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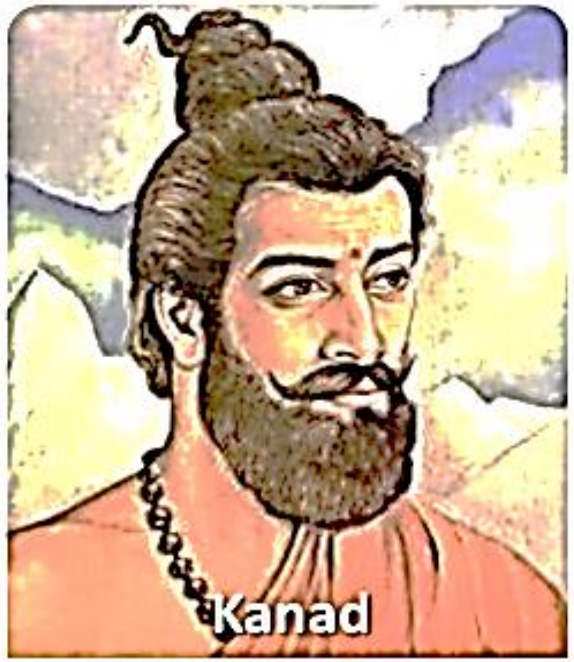
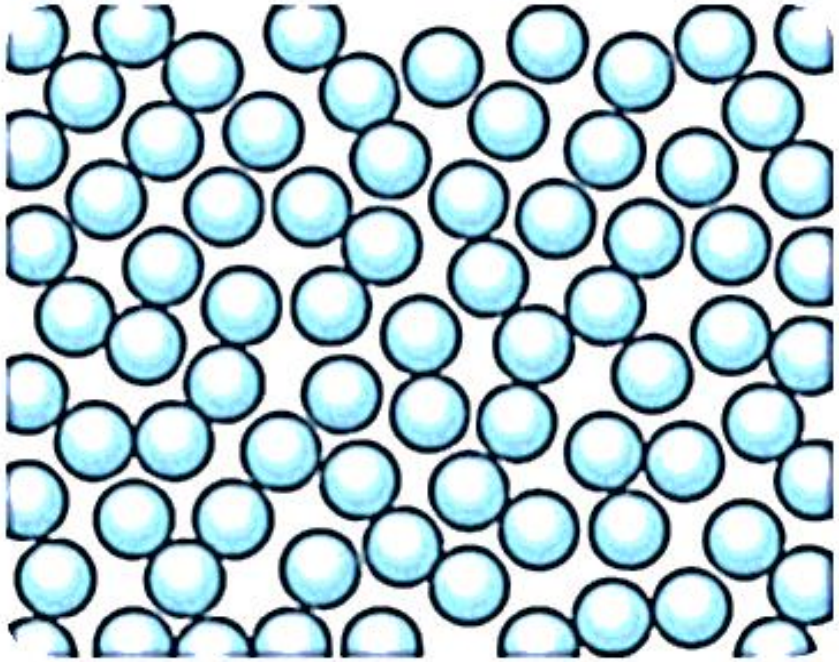
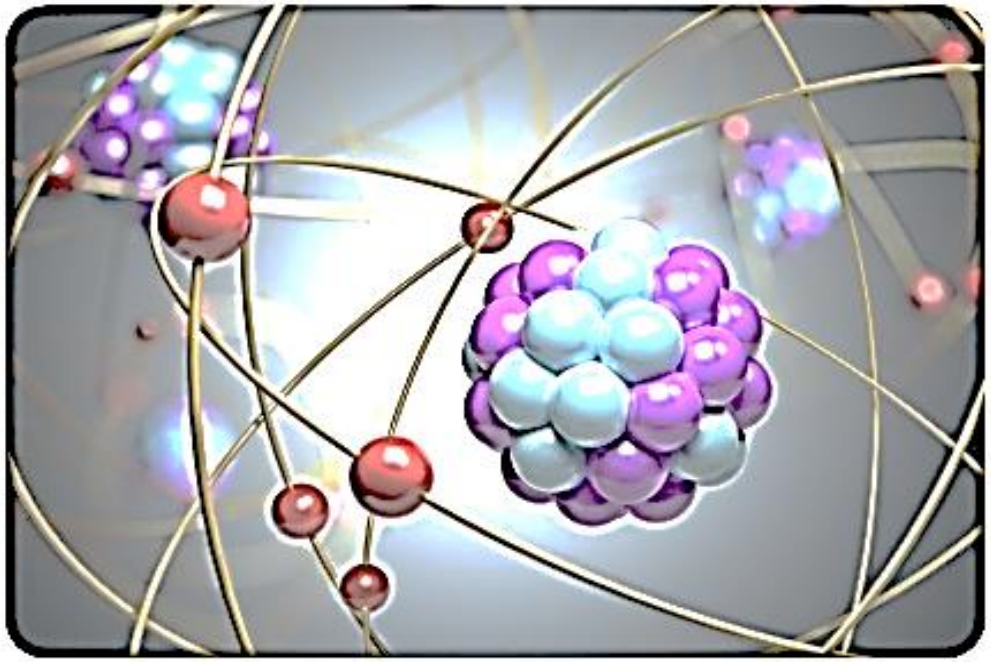
INTRODUCTION

- The idea of matter's divisibility was developed in India around 500 BC.
- Maharishi **Kanad** postulated that dividing matter yields smallest particles. He called them ***Parmanu.***
- **Pakudha Katyayama,** elaborated this doctrine stating these particles combine to form various matters.

