can conclude that acetic acid is an electrolyte - it does form ions when dissolved in water.

2M ACETIC ACID (AQUEOUS)

Dim light. (Dimmer than HCl), meaning that acetic acid is a WEAK ELECTROLYTE.

2M HYDROCHLORIC ACID (AQUEOUS)

Bright light. HCl is a stronger electrolyte than acetic acid.