BASIC CONCEPTS OF CHEMISTRY

ATOMS MOLECULES AND MOLE CONCEPTS

Dalton's Atomic Theory

1. Matter is made of extremely small indivisible particles called atoms.
2. Atoms of the same element are identical in all respects i.e. size, shape and and mass.
3. Atoms of different elements have different masses, sizes and different chemical properties.
4. Atoms of the same or different elements combine together to form compound atoms now called as molecules.
5. When atoms combine with one another to form molecules, they do so in simple whole number ratio.
6. An atom is the smallest particle that takes part in a chemical reaction.
7. An atom can neither be created nor destroyed.

MODERN ATOMIC THEORY

1. Atom is no longer considered indivisible.
2. Atoms of the same element may have different atomic weights. e.g. isotopes.
3. Atoms of different elements may have same atomic weights. e.g. isobars.
4. The ratio in which the different atoms combine with one another may be fixed and integral but may not always be simple. e.g. $C_{12}H_{22}O_{11}$
5. Atom is the smallest particle that takes part in a chemical reaction.
6. Atom is no longer indestructible.

BERZELIUS HYPOTHESIS

Berzelius hypothesis: - Equal volumes of all gases under similar conditions of temperature and pressure contain equal number of atoms.

When this hypothesis was applied to some chemical reactions, it was found that even a fraction of atom was involved in some cases. The idea is against the concept of Dalton's atomic theory.

To solve this problem of conflict between the Dalton's atomic theory and Berzelius hypothesis, Avogadro put forward a hypothesis known as ***Avogadro's Law***.

Avogadro's Law

Avogadro's Law - Equal volumes of all gases under similar conditions of temperature and pressure contain equal number of molecules.

In the formation of HCl, it is observed that 1volume of H_2 combines with 1volume of Cl_2 to give 2 volume of HCl.

Hydrogen	+	Chlorine	$\longrightarrow$	Hydrogen chloride
H_2	+	Cl_2		2HCl
1 volume		1 volume		2 volume
n molecules		n molecules		2n molecules
1/2 molecule		1/2 molecule		n molecule

It implies that one molecule of HCl is made up of 1/2 molecule of hydrogen and 1/2 molecule of chlorine. This result does not contradict Dalton's atomic theory.

ATOMS AND MOLECULES

Atom : - The smallest particle of an element which may or may not have independent existence is called an atom.

Hydrogen, oxygen, nitrogen- not independent existence

He,Ne and Ar have independent existence

Molecule: - The smallest particle of a substance(element or compound) which is capable of independent existence is called a molecule.

Homoatomic molecules:- atoms of the same element- H_2, N_2, O_3, P_4, S_8 etc.

Heteroatomic molecules :- atoms of the different elements- H_2O, HCl, CO_2 etc.

ATOMIC MASS

The *atomic mass* of an element is the average relative mass of its atoms as compared to the mass of an atom of carbon(C_{12}) taken as 12.

The atomic masses of elements are determined with an instrument called mass spectrometer.

It is found that atoms of the same element may possess different masses(called isotopes). In such cases, atomic mass of the element is taken as average value. For example, chlorine is a mixture of two isotopes with atomic masses 35 and 37 amu and they are present in the ratio 3:1. Hence the average atomic mass of chlorine would be

$$\frac{35*3+37*1}{3+1}$$

$$=35.5\text{amu}$$

GRAM ATOMIC MASS

The atomic mass of an element expressed in grams is called Gram atomic mass.

This amount of the element is also called **one gram atom**.

e.g. Atomic mass of oxygen = 16 amu

Gram atomic mass of oxygen =16 g

one gram atom of oxygen = 16 g

Molecular mass

Molecular mass :- molecular mass of a substance is the average relative mass of its molecule as compared to the mass of an atom of carbon(C_{12}) taken as 12.

Or molecular mass of a substance is the number of times the molecule of the substance is heavier than 1/12th the mass of of an atom of carbon-12 isotope.

Molecular mass of a substance can be calculated by adding the atomic masses of all the atoms present in one molecule of the substance

e.g. Molecular mass of H_2SO_4

=2*1+ 32 +4*16 =2+32+64 = 98 amu

GRAM MOLECULAR MASS

The molecular mass of a substance expressed in grams is called its gram molecular mass.

