The amount of product that is calculated to from when all of the limiting reactant reacts is called the theoretical yield.

The amount of product actually obtained in a reaction is called the actual yield.

The percent yield of a reaction relates the actual yield to the theoretical yield.

$$\text{Percent yield} = \left(\frac{\text{actual yield}}{\text{theoretical yield}}\right) \times 100$$

$$C_6H_{12}O_6 \xrightarrow{\text{yeast}} 2CH_3CH_2OH + 2CO_2$$

How much ethanol can be produced from 45.5 kg of sugar?

(45,000g $C_6H_{12}O_6$)(1 mol $C_6H_{12}O_6$/180.17g $C_6H_{12}O_6$) = 252.54 moles sugar

(252.54 $C_6H_{12}O_6$) (2 molCH_3CH_2OH/1 mol $C_6H_{12}O_6$) = 505.08 moles ethanol

(505.08 mol CH_3CH_2OH)(46.08g CH_3CH_2OH/1mol CH_3CH_2O) = 23274 g ethanol

"In theory"

If 21,456g are actually obtained, what is the percent yield?

(21,456 g/23,274 g)x100 = 92.19 percent yield

Properties of Solutes in Aqueous Solution

The term electrolyte simply means that the aqueous solution of the solute conducts electricity.

An ionic solid dissociates into ions in solution.

Nonionic compounds that form ions in solution are said to ionize.

Strong and Weak Electrolytes

Essentially all ionic compounds like NaCl and HCl exist in solution completely or nearly completely as ions. Thus NaCl and HCl are called strong electrolytes.

$$NaCl_{(aq)} \rightarrow Na^+_{(aq)} + Cl^-_{(aq)}$$

There are some compounds that produce a small concentration of ions when they dissolve; they are called weak electrolytes .

$$HC_2H_3O_{2\,(aq)} \rightleftharpoons H^+_{(aq)} + C_2H_3O_{2\,(aq)}$$

When a weak electrolyte such as acetic acid ionizes in in solution, we write the reaction in the following manner:

$$HC_2H_3O_2 \rightleftharpoons H^+ + C_2H_3O_2^-$$

The double arrow means that the reaction is significant in both directions. At any given moment some $HC_2H_3O_2$ molecules are ionizing to form H^+ and $C_2H_3O_2^-$. At the same time, H^+ and $C_2H_3O_2^-$ ions are recombining to form $HC_2H_3O_2$.

The balance between these opposing processes determines the relative concentrations of neutral molecules and ions.

This balance produces a state of chemical equilibrium (Ch 15).

Acids are compounds that release H^+ ions when dissolved in water. Acids also decrease the concentration of OH^- when dissolved in water.

Bases are compounds that accept (consume) H^+ ions when dissolved in water. Bases also increase the concentration of OH^- when dissolved in water.

The term salt has come to mean any ionic compound whose cation comes from a base and whose anion comes from as acid.

Metathesis Reactions (Double-replacement).

Two compounds exchange anions.

$$AX + BZ \longrightarrow AZ + BX$$

$$AgNO_{3(aq)} + KCl_{(aq)} \rightarrow AgCl_{(s)} + KNO_{3(aq)}$$

For a methathesis reaction to lead to a net change in a solution, ions must be removed from the solution.

1. Formation of an insoluble product (precipitate).
2. The formation of either a weak electrolyte or a nonelectrolyte.
3. The formation of a gas that escapes from solution.

Solubility Rules for Ionic Compounds

Compounds containing the following ions are generally soluble in water:

1. Li^+, Na^+, K^+, NH^{4+}
2. Acetate ion, $C_2H_3O_2^-$
3. Nitrate ion NO_3^-
4. Cl^-, Br^-, I^- (AgX, Hg_2X_2, and PbX_2 are insoluble exceptions)
5. SO_4^{2-} ($SrSO_4$, $BaSO_4$ and $PbSO_4$ are insoluble exceptions)

Compounds containing the following ions are generally insoluble in water:

6. CO_3^{2-} (Rule #1 exceptions are soluble)
7. CrO_4^{2-} (Rule #1 exceptions are soluble)
8. PO_4^{3-} (Rule #1 exceptions are soluble)
9. S^{2-} (Rule #1 exceptions are soluble)
10. OH^- (Rule #1 exceptions are soluble)

IONIC EQUATIONS

Consider the precipitation reaction between silver nitrate and sodium chloride.

$$AgNO_{3(aq)} + NaCl_{(aq)} \rightarrow AgCl_{(s)} + NaNO_{3(aq)}$$

The above equation, which shows the complete chemical formulas for reactants and products, is called a molecular equation.