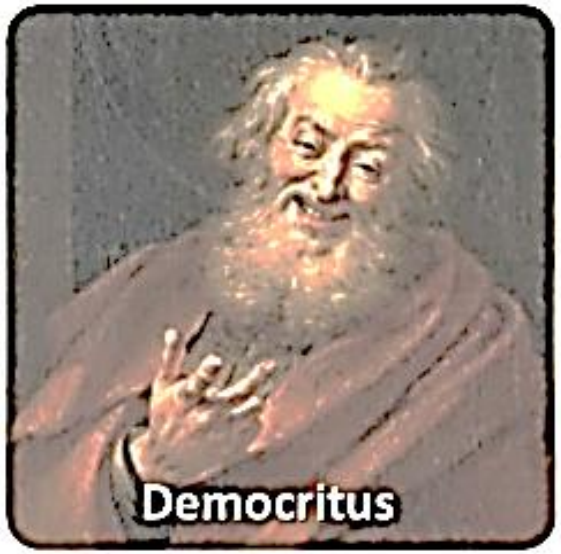


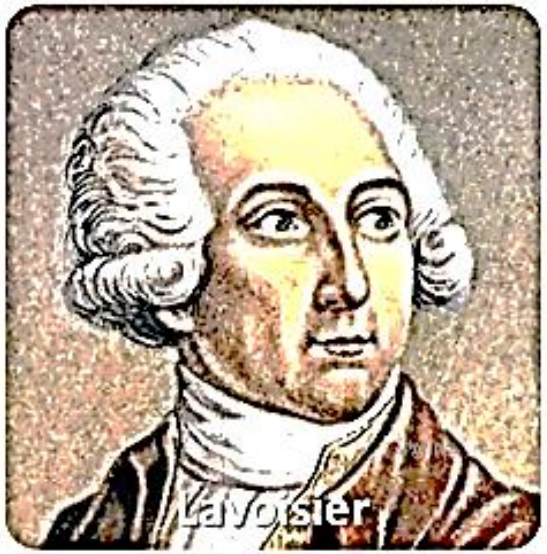


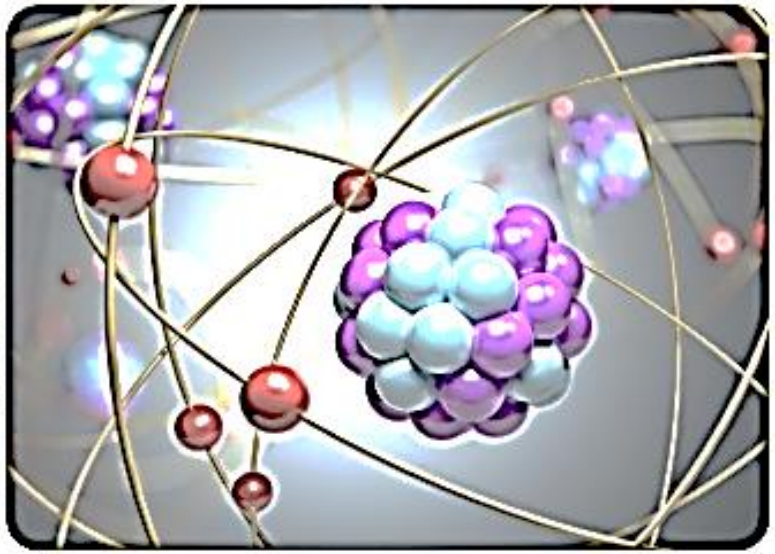


INTRODUCTION

- Greek philosophers **Democritus** & **Leucippus** suggested that matter can be divided into indivisible particles. **Democritus** called them **atoms** (meaning indivisible).
- These ideas were philosophical, with little experimental evidence.
- By the end of the 18th century, scientists distinguished between elements and compounds.
- **Antoine L. Lavoisier** laid the foundation of chemical sciences by establishing two important laws of chemical combination.







LAWS OF CHEMICAL COMBINATION

Proposed by **Lavoisier** and **Joseph L. Proust.**

Laws of chemical combination

- LAW OF CONSERVATION OF MASS
- LAW OF CONSTANT PROPORTIONS

Lavoisier

Joseph L. Proust

LAWS OF CHEMICAL COMBINATION

LAW OF CONSERVATION OF MASS

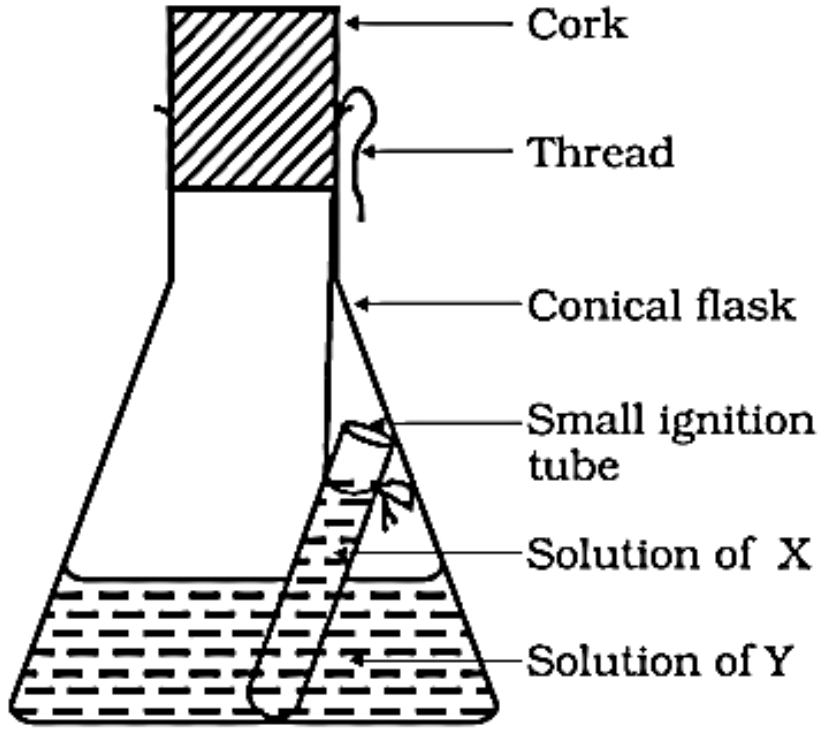
It states that ***mass can neither be created nor destroyed in a chemical reaction.***

Activity

- Take one of the following sets, X and Y of chemicals:

X	*Y*
(i) copper sulphate	sodium carbonate
(ii) barium chloride	sodium sulphate
(iii) lead nitrate	sodium chloride

- Prepare separately a 5% solution of one pair of substances (X and Y) each in 10 mL of water.
- Take some solution of Y in a conical flask and some solution of X in an ignition tube.



Ignition tube containing solution of X, dipped in a conical flask containing solution of Y

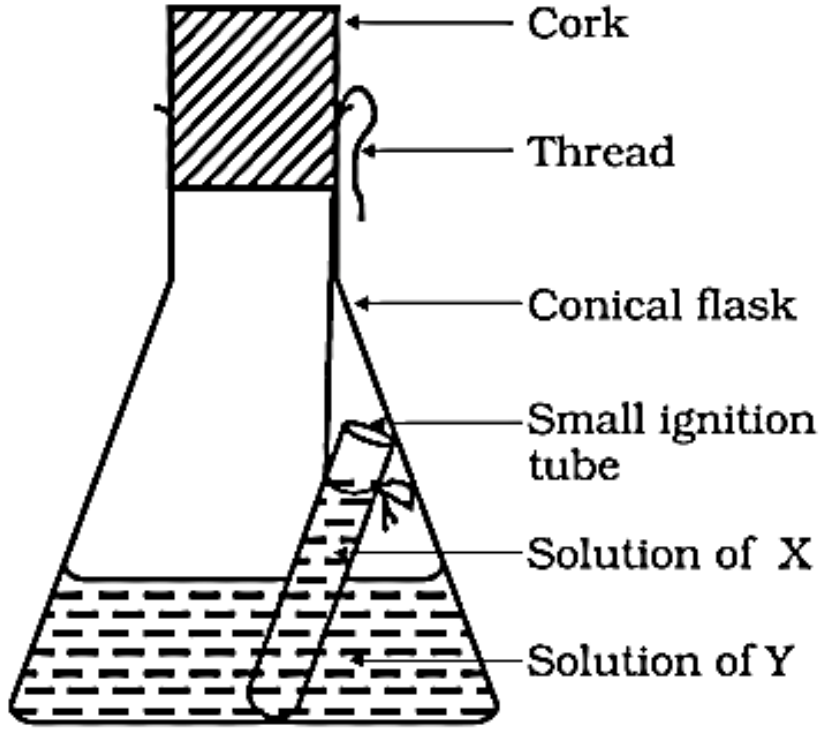
LAWS OF CHEMICAL COMBINATION

LAW OF CONSERVATION OF MASS

It states that ***mass can neither be created nor destroyed in a chemical reaction.***

Activity

- Hang the ignition tube in the flask carefully; ensuring the solutions do not mix. Put a cork on the flask.
- Weigh the flask with its contents.
- Tilt and swirl the flask to mix the solutions X and Y. A chemical reaction occurs in the reaction flask.
- The cork prevents the escape of gases and ensures accurate mass measurement.
- Weigh the flask again. It shows that mass of the flask and its contents do not change.