The amount of the substance is also called one gram molecule

e.g. Molecular mass of H_2SO_4 = 98amu

FORMULA MASS AND GRAM FORMULA MASS

In ionic compounds like NaCl, the term molecule is replaced by formula unit. Thus for ionic compounds the term molecular mass is replaced by formula mass, because in the solid state, the ionic compound do not exist as a single entity.

The **formula mass** is defined as the sum of the atomic masses of all the atoms present in a formula unit of an ionic compound.

Formula mass of NaCl = 1*at. mass of Na +1*at. Mass of Cl

= 1*23 + 1 * 35.5

= 23 + 35.5=58.5 u

Gram formula mass :- formula mass of an ionic substance expressed in grams is known as gram formula mass.

Formula mass of NaCl = 58.5 u

Gram formula mass of NaCl = 58.5 g

Formula mass of $AgNO_3$ = 170 u

Gram formula mass of $AgNO_3$ = 170 g

MOLE CONCEPT

MOLE CONCEPT AND AVOGADRO'S NUMBER

AVOGADRO'S NUMBER

It is found that one gram atom of any element contains the same number of atoms and one gram molecule of any substance contains the same number of molecules. This number has been experimentally determined an found to be equal to $6.022*10^{23}$. It is called as Avogadro's number.

Avogadro's Number(N) = $6.022*10^{23}$

Avogadro's number may be defined as the number of atoms in one gram atom of the element or the number of molecules in one gram molecule of the substance.

The amount of the substance containing one Avogadro's number of atoms or molecules is called a **MOLE**.

A mole of hydrogen atoms means $6.022*10^{23}$atoms of hydrogen whereas one mole hydrogen molecules means $6.022*10^{23}$ molecules of hydrogen.

What is mole

A mole is defined as that amount of the substance which has mass equal to gram atomic mass if the substance is atomic or gram molecular mass if the substance is molecular.

1 mole of carbon atoms = 12 g

1 mole of sodium atoms = 23 g

1 mole of O_2 atoms = 16 g

1 mole of O_2 molecules = 32 g

1 mole of CO_2 molecules = 44 g

Mole - 2nd definition

A mole is that amount of the substance which contains Avogadro's number of atoms if the substance is atomic or Avogadro's number of molecules if the substance is molecular

1 mole of carbon atoms = $6.022*10^{23}$ atoms of carbon

1 mole of H_2O molecules = $6.022*10^{23}$ molecules of H_2O

Mole -3rd definition

In case of gases a mole is that amount of the gas which has a volume of 22.4 Litres at STP.

1 mole of O2 gas = 22.4 litres of O2 at STP

1 mole of CO2 gas = 22.4 litres of CO2 at STP

A MOLE OF AN IONIC COMPOUND is that amount of the substance which has mass equal to gram formula mass or Avogadro's number of formula units.

1 mole of NaCl = 58.5 g of NaCl = 6.022*1023 formula units of NaCl

NUMERICALS

Ex. 1. Calculate the mass of (i) an atom of silver (ii) a molecule of CO_2.

Solution (i) 1 mole of Ag atoms = 108 g = $6.022*10^{23}$ atoms

$6.022*10^{23}$ atoms of Ag have mass = 108 g

1 atom of Ag have mass = $108/6.022*10^{23} = 17.93*10^{-23}$ g

(ii) 1 mole of CO_2 = 44 g = $6.022*10^{23}$ molecules

$6.022*10^{23}$ molecules of CO_2 have mass = 44 g

1 molecule has mass = $44/6.022*10^{23} = 7.307*10^{-23}$ g

Numerical

Ex. 2. Calculate the number of moles in each of the following:-

(i) 392 g of H_2SO_4 (ii) 44.8litres of CO_2 at STP (iii)$6.022*10^{23}$molecules of O_2 (iv) 9g of Al

solution:- (i) 1 mole of H_2SO_4 = 98 g

thus 98 g of H_2SO_4 = 1 mole of H_2SO_4

392 g of H_2SO_4 = 1/98*398 = 4 moles of H_2SO_4

(ii) 1 mole of CO_2 = 22.4 litres at STP

i.e.22.4 litres of CO_2 at STP = 1 mole

44.8 litres of CO_2 at STP = 1/22.4*44.8 = 2 moles of CO_2

(iii) 1mole of O2 molecules = $6.022*10^{23}$ molecules

6.022*1023 molecules = 1 mole of O2 molecules

(iv) 1 mole of Al = 27 g of Al

27 g of Aluminium = 1 mole of Al

9 g of Al = 1/27*9 = 0.33 mole of Al

EXERCISE

1 Calculate the number of molecules in 22 g of CO2 ?

2. Calculate the mass of CO_2 which contains the same number of molecules as contained in 40 g of O_2

Law of chemical combination deals with some empirical laws, that govern the chemical changes.

