Laws of Chemical Combination

Chemical Reactions

- In a chemical reaction, two or more molecules interact to produce new compounds and are called reactants, whereas the newly formed compounds are called products.
- In a chemical reaction, a chemical change must occur, which is generally observed with physical changes like precipitation, heat production, colour change, etc.

A number of Laws are proposed by the experimental studies.

The laws of chemical combination are: -

- The law of conservation of mass.
- The law of constant proportion.
- The law of multiple proportion.

Law of conservation of mass

- According to the law of conservation of mass, matter can neither be created nor destroyed in a chemical reaction. It remains conserved.
- Mass of reactants will be equal to the mass of products.
- It was proposed by Antoine Lavoisier in the year 1774.
- This law can be verified experimentally by the reaction between Barium Chloride and Sodium Sulphate.
- In a chemical reaction if , 4g OF Sodium Sulphate reacts with 10 g OF Barium Chloride,

results in the formation of 11.5g of Barium sulphate aliong with 2.5 g of Sodium chloride

- The above reaction satisfies the law of conservation of mass.
- The chemical reaction can be written as follows :-
- Na_2SO_4+ $BaCl_2$----------→ $BaSO_4$ + 2NaCl

  4g 10g 11.5g 2.5g

  Mass of Reactant- 4g + 10g=14g

  Mass of Product-11.5g + 2.5g =14g

  Hence , Mass of Reactant = Mass of Product

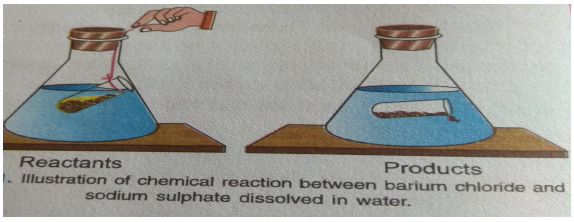
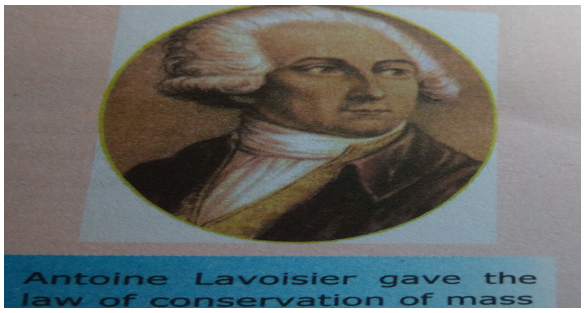
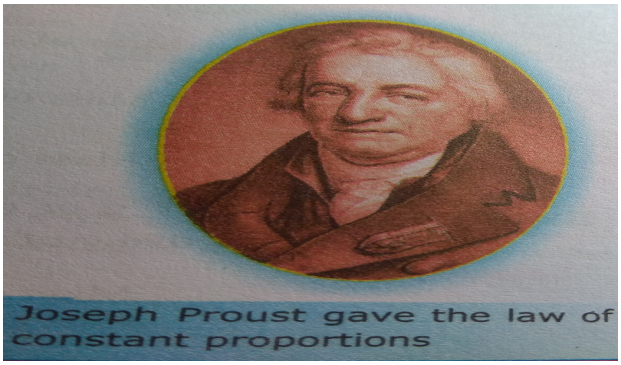


Illustration of chemical reaction between barium chloride and sodium sulphate dissolved in water.



Law of constant proportions

- A pure chemical compound contains the same elements combined together in a fixed proportion by mass is given by the law of definite proportions.
- For e.g., If we take water from a river or from an ocean, both have oxygen and hydrogen in the same proportion.
- It was proposed by the Chemist Joseph Proust in the year 1779.
- For Example, Carbon dioxide can be produced by various ways but the ratio between mass of carbon and oxygen remains fixed always.
- Ratio by mass in CO_2= 12:32 OR 3: 8



Atoms

An atom is the defining structure of an element, which cannot be broken by any chemical means.
The atomic symbol has three parts: -

- The symbol X: the usual element symbol
- The atomic number A: equal to the number of protons
- The mass number Z: equal to the total number of protons and neutrons in an element.

