Atoms and Molecules

Indian Philosophers → Kanad 500 B.C.

Greek

500 BC

Democritus

Atom

Atomos Greek word

meaning.

non-divisible

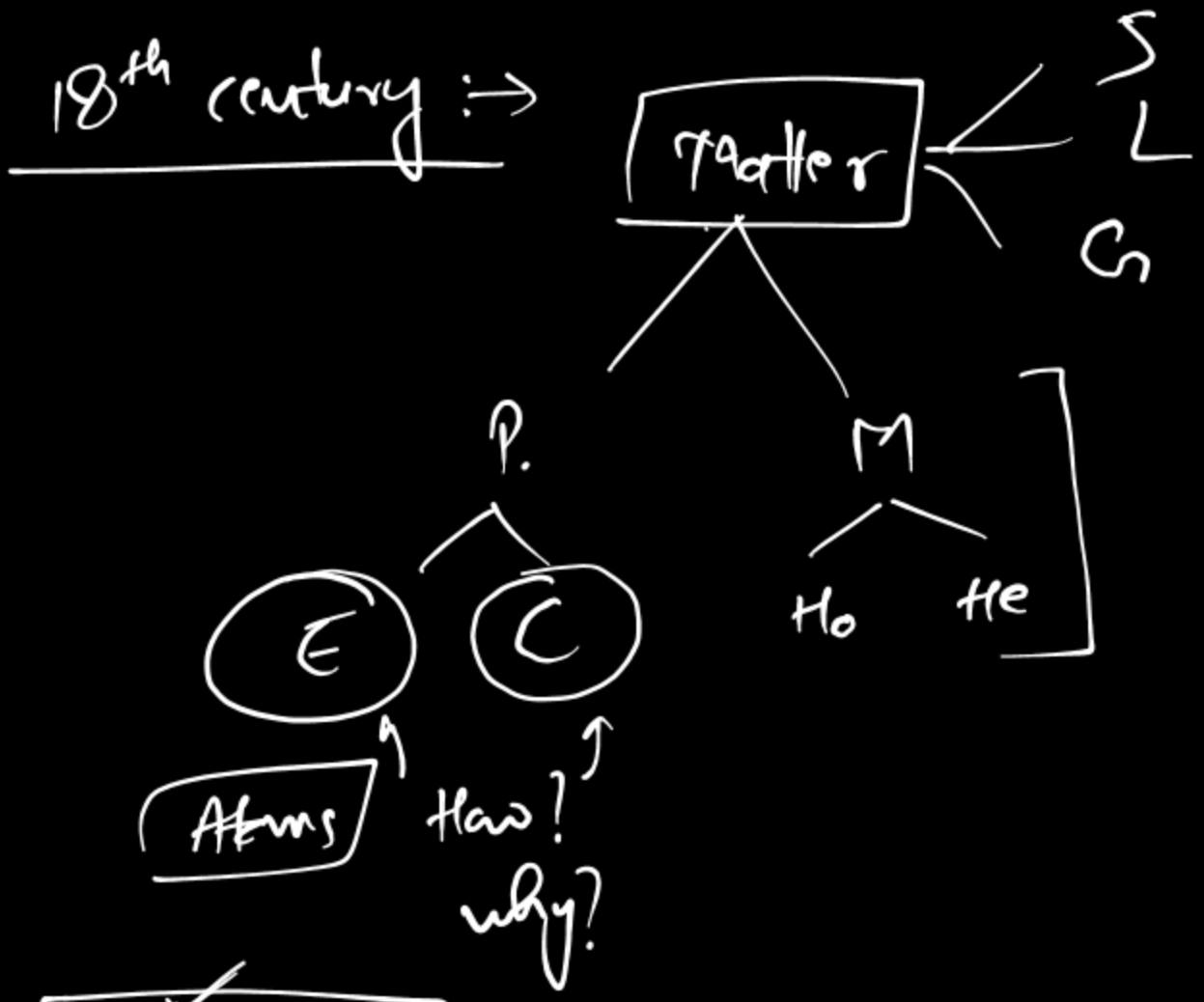
further cut X

Matter → Padarth

Smallest particle

Parmanu

18th century :⇒



Lavoisier ✓

↳ Chemistry foundation

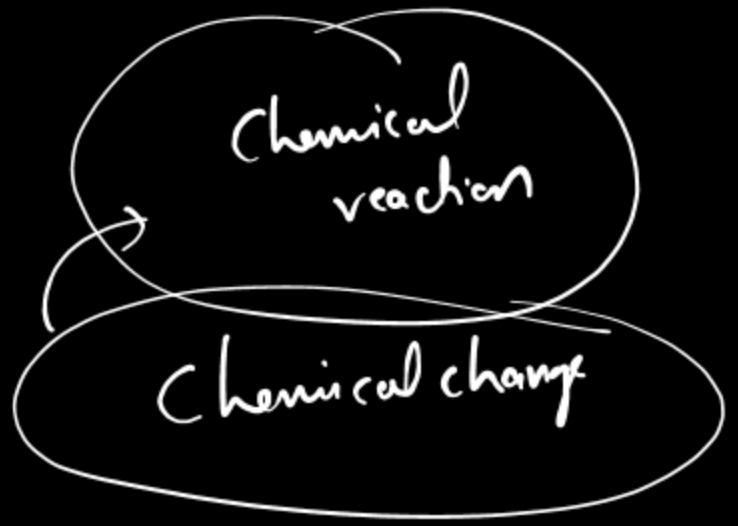
By ~~east~~ establishing laws of chemical combination

Laws of chemical combination (Lavoisier and Proust)

① Law of conservation of Mass

matter A + B matter $\xrightarrow[\text{combine}]{\text{Chemically}}$ AB matter

(5g) (6g) (11g)

