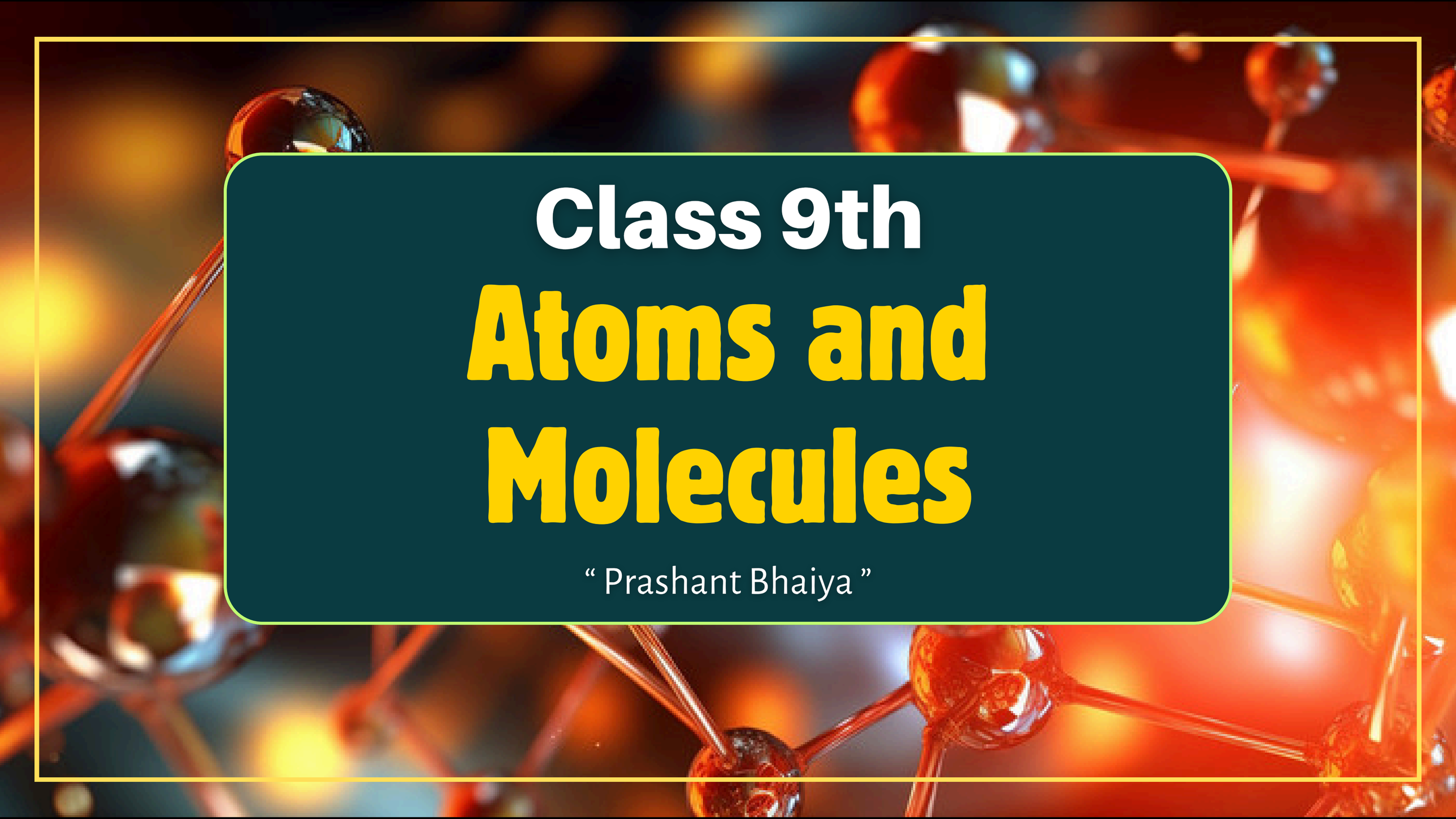


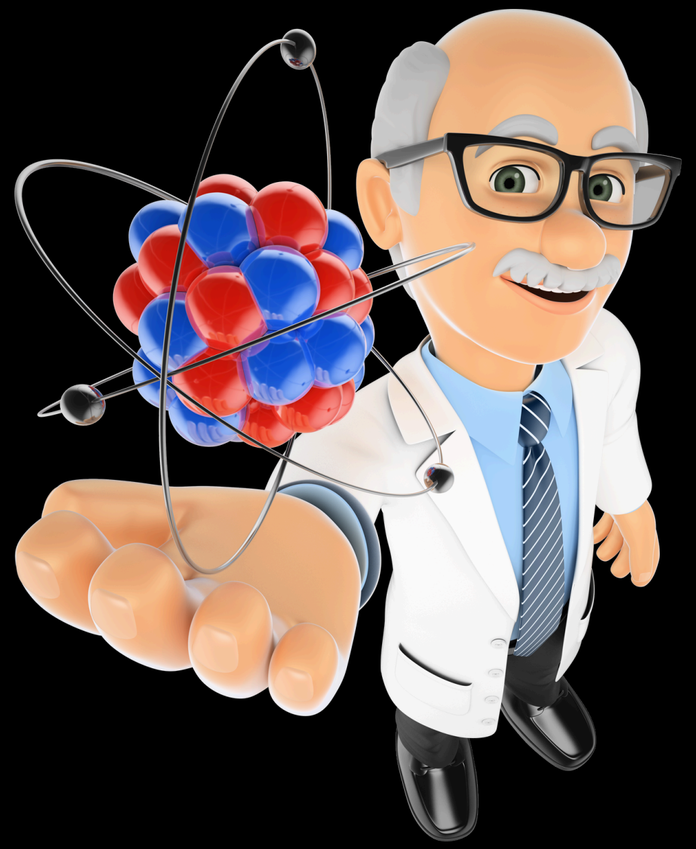
Class 9th

Atoms and Molecules

“ Prashant Bhaiya ”

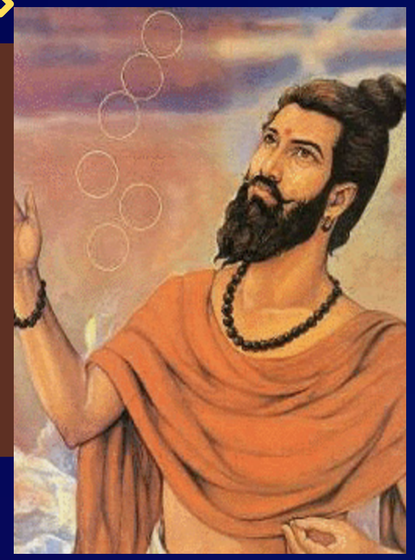
Topics to be Covered

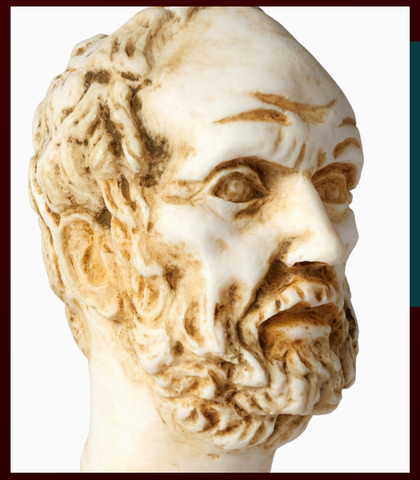
- Law of Chemical Combination
- Dalton’s atomic theory
- Modern day symbols of Elements
- Atomic Mass
- Molecule
- Chemical Formulae
- Molecular Mass
- Molar Concept



History

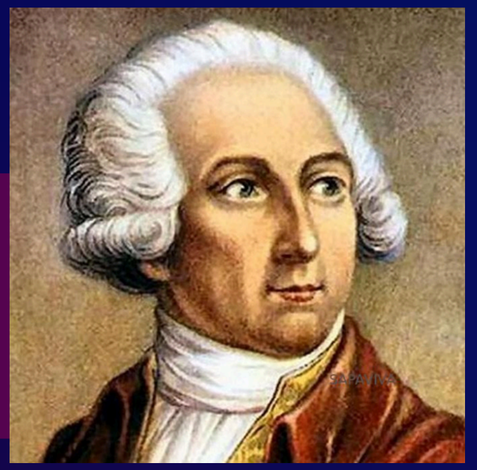
Around 500 B.C., Indian philosopher Maharishi Kanad, postulated the theory if we go on dividing matter (padarth), we will obtain smallest particle beyond which further division can't be possible which is known as 'parmanu'.





