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CHARACTERISTICS OF GASES, ATOMS AND MOLECULES

Around 500 BC, an Indian Philosopher Maharishi Kanad, first time postulated the concept of indivisible part of matter and named it 'pramanu.'

In 1808, John Dalton used the term 'atom' and postulated the atomic theory to the study of matter.

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

Law of Conservation of Mass

- During a chemical reaction, the sum of the masses of the reactants and products remains unchanged. This is known as the Law of Conservation of Mass

Law of Constant Proportions

- This law was stated by Proust as "In a chemical substance the elements are always present in definite proportions by mass". This law is also known as the Law of Definite Proportions.

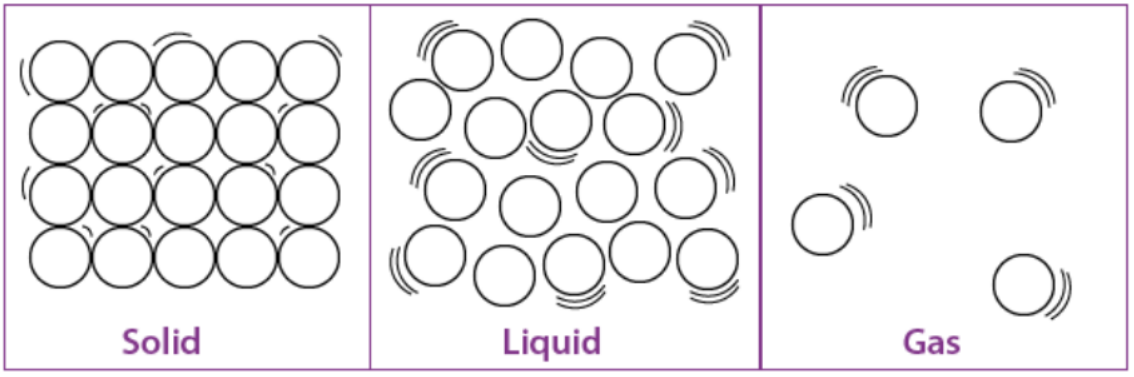
Dalton's atomic theory provided an explanation for the law of conservation of mass and the law of definite proportions. **According to Dalton's atomic theory,**

- All matter is made of very tiny particles called atoms, which participate in chemical reactions.
- 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.
- Atoms of different elements have different masses and chemical properties.
- To form a compound, atoms are combined in the ratio of small whole numbers.
- In a given compound, the relative number and kinds of atoms are constant.

Matter

Our cosmos is made up of matter. The matter is stated as any substance that has mass, takes volume and may be comprehended by the senses. Exceptions: Heat, electrical energy, light energy, sound energy, magnetism, vacuum, a shadow is not a matter because it has no mass and does not take up space.

The matter is composed of small constituent parts. The units of matter are very minute. We cannot see them even with a high power microscope.



Characteristics of Matter

- The matter is created out of small particles.
- The particles have intermolecular spaces amidst them.
- The particles of matter are locomotive in nature because they have kinetic energy. The motion of the constituent particles intensifies with a surge in temperature.
- The bits in matter draw each other, but this reciprocal force of pull is operational only when the particles are very close by to each other. In solids, these units are narrowly crammed, and hence they have superior intermolecular force attraction although, in gases, the groups are lightly held. Therefore, they have feeble forces of attractions.

Diffusion

- The intermingling of the particles of two or more materials on their own is called diffusion.
- Diffusion is quicker in gases. The speed of diffusion is different in different gases. Lighter gas intermingles at a faster speed than denser gases.
- Liquids, as well as solids, undergo dissemination. However, the speed of diffusion in solids is pretty low. As particles of liquids move slowly, diffusion in liquids is slower than gases.

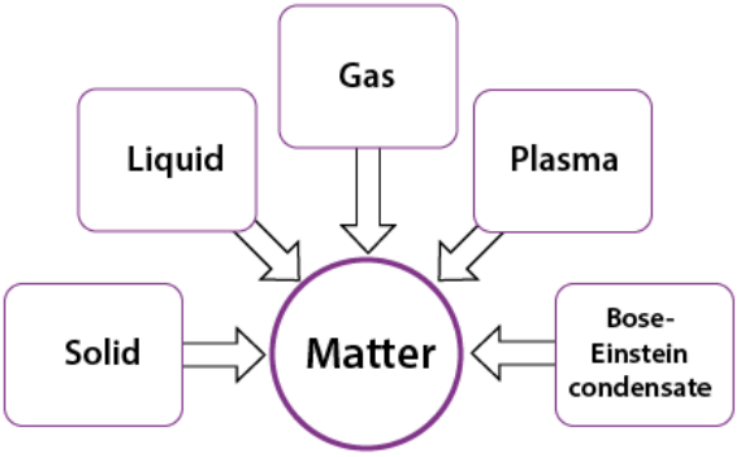
Factors Affecting Diffusion

1. Density - The rate of diffusion is inversely relative to the mass of liquid or a gas. Greater the density, the smaller the rate of diffusion.