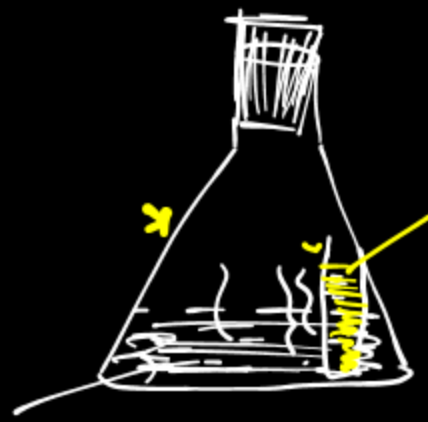


Total mass before chemical reaction = Total mass after chemical reaction

5g 6g
A + B → C + D
direction of reaction
occurrence of reaction
1g 10g
3g 8g

Reactants — Product

mass A + mass B = mass C + mass D



~~Solution~~
Sodium chloride ($NaCl$) Solution
10g

Sodium chloride + Lead nitrate
↓
{Lead chloride + Sodium nitrate}

Cork + Glass + T.T. + 15g

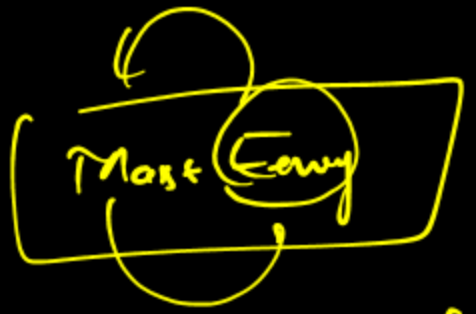
15g

Higgs field

$E = mc^2$

LHC ⇒

Chemical Reaction



⇒ Conservation

⇒ "Mass can neither be created nor be destroyed during any chemical reaction."

Chemical Reaction (electrons)

No change of elements

No new elements are created.

eg: $H_2 + O_2 \rightarrow H_2O$

$6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 + 6O_2$

$H + H \longrightarrow He$

Nuclear reaction.

(2) Law of constant Proportions / Law of definite proportions

	At. No.	Mass No.
H →	—	—
He	—	—
C	—	—
N	—	—
O	—	—
Na	—	—
K	—	—

Ratio by mass

$1g\ H_2 + 8g\ O_2$

$\downarrow$

$9\ g\ H_2O$

H_2O

River

Sea

Tap

Respiration

CO_2

NO_3

O

H_2O

H : O = 1 : 8 ✓

H : O : 1 : 1 X H_2O

CO_2

1 H

16 O

H

2 16

1 : 8

"In a chemical compound/substance, the elements are present in a definite proportions by mass"

Laws of Chemical Combinations :→

(i) Law of conservation of Mass ||→ Chemical reaction

(ii) Law of constant / definite proportions /

Ratio by mass

"In a given compound proportion of atoms (of elements) by mass always remains same, irrespective of the source of compound."

River →
Tap →
Ocean →

Water → H_2O → H : O = 1 : 8 by mass

Eg 2

CO_2

1C 2O

12 32

C : O

3 : 8

3 : 8

C → 12 u (a.m.u.)

O → 16 u (a.m.u.) atomic mass unit

unified mass

C : O

12 : 32

3 : 8

ratio by mass

- Burning of wood → CO_2
- Respiration → CO_2
- Burning of plastic → CO_2

C : O

3 : 8

Jhon Dalton (Theories)

on the basis of laws of chemical combinations

↓

" Dalton's Atomic Theory "

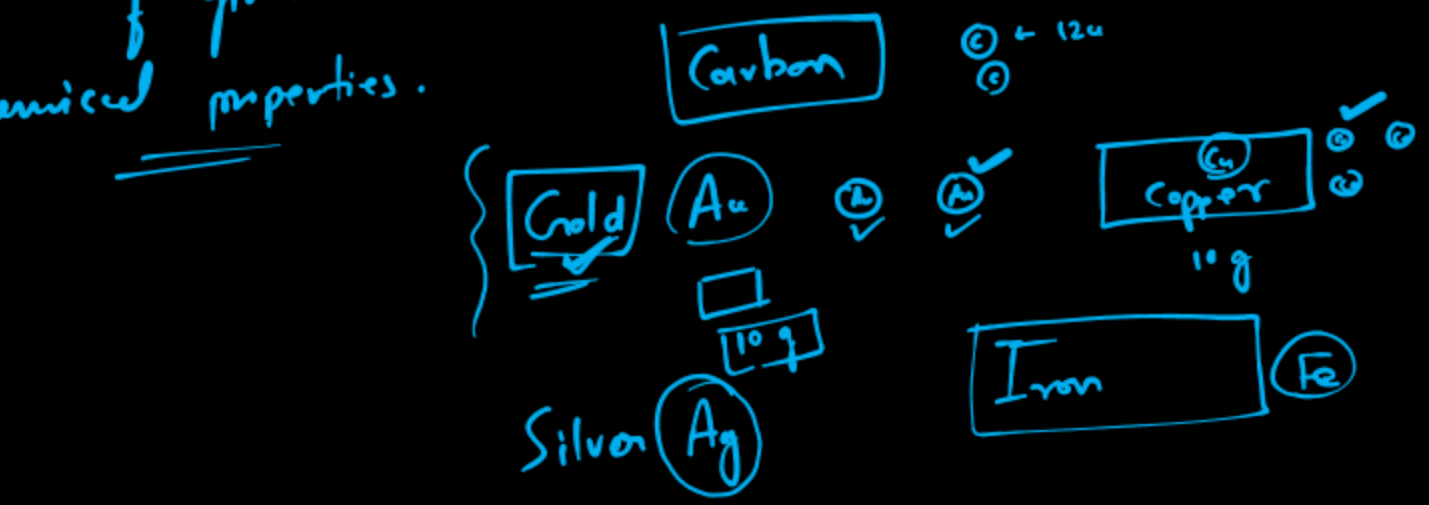
→ Atom → is the smallest particle of any matter.

