



## 9<sup>th</sup> – Atoms & Molecules II

The **empirical formula** of a compound gives the simplest whole-number ratio of the atoms of the elements present in a molecule of the compound. For example, the empirical formula of benzene (C<sub>6</sub>H<sub>6</sub>) is CH, while that of hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>) is HO. The empirical formula does not represent the actual formula of the compound

**Molecular or chemical**

molecular formula =  $n \times$  empirical formula,  
where  $n = 1, 2, 3, \dots$ , etc.

**formula:** A molecular formula is a representation of a chemical compound using a set of symbols for the atoms of elements present in a molecule of the compound, and shows the actual number of atoms of each element of the compound. In some cases, empirical and molecular formulas are same, e.g., methane (CH<sub>4</sub>), boron trichloride (BCl<sub>3</sub>), etc.

**Molecular mass:** The molecular mass of a substance is the sum of the atomic masses of all the atoms in a molecule of the substance. It is therefore, the relative mass of a molecule expressed in atomic mass units (u). E.g. the relative molecular mass of water H<sub>2</sub>O is 18 u, which can be calculated as

atomic mass of hydrogen = 1 u                      atomic mass of oxygen = 16 u

Molecular mass of water is =  $2 \times 1 + 1 \times 16 = 18$  u

Q: Determine the molecular mass of sulphuric acid, ammonia, Sulphur dioxide, phosphorus molecule, hydrogen molecule.

**Gram Molecular Mass:** the molecular mass of a substance expressed in grams is called the gram molecular mass of the substance. To find the gram molecular mass or molar mass we keep the numerical value same but change the units from 'u' to 'g'.

**Formula Unit Mass:** The simplest combination of ions that produces an electrically neutral unit is called a formula unit of the ionic compound e.g. formula unit for sodium chloride is NaCl. Formula unit for ammonium sulphate is (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub>. The formula unit mass of a substance is the sum of the atomic masses of all atoms in a formula unit of a compound. We use the term 'formula unit' for those substances, which have their constituent particles as ions. Similarly, we use 'molecular mass' for atoms

**Mole Concept:** Wilhelm Ostwald introduced the term 'mole' in 1896, which was accepted as unit to represent a large quantity of atoms in 1967. The mole is the amount of a substance which contains as many particles (atoms, ions, molecules, formula unit etc.) as in 12gm of C-12. Thus, one mole of any species is that quantity in number having a mass equal to its atomic or molecular mass in grams.

The number of particles present in 1 mole of any substance is same and fixed which is equal to  $6.022 \times 10^{23}$ . This is a constant, known as Avogadro constant or Avogadro number (N<sub>A</sub>) named in the honour of Italian scientist Amedeo Avogadro. Thus, mole is also defined as number of particles equal to the Avogadro constant.

**1 mole =  $6.022 \times 10^{23}$  particles.**

Derivation: We know that mass of 1 atom is measured in terms of united mass (u)

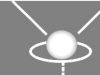
$1u = 1.6605 \times 10^{-24}$  g. So, 1g of the element contains  $\frac{1}{1.6605 \times 10^{-24}}$  atoms of the element. It comes out to be approximately  $6.0223 \times 10^{23}$ .

**Molar Mass and Moles:** Molar mass is defined as mass of a given substance divided by number of moles. Its SI unit is gm/mole.

|                                  |   |           |   |                     |
|----------------------------------|---|-----------|---|---------------------|
| Number of Particles(N)           | = | MOLES (n) | = | Weight(gm)          |
| Avogadro Number(N <sub>A</sub> ) |   |           |   | Molar Mass(gm/mole) |

### NUMERICALS





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1. Calculate the number of moles in 5.75 g of sodium. (Atomic mass of sodium=23.) (0.25mol)
2. How many grams of each of the following elements must be taken to get 1 mol of the element? a) Sodium b) chlorine c) copper (3gm, 35.5gm, 63.5gm)
3. What is the mass in grams of a single atom of chlorine? (atomic mass of chlorine=35.5) (5.9 X 10<sup>-23</sup>g)
4. The density of liquid mercury is 13.6g cm<sup>-3</sup>. How many moles of mercury are there in 1 litre of the metal? (Atomic mass of Hg=200.) (68mol)
5. The mass of a single atom of an element M is 3.15x10<sup>-23</sup>g. What is its atomic mass? What could the element be? (18.97, F)
6. An atom of neon has a mass of 3.35 x 10<sup>-23</sup>g. How many atoms of neon are there in 20g of the gas? (5.97 X 10<sup>23</sup>)
7. How many atoms are there in 100 amu of helium, if atomic mass of helium is 4 amu? (25)
8. How many grams of sodium will have the same number of atoms as 6 g of magnesium? (Na=23, Mg=24) (5.75gm)
9. If C-12 is used as a standard, the relative mass of an atom of sodium is 23 and the relative mass of an atom of phosphorus is 31. Find the relative masses of samples of sodium and phosphorus with respect to each other when each contains 3.0 x 10<sup>25</sup> atoms. (23/31)
10. Find the mass in grams of 2.42 mol of zinc. (158.29gm)
11. How many atoms of copper are present in 0.35 mol of pure copper metal? (2.1 X 10<sup>23</sup>)
12. How many moles of Cr are there in 85g of Cr<sub>2</sub>S<sub>3</sub>? (Cr=52, S=32) (0.85)
13. What is the mass of 5 mol of ammonia? (85g)
14. What mass in grams is represented by: (a) 0.40 mol of CO<sub>2</sub>, (b) 3.00 mol of NH<sub>3</sub> (c) 5.14 MOL OF H<sub>5</sub>IO<sub>6</sub>? (C=12, O=16, N=14, H=, I=127) (17.6, 51, 1171.92)
15. Calculate the volume in litres of 20 g of hydrogen gas at STP. (224 litre)
16. The molecular mass of H<sub>2</sub>SO<sub>4</sub> is 98 amu. Calculate the number of moles of each element in 294 g of H<sub>2</sub>SO<sub>4</sub>. (H=6,S=6,O=12)
17. Find the mass of oxygen contained in 1 kg of potassium nitrate (KNO<sub>3</sub>). (475.2g)
18. You are asked by your teacher to buy 10 mol of distilled water from a shop where small bottles each containing 20g of such water are available. How many bottles will you buy? (9)
19. Determine the mass of the following:
 

|                                    |                          |                  |
|------------------------------------|--------------------------|------------------|
| (a) 0.7 Mole of O <sub>2</sub> gas | (b) 0.7 Mole of O atoms. | (22.4gm, 11.2gm) |
|------------------------------------|--------------------------|------------------|
20. Determine the mass of the following:
 

|  |              |
|--|--------------|
| a) 6.022x10 <sup>23</sup> number of O <sub>2</sub>     | (32gm, 16gm) |
| b) molecules 6.022x10 <sup>23</sup> number of O atoms. |              |

**Percentage Composition:**

The percentage composition of elements in a compound is calculated from the molecular formula of the compound. The molecular mass of a compound is calculated from the atomic masses of various elements.

Percentage mass of the element =  $\frac{\text{Total mass of element}}{\text{Molecular mass}} \times 100$

1. What is the percentage of calcium in calcium carbonate (CaCO<sub>3</sub>)? (40%)
2. What is the percentage of sulphur in sulphuric acid H<sub>2</sub>SO<sub>4</sub>? (32.65%)
3. What are the percentage compositions of hydrogen and oxygen in water (H<sub>2</sub>O)? (H=1, O=16) (11.1%, 88.9%)