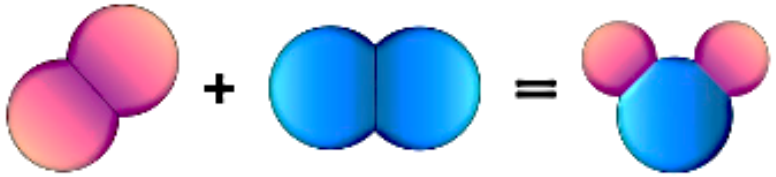
Ignition tube containing solution of X, dipped in a conical flask containing solution of Y

LAWS OF CHEMICAL COMBINATION

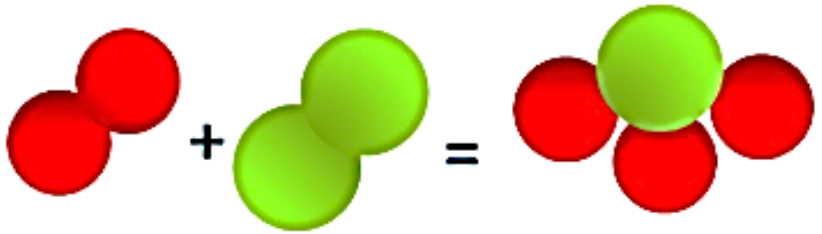
LAW OF CONSTANT PROPORTIONS

- **Lavoisier** and others noted that many compounds are made of elements in fixed proportions. E.g.,
  - ❖ In water, the ratio of the mass of hydrogen to oxygen is always 1:8, whatever the source of water. Decomposition of 9 g water yields 1 g hydrogen and 8 g oxygen.
  - ❖ In ammonia, the mass ratio of nitrogen to hydrogen is 14:3, regardless of its method or source of preparation.
- This observation led to the **Law of constant proportions (Law of definite proportions)** stated by **Proust:**

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



Hydrogen	Oxygen	Water
H_2	O_2	H_2O
1 g	8 g	9 g

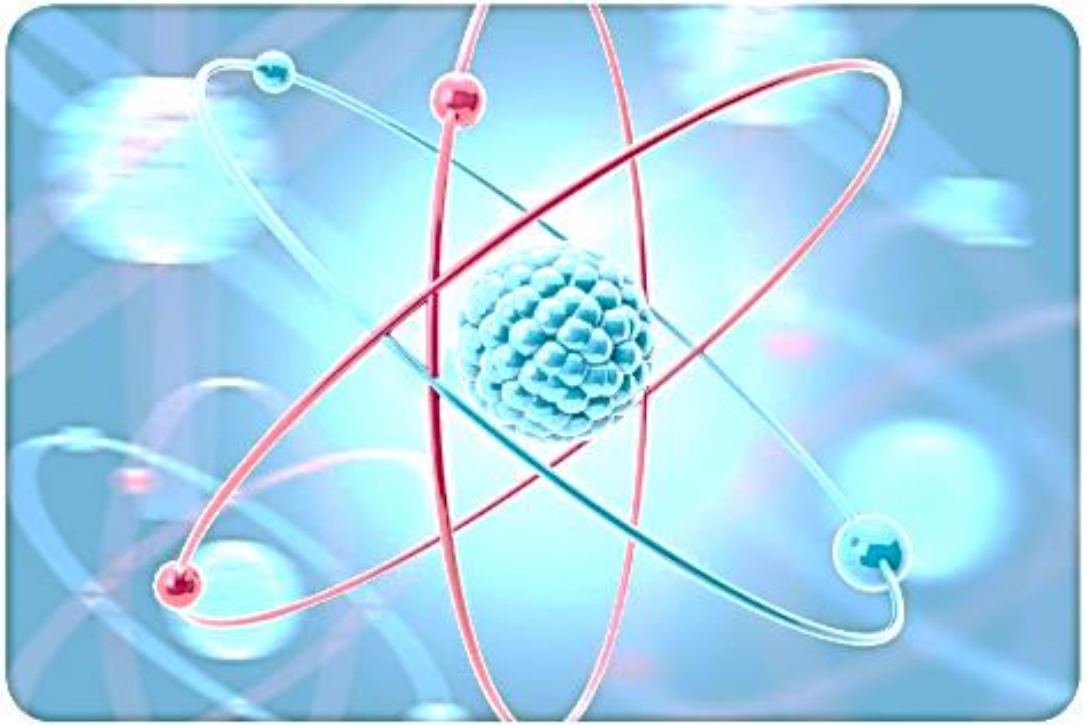


H_2	N_2	NH_3
3 g	14 g	17 g

LAWS OF CHEMICAL COMBINATION

LAW OF CONSTANT PROPORTIONS

- **John Dalton** proposed **Atomic Theory** (1808) based on the laws of chemical combination.
- It provided an explanation for the Law of conservation of mass and the Law of definite proportions.
- He said that the **smallest particles** of matter are **atoms.**



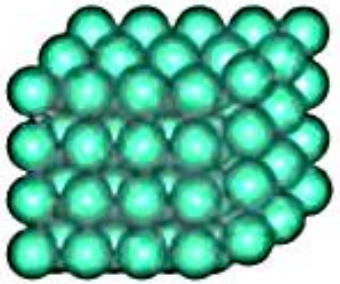
LAWS OF CHEMICAL COMBINATION

LAW OF CONSTANT PROPORTIONS

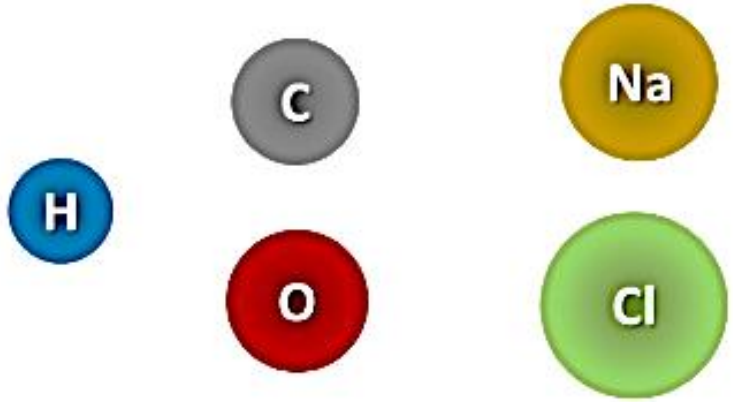
Postulates of Dalton's atomic theory

i. All matter is made of very tiny particles called **atoms,** which participate in chemical reactions.
ii. Atoms are **indivisible** 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.

Atom



Matter

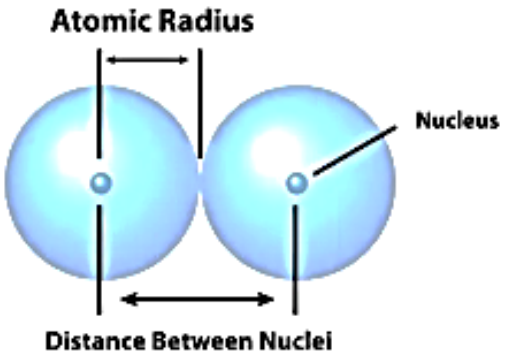


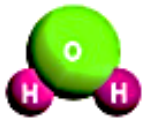
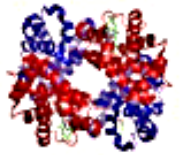
WHAT IS AN ATOM?