Dalton's Atomic Theory:

- All matter (element or compound / or mixture) is made up of small particles called atoms., and they participate in chemical reactions.

- Atoms are indivisible particles, that cannot be destroyed (broken down) in a chemical reaction.

- Atoms of given element are identical in mass and chemical properties.



- Atoms of different elements differ in mass and chemical properties.

- Atoms combines in the ratio of small whole numbers to form compounds.

  Eg: H_2O : H : O
  2 : 1

  CO_2 : C : O
  1 : 2

  H_2SO_4 : H : S : O
  2 : 1 : 4

  $C_{12}H_{22}O_{11}$ = C : H : O
  12 : 22 : 11

- The relative number and kinds of atom are constant in a given compound.

  H_2O : (H) (O)
  (2) (1)

  HNO_3 : H N O
  1 1 3

Sod. Carb (5.3g) + Act. Acid (6g) → CO_2 (2.2g) + Sodium acetate 8.2g + H_2O 0.9g

11.3 g

11.3g

Total mass of reactant = Total mass of product

=>

H : O

1 : 8

3 . 1

g

1 : 8 =

Atom !

→ Building block of matter

→ Smallest particle of matter that retains all the properties of that/given matter.

Size of atom : (very)^{100} small

→ Size of atom is measured in nano-metres (nm)

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

0.000000001 m

{millions of atoms

Hydrogen atom ⇒ 1 Å

C

Si →

$1\ Å = 10^{-10}\ m$

Ant → $10^{-3}\ m$

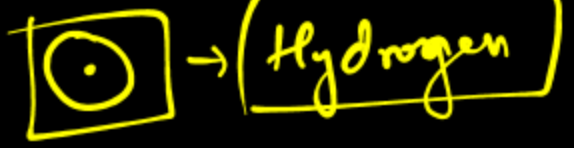
Sand particle → $10^{-4}\ m$

$10^{-9}\ m$

$10^{-10}\ m$

Symbols for atoms of various elements

Dalton



O_2O

International Union of Pure and Applied chemistry.

English Alphabet

- H — Hydrogen
- Si — Silicon
- Fe — Ferum

IUPAC

- Naming
- Measurement
- Symbols

Aluminium → Al

Sodium → Na (Natrium)

Carbon → C

Silicon → Si

Helium → He

Nitrogen → N

Lithium → Li

Silver → Ag

Gold → Au

Platinum → Pt.

Lead	Pb

Potassium → K

Uranium → U

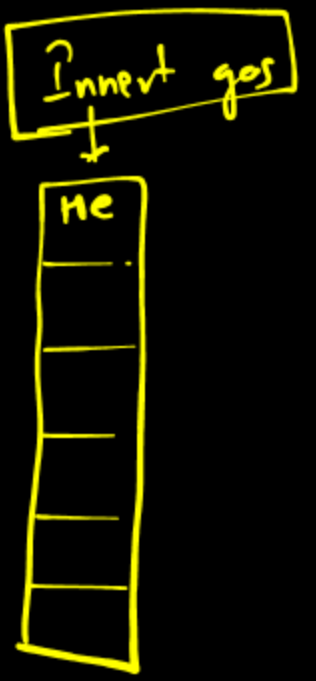
Plutonium → Pu

H

Li

Na

K



Atomic Mass :