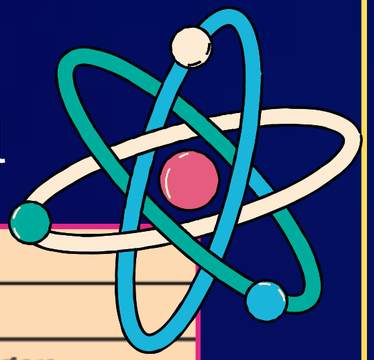
→ Ancient Greek philosophers – Democritus and Leucippus called these particles atoms.

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



ATOMS

- Atoms are **building blocks of all matter**.
- According to modern atomic theory, an atom is the smallest particle of an element which takes part in chemical reaction.
- Atoms are very small and which can't be seen even through very powerful microscope.



Atomic radius is measured in nanometres.

$1/10^{9}$ m = 1 nm

1 m = 10^{9} nm

Relative Sizes

Radii (in m)	Example
10^{-10}	Atom of hydrogen
10^{-9}	Molecule of water
10^{-8}	Molecule of haemoglobin
10^{-4}	Grain of sand
10^{-3}	Ant
10^{-1}	Apple

Lavoisier and Joseph L. Proust.

Law of Chemical Combination

Law of Conservation of Mass

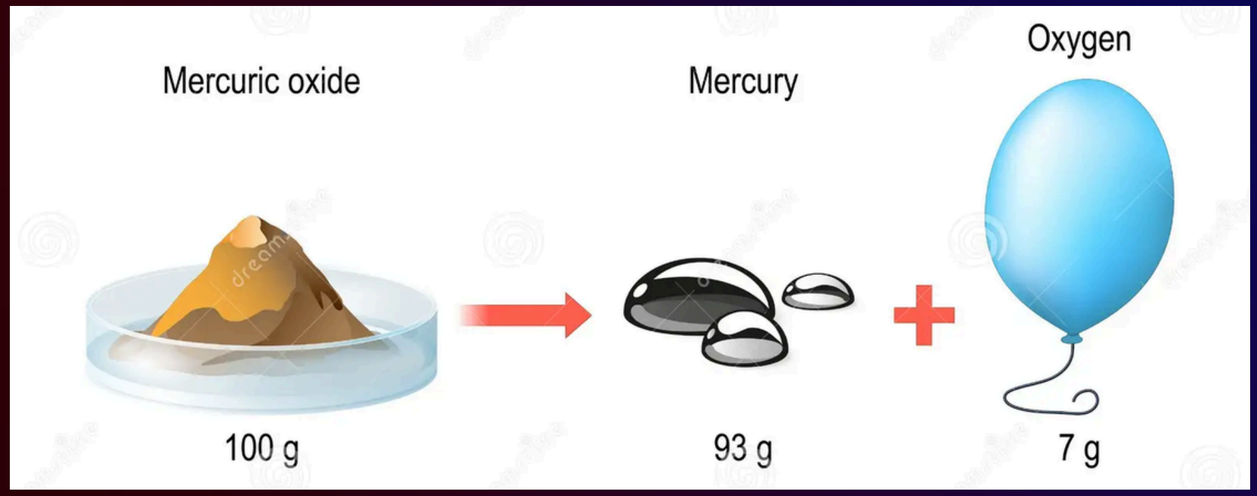
Law of Constant Proportions

Law of Conservation of Mass

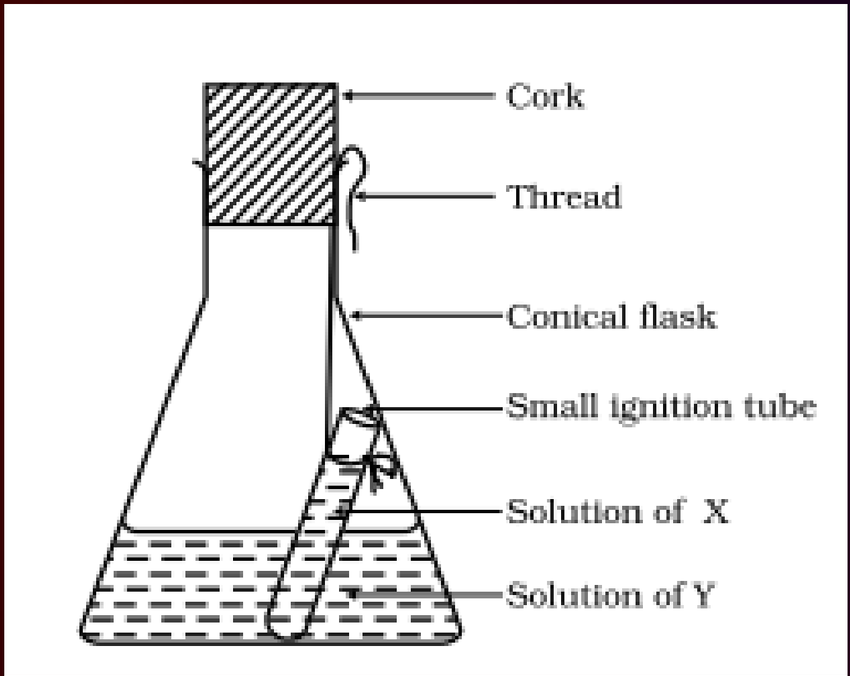
During a chemical reaction, the total mass of reactants will be equal to the total mass of the products.

➔ *Mass can neither be created nor destroyed in a chemical reaction.*

Total Mass of Reactants = Total Mass of Products



Activity 3.1



Set X: Copper sulphate (or barium chloride, or lead nitrate)

Set Y: Sodium carbonate (or sodium sulphate, or sodium chloride)

Solution Y in flask, Solution X in ignition tube.

↓

Weigh flask with both solutions.

↓

Tilt flask to mix X and Y.

↓

Re-weigh the flask after mixing.

↓

Check for any change in mass.

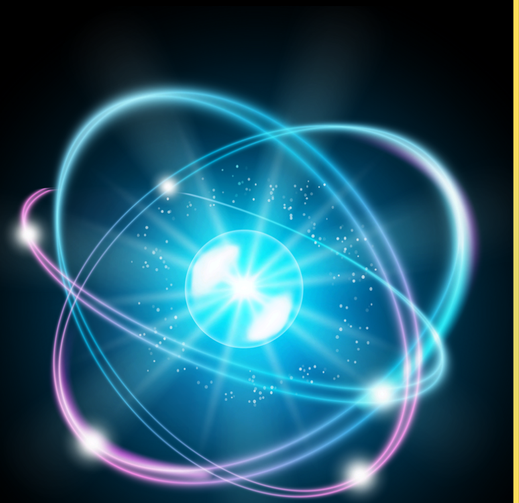
↓

Mass remains constant

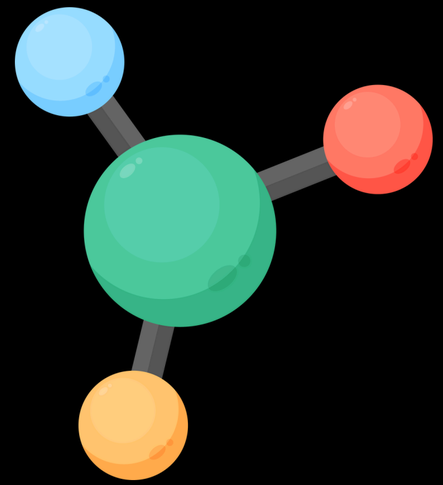
↓

(Law of Conservation of Mass).