- The building blocks of all matter are **atoms.**
- Atoms are very small. Even if millions of atoms were stacked, it would be only the thickness of a sheet of paper.
- **Atomic radius** is measured in **nanometres.**

$1/10^9$ m = 1 nm

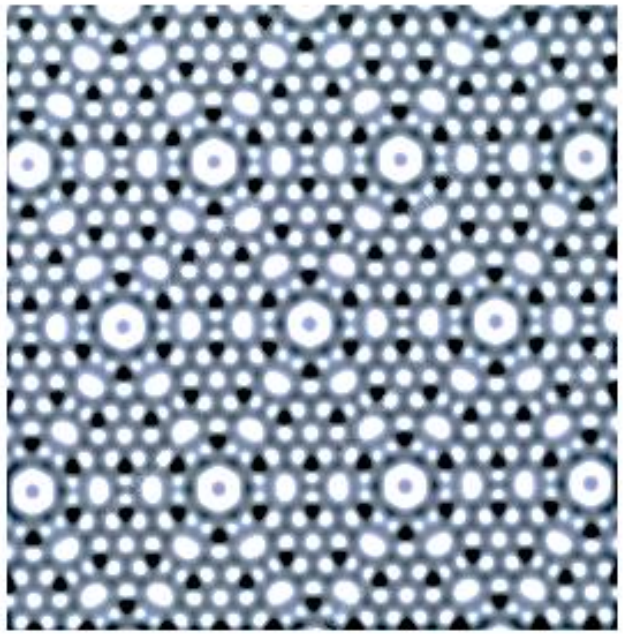
1 m = 10^9 nm

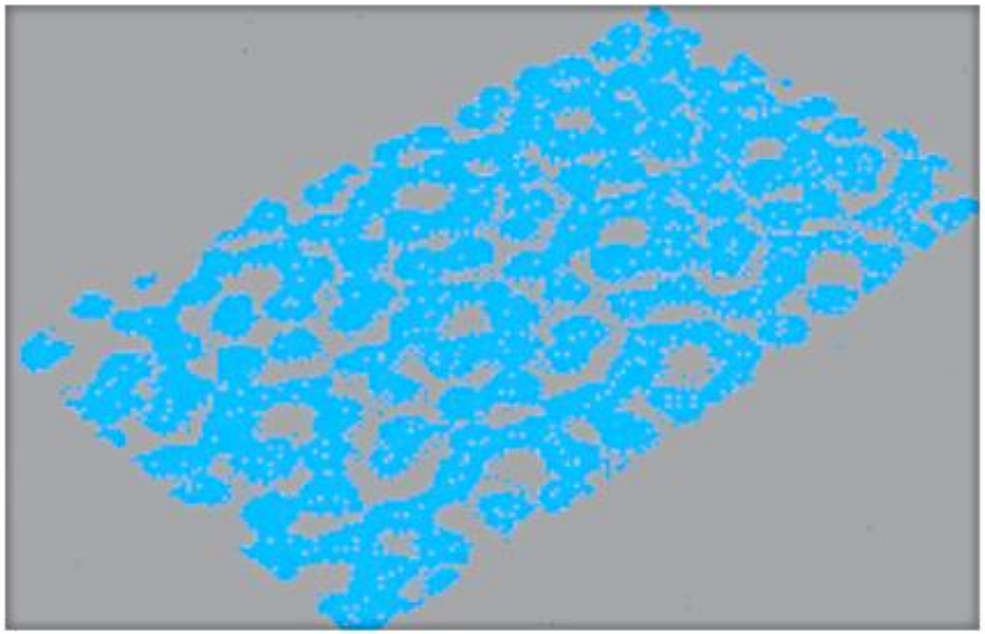


Relative Sizes	
Radii (in m)	**Example**
10^{-10}	Hydrogen atom 
10^{-9}	Water molecule 
10^{-8}	Haemoglobin molecule 
10^{-4}	Grain of sand 
10^{-3}	Ant 
10^{-1}	Apple 

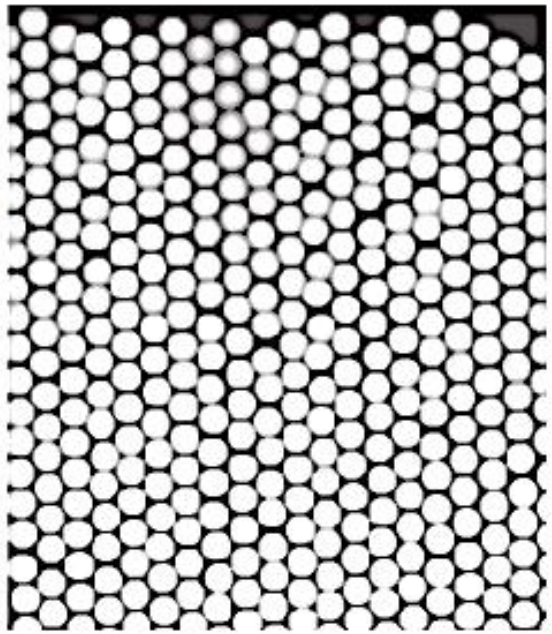
WHAT IS AN ATOM?

It is possible to produce magnified images of surfaces of elements showing atoms.





An image of the surface of silicon

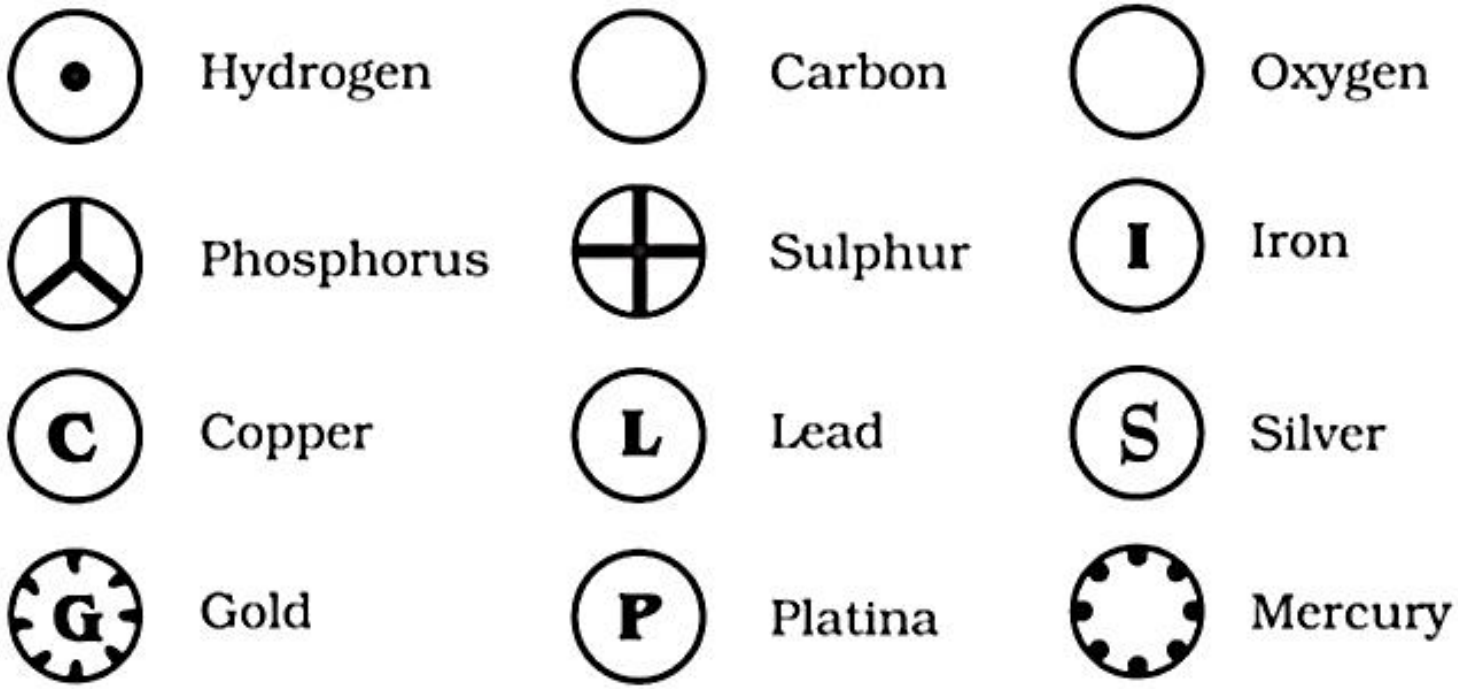


Atomic surface of pyrolytic graphite

WHAT IS AN ATOM?

WHAT ARE THE MODERN-DAY SYMBOLS OF ATOMS OF DIFFERENT ELEMENTS?