Mass of an atom → Standard

H → 1 amu

He ⇒ 2 amu

Li → 3 × 1 amu

→ 3 amu

Carbon → 12 × 1 amu

→ 12 amu

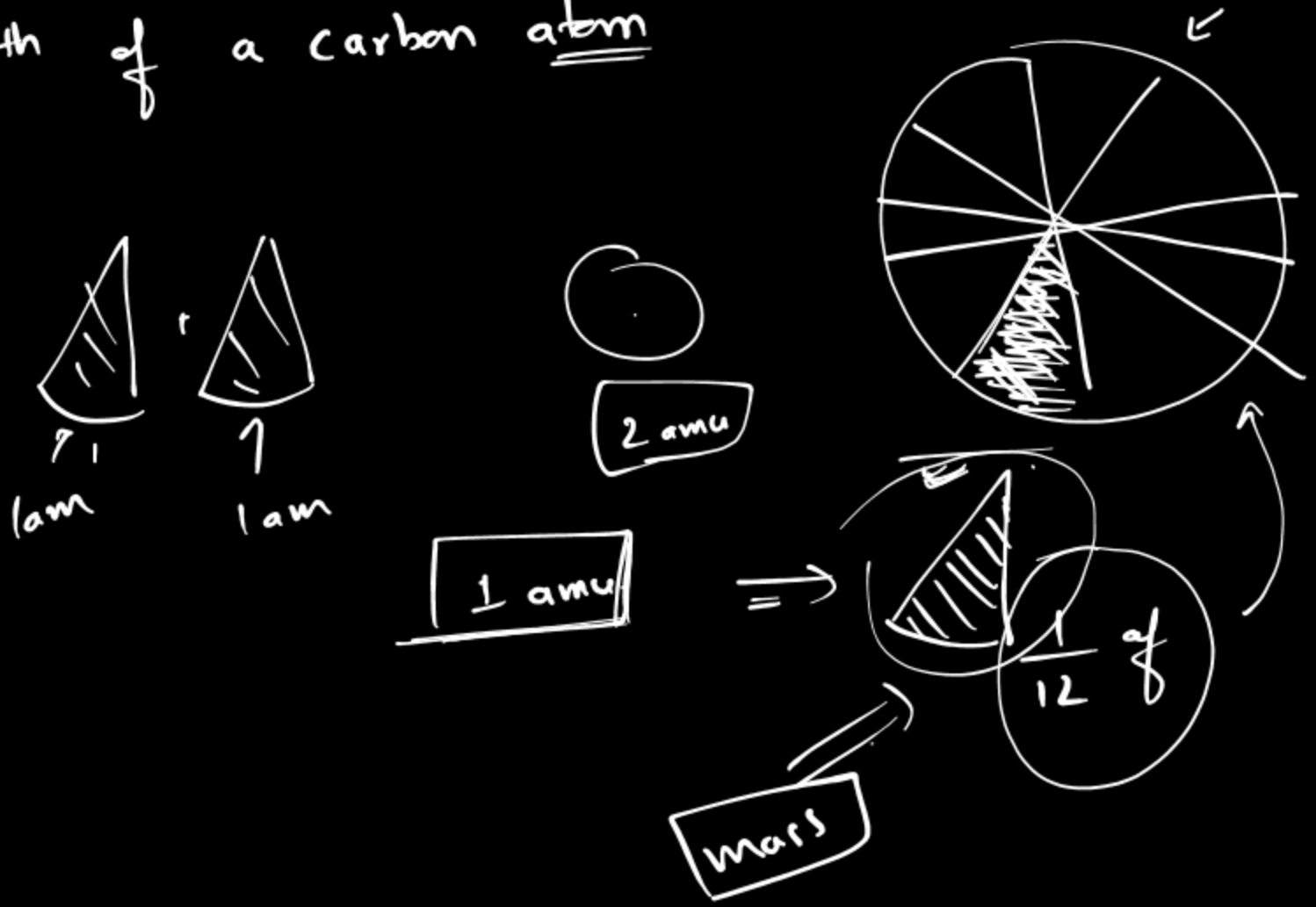
Relative atomic mass

1 H atom = 1.67×10^{-27} kg

⊛ . C-12 atom is choosen as latest standard for Relative atomic mass.

IUPAC

⇒ $\frac{1}{12}$ th of a carbon atom



u ⇒ unified mass

1 amu :→ (1 u)

1 amu is the mass of $\left(\frac{1}{12}\right)^{th}$ of the mass of 1 atom of Carbon-12.

Table 3.2

$_{1}H$	→	1 u
$_{11}Na$	→	23 u
$_{17}Cl$	→	35.5 u
$_{20}Ca$	→	40 u

Avg. value

How do atoms Exist ?

↳ Most of atoms are unstable / reactive

∴ they cannot exist alone / independent.

⇒ Hence, they combine with other atoms (same or different element) to form molecules ||

↳ stable

⇒ They can also form (ions) / are charged particle.

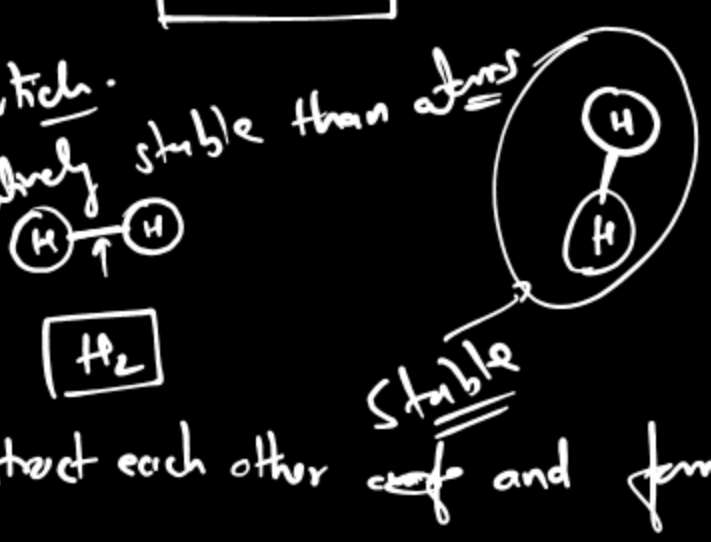
↳ ions are relatively stable than atoms

aggregates

(charged particles / atoms

H_2

⇒ Unlike charges attract each other and form stable aggregate (salt).



Molecules :

Unstable

Molecule

collection of two or more atoms

[In a molecule atoms are held together by a chemical bond

↓

attractive force

⇒ They are stable and can exist independently.

⇒ Hydrogen atom

(H) cannot exist independently.

(H)—(H)

Combine chemically to form a molecule of hydrogen

(H)—(H)

H_2

- molecule.
- exist in nature independently in nature.

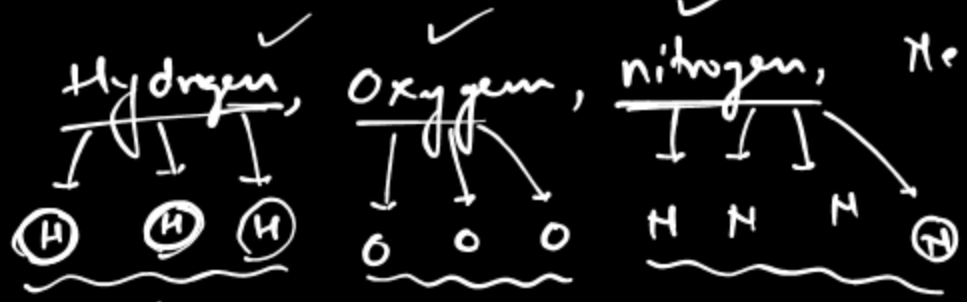
H_2 aka. hydrogen gas

H_2 is 1 molecule of hydrogen gas.