2. Temperature - The speed of diffusion is directly proportionate to the temperature. As the temperature increases the kinetic energy of the constituent units upsurges, and they travel with greater speed resulting in an amplified rate of diffusion.

Classification of Matter

The matter has been characterized into five states by the researchers i.e., solid, liquid, gas, plasma and Bose-Einstein Condensate. Amid these states, the most familiar states of matter that exist around us are as solids, liquids and gases.



1. Solid State

- When the particles are packed together firmly, they form solids. In solids, the particles only vibrate about their fixed positions, since their kinetic energy is low and not sufficient to let them breakdown away from their common force of the pull. Thus, solids have definite forms, volumes and are not compressible. That's why they do not flow or diffuse.

Exceptions

- A rubber band can be strained under force, and it recovers to the same shape when the force is removed.
- If a similar rubber band is stretched maximum with excessive force, it breaks.
- The sponge is one more example of solid, which has minuscule holes in which the air is confined.
- When it is squeezed with a hand, the air is ejected out, and it gets compressed.

2. Liquid State

- In liquids, the kinetic energies of the atoms are more than solids, and the atoms are not fixed to any positions. They move about at will, arbitrarily, all through the liquid. Though, they do not have sufficient kinetic energy to break out of the borderlines of the liquid form. That clarifies why liquids do not have fixed shapes and pour or diffuse at will, but they do have fixed volumes.
- Also, when equated to solids, there are more spaces amongst the atoms of liquids, but not sufficient to make liquids compressible.

3. Gaseous State

- In gases, the atoms are not crammed together at all, as their kinetic energies are high enough to let them break free from any boundaries. They are unrestricted to move about in arbitrary motion. That is why gases have no fixed figure or volume, and they flow and diffuse readily. They crash into each other, and off the walls of their container. That's how a gas applies pressure on its vessel. Also, as the spaces between the atoms are large, gases are exceedingly compressible.

4. Plasma State

- The fourth state of matter is Plasma. Plasma is comparable to the gaseous state. The state involves super active and super energized atoms in the form of ionized gases.
- Plasma is created by heating a gas until it loses all its electrons. It is existent in stars. The plasma is formed in the sun and stars because of very high temperature. The sun and stars radiate because of the existence of plasma in them.
- The fluorescent tube and neon sign bulbs contain plasma. The gas present inside these bulbs and tubes is an inert gas. When electricity is passed through them, the gas gets ionized and charged. This charging up creates a glowing plasma, having a particular colour depending on the nature of the gas.

5. Bose Einstein Condensates

- The model of BEC was thought of by the Indian physicist Satyendra Nath Bose in 1920 and was advanced by the theory of BEC. Later Albert Einstein prophesied a new state of matter – the Bose-Einstein Condensate (BEC).
- The BEC is created by freezing a gas of tremendously low density. Bose-Einstein condensate refers to the breakdown of atoms into a single quantum state. It is found at low temperatures when particles are not incapable of moving.

Atoms

- An atom is the smallest particle of an element that can take part in a chemical reaction.
- Atomic radius is measured in nanometers.
  $1/10^9$ m = 1 nm
  1 m = 10^9 nm
- Hydrogen atom is smallest atom of all. Atomic radius of hydrogen atom is 0.037×10^{-9}

Radii	Example
10^{-10}	Atom of hydrogen
10^{-9}	Molecule of water
10^{-8}	Molecule of hemoglobin
10^{-4}	Grain of sand
10^{-3}	Ant
10^{-1}	Apple

Atomic Mass

- Atomic mass is defined as the mass of a single atom of a chemical element.
- It is expressed in atomic mass units (symbol is u).
- The atomic mass is roughly equivalent to the number of protons and neutrons present in the atom.
- One atomic mass unit is a mass unit equal to exactly one-twelfth (1/12th) 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.