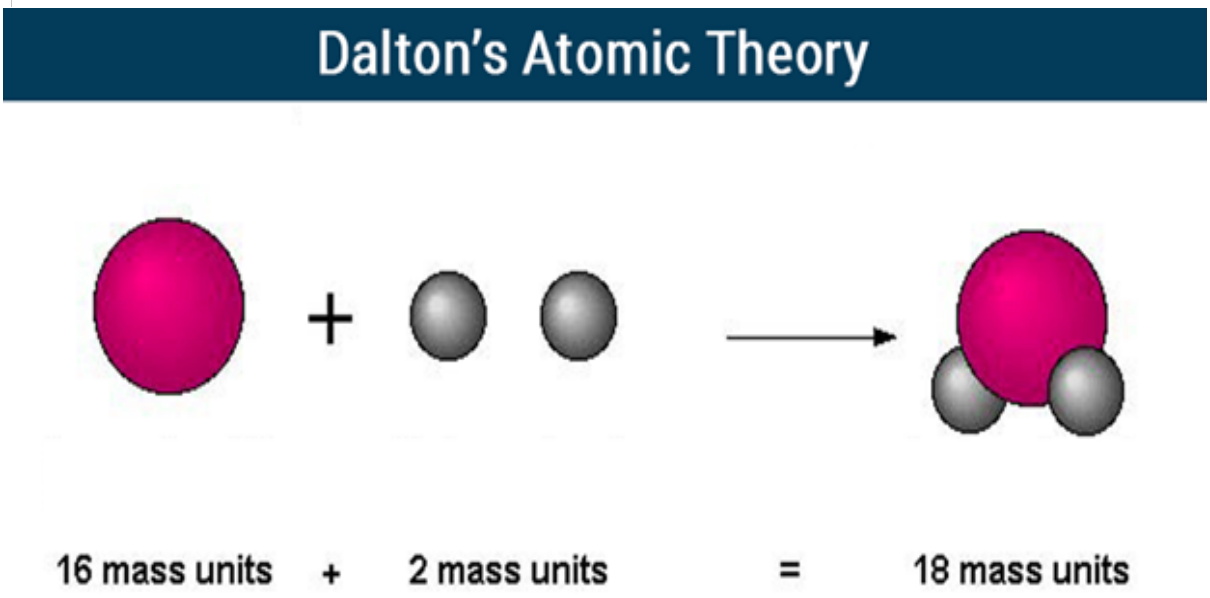
Dalton's Atomic Theory

1. The matter is made up of indivisible particles known as atoms.
2. The properties of all the atoms of a given element are the same, including mass. This can also be stated as all the atoms of an element have identical mass and chemical properties; atoms of different elements have different masses and chemical properties.
3. Atoms of different elements combine in fixed ratios to form compounds.
4. Atoms are neither created nor destroyed. The formation of new products (compounds) results from the rearrangement of existing atoms (reactants) in a chemical reaction.
5. The relative number and kinds of atoms are constant in a given compound.

DRAWBACKS OF DALTONS ATOMIC THEORY

- Atoms can be further divided into sub-atomic particles like -Electrons, Protons and Neutrons.
- Atoms of the same elements may have different mass number. The existence of isotopes proves that (6 C^{12} and 6 C^{14})
- Atoms of the different elements may have same mass number. The existence of isobars proves that ($18Ar^{40}$and $20Ca^{40}$)

Atoms of the different elements may not combine always with same whole number ratio to form compounds. Example Sucrose ($C_{12}H_{22}O_{11}$) in the ratio 12:22:11 which is not a whole number.