Dalton was the first scientist to use symbols for elements with specific meaning, representing one atom of that element. Some symbols are given below:



WHAT IS AN ATOM?

WHAT ARE THE MODERN-DAY SYMBOLS OF ATOMS OF DIFFERENT ELEMENTS?

- **Berzelius** suggested using one or two letters from the element's name as its symbol.
- Initially, element names were derived from **locations** where they were first discovered (e.g., copper from Cyprus) or from **colours** (e.g., gold from the English word for yellow).
- **International Union of Pure and Applied Chemistry (IUPAC)** approves element names, symbols, and units. Symbols often use the first one or two letters of the element's name in English.


Berzelius


A copper mine in Cyprus

Cu Cuprum (Copper)

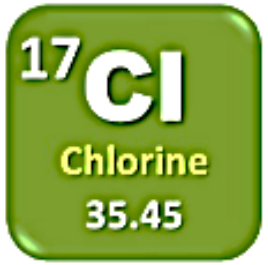
Au Aurum (Gold)

WHAT IS AN ATOM?

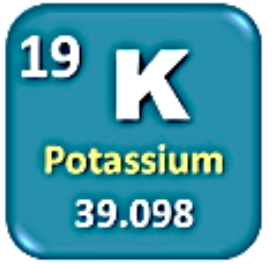
WHAT ARE THE MODERN-DAY SYMBOLS OF ATOMS OF DIFFERENT ELEMENTS?

- The **first letter** of a symbol is always written as a **capital letter** and the **second letter** as a **small letter.** E.g., hydrogen - H, aluminium - Al, cobalt - Co.

- Some symbols are formed from first letter and a letter appearing later in the name. E.g., chlorine - Cl, zinc - Zn.



- Other symbols are derived from Latin, German, or Greek names. E.g., iron - Fe from Latin *ferrum*, sodium - Na from *natrium*, potassium - K from *kalium*.



WHAT IS AN ATOM?

WHAT ARE THE MODERN-DAY SYMBOLS OF ATOMS OF DIFFERENT ELEMENTS?

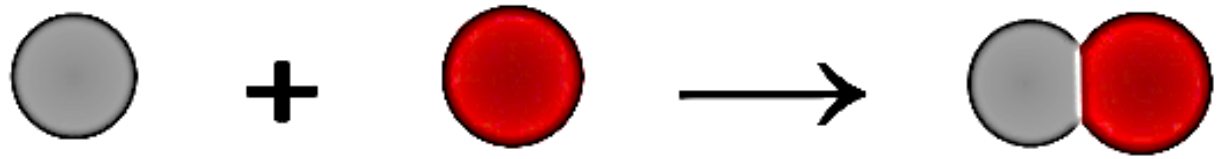
Symbols for some elements

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

WHAT IS AN ATOM?

ATOMIC MASS

- **Dalton's atomic mass concept** remarkably explained the **law of constant proportions.** It prompted scientists to measure atomic masses.
- Measuring the mass of an individual atom is difficult, so **relative atomic masses** are determined using the laws of chemical combinations and the compounds formed.
- E.g., **carbon monoxide (CO)** is formed by combining **3 g of carbon** with **4 g of oxygen.** i.e., carbon combines with 4/3 times its mass of oxygen.

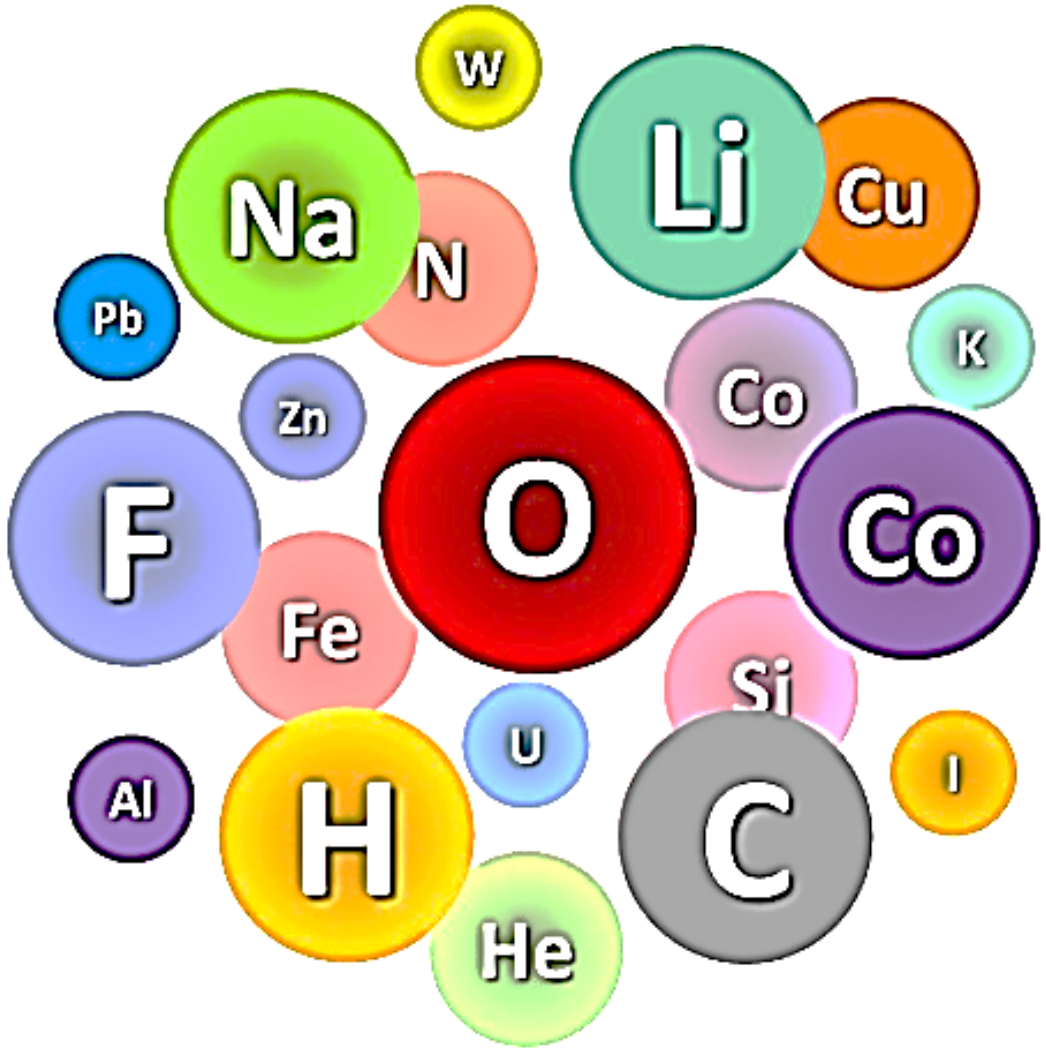


Carbon (C) 3 g + Oxygen (O) 4 g → Carbon monoxide

WHAT IS AN ATOM?

ATOMIC MASS

- If the **atomic mass unit (amu** or **unified mass unit, u** according to **IUPAC)** is defined as the mass of one carbon atom, atomic mass of carbon will be 1.0 u and oxygen 1.33 u.
- However, using whole or near-whole numbers is more convenient. To simplify, scientists initially used 1/16 of the mass of an oxygen atom as the atomic mass unit due to 2 reasons:
  - Oxygen reacts with a large number of elements.
  - It gives whole-number masses for most elements.



WHAT IS AN ATOM?