Q. Give an example of this law of conservation of mass when it applies to physical change.



Q. If 12 g of carbon is burnt in the presence of 32 g of oxygen, how much carbon dioxide will be formed?



Q. In a reaction 4.6 g of barium chloride reacted with 3.4 g of sodium sulphate. The products obtained were 2.8 g of sodium chloride and 5.2 g of barium sulphate.
The reaction takes place as follows:
Barium chloride + Sodium sulphate → Sodium chloride + Barium sulphate."
Show that the above observation is in agreement with the law of conservation of mass.

Law of Constant Proportions

The elements in a pure chemical compound are always present in the same proportions by mass, regardless of how the compound is created.

→ It was given by Joseph Proust.

Example:

(i) 18 gm of H_2O = 2 gm of hydrogen + 16 gm of oxygen

⇒ mass of hydrogen : mass of oxygen = 2:16 = 1:8

(ii) 36 gm of H_2O = 4 gm of hydrogen + 32 gm of oxygen

⇒ mass of hydrogen : mass of oxygen = 4:32 = 1:8

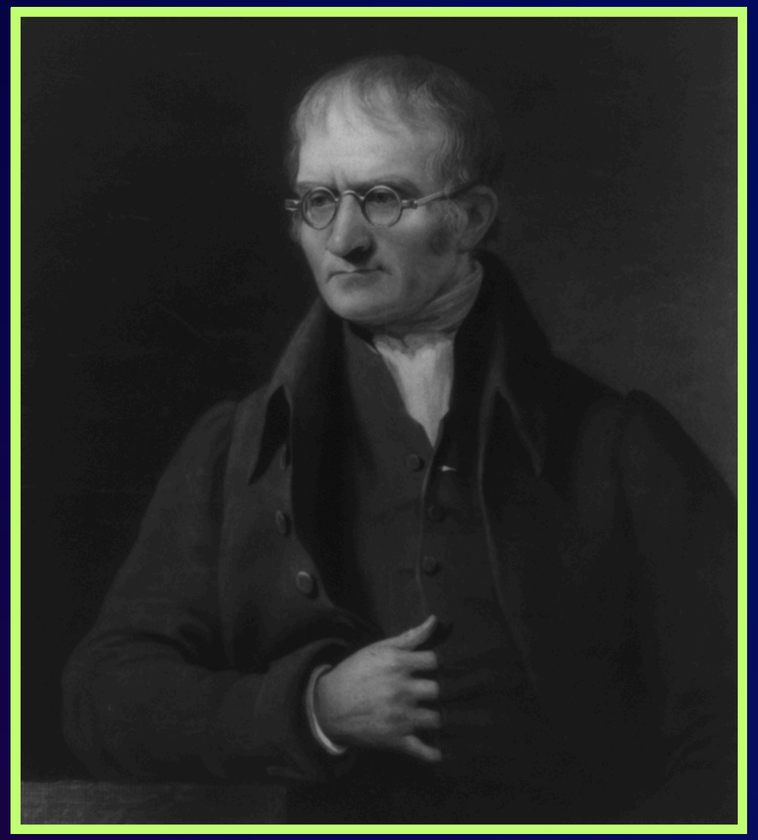
(iii) In water, the ratio of the mass of hydrogen to the mass of oxygen is always 1 : 8 respectively.

Q. Hydrogen and oxygen combine in the ratio of 1:8 by mass to form water. What mass of oxygen gas would be required to react completely with 5 g of hydrogen gas?

Q. Calculate the percentage of elements in 1.5 g of calcium carbonate if Ca = 40%, C = 12%, O = 48%.
If the law of constant proportion is true, what weight of these elements will be present in another sample?
(Atomic masses: Ca = 40 u, C = 12 u, O = 16 u)

Dalton’s Atomic Theory

According to Dalton’s atomic theory, all matter, whether an element, a compound or a mixture is composed of small particles called atoms.



John Dalton

Postulates of Dalton’s Atomic Theory:

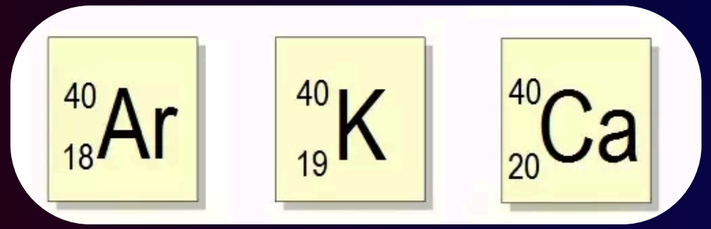
- All matter is made of very tiny particles called atoms.
- Atoms are indivisible particles, which cannot be created or destroyed in a chemical reaction.

- Atoms of a given element are identical in mass and chemical properties. (Law of conservation of mass)
- Atoms of different elements have different masses and chemical properties.
- Atoms combine in the ratio of small whole numbers to form compounds. (Law of constant proportion)
- The relative number and kinds of atoms are constant in a given compound.

Drawbacks of Dalton’s Atomic Theory:

- **No Subatomic Particles:** Dalton's theory said atoms were indivisible, but we now know about electrons, protons, and neutrons.
- **Isotopes Not Defined:** Dalton stated all atoms of an element have the same mass, but isotopes of elements have different masses.

- **No Isobars:** Dalton said atoms of different elements have different masses, but isobars have the same mass number.

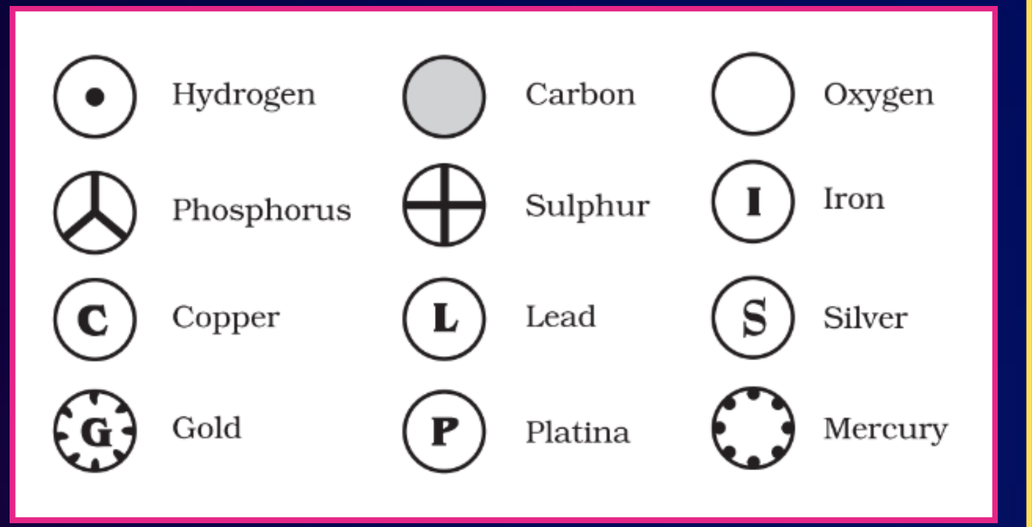


- **No Whole-Number Ratios Always:** Complex compounds like sugar (C12H22O11)) do not always follow simple whole-number ratios.

