THE MOLE CONCEPT

- The mole term is similar to the "dozen" term.
- Just as a dozen represents "12"; the mole represents 6.022 x 10^{23}. A very large amount.
- This is due to atoms & molecules being very small.

THE MOLE "n"

√ The mole is also referred to as Avogadro's number, N_A

√ 1 mole = N_A = n = 6.022 x 10^{23} particles

√ Particles could be atoms, molecules, ions, electrons, even eggs.

THE MOLE & MOLAR MASS

- The atomic or formula mass (weight) is measured in reference to the mole.
- The atomic/formula mass is also known as the MOLAR MASS.
- Molar mass = MM = m/n or mass/mole.
- Units for molar mass is grams per mole or g/mol.

For example:
H = 1.008 amu
= 1.008 g/mol
= 6.022 x 10^{23} atoms
= 1 molar mass

K_2CO_3 =
2K + C + 3O=
2(39.10 g/mol) +
12.011g/mol +
3(16.00g/mol) =
138.11g/mol

Calculations involving the mole

Mass(g) → (Molecular Mass) → MOLE → (Avogadro's # 6.022 x 10^{23}) → Atoms, Ions, or Molecules

1. Calculate the formula weight of sucrose, $C_{12}H_{22}O_{11}$.
2. Calculate the number of moles in 28.0 g of water.
3. How many oxygen atoms are present in 4.20 g of $NaHCO_3$?
4. Calculate how many methane (CH_4) molecules there are in 25.0 g of methane.

Workshop 3A on the MOLE

Mass(g) → (Molecular Mass) → MOLE → (Avogadro's # 6.022 x 10^{23}) → Atoms, Ions, or Molecules

Problem #1: Calculate the formula weight of calcium nitrate.

Problem #2: How many moles of glucose, $C_6H_{12}O_6$, are in 538 g?

Problem #3: How many glucose molecules are there in 5.23 g of glucose?

Problem #4: Calculate the number of moles in 325 mg of aspirin, which has the following structural formula:

PERCENT COMPOSITION

- *The percent composition is the mass percentage of each type of atom(element) in a compound.*

% X =
(total atomic mass of X / molar mass which contains X)

For Example:
Calculate the percent composition of nicotine, $C_{10}H_{14}N_2$.

☆Molar mass = 10C + 14H + 2N = 162 g/mol
%C = (10C / $C_{10}H_{14}N_2$)100 = (120 g/mol /162 g/mol)100=74.1%
%H = (14H / $C_{10}H_{14}N_2$)100 = (14 g/mol / 162 g/mol)100 = 8.6%
%N = (2 N / $C_{10}H_{14}N_2$)100 = (28 g/mol / 162 g/mol)100 = 17.3%

Workshop 3B on The Mole

1. Calculate the percent composition of aluminum sulfate and barium hydroxide dihydrate.
2. A solution of sulfuric acid contained 65% H_2SO_4 by mass and had a density of 1.56 g/mL. How many moles of acid are present in 1.00 L of the solution?
3. What mass of sodium will contain the same number of atoms as 100.0 g of potassium?

BALANCING CHEMICAL EQUATIONS

$Mg + O_2 \rightarrow MgO$

First list all atoms in order of metals, nonmetals, then "H" & "O" last. Leave the species that is split between more than one compound for last.

Mg - 1 | Mg - 1
O - 2 | O - 1

Next, start with the top atom; one Mg on the reactant side and one Mg atom on the product side. The Mg atom is balanced. Now do oxygen, two "O" atoms on the reactant side and one on the product side. The product side needs to change so place a "2" in front of MgO. Remember you can not change the formula.

$Mg + O_2 \rightarrow 2\ MgO$

This now makes the list:

Mg - 1 | Mg - 2
O - 2 | O - 2

If a two is placed in front of the Mg on the reactant side;

$2\ Mg + O_2 \rightarrow 2\ MgO$

Mg - 2 | Mg - 2
O - 2 | O - 2

Now the equation is balanced.

Balance the following molecular equations

1. $NaBr(aq) + Cl_2(g) \rightarrow NaCl(aq) + Br_2(l)$
2. $SbCl_3(aq) + Na_2S(aq) \rightarrow Sb_2S_3(s) + NaCl(aq)$
3. $Mg(OH)_{2\ (aq)} + H_2SO_{4\ (aq)} \rightarrow H_2O_{\ (l)} + MgSO_{4\ (aq)}$
4. $C_2H_4(g) + O_2(g) \rightarrow CO_2(g) + H_2O(g)$

WORKSHOP 3C

Balance the following molecular equations :

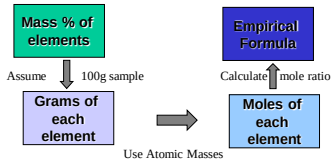
1. $KI(aq) + Cl_2(g) \rightarrow KCl(aq) + I_2(s)$

2. $FeBr_3(aq) + Li_2S(aq) \rightarrow Fe_2S_3(s) + LiBr(aq)$

3. $Al(OH)_{3\,(aq)} + H_2SO_{4\,(aq)} \rightarrow H_2O_{\,(l)} + Al_2(SO_4)_{3\,(aq)}$

4. $C_3H_8(g) + O_2(g) \rightarrow CO_2(g) + H_2O(g)$

EMPIRICAL FORMULA



EMPIRICAL FORMULA

Step 1: If given the % composition, assume a 100g sample then convert % to grams.

Step 2: Use the atomic masses to convert grams to moles.