Valency

- Valence electrons are those electrons which are present in the outermost orbit of the atom.
- The capacity of an atom to lose, gain or share valence electrons in order to complete its octet determines the valency of the atom.
- Examples: - The valency of hydrogen is one
- In hydrogen chloride molecule (HCl) one atom of chlorine combines with one

atom of hydrogen, hence valency of chlorine is 1

Variable Valency

- Some elements show more than one valency or simply variable valency.
- The suffix *ous* is used for the lower valency and the suffix *ic* is used for the higher valency
- For example, IRON (II) is known as Ferrous with valency 2 and IRON (III) is known as Ferric with valency 3.

SYMBOLS

1 - Hydrogen H	21 - Scandium Sc	41 - Niobium Nb
2 - Helium He	22 - Titanium Ti	42 - Molybdenum Mo
3 - Lithium Li	23 - Vanadium V	43 - Technetium Tc
4 - Beryllium Be	24 - Chromium Cr	44 - Ruthenium Ru
5 - Boron B	25 - Manganese Mn	45 - Rhodium Rh
6 - Carbon C	26 - Iron (Ferrum) Fe	46 - Palladium Pd
7 - Nitrogen N	27 - Cobalt Co	47 - Silver (Argentum) Ag
8 - Oxygen O	28 - Nickel Ni	48 - Cadmium Cd
9 - Fluorine F	29 - Copper (Cuprum) Cu	49 - Indium In
10 - Neon Ne	30 - Zinc Zn	50 - Tin (Stannum) Sn
11 - Sodium (Natrium) Na	31 - Gallium Ga	51 - Antimony (Stibium) Sb
12 - Magnesium Mg	32 - Germanium Ge	52 - Tellurium Te
13 - Aluminium (Aluminum) Al	33 - Arsenic As	53 - Iodine I
14 - Silicon Si	34 - Selenium Se	54 - Xenon Xe
15 - Phosphorus P	35 - Bromine Br	55 - Caesium (Cesium) Cs
16 - Sulfur S	36 - Krypton Kr	56 - Barium Ba
17 - Chlorine Cl	37 - Rubidium Rb	57 - Lanthanum La
18 - Argon Ar	38 - Strontium Sr	58 - Cerium Ce
19 - Potassium (Kalium) K	39 - Yttrium Y	59 - Praseodymium Pr
20 - Calcium Ca	40 - Zirconium Zr	60 - Neodymium Nd

Radicals

- A Radical is an atom of an element or a group of atoms of different elements that behaves like a single unit.
- Radicals are of two types: -
- Basic Radical: - They have positive charge and are also called Cations.
- Acid Radical: - They have negative charge and are also called Anions.

POSITIVE RADICALS

Name of Radical	Representation	Valency
Hydrogen	H^+	1
Sodium	Na^+	1
Potassium	K^+	1
Silver	Ag^+	1
Ammonium	NH_4^+	2
Magnesium	Mg^{2+}	2
Calcium	Ca^{2+}	2
Zinc	Zn^{2+}	2
Iron(II)	Fe^{2+}	2
Gold	Au^{2+}	2
Copper(II)	Cu^{2+}	2
Iron(III)	Fe^{3+}	3
Aluminium	Al^{3+}	3
Tin(IV)	Sn^{4+}	4
Platinum(IV)	Pt^{4+}	4

NEGATIVE RADICALS

Name of Radical	Representation	Valency
Chloride	Cl^-	1
Bromide	Br^-	1
Hydroxide	OH^-	1
Acetate	CH_3COO^-	1
Nitrate	NO_3^-	1
Nitrite	NO_2^-	1
Bisulphate	HSO_4^-	1
Bisulphite	HSO_3^-	1
Bicarbonate	HCO_3^-	1
Oxide	O^{2-}	2
Carbonate	CO_3^{2-}	2
Sulphate	SO_4^{2-}	2
Sulphite	SO_3^{2-}	2
Dichromate	$Cr_2O_7^{2-}$	2
Nitrite	N^{3-}	3
Phosphate	PO_4^{3-}	3

Ions

- An ion is defined as an atom or molecule which has gained or lost one or more of its valence electrons, giving it a net positive or negative charge.
- A negatively charged particle is called an anion, and a positively charged particle is called a cation.