Molecules → of element
Molecules → of compound

Molecules of elements

eg. of Some elements : Hydrogen, Oxygen, nitrogen, He, Na, Mg, C



Unstable

molecule of elements

molecule of elements

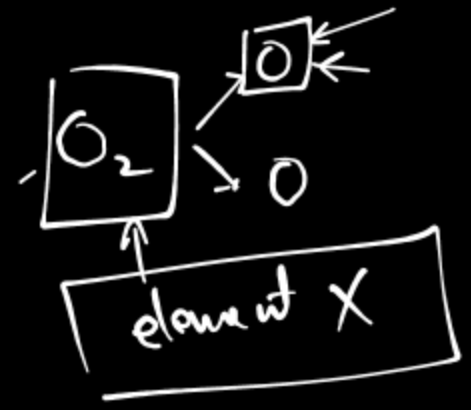
O_3 | Ozone

Atomicity: The number of atoms present in a molecule of an element.

- H_2 → atomicity is 2 [Diatomic molecule]
- O_3 → atomicity is 3 [Triatomic molecule]
- H_2 → 2

O

O_2 →



Carbon → element

Oxygen element

↓

Oxygen gas

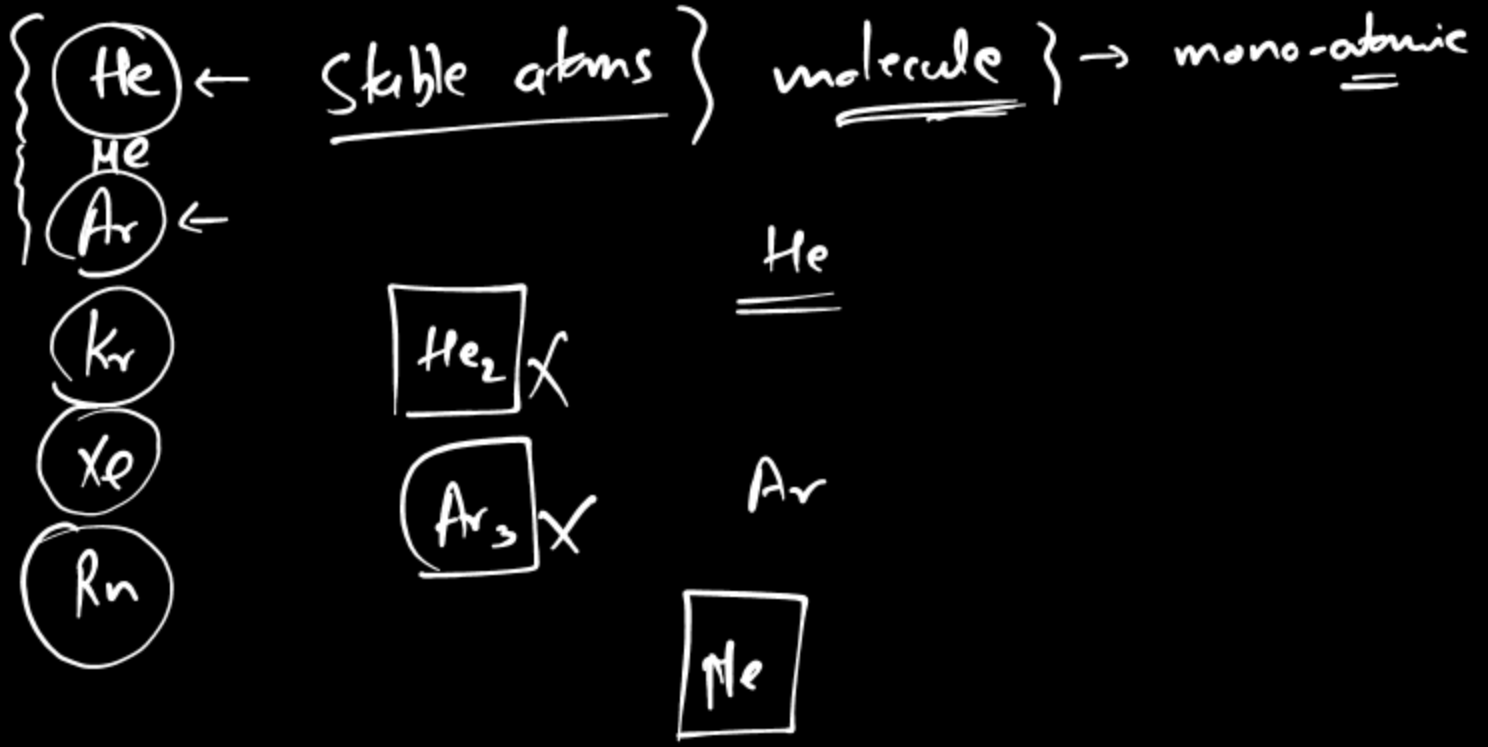
O=O

Tetra-atomic molecule :→ eg: P_4

(Poly atomic molecule) octa atomic → S_8

← Crown shape

Mono-atomic molecules : molecules made up of simple atom.

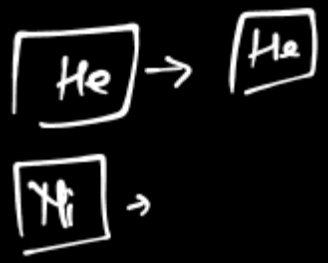


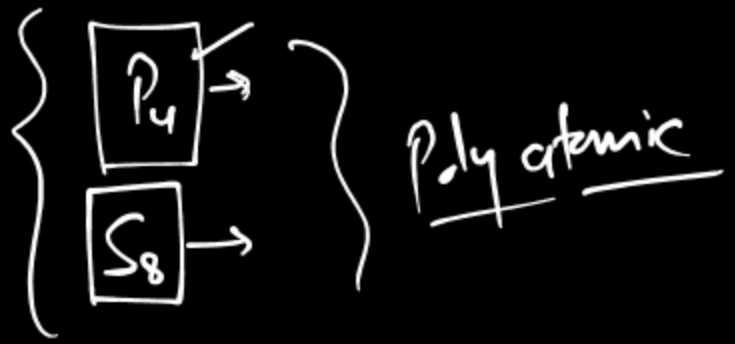
Metals and Carbon

Complex structure / arrangement of atoms

Several atoms are bonded together.