ATOMIC MASS

- In 1961, **carbon-12 isotope** was chosen as the standard reference for measuring atomic masses.
- It defines one **atomic mass unit** as a ***mass unit equal to exactly 1/12th the mass of one atom of carbon-12.***
- Relative atomic masses of all elements are based on this standard.
- It can be understood by an analogy:

Watermelon

12 pieces

1/12 of watermelon

A watermelon is cut into 12 equal pieces, defining its mass as 12 units **(fruit mass units, fmu).** This unit helps compare the mass of other fruits relative to one piece (relative fmu).

how the fruit seller can weigh the fruits

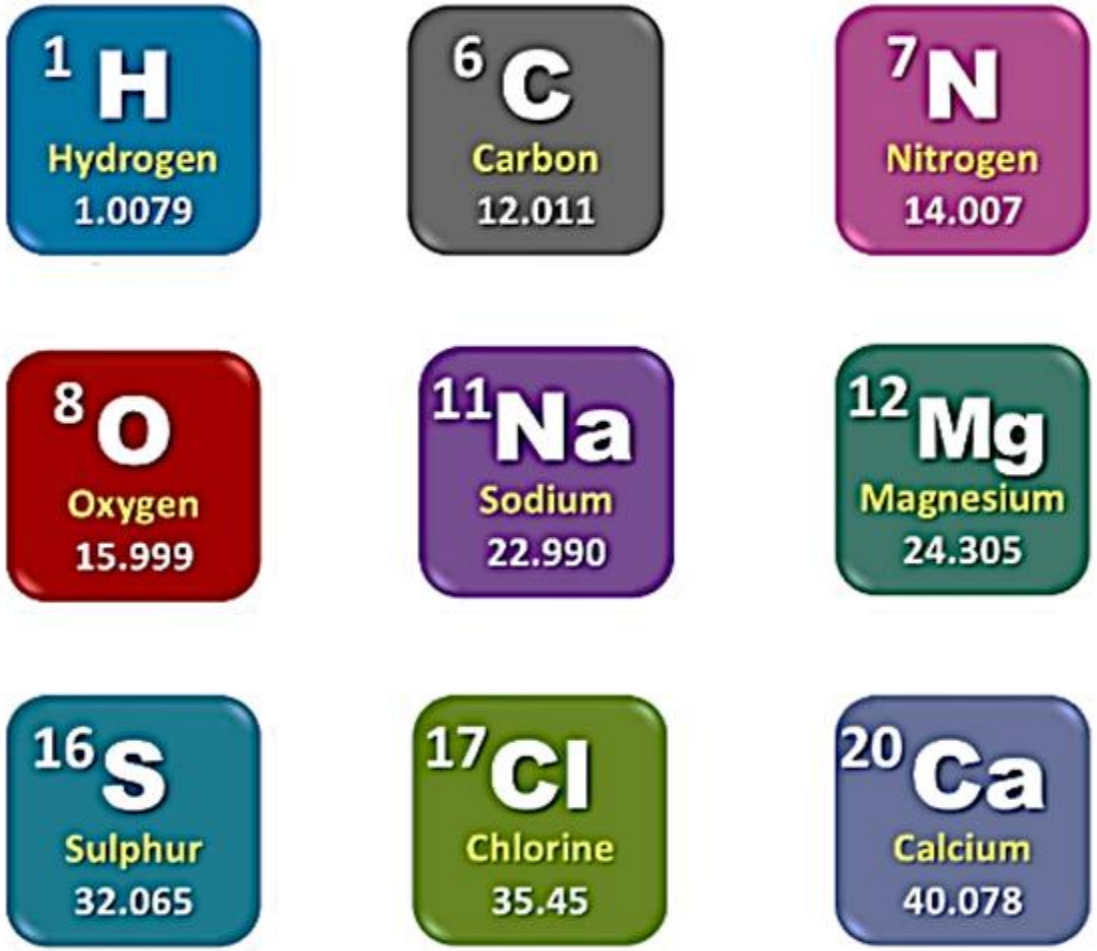
- Similarly, the relative atomic mass of the atom of an element is defined as *the average mass of the atom, as compared to 1/12th the mass of one carbon-12 atom.*

WHAT IS AN ATOM?

ATOMIC MASS

Atomic masses of a few elements

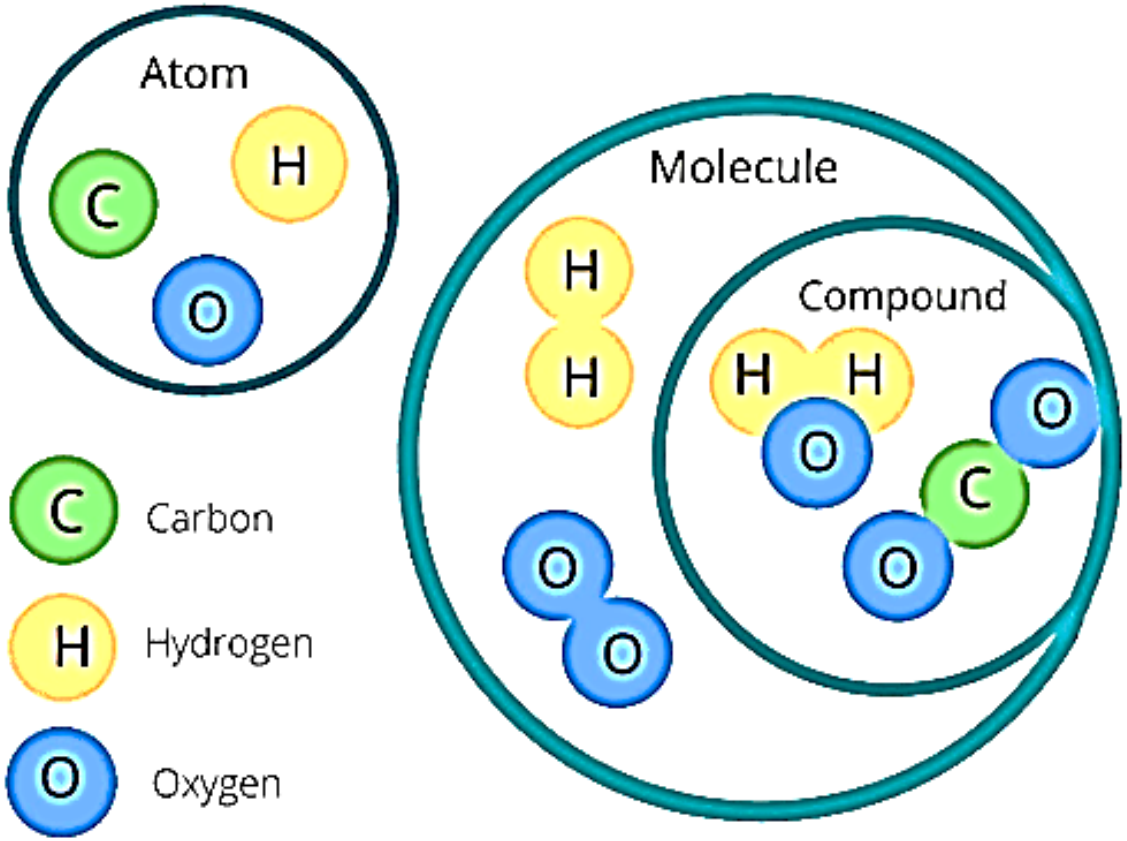
Element	Atomic Mass (u)
Hydrogen	1
Carbon	12
Nitrogen	14
Oxygen	16
Sodium	23
Magnesium	24
Sulphur	32
Chlorine	35.5
Calcium	40

