Atoms and Molecules

500 B.C maharishi Kanad

matter → Padarth → Parmanu ← Atom

Rice granule → 0 0 0 0

Democritus and Leucippus → Matter & Atoms

Pakudha Katyayama

He states that atoms may not exist in to be free state but may exist in the combined state in the form of molecules.

Oxygen $O_2 \longrightarrow O = O$ ← 2 oxygen atoms

molecule ↑ bond

→ $CO_2 \longrightarrow$ 1 Carbon atom & 2 Oxygen atom.

→ $H_2O \longrightarrow$ 2 Hydrogen atom & 1 oxygen atom.

Atom combine to form molecules → Element (Same atoms) / Compound (diff atoms)

O_2 is an element while CO_2 & H_2O are compounds.

they combine.
Antoine L. Lavoisier laid the foundation of chemical sciences by establishing two important laws of chemical combination.

\ Law of chemical Combination

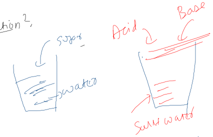
Elements — substances those molecules are made up of only one type of atoms.

Compounds :- Substances whose molecules are made up of more than one type of atoms are called compounds.

- Properties of compound are different from the properties of elements they are made up of.

- The combination takes place via chemical reaction following certain laws called laws of Chemical Combination

Chemical reaction?,



When two or more substances combine to form an entirely different product

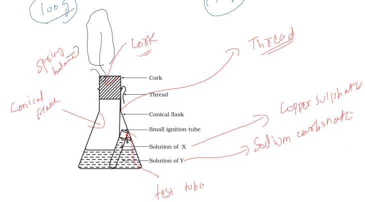
Antoine Lavoisier gave 1st law of chemical combination

Law of conservation of mass

Acid + Base ⟶ Salt water

Reactants — Products

100g — 100g



i) X gm

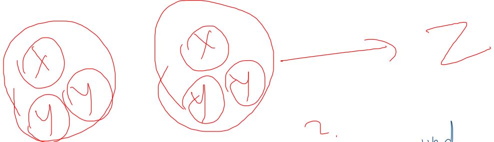
ii) X gm

Copper Sulphate + Sodium Carbonate → Copper Carbonate + Sodium Sulphate

In any chemical reaction, the total mass of reactants is equal to the total mass of the products.

Law of conservation of mass states that mass can neither be created nor destroyed in a chemical reaction.

a) Compound
b) Molecule
c) Element
d) Both a & b



Z - ?
a) compound
b) Molecule
c) Element
d) Both a & b

✓ Mass can created in chemical reaction.

Law of constant proportions

$H_2O \rightarrow$ 2H atoms & 1 oxygen atoms.

2 U   16 U

Mass of H / Mass of O $= 2/16 = 1:8$

9 mL of water → 1 mL of Hydrogen & 8 mL of Oxygen

$C + O_2 \rightarrow CO_2$ → $\frac{\cancel{12}\ 3}{\cancel{32}\ 8}$

Atomic → Oxygen = 8

"In a chemical substance the elements are always present in definite proportions by mass".

(1) When 4.2g of $NaHCO_3$ is added to a solution of HCl weighing 10g, it is observed that 2.2g of CO_2 is released into atmosphere. The residue left behind is found to weigh 12g.

is in agreement of which law: show me

$NaHCO_3 + HCl \longrightarrow CO_2 + NaCl + H_2O$

$4.2 + 10g = 14.2g$

mass of reactants = mass of products.

mass of products = 2.2g + 12g = 14.2g

✓ There is no loss or gain of mass during the reaction.

✓ Hence, the given observations prove the law of conservation of mass.

4) Calculate the mass of carbon present in 4g of CO_2

$CO_2 \rightarrow$ 12 : 32

3 : 8

3 g of carbon combine with 8g of oxygen to form 11g of CO_2

11g of CO_2 ~~contains~~ contains C = 3g

4g of CO_2 contains $= \frac{3}{11} \times 4 = \frac{12}{11}$

= 1.09

Q. $CaCO_3$ contains 40% calcium, 12% carbon and 48% oxygen by mass. Knowing that the law of constant composition holds good, calculate the mass of the constituent elements present in 2g of $CaCO_3$

$CaCO_3$ =

40% 12% 48%

0% of your marks

40

40g Ca + 12g of C + 48g of O = 100g $CaCO_3$

10g Ca + 3g of C + 12g of O = 25g of $CaCO_3$

2g of $CaCO_3$

25g $CaCO_3$ = 10g C

2g $= \frac{10}{25} \times 2 = 0.8g$ Ca

25g $CaCO_3$ = 3g C

2g $CaCO_3 = \frac{3}{25} \times 2 = 0.24g$ of C

25g of $CaCO_3$ = 12g of O

2g of $CaCO_3 = \frac{12}{25} \times 2$ oxygen

= 0.96g

2) What mass of $AgNO_3$ will react with 5.85g of NaCl to produce 14.35g of AgCl & 8.5g of $NaNO_3$, if the law of conservation of mass holds true.