Atomic Mass of Some Elements

Element	Atomic mass
Hydrogen	1
Carbon	12
Nitrogen	14
Oxygen	16
Sodium	23

Magnesium	24
Sulphur	32
Chlorine	35.5
Calcium	40

Molecule

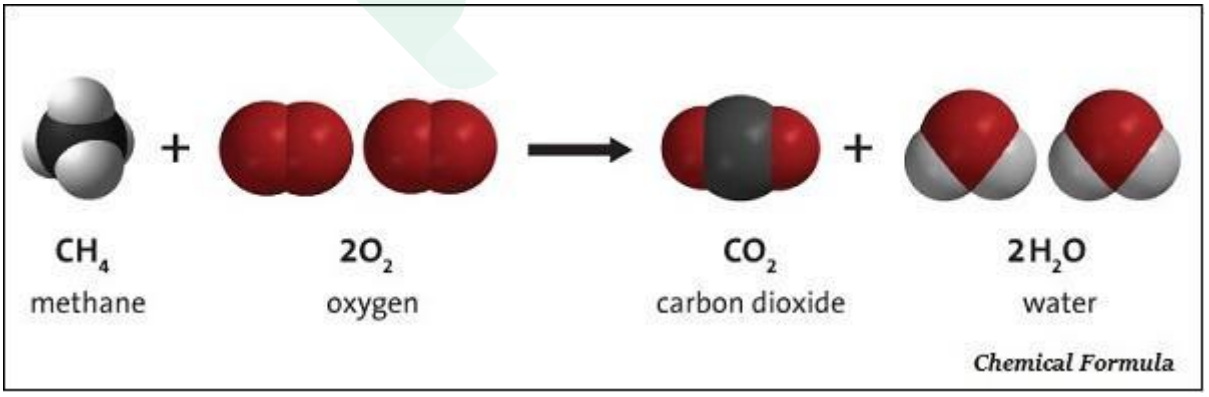
- The smallest particle of an element or a compound, which is capable to exist independently and shows all the properties of the respective substance.
- A molecule, normally, is a group of two or more atoms which are chemically bonded together.
- Atoms of the same element or of different elements can join (with chemical bond) together to form molecules.
- The number of atoms that constitute a molecule is known as its atomicity.

Ion

- A charged particle is known as ion; it could be either negative charge or positive charge.
- The positively charged ion is known as a 'cation'.
- The negatively charged ion is known as an 'anion.'

Chemical Formulae

A chemical formula of a compound demonstrations its constituent elements and the number of atoms of each combining element.



- The chemical formula of a compound is the symbolic representation of its Composition.
- The combining capacity of an element is known as its **'valency.'**

Molecular Mass

- The molecular mass of a substance is calculated by taking the sum of the atomic masses of all the atoms in a molecule of respective substance. For example, the molecular mass of water is calculated as –

    - Atomic mass of hydrogen = 1u
    - Atomic mass of oxygen = 16 u
- The water contains two atoms of hydrogen and one atom of oxygen.
- Molecular Mass of Water is = 2 × 1+ 1×16 = 18 *u* (*u* is the symbol of molecular mass).

Formula Unit Mass

- The formula unit mass of a substance is calculated by taking the sum of the atomic masses of all atoms in a formula unit of a compound.

Avogadro Constant

- The Avogadro constant 6.022×10^{23} is defined as the number of atoms in exactly 12 g of carbon-12.

Structure of An Atom

- By 1900, it was discovered that the atom was not a simple, indivisible particle, but rather it contains sub-atomic particles.
- **J.J. Thomson** discovered the sub-atomic particle namely **'electron.'**
- J.J. Thomson was the first one to propose a Model for the structure of an atom.
- In 1886, E. Goldstein discovered the presence of new radiations in a gas discharge and named them **canal rays.**
- Another positively charged sub-atomic particle was discovered with experiments of canal rays and named it **proton**.

Thomson's Model of Atom

- An atom consists of a positively charged sphere and the electrons are embedded in it.
- The negative and positive charges are equal in magnitude. So, the atom as a whole is electrically neutral.

Rutherford's Atomic Model

- E. Rutherford is popular as the 'Father' of nuclear physics.
- Rutherford is largely known for his work on radioactivity and the discovery of the nucleus of an atom with the gold foil experiment.
- Rutherford's model of the atom proposed that a very tiny nucleus is present inside the atom and electrons revolve around this nucleus. The stability of the atom could not be explained by this model.

