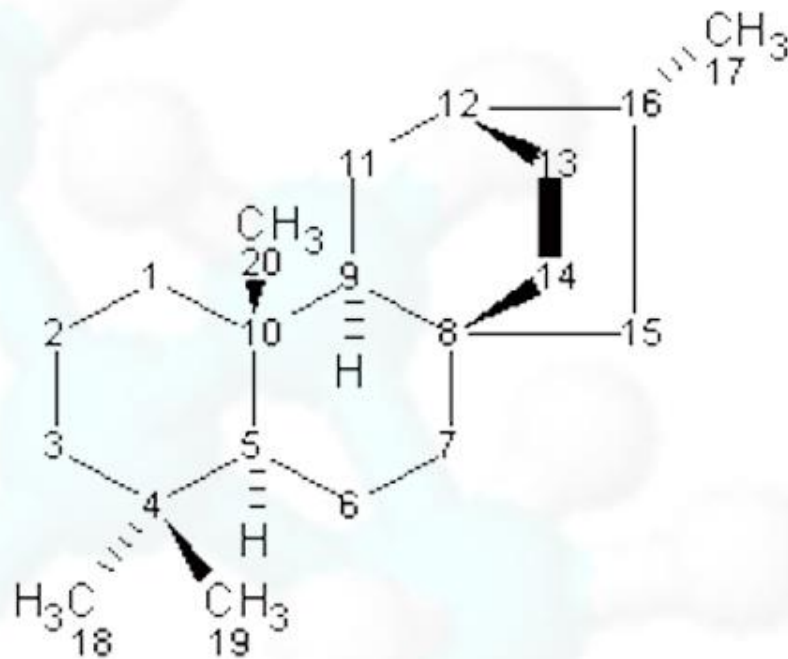
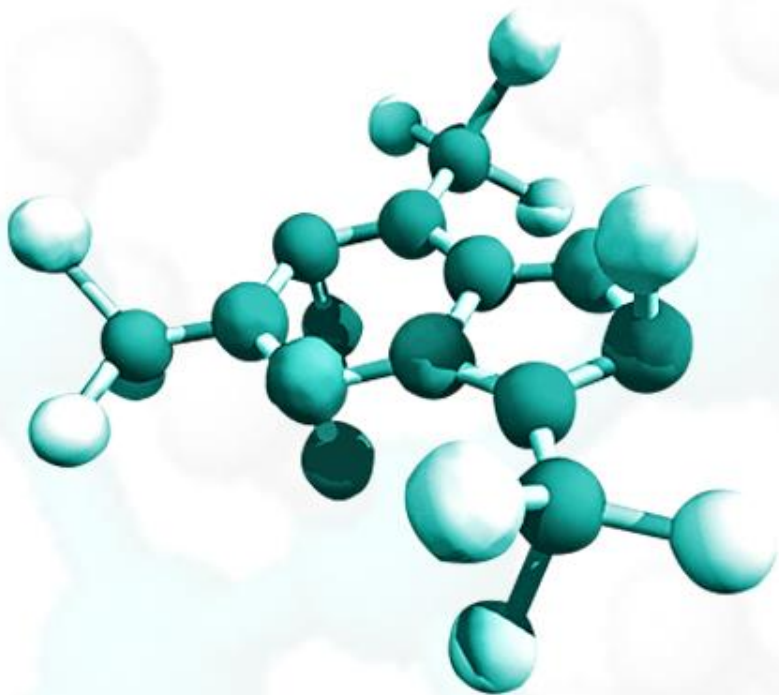
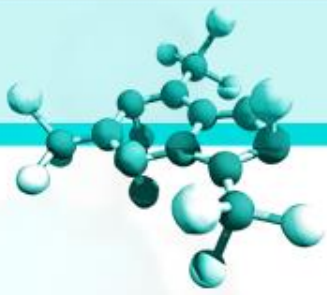