An equation with all soluble strong electrolytes shown as ions is called a complete ionic equation:

$$Ag^+_{(aq)} + NO^-_{3(aq)} + Na^+_{(aq)}\ Cl^-_{(aq)} \rightarrow AgCl_{(s)} + Na^+_{(aq)}\ NO_{3(aq)}$$

A net ionic equation has the spectator ions omitted.

$$Ag^+_{(aq)} + Cl^-_{(aq)} \rightarrow AgCl_{(s)}$$

OXIDATION NUMBERS

The concept of oxidation numbers (also called oxidation states) was devised as a simple way of keeping track of electrons in chemical reactions.

We define the ***oxidation number*** of an atom in a substance to be the actual charge of the atom if it is a monatomic ion; otherwise, it is the hypothetical charge assigned to the atom using a set of rules.

An oxidation-reduction reaction is one in which atoms change oxidation numbers, implying the transfer of electrons.

Oxidation occurs when there is an increase in oxidation number, whereas reduction occurs when there is a reduction in oxidation number.

- For an atom in its elemental form, the oxidation number is always zero.
- For any monatomic ion, the oxidation number equals the charge on the ion.
- Nonmetals usually have negative oxidation numbers,although they can sometimes be positive:
  - The oxidation # of oxygen is usually –2 in both ionic and molecular compounds (peroxides are an exception).
  - The oxidation # of hydrogen is +1 when bonded to nonmetal and –1 when bonded to metals
  - The oxidation # of fluorine is –1 in all compounds.
- The sum of the oxidation numbers of all atoms in a neutral compound is zero. For a polyatomic ion the sum of oxidation numbers must sum up to the charge of the ion.

Oxidation and Reduction

When a metal undergoes corrosion, it loses electrons and forms cations.

$$Mg + HCl \rightarrow MgCl_2 + H_2$$

Loss of electrons by a substance is called oxidation.

The gain of electrons by a substance is called reduction.

Two mnemonic devices:

"Leo" the Lion goes "ger" or think "oil rig".

When will oxidation and reduction occur?

$$A + BZ \rightarrow AZ + B$$

In order for this reaction to take place "A" must have "*more energy*" than "B".

An **activity** series (electromotive series p131) is a sequence of metals arranged according to their ability to undergo reaction.

Li>K>Ba>Sr>Ca>Na>Mg>Al>Mn> Zn>Fe

>Cd>Co>Ni>Sn >Pb> (H) >Cu>Ag>Hg>Au

$Fe + CuSO_4 \rightarrow FeSO_4 + Cu$

$Cu + FeSO_4 \rightarrow$ No reaction

$Fe + HCl \rightarrow FeCl_2 + H_2$

$Cu + HCl \rightarrow$ No reaction

Molar Concentration

A common expression of solution concentration is Molarity. Molarity (symbol **M**) is the number of moles of a solute dissolved in one liter of solution.

$$\frac{\text{moles of solute}}{\text{liter solution}} = M$$

Q What is the product of volume and strength?

A Moles

Consider the following:

$V_1 x M_1 = V_2 x M_2$

When one dilutes a solution the amount of solute remains constant.

A stock bottle of HCl is 12 M. How does one make a 1 litter solution that is 0.5 M?

How many grams of KCl are required to make 250 mL of 0.500M KCl solution?

1. Find the # of moles of KCl are needed?

   (0.250 L)(0.500 mol/L) = 0.125 moles KCl

2. Find the molar mass of KCl 39.1 +35.45 = 74.55g/mole

3. Multiply moles by molar mass to yield grams needed for 250 mL of solution.

   (0.125 moles)(74.55g/mole) = 9.319 g KCl

Titration: A procedure in which one substance (titrant) is carefully added to another (analyte) until complete reaction has occurred. The quantity of titrant required for complete reaction tells how much analyte is present.

Equivalence point: The point in a titration at which the quantity of titrant is exactly sufficient for stoichiometic reaction with the analyte.

End point: The point in a titration at which there is a sudden change in a physical property, such as indicator color, pH, conductivity, or absorbance. Used as a measure of the equivalence point.