According to this model:

- The atom contains large empty space.
- There is a positively charged mass at the centre of the atom, known as nucleus.

- The size of the nucleus of an atom is very small compared to the size of an atom.
- The electrons revolve around the nucleus in close circular paths called orbits.
- An atom as a whole is electrically neutral, i.e., the number of protons and electrons in an atom are equal.

Bohr's Model of an Atom

Niels Bohr's model of the atom was more successful. He proposed that electrons are distributed in different shells with discrete energy around the nucleus. If the atomic shells are complete, then the atom will be stable and less reactive.

In order to overcome the objections raised against Rutherford's model of the atom, Niels Bohr put forward the following postulates about the model of an atom:

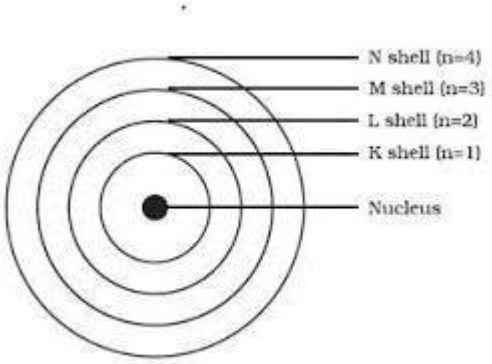
- Only certain special orbits known as discrete orbits of electrons, are allowed inside the atom.
- While revolving in discrete orbits the electrons do not radiate energy.
- These orbits or shells are called energy levels.

Neutrons

- J. Chadwick discovered the neutron.
- Neutrons are present in the nucleus of all atoms, except hydrogen.
- Mass of an atom equal to sum of the masses of protons and neutrons present in the nucleus.

Electrons Distributed in Different Orbits (Shells)

- Distribution of electrons into different orbits of an atom was suggested by Bohr and Bury.
- Maximum number of electrons present in a shell is given by the formula $2n^2$
  Where n = 1,2,3,4,….
- These orbits or shells are represented by the letters K,L,M,N,…
- The maximum number of electrons that can be accommodated in the outermost orbit is 8.
- Electrons are not accommodated in a given shell, unless the inner shells are filled. That is, the shells are filled in a step-wise manner.



Valence Electrons

- **Electrons** present in the outermost shell of an atom are known as the **valence electrons.**
- The elements with same number of electrons in the valence shell show similar properties and those with different number of valence electrons show different chemical properties.
- Elements, which have 1 or 2 or 3 valence electrons (except Hydrogen), are **metals**.
- Elements with 4 to 7 electrons in their valence shell are **non-metals**.

Valency

- Valency of an element is the combining capacity of the element with other elements and is equal to the number of electrons that take part in a chemical reaction.
- Valency of the elements having valence electrons 1, 2, 3, 4 is 1, 2, 3, 4 respectively.
- Valency of an element with 5, 6 and 7 valence electrons is 3, 2 and 1 (8–valence) respectively. Because 8 is the number of electrons required by an element to attain stable electronic configuration.
- Elements having completely filled outermost shell show Zero valency.

Atomic Number

- Atomic number of an element is the same as the number of protons in the nucleus of its atom.
- Atomic number is denoted by **'Z'**.
- Protons and neutrons collectively are known as **nucleons**.

Mass Number

- Mass number of an atom is equal to the number of protons and neutrons in a nucleus.

Isotopes

- Two or more forms of an element having the same atomic number, but different mass number are called Isotopes ($_{17}Cl^{35}$, $_{17}Cl^{37}$).
- For example, Hydrogen atom has three isotopes namely protium, deuterium, and tritium.
- The chemical properties of isotopes of an atom are similar but their physical properties are different.
- Applications:
    - An isotope of uranium is used as a fuel in nuclear reactors.
    - An isotope of cobalt is used in the treatment of cancer.
    - An isotope of iodine is used in the treatment of goitre.

Isobars

- Atoms of different elements having the same mass number, but different atomic numbers are called Isobars.

- For example, calcium's atomic number is 20 and argon's atomic number is 18; further, the number of electrons in these atoms is different, but the mass number of both these elements is 40. ($_{18}Ar^{40}$, $_{20}Ca^{40}$).

Isotones

- Atoms of different elements having the same number of neutrons, but different atomic number and different mass number are called Isotones ($_{6}C^{13}$, $_{7}N^{14}$).