Chapter Three

Chemical formula (Formula Weights, Empirical, and Molecular formula),



Atomic mass

- Atomic mass = number of protons + number of neutrons*

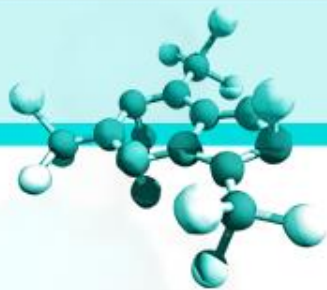
6 ← Atomic number

C

12.01 ← Atomic mass

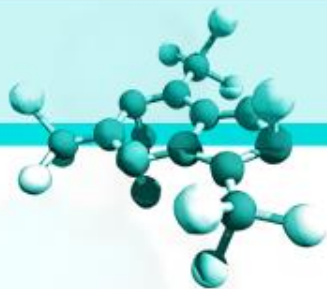
The atomic mass of elements is relative to a standard atom ^{12}C (6 protons, 6 neutrons)

- Atomic mass = the mass of atom in amu (atomic mass unit)*
- By definition: 1 atom ^{12}C weight 12 amu.*
- Setting the atomic mass of carbon-12 at 12 amu provide the standard for measuring the atomic mass for the other elements.*



- ***Molecular and Formula Weights***

- *The formula weight of a compound is the sum of all of the atomic weights of the atoms in a chemical formula.*
- *The formula weight of an **ionic compound** is found by adding up all of the atomic weights of the atoms in the compound.*
- *The molecular weight is the formula weight of **a molecule**.*



Molar Mass

- Molar mass (M) = the mass (in gram) of 1 mole of a substance.*

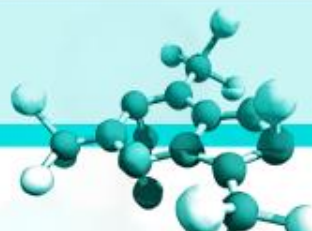
For any **element**

atomic mass (amu) = molar mass (grams/mole)

- Example:*

Atomic mass of Na is 22.99 amu then Molar mass is 22.99 g/mol

Atomic mass of P is 30.97 amu then Molar mass is 30.97 g/mol



Example 1: Calculate the formula weight of NaCl.

To do this we must count the number of each atom, multiply that number by the atomic weight of each atom and add these products together.

In NaCl, there is one sodium ion and one chloride ion.

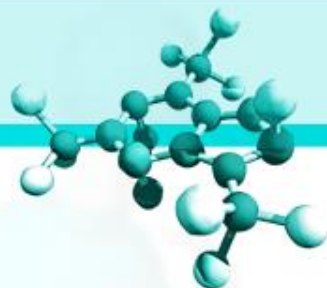
From the table of atomic weights, the atomic weight of sodium is 22.99 g/mol and the atomic weight of chlorine is 35.45 g/mol.

The formula weight is:

$$[(1)(22.99) + (1)(35.45)] = 58.44 \text{ g/mol}$$

the weight of one
mole of sodium

the weight of one
mole of chlorine



Example 2: Calculate the formula weight of Al_2O_3 .

In Al_2O_3 , there are 2 aluminum ions and 3 oxide ions.

Therefore, the formula weight is:

$$[(2)(26.98) + (3)(16.00)] = 101.96 \text{ g/mol}$$

Number
of Al's

Atomic
weight of
aluminum

Number
of O's

Atomic
weight of
oxygen



Molecular Mass

- The molecular mass (also called molecular weight) of compound is the sum of all molar mass of each of its elements.*

Example 3:

what is the Molecular mass for NaOH?

NaOH consists of Na, O, H

Then molecular mass (NaOH) = molar mass of Na + molar mass of O + molar mass of H

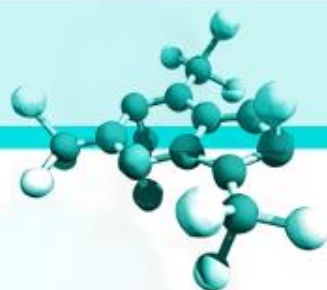
$$= 23 + 16.00 + 1 = 40 \text{ g/mol}$$

Example 4:

What is the Molecular mass of SO₂

Then molecular mass (SO₂) = molar mass of S + (molar mass of O)

$$= 32 + 2 \times 16 = 64 \text{ g/mol}$$



Calculate the formula weight of $\text{Ca}_3(\text{PO}_4)_2$.

