## ***Mole Theory***

Definition: A mole is an amount of substance that contains the same number of elementary entities (atoms, molecules, et.) as there are carbon-12 atoms in exactly 12 g of carbon-12. The mole can also be defined as the atomic or molecular weight of a substance expressed in grams. It is a metric unit for amount of substance and has the abbreviation *mol*.

## History

- Atomic weights were originally determined by weighting equal volumes of gases which according to Avogadro's Hypothesis contain the same number of particles.
- Since they contain the same number of particles, the mass of the equal volumes also represented the mass of the particles that comprised the gas.
- **One mole of a substance then is the atomic weight of the element expressed in grams.**
- The number of particles in this amount is termed **Avogadro's Number** and has been estimated at **$6.023 * 10^{23}$ particles.** Whenever we have Avogadro's number of particles in a sample we have one mole. This number is almost unimaginable.
    - **Avagadro Constant, $N_A = 6.02214199 \times 10^{23}$ mol$^{-1}$**

Examples of Avogadro's Number:

1) Imagine that each particle in a mole was a piece of paper. If we were to stack this paper one sheet on top of another, a mole of paper would stretch from the surface of the earth to the planet Pluto.
2) A mole of pennies, placed side by side would stretch for a million light years.
3) A mole of sand would cover an area approx. the size of Ontario, Manitoba, Saskatchewan, Alberta, British Columbia, the Yukon and NWT to a depth of 2 metres.
4) A mole of blood cells would be more than the total number of blood cells found in every human on earth

## ***Gram molecular weight (Molar Mass)***

- The mass of one mole of an element, expressed in grams is numerically the same as the atomic mass of that element.

- Units for molar mass are g mol$^{-1}$ or g/mol

Example $Ca(NO_3)_2$

| Element | Number of Atoms | Atomic Weight | Total weight |
|---|---|---|---|
| Ca | 1 | 40.08 | 40.08 |
| N | 2 | 14.01 | 28.02 |
| O | 6 | 16.00 | 96.00 |
| Gram Molecular weight (Molar Mass) ; 1 mole = | | | 166.10 g |

- **If the compound is a hydrate (containing water) then the mass of the water molecules is added to the weight of the other atoms.**

***Calculation with the Mole***

The mole has three values that can be used to do calculations with the mole. They are:

- a mass = the gram molecular weight or molar mass
- a volume of one mole in the gas state at $0^oC$ (*273.15 K, 32 ºF)* and 100 kPa.(called standard temperature and pressure STP ) = 22.4 L
- Likewise, 1 mole of a gas at SATP (standard ambient temperature and pressure, or $25^o$ C and 100 kPa is 24.8 L or $24.8 dm^3$.
- a # of particles = $6.023 \times 10^{23}$ (note – this could be particles or molecules depending on question)

This means that 9 separate calculations can be done with the mole. Ratios and proportions are an excellent way to set up equations for mole calculations.

Example #1: If 0.140 mol of acetylene gas has a mass of 3.64g, what is the molar mass of acetylene? (1 step calculation).

Example #2: Calculate the *mass in grams* of **35 moles of $CaCO_3$** (1 step calculation).

Example #3: Calculate the # of molecules in 820 L of $SO_2$ (g) given off by a chemical plant at SATP (2 step question)

***Percentage Composition***

- This refers to the number of parts per hundred of each element in a compound.
- Percentage composition can be determined in one of two ways:

1) If the correct chemical formula for the compound is known, then the percentage of each element is equal to the weight of that element divided by the total weigh of the compound. Example: What is the percentage composition of calcium chloride, $CaCl_2$?

2) The percentage composition can also be determined from laboratory data. If the weight of each element present in a compound can be determined, then the percentage of each is equal to the weight of the element present in the compound divided by the total weight of the compound.
Example: A sample of an unknown gas is found to consist of 10.48g of nitrogen and 11.96g of oxygen. What is the percentage composition of this gas?

1.5 Assignment

1) *Calculate the gram molecular weight (molar mass) of the following compounds.*

| Formula | Molar Mass |
|---|---|
| $K_3PO_4$ | |
| $(NH_4)_2SO_4$ | |
| $CuCO_3$ | |
| $Na_3PO_4 * 10\ H_2O$ | |

| | |
|---|---|
| $CO_2$ | |
| $Pb(CH_3COO)_2$ | |
| $MnO_2$ | |
| $Al(OH)_3$ | |

2) Mole Calculations using a periodic table
   a. Calculate the mass of 65 L of carbon dioxide ($CO_2$) at STP.

   b. Calculate the volume of 78 g of tetraphosphorus hexaoxide ( $P_4O_6$ ) at STP.

c. Calculate the volume of 47 moles of nitrogen dioxide ( $NO_2$ ) gas at SATP.

d. Calculate the number of particles in 120 grams of sodium nitrate.

e. Calculate the # of molecules in 89 L of CO gas at SATP.

f. Calculate the mass of $1.35 \times 10^{24}$ molecules of sulfur trioxide gas at STP.

g. Calculate the volume of 63 moles of dinitrogen tetraoxide at STP.

3) *Find the percentage composition of each compound listed below:*
   a. Zinc carbonate

   b. $SrCl_2$

   c. Barium hydroxide

4) A compound consisting of carbon, hydrogen, and oxygen weighs 40.85g. Analysis shows that the compound contains 10.90g of carbon and 0.90g of hydrogen. What is the percentage composition of the compound?

5) Challenge: Potassium-40 is one of the few naturally occurring radioactive isotopes of elements of low atomic number. Its percent natural abundance among K isotopes is 0.012%. How many $^{40}K$ atoms do you ingest by drinking one cup of whole milk containing 371 mg of K?