LAW OF CONSERVATION OF MASS

LAW OF CONSTANT COMPOSITION/ LAW OF DEFINITE PROPORTION

LAWS OF CHEMICAL COMBINATIONS

LAW OF MULTIPLE PROPORTION

LAW OF RECIPROCAL PROPORTION

LAW OF CONSERVATION OF MASS

- Established by French Chemist LAVOSIER

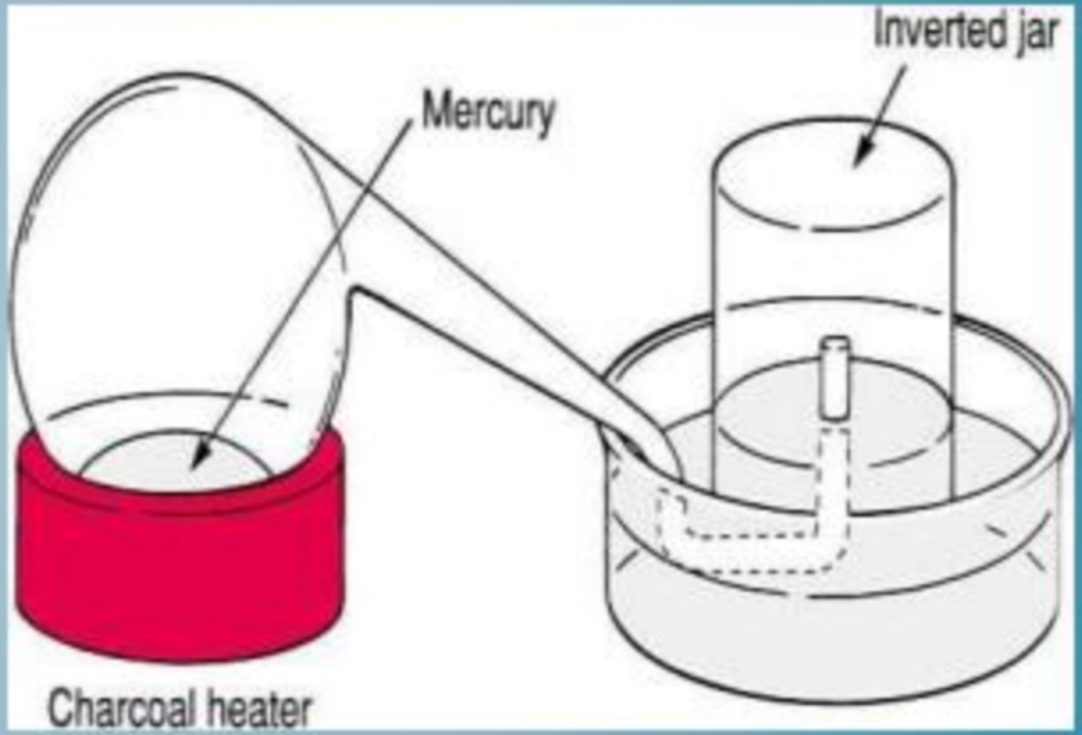
Does mass change during a chemical reaction?

STATEMENT:

“ In any chemical reaction, the initial weight of reacting substances is equal to the final weight of the product.”

EXPERIMENT:

- Lavoisier performed his experiment in a closed system. He found that the total weight of the system is not changed in a chemical reaction. He performed the decomposition reaction of the red oxide of mercury to form metallic mercury and oxygen.