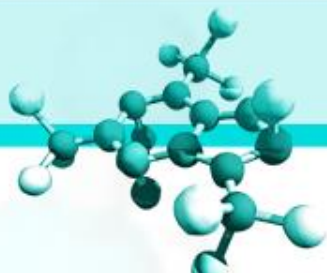
In $\text{Ca}_3(\text{PO}_4)_2$, how many calcium ions are there? 3

How many phosphorus atoms are there? 2

How many oxygen atoms are there? 8

Therefore, the formula weight is:

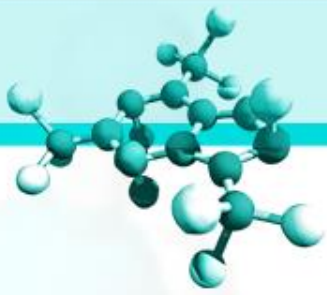
$$\begin{array}{ccccccc} [(3)(40.08) + (2)(30.97) + (8)(16.00)] & = & 310.18 & \text{g/mol} \\ \text{calcium} & & \text{phosphorus} & & \text{oxygen} \end{array}$$



- *Find the molecular mass of glucose, which has a molecular formula $C_6H_{12}O_6$.*

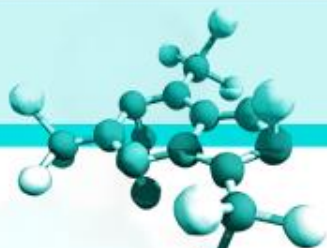
$$\text{molecular mass } C_6H_{12}O_6 = 6(12.01) + 12(1.008) + 6(16.00) = 180.16$$

- ☐ *Find the molecular mass of acetic acid, which has a formula CH_3COOH*
- ☐ *Find the molecular mass of tartaric acid, which has a formula $HO_2CCH(OH)CH(OH)CO_2H$.*



Avogadro's number

- ***The mole (mol)*** is the amount of a substance that contains as many elementary entities as there are atoms in exactly 12.00 grams of C-12.
- They calculate this number and it was found to be $6.022 \times 10^{+23}$
- This number was called ***Avogadro's number (NA)*** (after Italian scientist Amedeo Avogadro).
- $1 \text{ mole of H}_2\text{O} = 6.022 \times 10^{+23} \text{ H}_2\text{O atom}$
- $1 \text{ mole of CO}_2 = 6.022 \times 10^{+23} \text{ CO}_2 \text{ atom}$



Molar Mass

- To calculate number of particle (atoms or molecules) :*

Number of particle = Avogadro's number $\times$ number of moles.

Example1:

Calculate the number of atoms in 2 mole of hydrogen?

Number of atoms = $6.022 \times 10^{+23} \times 2 = 12.044 \times 10^{+23}$.

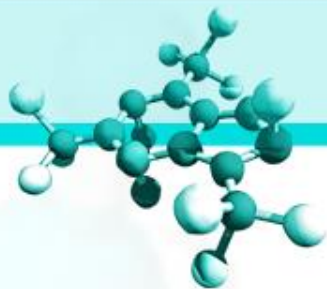
Example 2 :

Calculate the number of moles in $6 \times 10^{+20}$ atom of helium (He)?