- **No Allotropes Defined:** Allotropes like graphite and diamond have different properties that Dalton's theory can't explain.

Modern Day Symbols of Elements

- Dalton: First scientist to use symbols for elements.
- Berzelius: Suggested using one or two letters from the element's name for its symbol.
- Element Naming: Initially, elements were named after their discovery locations **(e.g., Copper from Cyprus).**



- IUPAC: Now responsible for approving element names, symbols, and units. Symbols typically use one or two letters from the element's English name **(e.g., H for Hydrogen, Al for Aluminium).**
- Special Cases: Some symbols are derived from Latin, German, or Greek names **(e.g., Fe for Ferrum, Na for Natrium, K for Kalium).**

Steps to Write Symbols:

- First Letter - Capital
- Second Letter - Small

IUPAC name of some Elements

International Union of Pure and Applied Chemistry

Element	Symbol	Element	Symbol	Element	Symbol
Aluminium	Al	Copper	Cu	Nitrogen	N
Argon	Ar	Fluorine	F	Oxygen	O
Barium	Ba	Gold	Au	Potassium	K
Boron	B	Hydrogen	H	Silicon	Si
Bromine	Br	Iodine	I	Silver	Ag
Calcium	Ca	Iron	Fe	Sodium	Na
Carbon	C	Lead	Pb	Sulphur	S
Chlorine	Cl	Magnesium	Mg	Uranium	U
Cobalt	Co	Neon	Ne	Zinc	Zn

Trick to Rememeber First 20 Elements of Periodic Table

1. Hydrogen (H)
2. Helium (He)
3. Lithium (Li)
4. Beryllium (Be)
5. Boron (B)
6. Carbon (C)
7. Nitrogen (N)
8. Oxygen (O)
9. Fluorine (F)
10. Neon (Ne)
11. Sodium (Na)
12. Magnesium (Mg)
13. Aluminum (Al)
14. Silicon (Si)
15. Phosphorus (P)
16. Sulfur (S)
17. Chlorine (Cl)
18. Argon (Ar)
19. Potassium (K)
20. Calcium (Ca)

Atomic Mass

- Dalton’s Atomic Theory: Introduced the concept of atomic mass, explaining the law of constant proportions.

- **Atomic Mass: Mass of an atom of an element.**

- IUPAC (1961): Adopted the term "**atomic mass unit (u)**" to express atomic and molecular masses.
- **1 atomic mass unit (u)** = 1/12 of the mass of a carbon-12 atom.

$$1\ amu = \frac{1}{12} of\ a\ carbon\ atom = \frac{1}{12} \times \frac{12}{6.023 \times 10^{23}} = 1.66 \times 10^{-24}$$

- Example: Hydrogen atom has a mass of 1 u or 1.673×10^{-24} grams.

Atomic Mass

The carbon-12 atom has been given an atomic mass of exactly 12 atomic mass units. Previously, atomic mass units were abbreviated as 'amu,' but now they are represented by the letter 'u.' Therefore, a carbon-12 atom's atomic mass is exactly 12 u. Since a carbon-12 atom has an atomic mass of 12 atomic mass units, the atomic mass unit is defined as one-twelfth (1/12) of the mass of a carbon-12 atom.

$$Atomic\ Mass = \frac{Mass\ of\ 1\ atom\ of\ an\ element}{\frac{1}{12} \times mass\ of\ C-12\ atom}$$

Atomic masses of a few elements

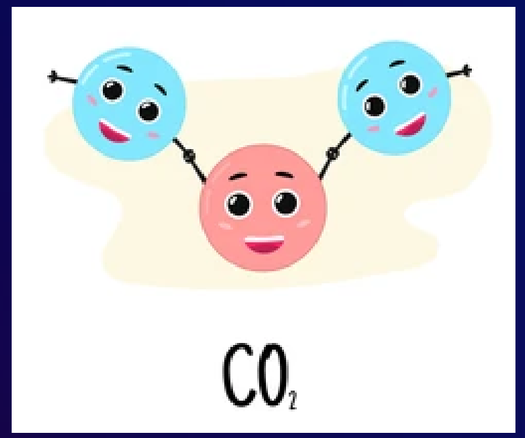
Element	Atomic Mass (u)
Hydrogen	1
Carbon	12
Nitrogen	14
Oxygen	16
Sodium	23
Magnesium	24
Sulphur	32
Chlorine	35.5
Calcium	40

Atoms Existence

- Most elements' atoms are highly reactive and do not exist freely.
- Only noble gas atoms (He, Ne, Ar, Kr, Xe, Rn) are chemically inert and can exist as single atoms.
- Atoms of all other elements combine together to form molecules or ions.

Atom → Ion (electrically charged)

Atom → Molecules (electrically neutral)



Ions

An ion may be defined as an atom or group of atoms having positive or negative charge.

Cations

Some positively charged ions) : Na^{+} , K^{+}, Ca^{2+} , Al^{3+}

Anions

(Some negatively charged ions) : Cl^{-} (chloride ion), S^{2-} (sulphide ion), OH^{-} (hydroxide ion), SO_4^{2-} (sulphate ion)

Simple Ions — Mg^{2+} (Magnesium ion) , Na^{+} (Sodium ion), Cl^{-} (Chloride ion), Al^{3+} (Aluminium ion)

Compound Ions — NH^{4+} (Ammonium ion), CO_3^{2-}(Carbonate ion), SO_4^{2-} (Sulphate ion), OH^{-} (Hydroxide ion)

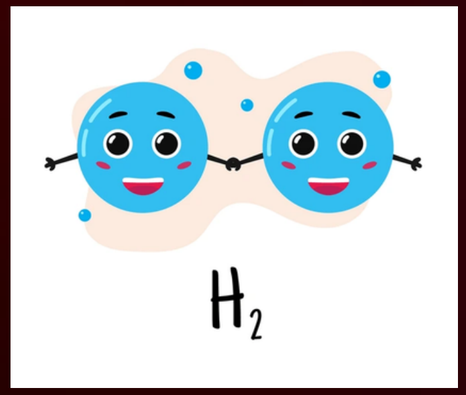
Names and symbols of some ions

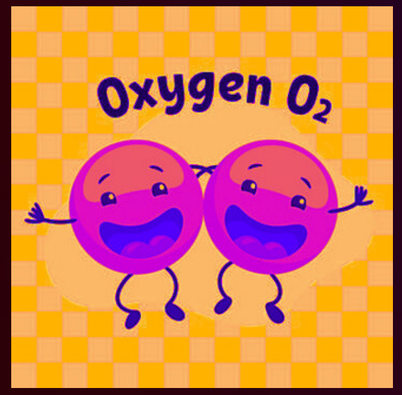
Vale-ncy	Name of ion	Symbol	Non-metallic element	Symbol	Polyatomic ions	Symbol
1.	Sodium	Na^+	Hydrogen	H^+	Ammonium	NH_4^+
	Potassium	K^+	Hydride	H^-	Hydroxide	OH^-
	Silver	Ag^+	Chloride	Cl^-	Nitrate	NO_3^-
	Copper (I)*	Cu^+	Bromide	Br^-	Hydrogen	
			Iodide	I^-	carbonate	HCO_3^-
2.	Magnesium	Mg^{2+}	Oxide	O^{2-}	Carbonate	CO_3^{2-}
	Calcium	Ca^{2+}	Sulphide	S^{2-}	Sulphite	SO_3^{2-}
	Zinc	Zn^{2+}			Sulphate	SO_4^{2-}
	Iron (II)*	Fe^{2+}				
	Copper (II)*	Cu^{2+}				
3.	Aluminium	Al^{3+}	Nitride	N^{3-}	Phosphate	PO_4^{3-}
	Iron (III)*	Fe^{3+}				