The mass of the reactants (starting materials) equals the mass of the products

$$2Mg\ (s) + O_2\ (g) \rightarrow 2MgO\ (s)$$

48.6 g   32.0 g   80.6 g

For example:

This equation describes Lavoisier's experiment:

$$2HgO \longrightarrow 2Hg + O_2$$

mercury oxide → mercury oxygen

433.2 g   401.2 g 32.0 g

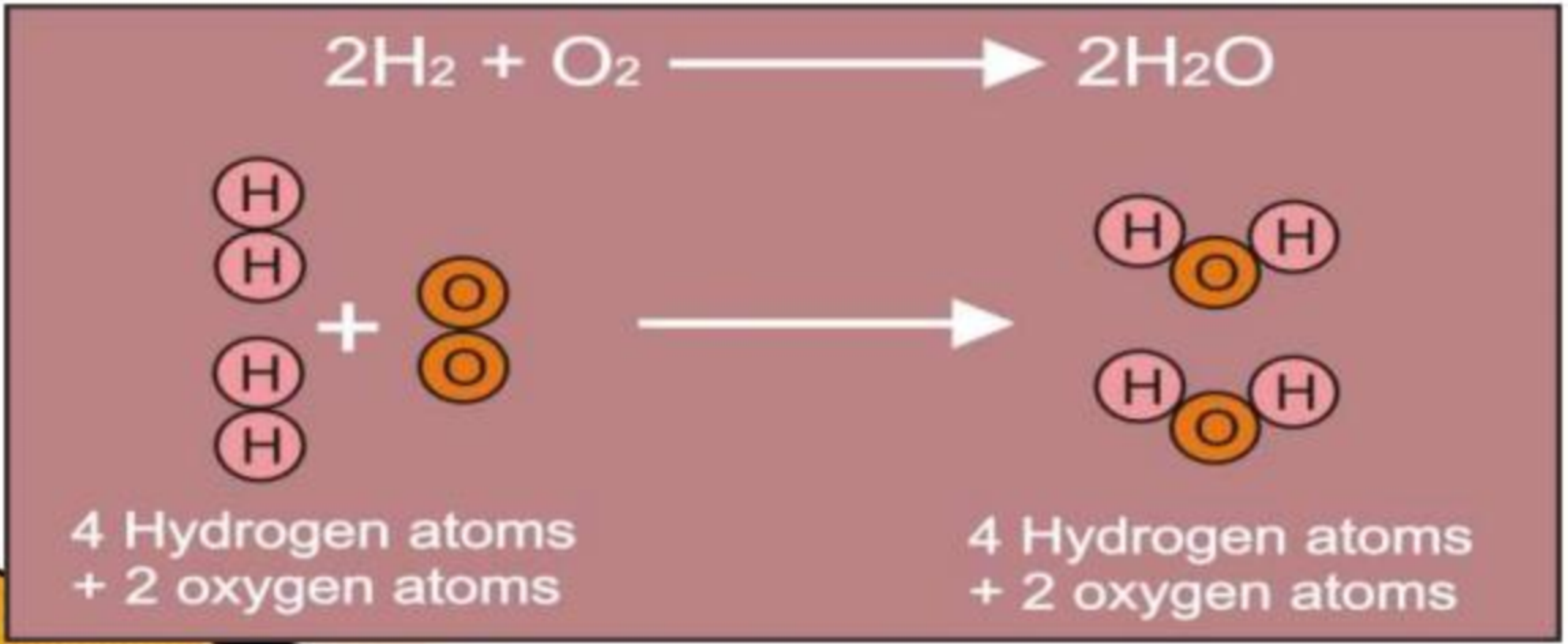
Another example of how mass is conserved:

$$2Na + Cl_2 \longrightarrow 2NaCl$$

sodium chlorine → sodium chloride

46.0 g 70.9 g   116.9 g

- The law of conservation of mass can be demonstrated by the union of hydrogen and oxygen. If the H_2O and O_2 are weighed before they unite, it will be found that there combined weight is equal to the weight of water formed.



- The Law of Conservation of Mass is also called **"The Law of Indestructibility of Matter."**
- The practical verification of this law was given by a German Chemist **H. Landolt.**

- Hence the law of conservation of mass can also be stated as:

"there is no detectable gain or loss of mass in a chemical reaction."


In chemical changes, no matter how big the bang, mass is neither gained nor lost.
CHEMISTRY IS A BLAST
BANG! Chemical Reaction
SAFETY FIRST!
70 kg
70 kg
Before
After

LAW OF CONSTANT COMPOSITION/ LAW OF DEFINITE PROPORTION:

- ESTABLISHED BY LOUIS PROUST

What makes compounds different?