Number of mole = number of atom / avogadro's number

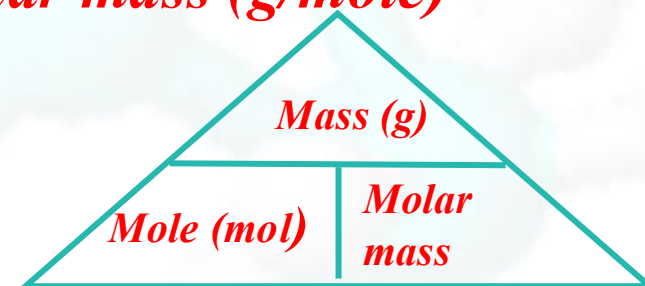
$$= 6 \times 10^{+20} / 6.022 \times 10^{+23}$$

$$= 0.99 \times 10^{-3} \text{ mole.}$$



Molar Mass

- Relationships between mole and molar mass:
- **n (number of moles)= mass (g) / molar mass (g/mole)**



- Example 1:

How many grams of Zn in 0.356 mole of Zn?

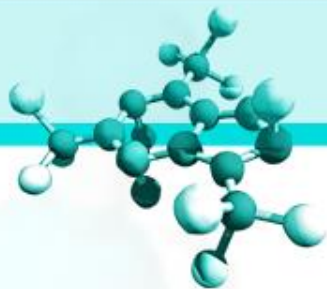
First find the molar mass of Zn from periodic table 65.39 g/mole

Number of mole = mass / molar mass

Mass = number of mole x molar mass

= 0.356 (mole) x 65.39 (g/mole)

= 23.3 g.



- **Example 2 :**

Calculate the number of atoms in 6.46 grams of helium (He)?

The molar mass of He is 4 g/mole

First calculate number of moles of He:

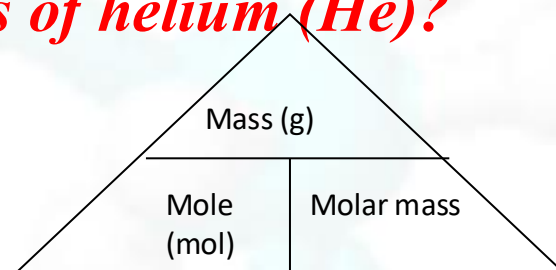
$$n = 6.46 \text{ (g)} / 4 \text{ (g/mole)}$$

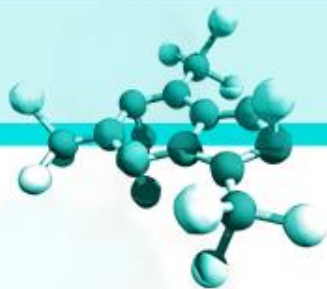
$$= 1.62 \text{ mole}$$

Number of atom = Avogadro's number x number of mole

$$= 6.022 \times 10^{+23} \times 1.62$$

$$= 9.73 \times 10^{23} \text{ atoms}$$





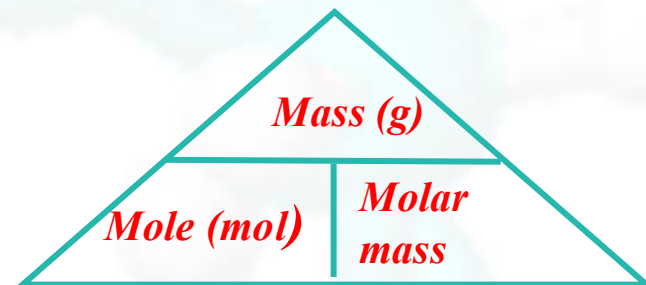
- Example 2 :

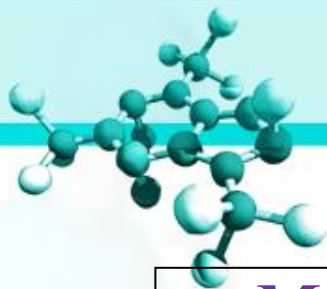
Calculate the number of molecules in 10 grams of hydrogen (H₂)?

