L9

Molecule & Atom

Atoms are the smallest particles of elements that contain the characteristics of elements. For example: Nitrogen atoms contain the characteristic features of nitrogen while oxygen atoms contain the same of oxygen.

When two or more atoms remain connected with each other in chemical bond, it is known as molecule.

Two oxygen atoms (O) bond each other to form an oxygen molecule (O_2). Again, a carbon atom (C) bonds with two oxygen atoms (O) to generate a carbon dioxide (CO_2) molecule. When more than one atoms of a specific element bond each other, they produce that element's molecule, like O_2. When atoms of different elements bond together to produce a molecule, it is called molecule of compound, like CO_2.

Symbol of Elements

The abbreviated form of English or Latin name of element is called its symbol. Each element has its own symbol. There is a system of writing symbol of element.

Table 3.01: Symbols of Elements

Element	Symbol
Hydrogen	H
Oxygen	O
Nitrogen	N

a. The first letter of English name of an element is usually the symbol and that has to be written using capital letter.

Table 3.02: Symbols of Elements (First letter same)

Element	Symbol	Element	Symbol
Carbon	C	Cobalt	Co
Chlorine	Cl	Cadmium	Cd
Calcium	Ca	Chromium	Cr

Table 3.02: Symbols of Elements (Latin Name)

Element	Latin Name	Symbol	Element	Latin Name	Symbol
Sodium	Natrium	Na	Gold	Aurum	Au
Copper	Cuprum	Cu	Lead	Plumbum	Pb
Potassium	Kalium	K	Tungsten	Wolfram	W
Silver	Argentum	Ag	Iron	Ferrum	Fe
Tin	Stannum	Sn	Mercury	Hydrurgyrum	Hg
Antimony	Stibium	Sb			

b. When the first letter of two or more elements is same, one of them is expressed by the first letter. The other element(s) get the first two letters; the first letter is capitalized, followed by small hand second letter.

c. Some elements have got their symbols from their Latin name.

Atomic Model

Rutherford's Atomic Model

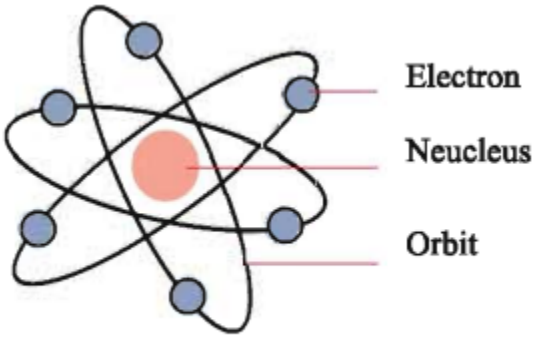

Fig 3.01: Rutherford's Atomic Model

What Rutherford Discovered

Rutherford's atomic model was based on his famous **gold foil experiment**. It showed that atoms are not solid objects but mostly empty space, with a tiny, dense center. This model changed how scientists understood atoms.

Key Features of Rutherford's Atomic Model

1. **The Nucleus**:
    - At the center of an atom is a **small, dense, and positively charged nucleus**.
    - This nucleus contains **protons** (positively charged particles) and most of the atom's mass.
2. **Electrons Around the Nucleus**:
    - The negatively charged **electrons** move around the nucleus at a distance.
    - These electrons occupy the empty space of the atom.
3. **Mostly Empty Space**:
    - Most of the atom is empty space, allowing particles to pass through it without hitting anything.
4. **Size of the Nucleus**:
    - The nucleus is very tiny compared to the size of the entire atom.

Limitations of Rutherford's Model

1. **Stability of Electrons**:
    - The model couldn't explain why electrons, being attracted to the positive nucleus, don't spiral into it.

2. **Energy Levels**:
    - It didn’t explain the arrangement or behavior of electrons around the nucleus.

Bohr’s Atomic Model

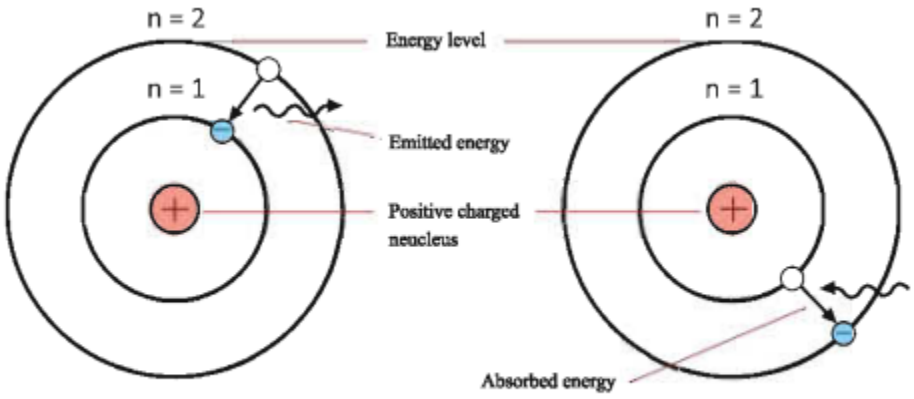

Fig 3.03: Bohr’s Atomic Model

What Bohr Proposed

Niels Bohr improved Rutherford's model by explaining how electrons are arranged around the nucleus and why they don’t collapse into the nucleus. He introduced the concept of energy levels or orbits where electrons move in fixed paths.