Molecules

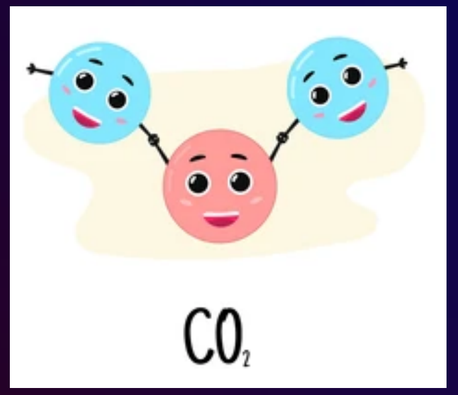
- A molecule is a group of two or more atoms chemically bonded together by attractive forces.
- It is the smallest particle of an element or compound that can exist independently and exhibits all the properties of that substance.
- Molecules can be formed by atoms of the same or different elements.

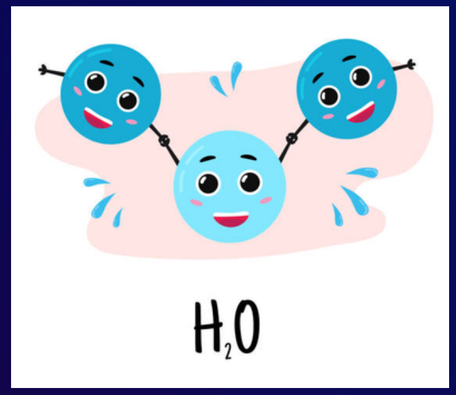
Molecules of Element





Molecules of Compound

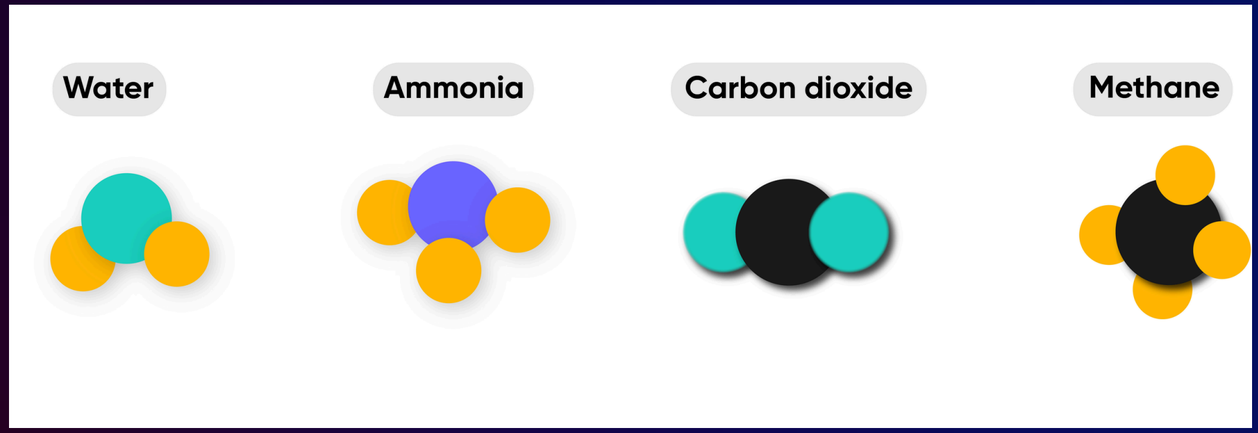




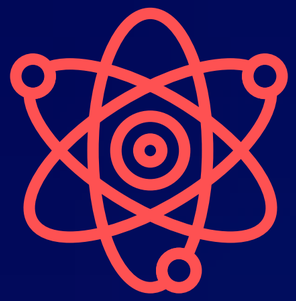
Molecules of a Compound

The molecules of a compound consist of two or more atoms of different elements combined together in a definite proportion by mass to form a compound that can exist freely.

Compound	Combining Elements	Ratio by Mass
Water (H_2O)	Hydrogen, Oxygen	1:8
Ammonia (NH_3)	Nitrogen, Hydrogen	14:3
Carbon dioxide (CO_2)	Carbon, Oxygen	3:8



Atomicity



- Atomicity referes to the number of atoms present in a single molecule of an element, substance or compound.

- **Monoatomic - Consists of one atom.**
- **Diatomic - Consists of two atoms.**
- **Triatomic - Consists of three atoms.**
- **Polyatomic - Consists of more than 3 atoms.**
- **Generally metals are monoatomic.**

Name of the Class	Atomicity	Examples
Monatomic	1	i) Noble gases: Helium (He), Argon (Ar), Neon (Ne), Krypton (Kr) ii) Metals: Sodium (Na), Magnesium (Mg), Aluminium (Al) iii) Carbon (C)
Diatomic	2	Hydrogen (H_2), Oxygen (O_2), Chlorine (Cl_2), Fluorine (F_2), Nitrogen (N_2)
Triatomic	3	Ozone (O_3)
Tetratomic / Polyatomic	4 or more	Phosphorus (P_4), Sulphur (S_8), Fullerenes (C_{60})

Molecules of a Compound

Compound	Combining Elements	Atomicity	Ratio by Mass
Hydrogen chloride (HCl)	Hydrogen, Chlorine	Diatomic	1 : 35.5
Water (H_2O)	Hydrogen, Oxygen	Triatomic	1 : 8
Ammonia (NH_3)	Hydrogen, Nitrogen	Tetratomic	1 : 4.67
Carbon dioxide (CO_2)	Carbon, Oxygen	Triatomic	1 : 2.67

Q. Give the atomicity of the following Molecules/ Compounds:

1. Oxygen
2. Phosphorus
3. Sulphur
4. Argon
5. Calcium Hydroxide ($Ca(OH)_2$)
6. Magnesium Bicarbonate ($Mg(HCO_3)_2$)
7. Sulphuric Acid (H_2SO_4)
8. Aluminium Sulphate ($Al_2(SO_4)_3$)
9. Magnesium Chloride ($MgCl_2$)

Molecular Mass

It is the sum of atomic masses of all the atoms in a molecule of that substance.

Example:

Molecular mass of H_2O = 2 X Atomic mass of Hydrogen + 1 X Atomic mass of Oxygen

So, **Molecular mass of H_2O** = 2 X 1 + 1 X 16 = 18 u

Molecular Mass

Molecular mass of $Al_2(SO_4)_3$ =

Molecular mass of $C_6H_{12}O_6$ =

Molecular mass of $CuSO_4.5H_2O$ =

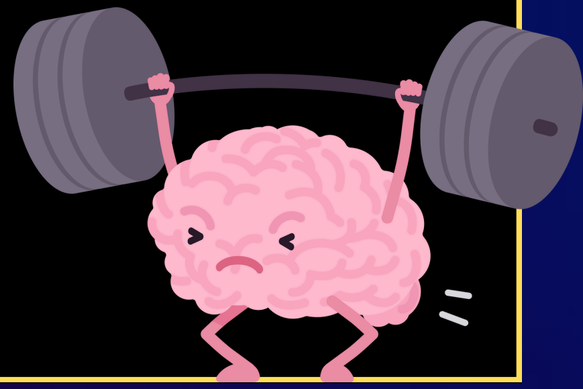
Q. Calculate the molecular mass of the following:

(a) Ammonia (NH_3)

(b) Nitric acid (HNO_3)

(c) Sodium chloride ($NaCl$)

(d) Calcium chloride ($CaCl_2$)



Formula Unit Mass

It is the sum of atomic mass of ions and atoms present in formula for a compound.