ELECTROVALENCY

- The property of an element to lose or gain electrons to form positive or negative ions is known as Electro valency.
- An ion with a positive charge is known as Cation, Example, Calcium (Ca2+), Sodium (Na+) etc.
- An ion with a negative charge is known as Anion, Example, Chlorine (Cl-) and Oxygen (O2-)
- These elements always form Ionic Bond or Electrovalent Bond.
- The number of electrons present in the outermost shell is known as Valence Electrons.

COVALENCY

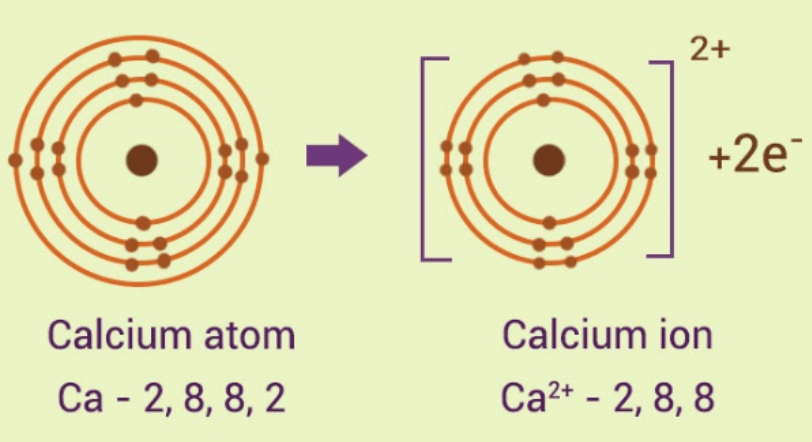
- The property of the element to share electrons to form covalent bond is known as Covalency.
- Covalent Compounds have low Melting point.
- For example, carbon share its four electrons with four hydrogen atoms to forms methane (CH4)

Ionic compounds: chemical formula

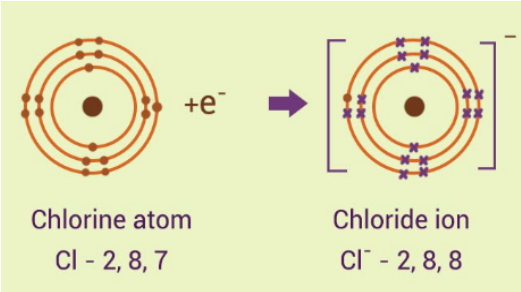
- Ionic compounds are chemical compounds in which ions are held together by specialised bonds called ionic bonds.
- An Ionic compound always contains an equal amount of positive and negative charge.

For example: In Calcium chloride, the ionic bond is formed by oppositely charged calcium and chloride ions.

Calcium atom loses 2 electrons and attains the electronic configuration of the nearest noble gas (Ar). By doing so, it gains a net charge of +2.



- The two Chlorine atoms take one electron each, thus gaining a charge of -1 (each) and attain the electronic configuration of the nearest noble gas (Ar).



Compounds

- When two or more elements chemically combine in a fixed ratio by mass, the obtained product is known as a compound.
- Compounds are substances consisting of two or more different types of elements in a fixed ratio of its atoms.

WRITING A CHEMICAL FORMULA OF A COMPOUND

To write the chemical formula, the following steps must be followed.

1. Write the Symbols
2. Interchange the valence number
3. Write the valency of the symbols.
4. Write the interchanged numbers at the base.
5. Write the formula of the compound

For example, the step wise method for writing the formula of CALCIUM OXIDE is given below

CALCIUM OXIDE

Step 1: Write the symbols and valencies.

Symbols	
Calcium	Oxide
Ca	O

Valencies	
Calcium	Oxide
2^+	2^-

Step 2: Ca^{2+} O^{2-}

Step 3: Ca^{2+} O^{2-}

Step 4: Ca_2O_2

Step 5: Reduce the valency numbers to the lowest ratio, if possible.

