ATOMS AND MOLECULES

Laws of Chemical Combination:

The Law of conservation of mass: This law states that, the total mass of reactants is equal to the total mass of products. In any chemical reaction, the total mass of the substance before and after the reaction is the same although its matter undergoes a physical change.

Law of Definite Proportions: According to law of definite proportions, in a chemical substance, the elements are always present in definite proportions by mass.

Law of Multiple Proportions: When two elements combine to form different compounds, then the weight of one is constant and the other has a simple ratio.

Atom: After a series of experiments Dalton concluded that all matter must be composed of tiny particles, which cannot be further divided. He called them atoms.
Definition of an atom: The smallest particle of an element is called an atom.

Dalton's Postulates:

- Matter is made of atoms.
- Atoms are indivisible and indestructible.
- Atoms of a given element are identical in mass and in properties.
- Compounds are formed by a combination of two or more different kinds of atoms and. A chemical reaction is a rearrangement of atoms.
- Atoms of different elements have different masses and chemical properties.

Draw backs of Dalton's atomic theory:

- According modern atomic theory atoms are divisible and are composed of particles. The three main sub-atomic particles are proton, neutron and electron.
- The assumption, atoms of a given element are identical in mass and in properties not applicable for isotopes of an element.

Examples: Chlorine has 2 isotopes having mass numbers 35 and 37.

Elements and symbols: Dalton proposed a scheme of notation to represent elements
Dalton's Symbols of Elements

The symbols used today were suggested by Berzelius.

Berzelius - Symbols of Elements: Berzelius Suggested to abbreviate the names of the elements using one or two letters.

The first letter of the symbol is always in upper case. Some elements were represented by the starting alphabet of its name. For instance,

Carbon is represented as C

Boron as B

Oxygen as O

Sulphur as S

Nitrogen is written as N and

Hydrogen as H

Symbols of some elements were the first two alphabets, where the second alphabet is in the lower case.

Examples: Aluminium is represented as Al

Chlorine as Cl.

An element is represented by either the first or the first and any other letter of its Latin name. There are some exceptions while writing the symbols for some of the elements. These names were derived from Latin. In general, the first letter and the second letter of their Latin names are used to represent the symbols of these elements.

Examples:

Element	Symbol	Latin Name	Element	Symbol	Latin Name
Antimony	Sb	Stibium	Mercury	Hg	Hydragyrum
Copper	Cu	Cuprum	Potassium	K	Kalium
Gold	Au	Aurum	Silver	Ag	Argentum
Iron	Fe	Ferrum	Sodium	Na	Natrium
Lead	Pb	Plumbum	Tin	Sn	Stannum

Atomic mass:

Atomic mass is the mass of an atom.

The relative atomic mass of an atom of an element is the number of times an atom of that element is heavier than $1/12^{th}$ of the mass of a carbon-12 atom.

Molecule: A molecule is the smallest particle of an element or compound that can exist independently.

Examples:

H_2O, O_2, O_3 etc.

Single Hydrogen is not a molecule. When this hydrogen bonds to other hydrogen (H_2) or to other elements like oxygen (H_2O), a molecule is formed.

Atomicity: The number of atoms constituting a molecule is referred to as atomicity.
A molecule which contains only one atom is called monatomic
Example: Noble gases like Helium (He), Neon (Ne), Argon (Ar) etc.

A molecule which contains two atoms is called diatomic
Example: Hydrogen (H_2), Chlorine (Cl_2), Nitrogen (N_2) etc.

A molecule which contains three atoms is called triatomic.
Example: O_3, H_2O.

A molecule which contains four atoms is called teraatomic.
Example: Phosphorus (P_4).

A molecule which contains more atoms is called polyatomic.
Example: Sulphur (S_8).

Compound: Elements combine to form compounds. Thus a molecule of a compound has two or more elements.
Example: Water (H_2O), Glucose ($C_6H_{12}O_6$), Calcium oxide (CaO), Sodium chloride (NaCl) etc.

Differences between a molecule and a compound: A molecule is formed when two or more atoms bonded chemically. A compound is formed when different elements bonded chemically. Thus a molecule of a compound has two or more elements.
All compounds are molecules but all molecules are not compounds.
Example: Molecular hydrogen (H_2) is a molecule but not compound. Hydrogen molecule is made up of two atoms of hydrogen. Water is a compound. Water is made up of two atoms of oxygen and one atom of oxygen these atoms combined to form a compound known as water. Smallest particle of water is called a molecule.

Common salt is a compound of sodium and chlorine, where sodium is a positively charged particle and chlorine a negatively charged particle, and each of this is called an ion.

Ion:
An ion is a charged particle.

Cation:
A positively charged particle in a molecule is called cation.
Example: Na^+, Ca^{+2}.

Anion:
An anion is a negatively charged particle in a molecule.
Example: F^-, Cl^-.

Differences between Cation & Anion:

Cation	Anion
• Cation is a positively charged particle • Cation is formed from Metals • During electrolysis cation moves towards cathode • The size of cation is smaller than its parent atom Example: Na^+, K^+.	• An anion is a negatively charged particle • Anion is formed by Non-metals • During electrolysis anion moves towards anode • The size of anion is larger than its parent atom. Example: Cl^-, Br^-.

Valency: The combining capacity of an element is known as valency.
The combining capacity of the atoms to form molecules either with same or different elements is defined as valency.