Example: In NaCl,

Na = 23 a.m.u.
Cl = 35.5 a.m.u.
So, Formula unit mass = **1 X 23 + 1 X 35.5 = 58.5 u**

Q. Calculate the formula unit mass of the following:

(a) Sodium chloride (NaCl)

(b) Calcium chloride ($CaCl_2$)

(c) Zinc oxide (ZnO)

Q. State the number of atoms present in each of the following chemical species:

A. CO_3^{2-}

B. PO_4^{3-}

C. P_2O_5

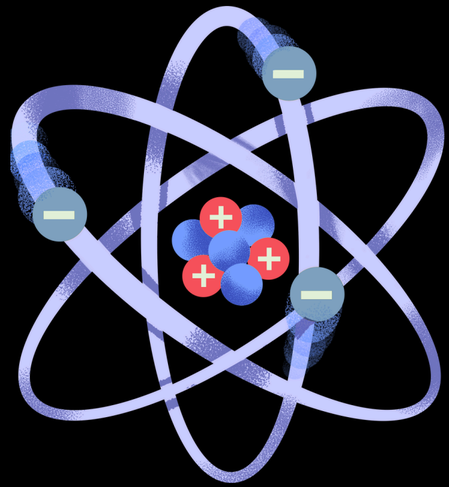
D. CO

Q. Write the cations and anions present (if any) in the following compounds:

(a) CH_3COONa

(b) NaCl

(c) NH_4NO_3



Why do Atoms Combine?

The atoms combine to attain a noble or inert gas electronic configuration, in order to complete their octet by formation of a chemical bond either by sharing, losing or gaining electrons.

Valency

- The combining capacity of an element is called its valency.
- It shows how many atoms of other elements one atom of an element can combine with.
- Valency equals the number of electrons gained, lost, or shared to achieve a noble gas configuration.
- Examples: Sodium (Na): Valency = 1, Magnesium (Mg): Valency = 2, Chlorine (Cl): Valency = 1

Chemical Formulae

It is the symbolic representation of the composition of a compound.

Characteristics of chemical formulae:

- The valencies or charges on ion must balance.
- When a compound is formed of metal and non-metal, symbol of metal comes first. E.g., CaO, NaCl, CuO.
- When polyatomic ions are used, the ions are enclosed in brackets before writing the number to show the ratio. E.g., $Ca(OH)_2$, $(NH_4)_2SO_4$

Rules for writing chemical formulae:

(i) We first write symbols of elements which form compound.

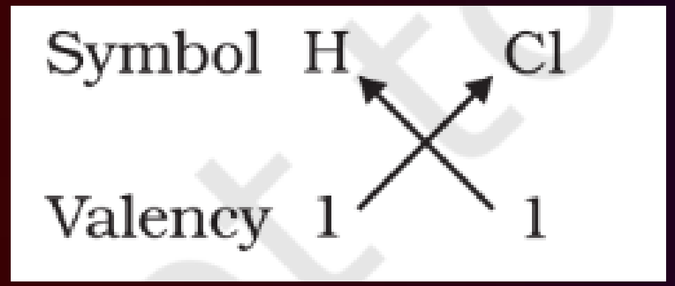
(ii) Below the symbol of each element, we should write their valency.

(iii) Now cross over the valencies of combining atoms.

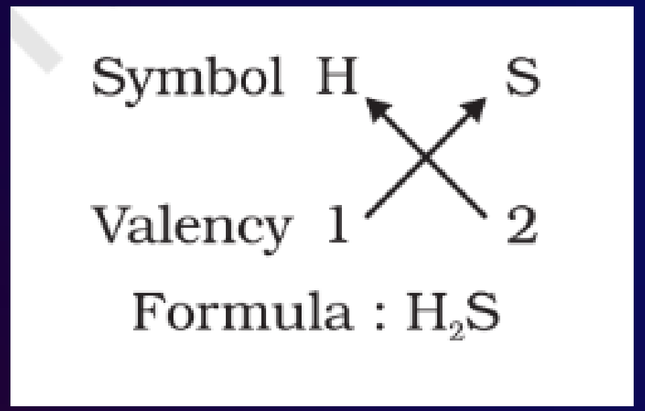
(iv) With first atom, we write the valency of second atom (as a subscript).

(v) With second atom, we write the valency of first atom (subscript).