$\therefore$ the formula is CaO

Atomic mass and atomic mass unit

- Atomic mass is the total of the masses of the electrons, neutrons, and protons in an atom, or in a group of atoms, the average mass.

- Mass of an atomic particle is called the atomic mass.
- This is commonly expressed as per the international agreement in terms of a unified atomic mass unit (AMU).
- It can be best defined as 1/12 of the mass of a carbon-12 atom in its ground state.

Molecular mass

Molecular mass of an element is defined as the sum of the masses of the elements present in the molecule.

- Molecular mass is obtained by multiplying the atomic mass of an element with the number of atoms in the molecule and then adding the masses of all the elements in the molecule.
- Molecular mass is the algebraic sum of the masses of all the atoms present in a given molecule.
- Molecular mass of H_2O (water) can be calculated
- (2 X Atomic Mass of Hydrogen) + (1 X Atomic Mass of Oxygen)
- (2X1) + (1X16) = 18 Units
- For example, in sulphuric acid (H_2SO_4), the ratio of hydrogen, Sulphur and oxygen is 2:1:4

MORE EXAMPLES

- For example, molecular mass of ammonia NH_3= (1 X14) + (3 X 1) =17 Unit
- For example, molecular mass of water H_2O = (2 X At. Mass of H) + (1 X At. Mass of Oxygen) = (2 X 1) + (1X 16) =18 Unit
- For example, molecular mass of SO_2= (1X 32) + (2 X 16) =64 Unit (u)
- For example, molecular mass of CO_2 = (1 X 12) + (2 X16) = 44 u

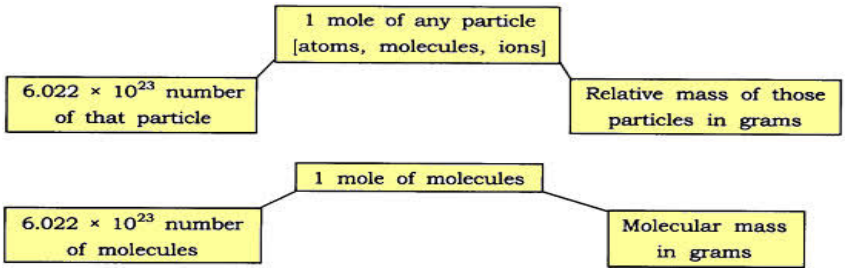
Mole Concept

Mole concept & Avogadro Number

- In a substance, the number of entities present for e.g., atoms, molecules, ions, is defined as a mole. A mole of any substance is 6.022×10^{23} molecules.
- Mole concept is one of the most convenient ways of expressing the number of reactants and product in the reaction.

The value of Avogadro's number is approximately 6.022×10^{23}. The definition of Avogadro's number is that it tells us the number of particles in 1 mole (or mol) of a substance. These particles could be electrons or molecules or atoms.

- A Mole of a substance is defined as the aggregate of 6.022 *X 10 23* number of atoms /molecules/particles or ions.
- The value of 6.022 X 10 23 is known as Avogadro's Constant or Avogadro's Number.
- The different relationship in terms of other quantities with mole is given as follows:



Molar mass

A substance is something which has mass and occupies space. The molar mass/molecular weight is actually the sum of the total mass in grams of the atoms present to make up a molecule per mole. The unit of molar mass is grams/mole.

FORMULA INVOLVING MOLE CONCEPT

- Number of Moles (n) = Mass in grams / Molar Mass

- n = m/M
- Where n= Number of Moles

  m= Mass in grams

  M=Molar Mass / Molecular Mass

Number of Moles (n) = Number of particles / Avogadro's Number.

n= N/NA

Where -

n=Number of Moles

N=Number of particles/ Atoms/Ions

N_A = Avogadro's Number 6.022 X 10 23

Finally, the expression can be given as follows:

m/M = N/ NA