The molar mass of H is 1 g/mole

$$\begin{aligned}\text{No. of moles} &= \text{mass} / \text{molar mass} \\ &= 10 / (1 \times 2) = 5 \text{ moles}\end{aligned}$$

$$\begin{aligned}\text{Number of atom} &= \text{Avogadro's number} \times \text{number of mole} \\ &= 6.022 \times 10^{23} \times 5 \\ &= 30.11 \times 10^{23} \text{ atoms}\end{aligned}$$





• *Chemical Formula*

• *Molecular Formula*

*It's a formula shows the exact number of atoms of each elements in the smallest unit of a substance
The actual numbers of atoms in a molecule*



• *Empirical Formula*

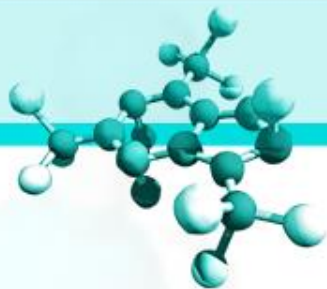
shows the simplest whole-number ratio of the atoms in a substance.

The simplest whole number ratio of elements in a compound

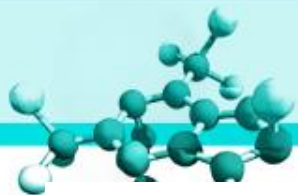


Structural Formula

Show the relative arrangements of atoms in a molecule



	Hydrogen	Water	Ammonia	Methane
Molecular formula	H_2	H_2O	NH_3	CH_4
Empirical Formula	H_2	H_2O	NH_3	CH_4
Structural formula	$H-H$	$H-O-H$	$ \begin{array}{c} H-N-H \\ \\ H \end{array} $	$ \begin{array}{c} H \\ \\ H-C-H \\ \\ H \end{array} $



Calculating Empirical Formula

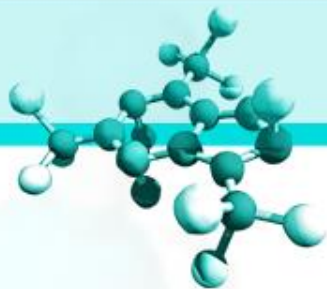
An oxide of aluminum is formed by the reaction of 4.151 g of aluminum with 3.692 g of oxygen. Calculate the empirical formula.

1. Determine the number of grams of each element in the compound.

$$\text{No. of moles of } = \frac{\text{mass}}{\text{atomic mass}}$$

$$\text{No. of moles of Al} = \frac{4.151 \text{ g}}{26.98 \text{ g}} = 0.1539 \text{ mol Al}$$

$$\text{No. of moles of O} = \frac{3.692 \text{ g}}{16.00 \text{ g}} = 0.2308 \text{ mol O}$$



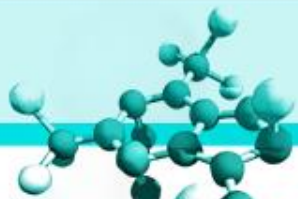
3. *Find ratio by dividing each element by smallest amount of moles.*

$$\frac{0.1539 \text{ moles Al}}{0.1539} = 1.000 \text{ mol Al}$$

$$\frac{0.2308 \text{ moles O}}{0.1539} = 1.500 \text{ mol O}$$

4. *Multiply by common factor to get whole number. (cannot have fractions of atoms in compounds)*

$$\begin{array}{l} \text{O} = 1.500 \times 2 = 3 \\ \text{Al} = 1.000 \times 2 = 2 \end{array} \quad \text{therefore,} \quad \mathbf{Al_2O_3}$$



A 4.550 g sample of cobalt reacts with 5.475 g chlorine to form a binary compound. Determine the empirical formula for this compound.