Indefinite





Molecules of Compounds

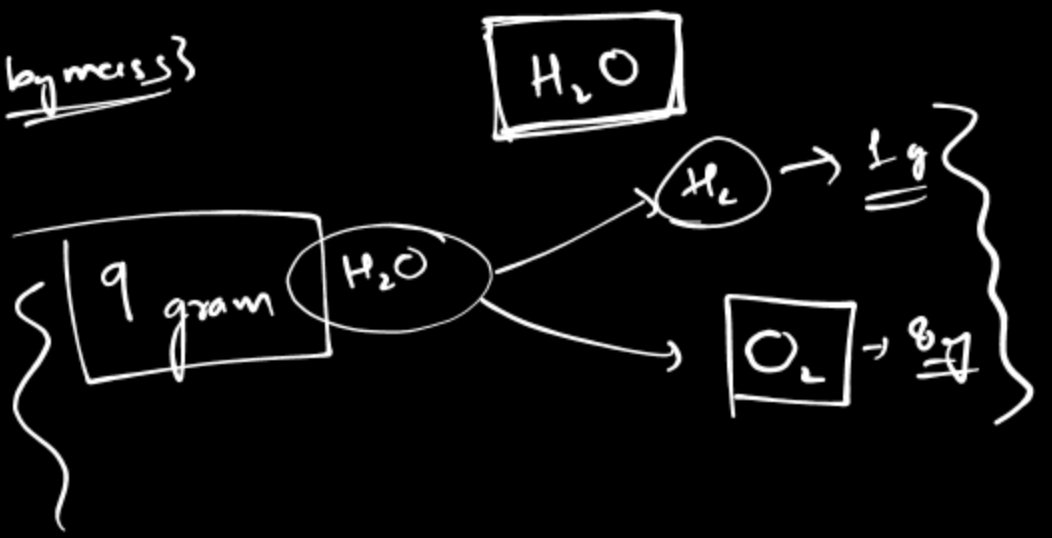
→ Molecules of compounds is made up of atoms of different elements, combined in a fixed ratio.

eg: Water is a compound of Hand hydrogen and oxygen.

H_2O

H : O
1 : 8 by mass

2 : 1
by no. of atoms



(II) Glucose : $C_6H_{12}O_6$ → 1 molecule of glucose

(III) $KMnO_4$? ionic compound

(IV) CH_4 methane → Biogas

1C + 4H

12u 4u

C : H

12 : 4

3 : 1

(V) CO_2

C : O

12 : 32

3 : 8

C → 12u

O → 16u

(VI) CO

C : O

12 : 16

3 : 4

bymass

• Ammonia (NH_3) =>

N => 14u

N : H

14 : 3

H : N

3 : 14

#4.

Ion

→ Charged atoms / group of atoms

- Two types
  - +ve → Cation → metal atoms
  - -ve → anion → non-metal atoms

Ions

When a Metal combines with a non-metal to form compound, then the atoms of metals carry +ve charge and atom(s) of non-metal becomes negatively charged.

Ionic compound

(+) (+) Repel

(+) (−) attract eachother

Sodium (metal)

Na — Reactive

Solid metal

Na^+ → ← Cl^-

Cl — gas (Reactive)

NaCl — stable substance

Common salt

Na^+ → Sodium ion

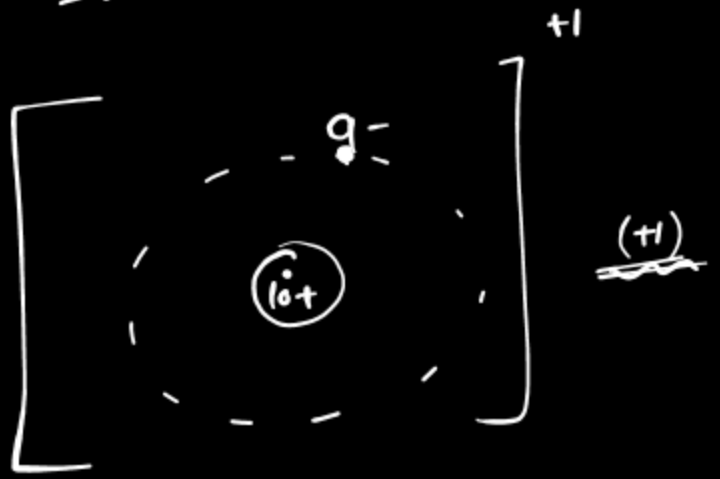
Cl^- → Chloride ion ide

→ Charge can be either on single atom or group of atoms.

eg Ammonium ion $(NH_4)^+ \equiv NH_4^+$ ←

Hydroxide ion $(OH)^- \equiv OH^-$ ←

Polyatomic anion



NaCl

Metal Non-metal.

↓

$(Metal)^+$ $(Non\text{-}metal)^-$

NaCl

Na^+ Cl^-

Sodium ion

Chloride ion

"Sodium chloride" NaCl.