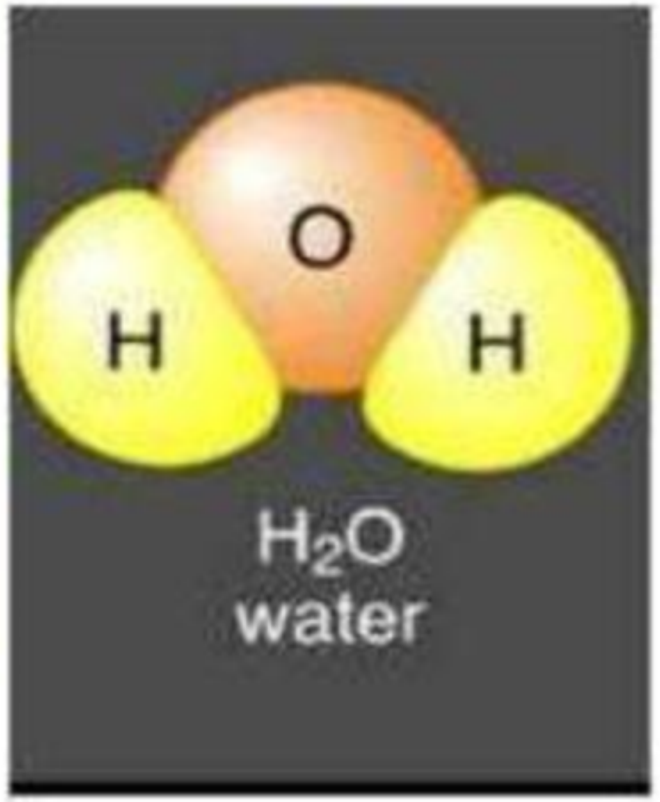
- The law states that:

  “ Different samples of the same compound always contain the same elements combined together in the same proportions by mass.

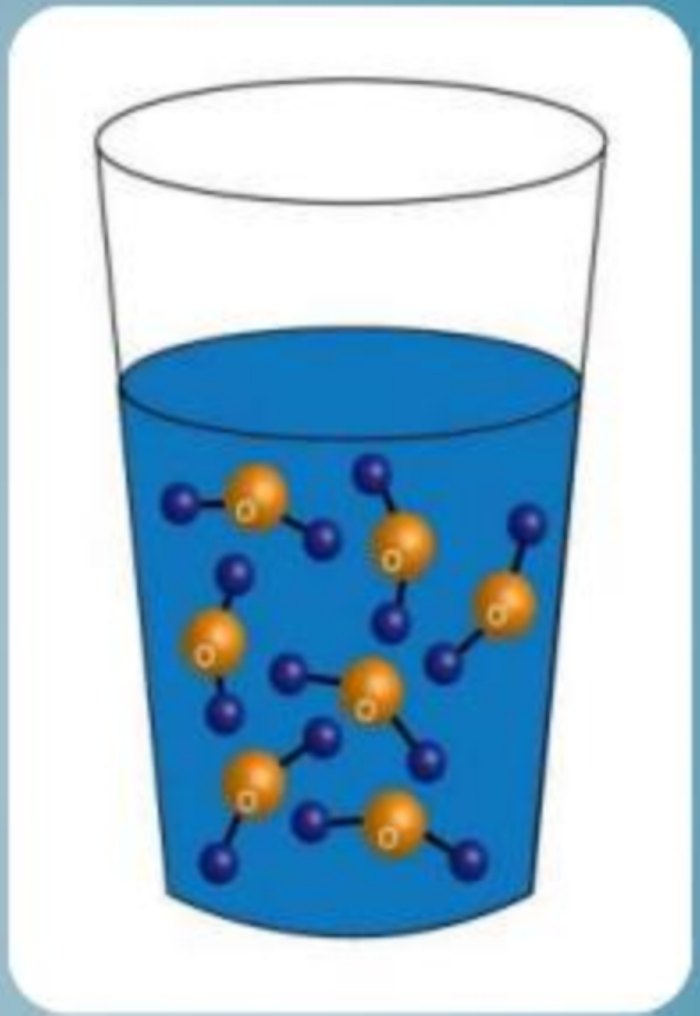
OR,

"A chemical compound contains the same elements in exactly the same proportions (ratios) by mass regardless of the size of the sample or source of the compound."