Mass of reactants = Mass of products

$x + 5.85 = 8.5 + 14.35$

3) CuO was prepared by 2 diff methods. In one case, 1.75g of the metal gave 2.19g of oxide. In the 2nd case, 1.14g of the metal gave 1.43g of oxide. Show that given data illustrates law of constant proportions.

$2Cu + O_2 \xrightarrow{500°C} 2CuO$

1.75g of Cu $\longrightarrow$ 2.19g of CuO

1.14g of Cu $\rightarrow$ 1.43g

% of Cu in the oxide $= \frac{1.75}{2.19} \times 100 = 79.9\%$

% of oxygen $= 100 - 79.9 = 20.1\%$

CuO

% of Cu in the oxide $= \frac{1.14}{1.43} \times 100 = 79.\%$

= 20. %

law of constant proportion

Dalton's Atomic Theory

(i) All matter is made of very tiny particles called atoms, which participate in chemical reactions.
(ii) Atoms are indivisible particles, which cannot be created or destroyed in a chemical reaction.
(iii) Atoms of a given element are identical in mass and chemical properties.
(iv) Atoms of different elements have different masses and chemical properties.
(v) Atoms combine in the ratio of small whole numbers to form compounds.
(vi) The relative number and kinds of atoms are constant in a given compound.

cell is the fundamental of life
Atom is the fu... unit of matter

In chemical reaction, arrangement of atoms occured

$H_2 + O \rightarrow H_2O$

$O_2 = O = O$ 16 units 16 units

$HCl \rightarrow H + Cl$

$H_2O \rightarrow 2:1$
$CO_2 \rightarrow 1:2$

$H_2O \rightarrow$ 2H atoms
1 - O atoms

Limitations of Dalton's atomic Theory

i) Atom is no longer considered as the smallest indivisible masses

p^+, e^- & neutrons.
In Nucleus $\rightarrow$ $p^+ + n$
Atomic mass = $p^+ + n$
Atomic No = No of protons

(ii) Atoms of the same element may have different masses.

$^{12}_{6}C$ $^{13}_{6}C$ $^{14}_{6}C$ $\leftarrow$ Isotopes of carbon

(iii) Atoms of the different element may have same masses.

$^{40}_{19}K$ $^{40}_{20}Ca$ Isobars

iv) Substances made up of the same kind of atoms may have different properties

Diamond $\rightarrow$ Hardest, Bad conductor of electricity
Graphite $\rightarrow$ weak, Good conductor of electricity.

What is an Atom?

$\rightarrow$ An atom is defined as the smallest particle of an element which may or may not be capable of free existence.

$\rightarrow$ However, it is the smallest particle that takes part in a chemical reaction.

STM - Scanning Tunelling Microscope.
↳ to see atom.

$\rightarrow$ An atoms are considered to be spherical.

$\rightarrow$ Sizes are expressed in terms of their radii, called atomic radii

radius
distance from Nucleus to outermost shell

$\rightarrow$ Atoms are so small in size that their radii are usually expressed in nanometers (nm).

$1 m = 10^9 nm$, $1 nm = 10^{-9} m$

radii of the atoms are in the order of $10^{-10} m$

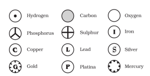


Fig. 3.3: Symbols for some elements as proposed by Dalton

Modern Symbol of Elements

$\rightarrow$ When more & more elements were discovered, international Committee was set up, called International Union of Pure and Applied Chemistry (IUPAC), which approved the names of diff. elements

$\rightarrow$ Name of most of the elements have been taken from English, some elements have been named from Latin, German or Greek.

	Latin	Symbol
Copper	Cuprum	Cu
Iron	Ferrum	Fe
Gold	Aurum	Au
Silver	Argentum	Ag
Mercury	Hydrargyrum	Hg
Sodium	Natrium	Na
Potassium	Kalium.	K

Atomic mass

For ex - actual mass of an atom of hydrogen is $1.673 \times 10^{-24} g$

✓ It was found convenient to compare the masses of atoms of different element with some reference atom.