~ 3000°C

Name of ion	Symbol
Sodium	Na^+
Potassium	K^+
Silver →	Ag^+
Copper (I) →	Cu^+
Magnesium →	Mg^{2+}
Calcium →	Ca^{2+}
Copper (II) →	Cu^{2+}
Iron (II) →	Fe^{2+}
Zinc →	Zn^{2+}
Aluminium →	Al^{3+}
Iron (III) →	Fe^{3+}

Hydrogen H^+ ← metallic

Hydride H^- ← non-metallic

Chloride → Cl^-

Bromide → Br^-

I^-

Oxide → O^{2-}

Sulphide → S^{2-}

Nitride → N^{3-}

Polyatomic ions :

Ammonium ion $(NH_4)^+$ NH_4^+

Hydroxide ion → OH^-

Bicarbonate ion / Hydrogen carbonate ion } HCO_3^-

Nitrate ⇒ NO_3^{-1}

= Carbonate ion CO_3^{2-}

Sulphate ion SO_4^{2-}

Sulphite SO_3^{2-}

= Phosphate PO_4^{3-}

Chemical formula of chemical compounds

↓

Symbolic represent of a chemical compound.

↓

atomic symbol.

To write a chemical formula, we must know –

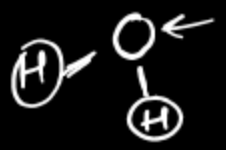
(i) atomic symbols of elements.

(ii) Valency of elements.

↳ "combining capacity of elements"

↓

bond formation



H^+

O^{2-}

$(OH)^-$

↑

Poly atomic • ion

Ca^{2+}

↑

$Fe^{2+} \mid Fe^{3+}$

$Cu^{+} \mid Cu^{2+}$

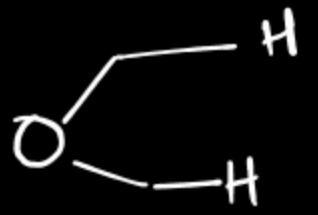
Rules for writing chemical formula

① Valencies / charges on the ions must be balanced

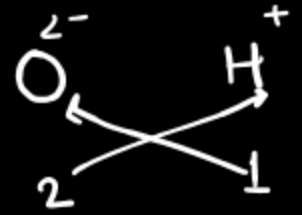
eg: O^{2-} → valency = 2

eg: NaCl

$Na^{\oplus}$ $Cl^{\ominus}$



→ H_2O ✓



H^+ → valency = 1 H—

→ OH_2 ✓ H_2O

(11) In case, when metal (cation) and non-metal (anion), both are present in a compound, then the name or symbol of the metal (cation) is is written first.

eg: • Sodium chloride (NaCl)

• Calcium Carbonate (Ca^{2+} CO_3^{2-} => $CaCO_3$

Calcium oxide

CaO

(iii) In case of polyatomic ions, the ion is written in a bracket, before writing the number of the ions.

Cl^- →

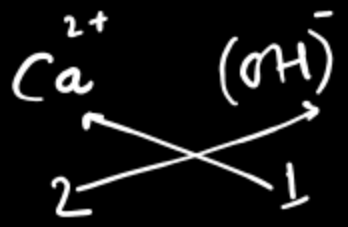
Br^- →

NH_4^+ →

eg: Calcium hydroxide

Ca^{2+} $(OH)^-$ —(OH)

$Ca(OH)_2$

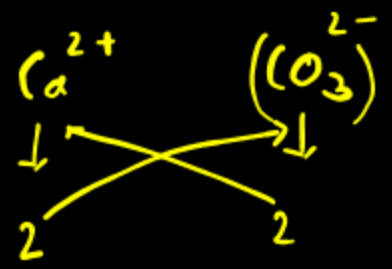


$Ca_1(OH)_2$

$Ca(OH)_2$

NH_4Cl

Calcium carbonate

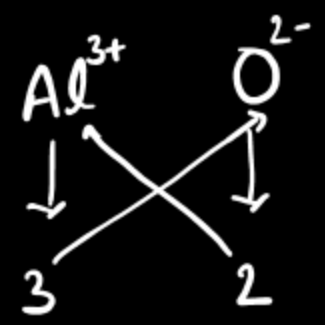


$Ca_2(CO_3)_2 \rightarrow Ca(CO_3) \rightarrow CaCO_3$

Water

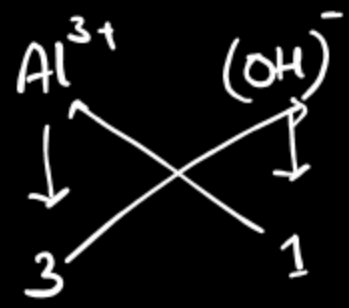
H_2O

Aluminium oxide



$\Rightarrow Al_2O_3$

Aluminium hydroxide



$\Rightarrow Al_1(OH)_3$

$\Rightarrow Al(OH)_3$

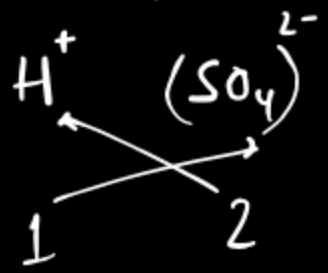
Calcium oxide

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

2 2

Ca_2O_2 $\Rightarrow CaO$

Hydrogen sulphate



$H_2(SO_4)_1$

H_2SO_4

Sulphuric acid

Ammonium sulphate

$(NH_4)^{+}$ $(SO_4)^{2-}$

$(NH_4)_2SO_4$ ✓

$NH_4{}_2SO_4$ ✗

$AlCl_3$ → Aluminium chloride

$Al_2(SO_4)_3$ → Aluminium sulphate

$W = m \cdot g$

$9.8\ N = m \cdot (9.8\ m/s^2)$

$m = 1\ kg$

mass on earth: $1\ kg$

mass on moon = $1\ kg$

Symbols

ionic symbol. (atomic symbol / group of atoms) +/- charge.