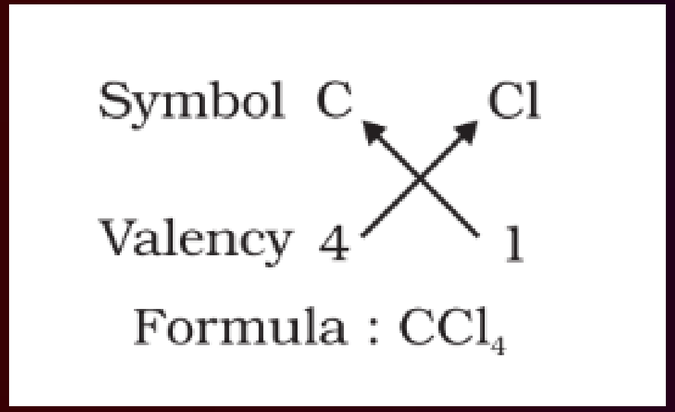
Formula of hydrogen chloride



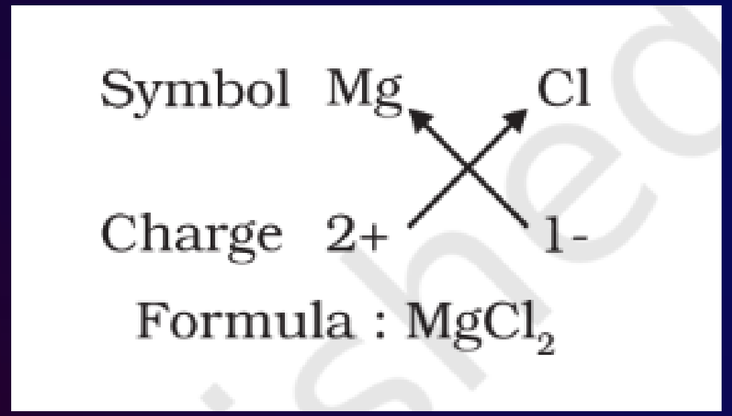
Formula of hydrogen sulphide



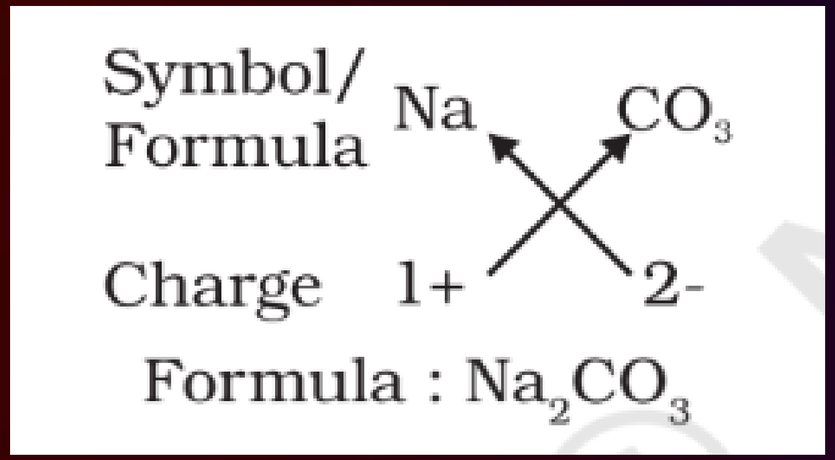
Formula of carbon tetrachloride



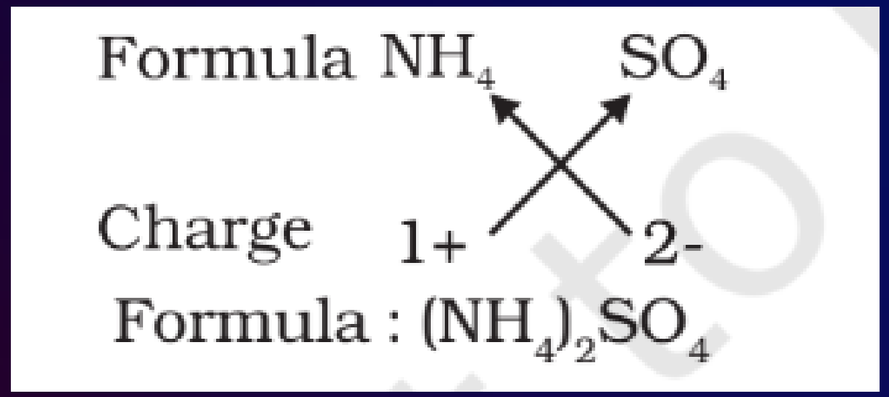
Formula of magnesium chloride



Formula of sodium carbonate

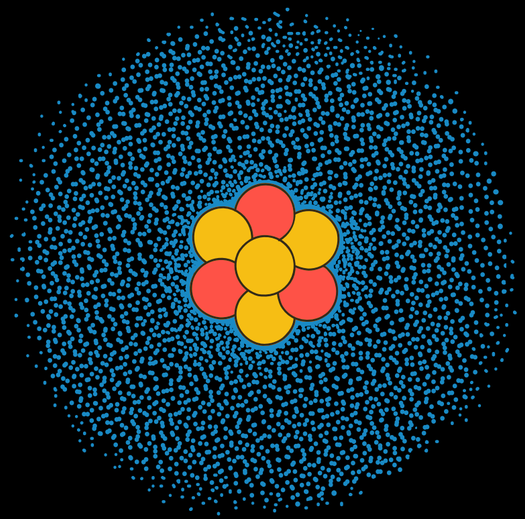


Formula of ammonium sulphate



Q. Write the chemical formula for the following compounds:

- (a) Copper (II) bromide
- (b) Ammonium carbonate
- (c) Aluminium oxide
- (d) Magnesium chloride
- (e) Sodium hydroxide
- (f) Zinc phosphate
- (g) Lead carbonate
- (h) Aluminium nitrate
- (i) Magnesium hydrogen carbonate
- (j) Sodium sulphate
- (k) Magnesium hydroxide



Mole Concept

A group of 6.022×10^{23} particles (atoms, molecules or ions) of a substance is called a mole of that substance.

1 mole of atoms = 6.022×10^{23} atoms

- 1 mole of molecules = 6.022×10^{23} molecules
  Example, 1 mole of oxygen = 6.022×10^{23} oxygen atoms

Note: 6.022×10^{23} is Avogadro Number (L).

- 1 mole of atoms of an element has a mass equal to gram atomic mass of the element.

Molar Mass

- The molar mass of a substance is the mass of 1 mole of that substance.
- It is equal to the 6.022×1023 atoms of that element/substance.

Examples:

(a) Atomic mass of hydrogen (H) is 1 u. Its molar mass is 1 g/mol.

(b) Atomic mass of nitrogen is 14 u. So, molar mass of nitrogen (N) is 14 g/mol.

(c) Molar mass of S_8 = Mass of S×8 = 32×8 = 256 g/mol

(d) Molar mass of HCl = Mass of H + Mass of Cl = 1 = 35.5 = 36.5 g/mol

Formulae

$$1.\ Mole(n) = \frac{Mass\ of\ given\ substance(m)}{Molar\ Mass(M)}$$

$$2.\ Mole(n) = \frac{Given\ number\ of\ particles(N)}{Avogadro's\ number(N_A)}$$

OR

$$3.\ Mole\ (n) = \frac{m}{M} = \frac{N}{N_A}$$

Question

ANSWERS

Q. Match the following:

Column-I	Column-II
(1) $NaHCO_3$	(A) Sodium bicarbonate
(2) Na_3PO_4	(B) Sodium carbonate
(3) Na_2CO_3	(C) Sodium chloride
(4) NaCl	(D) Sodium phosphate

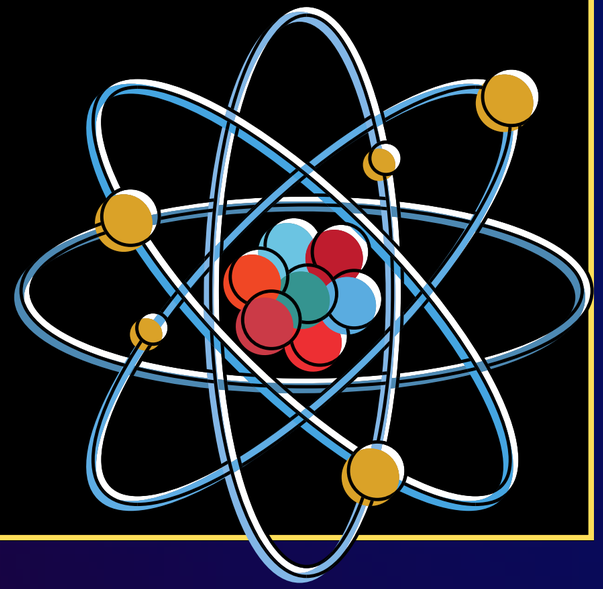
Options:

(a) 1-B, 2-D, 3-A, 4-C

(b) 1-C, 2-A, 3-D, 4-B

(c) 1-A, 2-D, 3-B, 4-C

(d) 1-A, 2-C, 3-D, 4-B



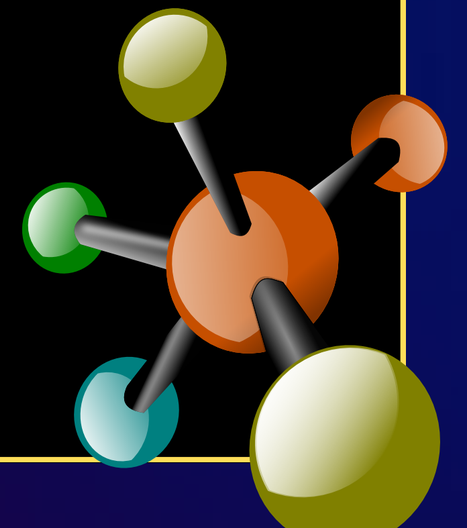
Q. (i) What is the ratio by mass of the combining elements in the following:

(a) H_2O

(b) CO_2

(c) NH_3

(ii) Calculate the ratio by mass of atoms present in a molecule of carbon dioxide (Given: C = 12 u, O = 16 u).