✓ The masses thus obtained are called relative atomic masses.

✓ Reference chosen in the beginning was hydrogen atom because it was the lightest element.

↳ Using hydrogen as the reference, the masses of atoms of other elements came out to be fractional.

↳ reference was changed to oxygen taken as 16.

↳ oxygen combined with most of the elements.

considered relevant due to two reasons:
- oxygen reacted with a large number of elements and formed compounds.
- this atomic mass unit gave masses of most of the elements as whole numbers.

However, in 1961 for a universally accepted atomic mass unit, carbon-12 isotope was chosen as the standard reference for measuring atomic masses. One atomic mass

^{12}C

Atomic mass

$\rightarrow$ The atomic mass of an element is the relative mass of its atoms as compared with the mass of an atom of Carbon twelve isotope taken as 12 units

measuring atomic masses. One atomic mass unit is a mass unit equal to exactly one-twelfth ($1/12^{th}$) the mass of one atom of carbon-12. The relative atomic masses of all elements have been found with respect to an atom of carbon-12.

✓ $1 amu = \frac{1}{12}^{th}$ of mass C-12 isotope

✓ Atomic mass of an element may, therefore, also be defined as the number of times an atom of that element is heavier than $\frac{1}{12}^{th}$ of the mass of an atom of C-12 isotope.

What is a Molecule?

↳ A molecule is a group of two or more atoms which are held together strongly by some kind of attractive forces.

↳ Such an attractive force holding the atoms together is called a chemical bond.

↳ Depending upon whether the molecule contains one, two, three, four etc. atoms, are called monoatomic, diatomic, triatomic etc.

Molecules of an element

Monoatomic molecule

↳ Noble gases $\rightarrow$ helium, neon etc exist in single atoms
$\rightarrow$ Hence their molecules are monoatomic.
(He) $\leftarrow$ Symbols for their molecules & atoms are same.

Diatomic molecule

Ex - H_2, N_2, O_2
two atom of hydrogen exist together ~~2H~~

H—H
N≡N
O=O

Triatomic Molecule

↳ ozone
(O_3) three atoms of oxygen exist together as one species

Tetratomic molecule

Ex P_4

Molecules containing more than four atoms are called polyatomic

S_8 $\rightarrow$ Octatomic

$\rightarrow$ The number of atoms present in one molecule of the substance is called atomicity

Molecules of a compound

→ Molecules of a compound means two or more atoms of different elements combined together in a definite proportion by mass to form a species that can exist freely.

Eg - Molecule of water, Molecules of HCl.

H O H

Diatomic Molecules

Eg - HCl, Co

Triatomic Molecule

Eg - CO_2, H_2O

O=C=O

Tetraatomic molecules

Eg - hydrogen Peroxide (H_2O_2), ammonia (NH_3)

Molecular mass

→ Molecular mass of a substance (element or Compound) is the relative mass of its molecules as compared with that of an atom of C-12 isotope taken as 12.

→ In other words, molecular mass of a substance represents the number of times the molecule of that substance is heavier than $\frac{1}{12}$th mass of an atom of C-12 isotope.

Calculation of Molecular Mass

$O_3 \rightarrow 3 \times 16 = 48u$.

$H_2O \rightarrow$ 2 x atomic mass of hydrogen + 1 x atomic mass of oxygen.

$\rightarrow 2 \times 1 + 16 = 18u$

$CO_2 \rightarrow$ 1x atomic mass of carbon + 2 x atomic mass of oxygen.

$\rightarrow 12.0 + 2 \times 16 = 44u$

a(i) $C_{12}H_{22}O_{11} \rightarrow 12 \times 12 + 1 \times 22 + 16 \times 11$

$= 144 + 22 + 176$

$= 342\ u$

(b) $Al_2(SO_4)_3 \rightarrow 27 \times 2 + 3 \times [16 \times 4 + 32]$

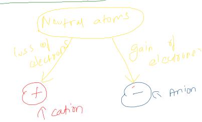
$= 342$

63.5u

(c) $CuSO_4.5H_2O \rightarrow 63.5 + 32 + (16 \times 4) + 5(2 \times 1 + 16)$

$= 249.5u$

Ions & Ionic compounds



→ An atom or a group of atoms which carries positive or negative charge is called an ion.