For example, water always consists of oxygen and hydrogen atoms, and it is always 89 percent oxygen by mass and 11 percent hydrogen by mass.



Every sample of pure water, though prepared in the laboratory or obtained from rain, river or water pump, contains 1 part hydrogen and 8 parts oxygen by mass.



Berzelius Experiment:

Berzelius heated 10g lead (Pb) with various amounts of sulphur (S). But every time he got exactly 11.56g of Lead sulphide, and the excess of sulphur was left over.

This shows the significance of law of constant composition.

LAW OF MULTIPLE PROPORTIONS

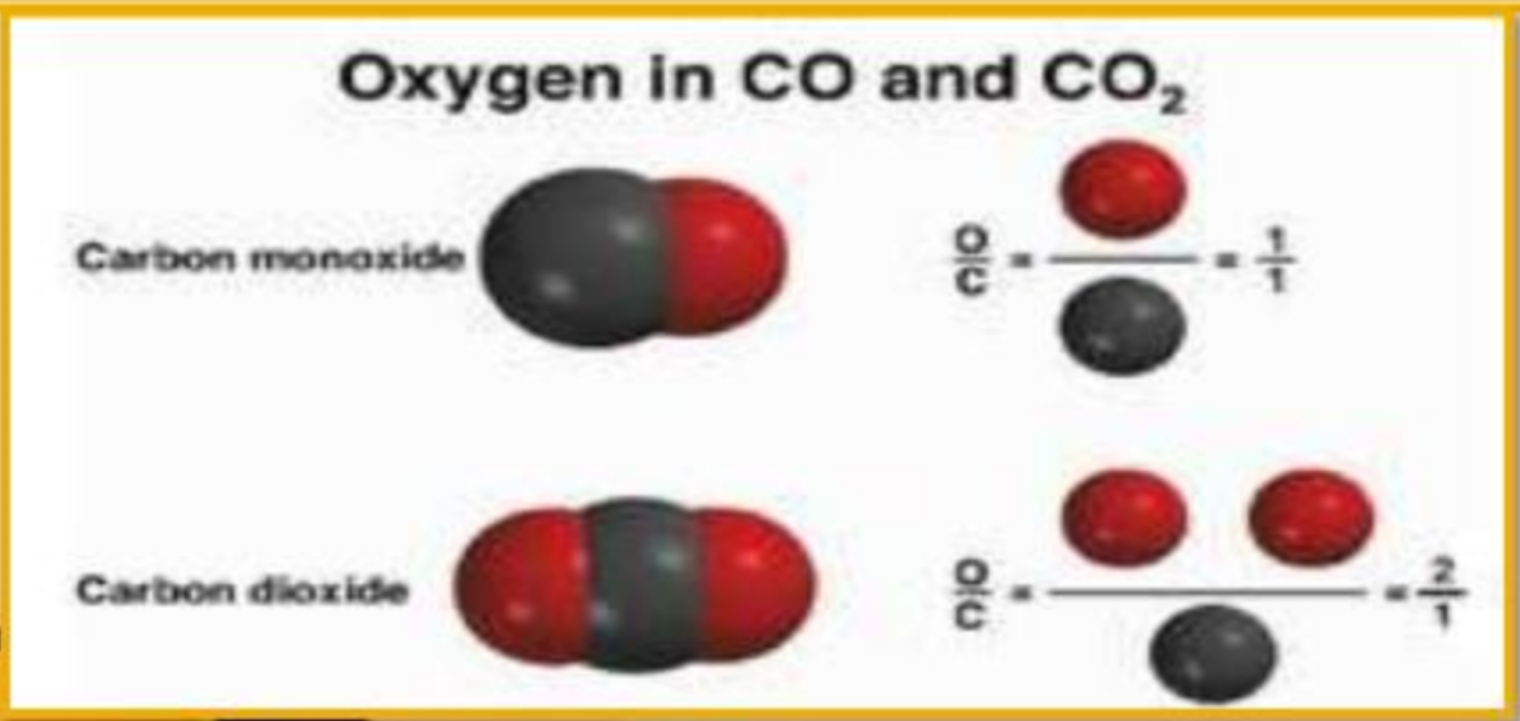
- PUBLISHED BY JOHN DALTON

It states that:

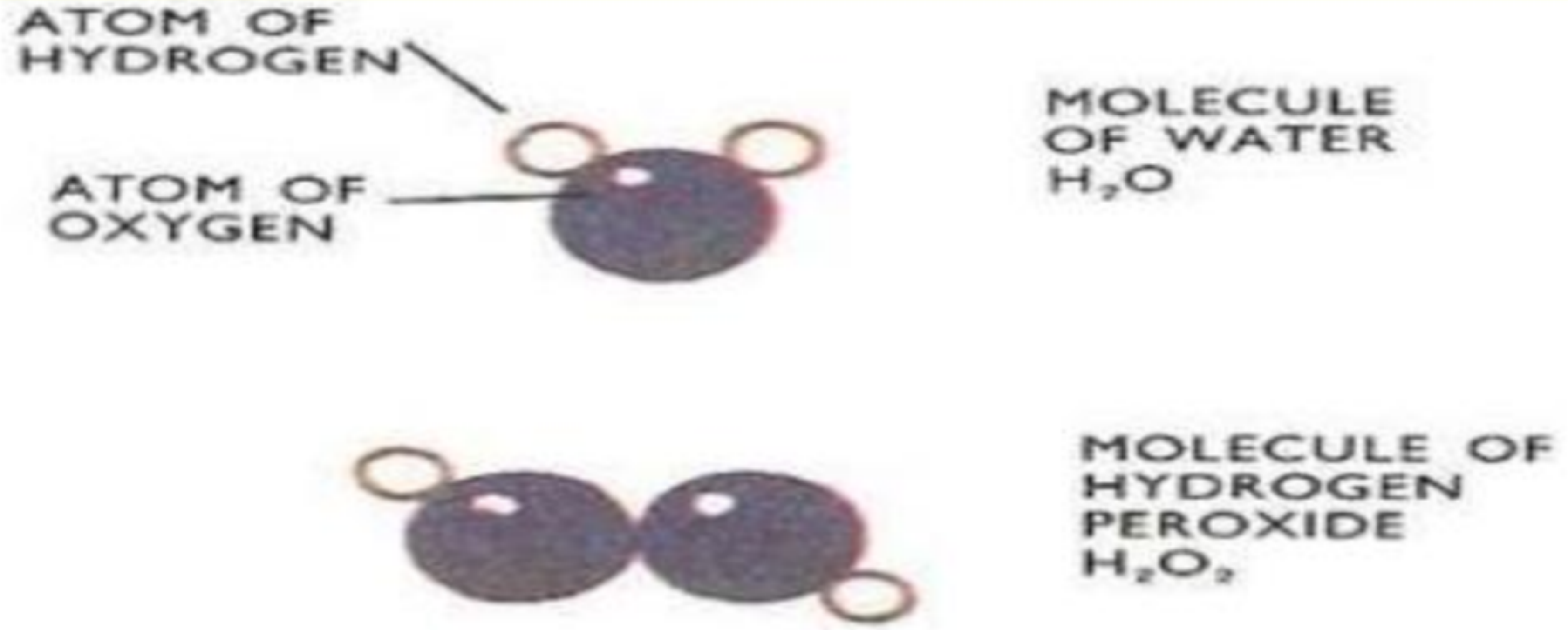
"When two elements combine to form more than one compound, the masses of one element which combine with a fixed mass of the other element are in ratios of small whole numbers or simple multiple ratio."

For Example carbon forms 2 stable compounds with oxygen:

- **Carbon monoxide (CO):** 12 parts by mass of carbon combines with 16 parts by mass of oxygen.
- **Carbon dioxide (CO_2):** 12 parts by mass of carbon combines with 32 parts by mass of oxygen.
- Ratio of the masses of oxygen that combines with a fixed mass of carbon (12 parts) 16: 32 or 1: 2