Step 3: Divide the moles of each element by the SMALLEST mole fraction.

Step 4: The results from step 3 should be a whole number, if not, make it so by multiplying by a common factor.

Empirical Formula

Hydroquinone, used as a photographic developer, is 65.4% carbon, 5.5% hydrogen, and 29.1% oxygen by mass. What is the empirical formula of hydroquinone?

Molecular Formula

Adipic acid is used in the manufacture of nylon. The percent composition of the acid is 49.3% carbon, 6.9% hydrogen, and 43.8% oxygen by mass. The molecular weight of the compound is 146 g/mol. What is the molecular formula?

Workshop 3D on Percent Composition, Empirical Formula, and Molecular Formula Determination

1. Calculate the percentage composition of sucrose, $C_{12}H_{22}O_{11}$.

2. Ascorbic acid (vitamin C) contains 40.92 percent C, 4.58 percent H, and 54.50 percent O by mass. What is the empirical formula of ascorbic acid?

3. Mesitylene, a hydrocarbon that occurs in small amounts of crude oil, has an empirical formula of C_3H_4. The experimentally determined molecular weight of this substance is 121 amu. What is the molecular formula of mesitylene?

4. Sorbitol, used as a sweetener in some sugar-free foods, has a molecular formula of 182 amu and a mass percent composition of 39.56% C, 7.74% H, and 52.70% O. What are the empirical and molecular formulas of sorbitol?

Empirical Formula Combustion Analysis

Menthol (MM = 156.3 g/mol), a strong smelling substance used in cough drops, is a compound of carbon, hydrogen, and oxygen. When 0.1595 g of menthol was subjected to combustion analysis, it produced 0.449 g of CO_2 and 0.184 g of water. What is its molecular formula?

Extra Lecture problems

1. A 5.325-g sample of methyl benzoate, a compound used in the manufacture of perfumes, is found to contain 3.758 g of C, 0.316 g of H, and 1.251 g of O. What is the empirical formula of this substance?

2. A compound contains only carbon, hydrogen, and oxygen. Combustion of 10.68 mg of the compound yields 16.01 mg of CO_2 and 4.37 mg of H_2O. The molar mass of the compound is 176.1 g/mol. What are the empirical and molecular formulas of the compound?

Workshop 3E on Combustion Analysis

1. Cyclopropane, a substance used with oxygen as a general anesthetic, contains only two elements, carbon and hydrogen. When 1.00 g of this substance is completely combusted, 3.14 g of CO_2 and 1.29 g of H_2O are produced. What is the empirical formula of cyclopropane?

2. Isobutyl propionate is the substance that provides the flavor for rum extract. Combustion of a 1.152 g sample of this carbon-hydrogen-oxygen compounds yields 2.726 g CO_2 and 1.116 g H_2O. What is the empirical formula of isobutyl propionate?

WRITING CHEMICAL EQUATIONS

Reactants (starting materials) → Products (ending materials)

(g) = gas	(l) = liquid	(s) = solid
(aq) = aqueous (dissolved in water)	Δ = heat	→ = yields
$\xrightarrow{X}$ = catalyst	+ = combines	

The number of molecules (moles) involved in the reaction are written in the front of the chemical formula.

CHEMICAL EQUATIONS

CHEMICAL EQUATIONS represent chemical reactions which, in turn, are driven by changes like:

Change	Observation
• formation of a precipitate	solid is formed
• formation of water	heat is formed
• formation of a gas	bubbles formed

other changes are:

- **Electrochemistry** — electrons are transferred
- **Thermochemistry** — heat is transferred

CHEMICAL EQUATIONS

There are three basic types of chemical equations:
Molecular, Ionic, & Net ionic.

- **MOLECULAR EQUATIONS are written as if all substances were molecular, even though some substances may exist as ions.**
  $HCl\ (aq) + NaOH\ (aq) \rightarrow NaCl\ (aq) + H_2O\ (l)$
- **IONIC EQUATIONS have the substances which exist as ions written in ionic form.**
  $H^+_{(aq)} + Cl^-_{(aq)} + Na^+_{(aq)} + OH^-_{(aq)} \rightarrow Na^+_{(aq)} + Cl^-_{(aq)} + H_2O_{(l)}$
- **Precipitation, Acid/base, and Redox reactions can all be written depicting the appropriate substances as ions**
- **NET IONIC EQUATIONS are ionic equations with the Spectator ions removed.**
  $H^+_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(l)}$
- **SPECTATOR IONS do not participate in a reaction (that is they do not react to form a new substance). Common Spectator ions are Group I, many Group II, and NO_3^- (nitrate) and $C_2H_3O_2^-$ (acetate) ions.**

Write the molecular, ionic, & net ionic equations.

1. Aqueous Ammonium hydroxide decomposes into ammonia gas and liquid water.

2. Solid calcium carbonate reacts with hydrochloric acid to produce a gas, water, and aqueous salt.

3. The following two solutions are mixed; cobalt iodide & lithium sulfate, what happens?

Workshop 3F
Write the molecular, ionic, & net ionic equations.

1. **Aqueous sodium acetate is mixed with aqueous cobalt (II) chloride to produce cobalt (II) acetate and sodium chloride solutions.**
2. **Solid silver chloride is dissolved in nitric acid to produce aqueous silver nitrate and hydrochloric acid.**
3. **Solid iron (II) sulfide reacts with hydrobromic acid to produce hydrogen sulfide gas and iron (II) bromide solution.**
4. **Sulfuric acid is mixed with potassium hydroxide.**