→ The ion carrying positive charge is called a cation & the ion carrying -ve charge is called anion

→ ion consisting of only single atoms are called monoatomic ions whereas an ion consisting of a group of atoms is called a Polyatomic ion.

→ Compounds consisting of cations & anions are called ionic compounds.

→ In any ionic compound, the total positive charge carried by the cation is equal to the total negative charge carried by the anion so that as whole, the ionic compound is electrically neutral.

Naming

✓ Cations is always named first followed by anions.

→ $Al_2(SO_4)_3$ → Aluminium sulphate

Al^{3+} SO_4^{2-} → $Al_2(SO_4)_3$

Writing Chemical Formula

Na^+ → 1 unit +ve charge.

Ca^{2+} → 2 unit of +ve charge

Al^{3+} →

Cl^- → 1 unit -ve charge

O^{2-} → 2 unit -ve charge.

(Valency = 1)

Monovalent cations

H^+, Na^+, K^+

(Valency = 2)

Divalent cations

Ca^{2+}, Mg^{2+}

(Valency = 3)

Trivalent cations

Al^{3+}, Fe^{3+}

Formula of Simple Molecular Compounds

water

H O

1 2 → H_2O

hydrogen sulphide

H S

1 2 → H_2S

H Cl → HCl
valency 1 1

(NH) (OH) (CO) (NaCl) (Mg 4) (CO) (NO) (KNO_3) (Na_2SO_4) ($CaNO_3$) ($CuSO_4$)

K Cl
2 5 → (3)

N H , NH_3
3 1

K
2 1

C H (CH_4) (6)
4 1
methane

K L M N
2 (4)

C O → CO_2
4 2
2 1

Dividing by common factor 2

Formula of simple ionic compounds

Na Cl → NaCl
1^+ 1^-

Mg Cl → $MgCl_2$
2^+ 1^-

NO_3^-

SO_4^{2-}

Potassium nitrate – KNO_3

Sodium sulphate – Na_2SO_4

Calcium Nitrate – Ca NO_3 → $Ca(NO_3)_2$
2^+ 1^-

Copper sulphate $CuSO_4$

Aluminium sulphate $Al_2(SO_4)_3$

Gram atomic mass

Atomic mass of an element is expressed in amu or u because it is the relative mass of the atom of that element.

Atomic mass expressed in grams is called gram atomic mass of that element.

for ex
Atomic mass of oxygen = 16 u
Gram Atomic " = 16 g

The amount of an element having mass equal to gram atomic mass is called "gram atom" of that element.

Gram molecular mass

Molecular mass H_2O → 1×2 + 16 = 18 u

Molecular mass expressed in grams is called gram molecular mass of that substance.

The amount of the substance having mass equal to its gram molecular mass is called "gram molecule" of the substance.

Mole Concept

For measurement we use certain units → 1 kg of Apple, 1 dozen banana

Article nos

12 banana

1 Score = 20 articles
1 Gross = 144 articles

Particles → Atoms, molecules, ions, e^-, p^+, n.

1 dozen = 12
1 score = 20
1 Gross = 144
1 mole of any substance = 6.022×10^{23} particles of that substance

Avogadro No. (N_A)

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

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

Mass of 1 H atom = 1 u.
6.022×10^{23} atoms of H = 1 g → Gram atomic mass
1 mole of hydrogen = 1 g = Gram atomic mass = Molar mass

Mass of 1 Oxygen atom = 16 u ✓

Mass of 1 mole of O atom = 16 g ✓

6.022×10^{23} atoms

1 mole of O = Gram Atomic mass = Molar mass

Mass of 1 molecule of H_2O = 18 u

Mass of 1 mole of H_2O molecule = 18 g

6.022×10^{23} molecules

Molar mass = Gram molecular mass

Proof

Atomic mass of O = $p^+ + n$

mass of 1 O atom in gram

$= 8p + 8n$

$= (8+8) \times 1.67 \times 10^{-24}$ g

$1p^+ = 1.67 \times 10^{-24}$ g

$1n =$ "

$= 16 \times 1.67 \times 10^{-24}$ g

6.022×10^{23} atoms of oxygen = $16 \times 1.67 \times 10^{-24} \times 6.022 \times 10^{23}$ g

$= 16 \times 10.03 \times 10^{-1}$

$= 16 \times \frac{10.03}{10}$

$= 16 \times 1$

$= 16$ g