$(OH)^{-1}$

NH_4^+

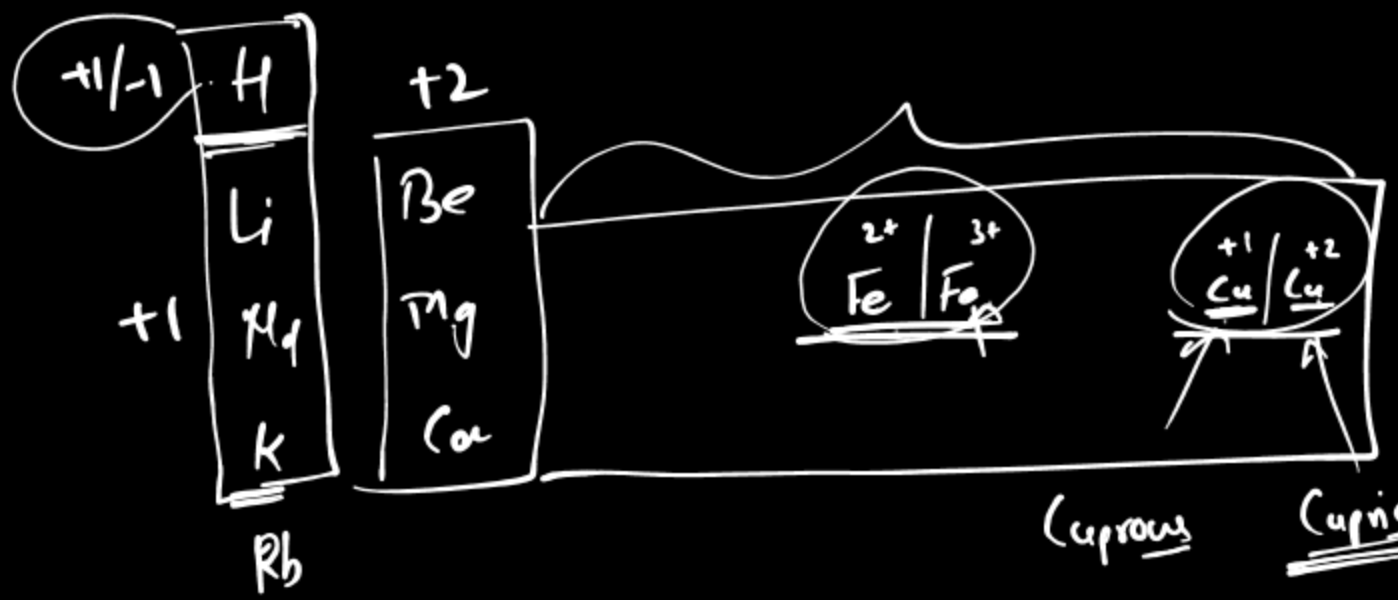
Calcium phosphate

Ca^{2+} $(PO_4)^{3-}$

2 3

$Ca_3(PO_4)_2$

Magnesium phosphate



Ferrous chloride | Iron (II) chloride

Ferric chloride | Iron (III) chloride

ous — copper(I) oxide

⇒ copper(II) chloride

$CuCl_2$

2 1

Hydrogen nitride

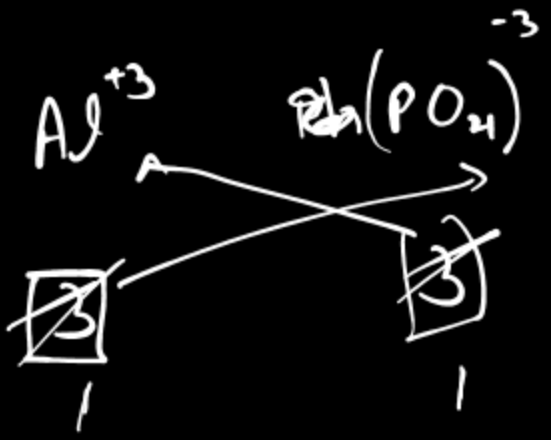
H_3N_1

H_3N

$NH_3 \Rightarrow$ Ammonia

H_2O

Aluminium phosphate



$Al_x(PO_4)_x$

$AlPO_4$

$\frac{3x}{x} = \frac{3x}{x}$

$\frac{LCM}{HCF} = 2$

Molecular mass :- / (Relative m.m)

⇒ H_2O → a molecule of water

mass of 1 molecule of a substance/ compound.

⇒ ~~Sum of~~ a "add all the atomic masses present in 1 molecule of a compound."

"Sum of atomic masses of all the atoms present in one molecule of a compound."

Ionic compound :- "formula unit"

Covalent compound :- molecule

$C_6H_{12}O_6$ ⇒ covalent

molecule

Na^+Cl^- → formula unit of common salt.

H_2O → molecule of water

Calculate the molecular mass of (i) water (H_2O) and (ii) nitric acid (HNO_3)

$H_2O = 2 \times H + O$

$= 2 \times 1u + 16u$

$= 2u + 16u$

$= 18u$

$HNO_3 = 1 \times H + 1 \times N + 3 \times O$

$= 1 \times 1u + 1 \times 14u + 3 \times 16u$

$= 1u + 14u + 48u$

$= 63u$

$H_2SO_4 = 2 \times H + 1 \times S + 4 \times O$

$= 2 \times 1u + 1 \times 32u + 4 \times 16u$

$= 98u$

$S = 32u$

Formula unit mass

↳ Instead of molecule we use formula unit of a substance (ionic Compound)

Eg. Calculate formula unit mass of (i) NaCl. (ii) $CaCl_2$

$NaCl = 1 \times Na + 1 \times Cl$

$= 1 \times 23u + 1 \times 35.5u$

$= 58.5\ u$

$Na = 23u$

$Cl = 35.5$

Ca → 40

$40 + 2 \times 35.5$

$(40 + 71)\ u$

111 u