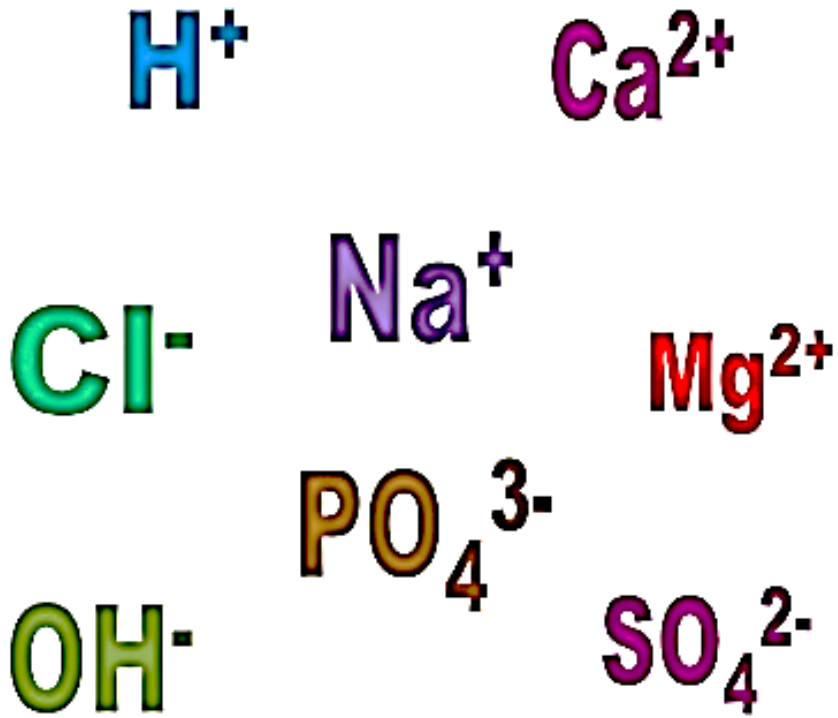


WHAT IS AN ATOM?

HOW DO ATOMS EXIST?

- Atoms of most elements **cannot exist independently.**
- Atoms form **molecules** and **ions.** They aggregate in large numbers to form the **matter.**

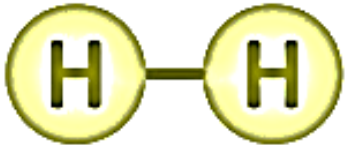




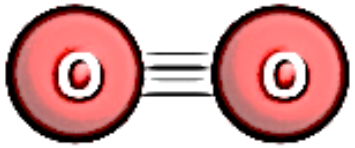
Some ionic forms

WHAT IS A MOLECULE?

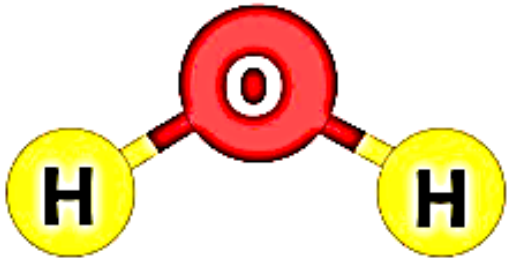
- A **molecule** is a group of two or more atoms chemically bonded together by attractive forces.
- It is defined as ***the smallest particle of an element or a compound that can exist independently and shows all the properties of that substance.***
- Molecules can consist of atoms of the same element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



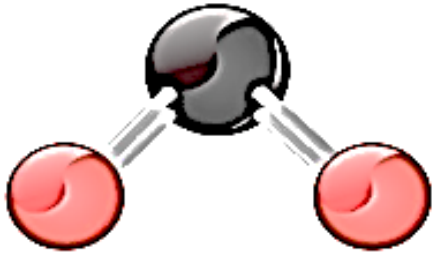
Hydrogen molecule (H_2)



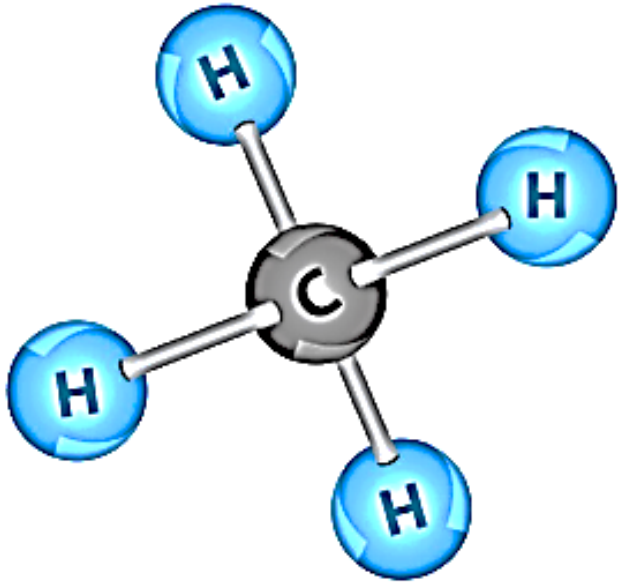
Oxygen molecule (O_2)



Water molecule (H_2O)



Carbon dioxide molecule (CO_2)

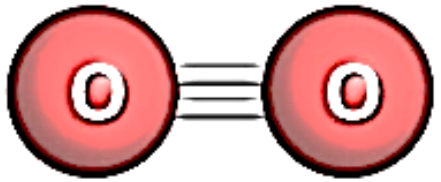


Methane molecule (CH_4)

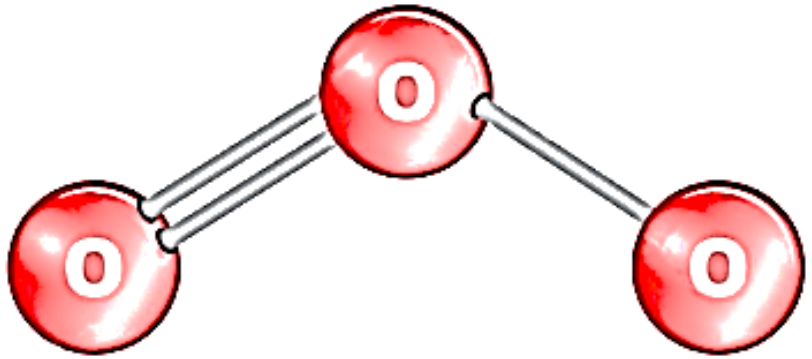
WHAT IS A MOLECULE?

MOLECULES OF ELEMENTS

- Molecules of an element are made up of the same type of atoms.
- Some elements, like argon (Ar) and helium (He), are made up of only one atom. Molecules of most of the nonmetals have more than one atom. E.g.,
  - ❖ **Oxygen (O_2)** is a **diatomic molecule,** consisting of two oxygen atoms.
  - ❖ **Ozone (O_3)** is a molecule with three oxygen atoms.
- Number of atoms in a molecule is called its **atomicity.**
- Metals & elements like carbon consist of a large, indefinite number of atoms bonded together.



Oxygen molecule (O_2)