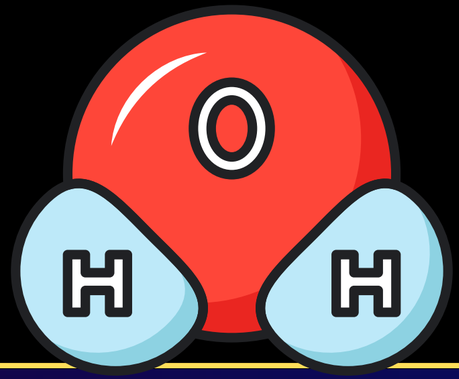
Q. Give the formulae of the compounds formed from the following sets of elements:

(a) Calcium and fluorine

(b) Hydrogen and sulphur

(c) Nitrogen and hydrogen

(d) Carbon and chlorine



Q. Which of the following symbols of elements are incorrect? Give their correct symbols.

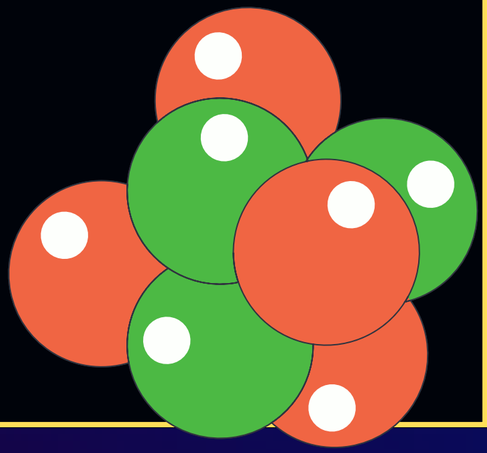
(a) Cobalt CO

(b) Carbon C

(c) Aluminium Al

(d) Helium He

(e) Sodium So



TOP 5 Questions

1. 10 g of silver nitrate solution is added to 10 g of sodium chloride solution. What change in mass do you expect after the reaction and why?
A. Increase in mass due to the formation of a precipitate.
B. Decrease in mass as gas is released.
C. No change in mass because the total mass of reactants equals the total mass of products.
D. Increase in mass because of the absorption of water.

TOP 5 Questions

2. Element ‘X’ has a valency of 2, and element ‘Y’ has a valency of 3. What are the correct formulas for their oxides?

A) XO, YO_3

B) X_2O_3, Y_2O_3

C) XO_2, Y_2O_3

D) X_2O, Y_3O_2

TOP 5 Questions

3. **Assertion:** Water molecules always contain hydrogen and oxygen in the ratio 1:8.
Reason: Water obeys the law of constant proportions irrespective of source and method of preparation. (Options:
a) Both assertion and reason are true, and reason is the correct explanation of assertion.
b) Both assertion and reason are true, but reason is not the correct explanation of assertion.
c) Assertion is true, but reason is false.
d) Assertion is false, but reason is true.)

TOP 5 Questions

4. Which statement correctly explains the difference between 2O, O_2, and O_3?

A) 2O represents two separate oxygen atoms, O_2 is a molecule of oxygen, and O_3 is a molecule of ozone.

B) 2O is a molecule of oxygen, O_2 represents ozone, and O_3 is two separate oxygen atoms.

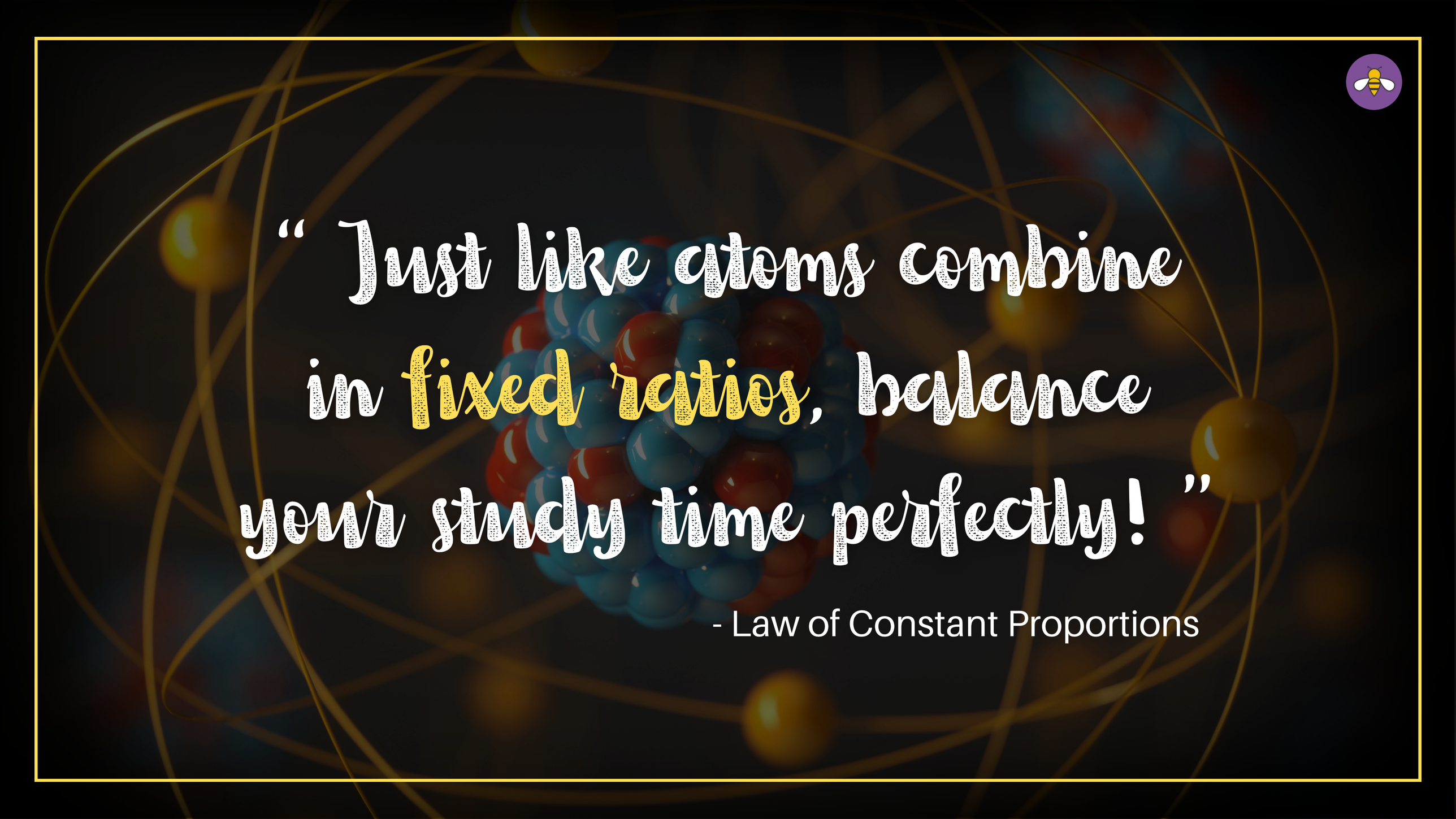
C) 2O and O_2 are both molecules of oxygen, while O_3 is a single oxygen atom.

D) 2O is a single oxygen atom, O_2 is ozone, and O_3 is a molecule of oxygen.

TOP 5 Questions

5. **Assertion:** The formula unit mass and molecular mass of a substance is defined as the sum of atomic masses of all the atoms present in the formula unit or molecular formula of a compound.
Reason: There is only one difference between molecular mass and formula unit mass which is the molecular mass is used for molecular compounds i.e., covalent compounds and formula unit mass is used for ionic compounds. However, they have same numerical values

A. Both (A) and (R) are true and reason (R) is the correct explanation of assertion (A).
B. Both (A) and (R) are true and reason (R) is not the correct explanation of assertion (A).
C. (A) is true but (R) is false
D. (A) is false but (R) is true


" Just like atoms combine
in fixed ratios, balance
your study time perfectly! "
- Law of Constant Proportions