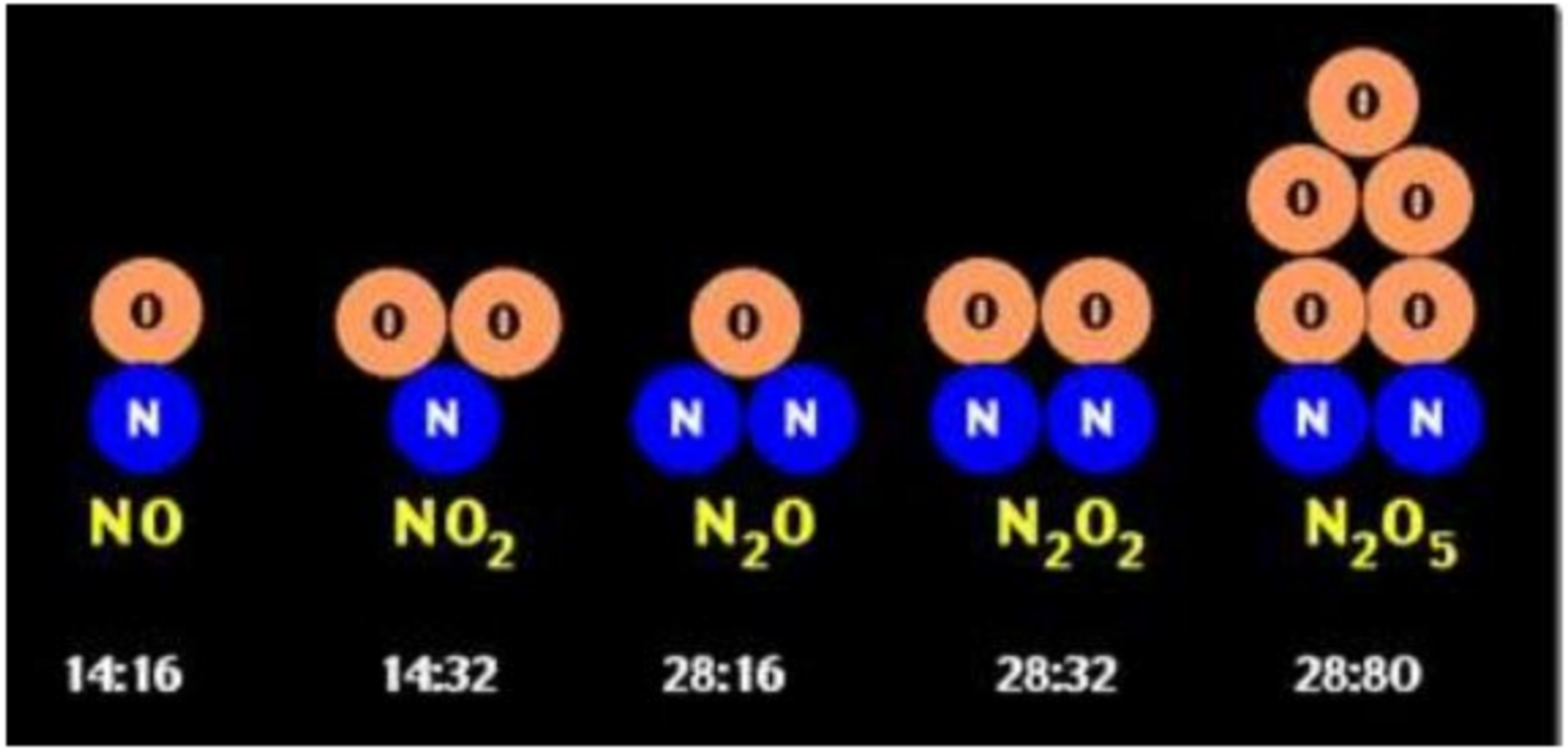


- Another illustration of this law is the formation of **Water** and **Hydrogen Peroxide.**



The ratio of weights of oxygen to combine with 2 grams of hydrogen is 16:32 or more simply 1:2.

The excellent example of law of multiple proportions can be seen when the elements nitrogen and oxygen combine together to form a series of compounds.



LAW OF RECIPROCAL PROPORTIONS

- ESTABLISHED BY RITCHER

The law states that:

"**When two different element separately combine with the fixed mass of third element, the proportion in which they combine with each other shall be either in the same ratio or some simple multiple of it.**

- For example, when two elements C and O combine separately with H, they form CH_4 (methane) and H_2O (water) respectively.
- Now when C and O combine with each other they form CO_2.