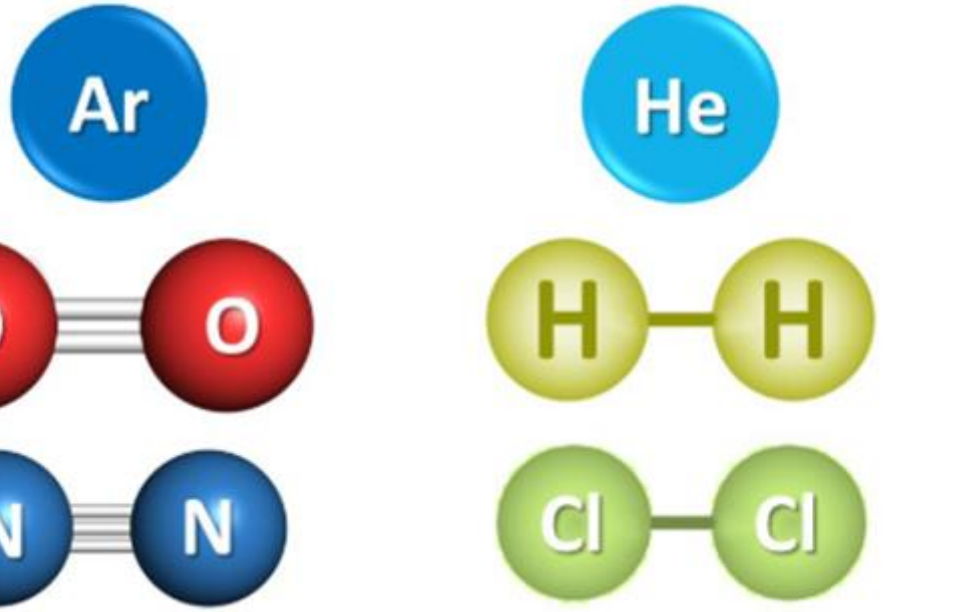


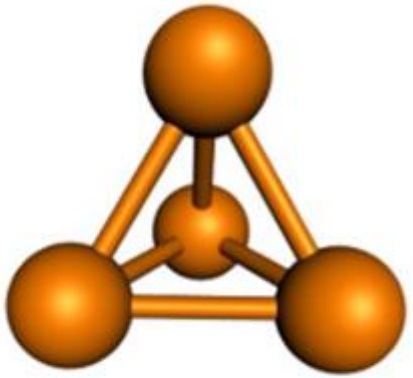
Ozone molecule (O_3)

WHAT IS A MOLECULE?

MOLECULES OF ELEMENTS

Atomicity of some elements		
Type of Element	**Name**	**Atomicity**
Non-Metal	Argon	Monoatomic
	Helium	Monoatomic
	Oxygen	Diatomic
	Hydrogen	Diatomic
	Nitrogen	Diatomic
	Chlorine	Diatomic
	Phosphorus	Tetra-atomic
	Sulphur	Poly-atomic





Phosphorus molecule

Sulphur molecule

WHAT IS A MOLECULE?

MOLECULES OF COMPOUNDS

Atoms of different elements join together in definite proportions to form molecules of compounds. E.g.,

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

The ratio by number of atoms for a water molecule is H:O = 2:1.

It can be found as:

Element	Ratio by mass	Atomic mass (u)	Mass ratio/ atomic mass	Simplest ratio
H	1	1	$\frac{1}{1} = 1$	2
O	8	16	$\frac{8}{16} = \frac{1}{2}$	1

WHAT IS A MOLECULE?

WHAT IS AN ION?

- Compounds composed of metals and nonmetals contain charged species called **ions.**
- Ions may consist of a single charged atom or a group of atoms that have a net charge on them.
- A negatively charged ion is called an **anion** and the positively charged ion, a **cation.** E.g., In NaCl, **sodium ions (Na^+)** are cations and **chloride ions (Cl^-)** are anions.
- A group of atoms carrying a charge is known as a **polyatomic ion.**

Some ionic compounds

Ionic Compound	Constituting Elements	Ratio by Mass
Calcium oxide	Ca and O	5:2
Magnesium sulphide	Mg and S	3:4
Sodium chloride	Na and Cl	23:35.5

WRITING CHEMICAL FORMULAE

- The chemical formula of a compound is a **symbolic representation of its composition.**
- The combining power (or capacity) of an element is known as its **valency.** It is used to find out how the atoms of an element will combine with the atom(s) of another element to form a chemical compound.
- Valency can be imagined as the "arms" of an atom. E.g., if an octopus (O) with eight arms holds four humans (H), each with two arms, all arms would be locked. This can be represented as the formula OH_4. The subscript 4 indicates the number of humans held.

H_2O CO_2 CH_4 FeS NH_3 $CaCl_2$ H_2SO_4 NaCl CuO NaOH

WRITING CHEMICAL FORMULAE

Names and symbols of some ions

Valency	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 carbonate	HCO_3^-
			Iodide	I^-		
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+}				

** Some elements show more than one valency. A Roman numeral shows their valency in a bracket.*

WRITING CHEMICAL FORMULAE

Rules of writing a chemical formula:

- The valencies or charges on the ion must balance.
- For compounds consisting of a metal and a non-metal, the metal's name or symbol is written first. E.g., calcium oxide (CaO), sodium chloride (NaCl), iron sulphide (FeS), copper oxide (CuO), etc.
- In compounds formed with polyatomic ions, the number of ions is indicated by enclosing the formula of ion in a bracket and number of ions outside the bracket. E.g., $Mg(OH)_2$. If only one polyatomic ion is present, no bracket is needed. E.g., NaOH.

H_2O CO_2 CH_4 FeS NH_3 $CaCl_2$ H_2SO_4 NaCl CuO NaOH $Mg(OH)_2$ CaO

WRITING CHEMICAL FORMULAE

FORMULAE OF SIMPLE COMPOUNDS

The simplest compounds made up of two different elements are called **binary compounds.**

Method of writing the chemical formulae for some compounds

Formula of hydrogen chloride	Symbol H Cl Valency 1 1	Formula: HCl
Formula of carbon tetrachloride	Symbol C Cl Valency 4 1	Formula: CCl_4
Formula of hydrogen sulphide	Symbol H S Valency 1 2	Formula: H_2S

WRITING CHEMICAL FORMULAE

FORMULAE OF SIMPLE COMPOUNDS

The **positive and negative charges** balance each other and the overall structure is **neutral.**

Formula of magnesium chloride	Symbol Mg Cl Valency 2+ 1-	Formula: $MgCl_2$

Formula of aluminium oxide	Symbol Al O Charge 3+ 2-	Formula: Al_2O_3

Formula of sodium nitrate	Symbol Na NO_3 Charge 1+ 1-	Formula: $NaNO_3$

WRITING CHEMICAL FORMULAE

FORMULAE OF SIMPLE COMPOUNDS

Formula of calcium oxide	Symbol Ca O Charge 2+ 2-	Formula: CaO

Here, the valencies of two elements are same. Instead of Ca_2O_2, it is simplified as CaO.

Formula of calcium hydroxide	Symbol Ca OH Charge 2+ 1-	Formula: $Ca(OH)_2$

Formula of calcium hydroxide is $Ca(OH)_2$ and not $CaOH_2$. It is due to the presence of more two polyatomic ions (OH). It indicates that there are two atoms each of oxygen and hydrogen in calcium hydroxide.

Formula of sodium carbonate	Symbol Na CO_3 Charge 1+ 2-	Formula: Na_2CO_3

Formula of ammonium sulphate	Symbol NH_4 SO_4 Charge 1+ 2-	Formula: $(NH_4)_2SO_4$

MOLECULAR MASS

- It is the sum of the atomic masses of all the atoms in a molecule of the substance.
- It is expressed as the relative mass of a molecule in **atomic mass units (u).**

Example

a) Calculate the relative molecular mass of water (H_2O).

b) Calculate the molecular mass of HNO_3.

Solution:

a) Atomic mass of hydrogen = 1u, oxygen = 16 u

So the molecular mass of water, which contains two atoms of hydrogen and one atom of oxygen is

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

b) The molecular mass of HNO_3 = the atomic mass of H + the atomic mass of N + 3 × the atomic mass of O

$= 1 + 14 + 48 =$ **63 u**

MOLECULAR MASS

FORMULA UNIT MASS

- It is the **sum of the atomic masses** of all atoms in a formula unit of a compound.
- It is calculated similarly to molecular mass. The difference is that it is used for compounds with ions as constituent particles. E.g.,

Formula unit mass of sodium chloride (NaCl)

Atomic mass of Na + atomic mass of Cl

$1 \times 23 + 1 \times 35.5 =$ **58.5 u**

Formula unit mass of calcium chloride $CaCl_2$

Atomic mass of Ca + (2 × atomic mass of Cl)

$= 40 + 2 \times 35.5 = 40 + 71 =$ **111 u.**


thank you