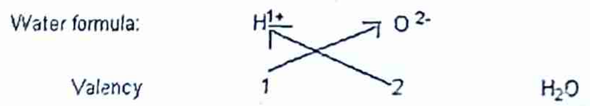
Atom contains less than four electrons in its outermost shell; the valency of an atom is equal to the number of electrons present in the valence shell.
Examples:
Sodium has one electron in its outermost shell, so the valency of sodium is 1.
Calcium has two electrons in its outermost shell, so the valency of calcium is 2.
Aluminum has three electrons in its outermost shell, so the valency of aluminum is 3.

If the outer shell has more than four electrons, the valency = 8 - the number of electrons in the outer shell.
Question: Find the valency of chlorine?
Solution: The atomic number of chlorine is 17
Electronic configuration of Chlorine = 2 8 7
Valency = 8 - 7 =1
Valency of chlorine is 1

Formula of simple compounds:
Steps for writing the formula of simple compound like H_2O is:

- Write the symbols of the constituent elements.
- Write the valencies of each element below its symbol.
- Criss cross the valencies of the constituent elements and place as the subscripts to get the desired formula.

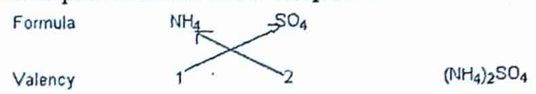
Example : Water



Steps for writing the formulae of simple/complex ionic compounds like Na_2O and $(NH_4)_2(SO_4)_2$ are:-

- Identify the cation and the anion. Write the symbols of the ions along with the charges on them. Always the cation is followed by the anion.
- Cross multiply the valency of ions.
- For poly-atomic ions place the sub script after enclosing the ion in the brackets. In the final formula, the charges on the ions are not indicated.

Example: Ammonium sulphate



Mole: Mole is the measurement in chemistry. It is used to express the amount of a chemical substance.

One mole is defined as the amount of substance of a system which contains as many entities like, atoms, molecules and ions as there are atoms in 12 grams of carbon - 12".

Avogadro number: The number of the particles present in one mole of any substance is equal to 6.022×10^{23}. This is called avogadro's number or avogadro's constant.

Number of particles in 1 mole:

1 mole of hydrogen atoms represents 6.022×10^{23} hydrogen atoms.

1 mole of hydrogen molecules represents 6.022×10^{23} hydrogen molecules.

1 mole of water molecules represents 6.022×10^{23} water molecules.

Atomic mass: The atomic mass of an element is the mass of one atom of that element in atomic mass units or (u).

Atomic mass unit (amu): $1/12^{th}$ of the mass of an atom of carbon-12 is called atomic mass unit. It is a unit of mass used to express atomic masses and molecular masses.

Molar mass: The molar mass of an element is equal to the numerical value of the atomic mass. However, in case of molar mass, the units change from 'u' to 'g'. The molar mass of an atom is also known as gram atomic mass.

For example, the atomic mass of carbon =12 atomic mass units. So, the gram atomic mass of carbon = 12 grams.

Molecular mass of the molecule: The sum of the atomic masses of all the atoms in a molecule of a substance is called the molecular mass of the molecule.

Molecular mass - calculation: Generally we use relative atomic masses of atoms for calculating the molecular mass of 1 mole of any molecular or ionic substances.

Example: Molecular mass of H_2SO_4

Atomic mass of Hydrogen = 1

Atomic mass of sulphur = 32

Atomic mass of oxygen = 16

Molecular mass of H_2SO4 = 2(Atomic mass of Hydrogen) + 1 (Atomic mass of sulphur) + 4 (Atomic mass of oxygen)

= 2×1 + 32 + 4× 16 = 98 u.

Calculation of molecular mass of hydrogen chloride:

Atomic mass of hydrogen + Atomic mass of chlorine = 1 + 35.5 = 36.5 u.

Formula unit mass: The formula unit mass of a substance is the sum of the atomic masses of all atoms in a formula unit of a compound. The term 'formula unit' is used for those substances which are made up of ions.

Formula unit mass of NaCl: 1 X Atomic mass of Na + 1 X Atomic mass of Cl

1x23 +1 x 35.5 = 58.5 atomic mass units.

Formula unit mass of ZnO:

= 1 X Atomic mass of Zn + 1 X Atomic mass O

= 1 X 65 + 1 X 16 = 81 u.

Avogadro's number, number of particles and moles - conversion formulae:

Number of moles (n) = Given number of particles (N) / Avogadro number (N_0)

Example: Find the number of moles present in 24.088×10^{23} particles of carbon dioxide

1 mole of carbon dioxide contains 6.022×10^{23}

Solution: The number of moles (n) = Given number of particles (N) / Avogadro number (N_0).

= $24.088 \times 10^{23} / 6.022 \times 10^{23}$

= 4 moles.

Number of atoms (n) = Given mass (m) / Molar mass (M) x Avogadro number (N_0)

Example: Calculate the number of atoms in 48g of Mg

Solution: Number of atoms (n) = Given mass (m) / Molar mass (M) x Avogadro number (N_0).

= $48/24 \times 6.022 \times 10^{23}$

= 12.04×10^{23} atoms.

Number of molecules (n) = Given mass (m) / Molar mass (M) x Avogadro number (N_0)

Example: Calculate the number of molecules in 3.6 g of water

Solution: The molecular weight of H_2O = 18

18g of water - 6.022×10^{23} molecules

3.6g of water - 6.022×10^{23} X 3.6/18

= 1.206×10^{22} molecules.

Number of particles (n) = Number of moles of particles (n) x Avogadro number (N_0)

Example: Calculate the number of atoms in 0.5 moles of carbon

Solution: Number of atoms = 0.5 X 6.022×10^{23}

= 3.0115 atoms