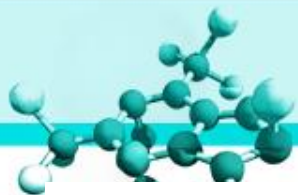
$$\text{No. of moles of Co} = \frac{4.550 \text{ g Co}}{58.93 \text{ g Co}} = 0.07721 \text{ mol Co}$$

$$\text{No. of moles of Cl} = \frac{5.475 \text{ g Cl}}{35.45 \text{ g Cl}} = 0.1544 \text{ mol Cl}$$

$$\frac{0.07721 \text{ mol Co}}{0.07721} = 1$$

$$\frac{0.1544 \text{ mol Cl}}{0.07721} = 2$$





When a 2.000 g sample of iron metal is heated in air, it reacts with oxygen to achieve a final mass of 2.573 g. Determine the empirical formula.

$$\text{Fe} = 2.000 \text{ g}$$

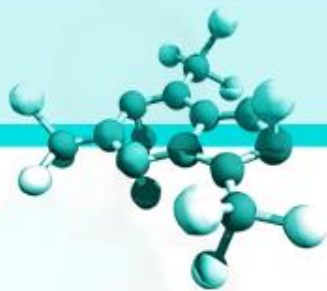
$$\text{O} = 2.573 \text{ g} - 2.000 \text{ g} = 0.5730 \text{ g}$$

$$\frac{2.000 \text{ g Fe}}{55.85 \text{ g Fe}} = 0.03581 \text{ mol Fe}$$

$$\frac{0.573 \text{ g O}}{16.00 \text{ g}} = 0.03581 \text{ mol Fe}$$



1 : 1

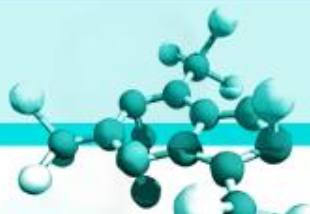


Percent Composition of Compounds

- *The percentage by mass of each element in a compound*

Mass percent *is the ratio of the atomic weight of all the atoms of a certain element to the total formula of molecular weight of the substance.*

$$\text{Percent} = \frac{\text{Mass of each element}}{\text{Total Mass}} \times 100\%$$



Example: *What is the percent composition of Potassium Permanganate (KMnO₄)?*

Molar Mass of KMnO₄ = 158 g

$$\% \text{ K } \frac{39.1 \text{ g K}}{158 \text{ g}} \times 100 = 24.7 \%$$

$$\% \text{ Mn } \frac{54.9 \text{ g Mn}}{158 \text{ g}} \times 100 = 34.8 \%$$

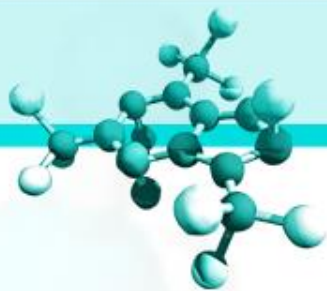
$$\text{K} = 1(39.10) = 39.1$$

$$\text{Mn} = 1(54.94) = 54.9$$

$$\text{O} = 4(16.00) = \underline{64.0}$$

$$\text{MM} = 158$$

$$\% \text{ O } \frac{64.0 \text{ g O}}{158 \text{ g}} \times 100 = 40.5 \%$$



Determine the percentage composition of sodium carbonate
(Na₂CO₃)?

Molar Mass

$$\text{Na} = 2(23.00) = 46.0$$

$$\text{C} = 1(12.01) = 12.0$$

$$\text{O} = 3(16.00) = \underline{48.0}$$

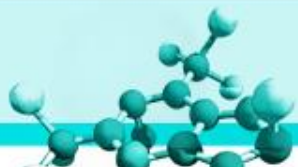
$$\text{MM} = 106 \text{ g}$$

Percent Composition

$$\% \text{ Na} = \frac{46.0 \text{ g}}{106 \text{ g}} \times 100\% = 43.4 \%$$

$$\% \text{ C} = \frac{12.0 \text{ g}}{106 \text{ g}} \times 100\% = 11.3 \%$$

$$\% \text{ O} = \frac{48.0 \text{ g}}{106 \text{ g}} \times 100\% = 45.3 \%$$



Determine the percentage composition of ethanol (C₂H₅OH)?

% C = 52.13%, % H = 13.15%, % O = 34.72%

Determine the percentage composition of sodium oxalate (Na₂C₂O₄)?

% Na = 34.31%, % C = 17.93%, % O = 47.76%