Key Features of Bohr’s Atomic Model

1. **Electrons Move in Fixed Orbits**:
    - Electrons revolve around the nucleus in specific circular paths called **orbits** or **shells** (like planets around the Sun).
    - Each orbit has a fixed energy, so electrons in these orbits don’t lose energy and fall into the nucleus.
2. **Energy Levels Are Quantized**:
    - Each orbit has a specific energy, and electrons can only occupy these fixed energy levels.
    - These energy levels are denoted as KKK, LLL, MMM, etc., starting from the closest to the nucleus.
3. **Electron Transitions (Jumping Between Orbits)**:
    - Electrons can move to a higher orbit if they **absorb energy**.

    - Electrons release energy (as light or heat) when they return to a lower orbit.
4. **Nucleus**:
    - The nucleus is at the center of the atom and contains protons and neutrons.

Limitations of Bohr's Model

1. It worked well for simple atoms like hydrogen but failed to explain the behavior of electrons in multi-electron atoms.
2. Could not fully describe the complex nature of atomic spectra.
3. It didn't account for the wave-like properties of electrons.

Difference Between Rutherford and Bohr's Atomic Models

Aspect	Rutherford's Atomic Model	Bohr's Atomic Model
Electron Path	Electrons move randomly around the nucleus.	Electrons move in fixed, circular orbits (energy levels).
Stability of Electrons	Did not explain why electrons don't spiral into the nucleus due to attraction.	Explained stability using fixed energy orbits where electrons do not lose energy.
Energy Levels	No concept of energy levels for electrons.	Introduced quantized energy levels or shells.
Nucleus	A dense, positively charged nucleus at the center.	Also a dense, positively charged nucleus at the center (same as Rutherford).
Energy Emission	Could not explain why atoms emit light in specific colors (spectral lines).	Explained spectral lines as a result of electrons jumping between energy levels.
Applicability	Did not describe the atom's stability or spectra.	Successfully described the hydrogen atom's spectrum.
Model Structure	Focused on the nucleus; lacked clarity on electron arrangement.	Provided a structured model with fixed electron paths.

Basis of Chemical Bonding

What is Chemical Bonding?

Chemical bonding is the way atoms stick together to form larger structures like molecules, compounds, or crystals. Atoms bond because they want to become more stable, which often happens when they fill their outermost layer of electrons (called the valence shell).

Why Do Atoms Bond?

1. **To Gain Stability**:
    - Atoms are more stable when their outer shell of electrons is full.
    - Most atoms want 8 electrons in their outer shell (this is called the **octet rule**).
    - A few exceptions like hydrogen and helium only need 2 electrons to be stable (**duplet rule**).
2. **To Lower Energy**:
    - When atoms bond, they release energy and move to a lower, more stable energy state.

How Do Atoms Bond?

Atoms can bond in three main ways: **sharing**, **giving**, or **taking electrons**. These actions create different types of bonds.

Types of Chemical Bonds

1. Ionic Bond (Giving and Taking Electrons)**:** A bond formed by the transfer of electrons from one atom to another.

What Happens:

- One atom **gives away** its electron(s), becoming positively charged (called a **cation**).
- Another atom **takes** these electrons, becoming negatively charged (called an **anion**).
- The two opposite charges attract each other and form a bond.

Example:

- **Sodium chloride (NaCl)**:
    - Sodium gives one electron to chlorine. Sodium becomes Na^{+}, and chlorine becomes Cl^{-}.
    - The positive and negative ions stick together to form table salt.

- $Na^+ + Cl^- \rightarrow$ NaCl

2. Covalent Bond (Sharing Electrons)**:** A bond formed by the **sharing of electrons** between two atoms.

What Happens:

- Instead of giving or taking, some atoms **share electrons** to fill their outer shell.
- The shared electrons are like a "bridge" holding the atoms together.

Example:

- **Water (H_2O)**:
  - Oxygen shares one electron with each of the two hydrogen atoms.
  - This completes the outer shells for all the atoms (oxygen gets 8 electrons, and each hydrogen gets 2).

States of Matter (Solids, Liquids, Gases)

Matter exists in three main states: solid, liquid, and gas. Each state has distinct properties and behaves differently based on the arrangement of particles, energy levels, and the forces between them**.**

Solid

- **Definition**: A **solid** is a state of matter that has a **definite shape and volume**. This means that a solid maintains its shape regardless of the container it is in.
- **Particle Arrangement:** Particles are closely packed together in a regular pattern. They vibrate in place but do not move freely.
- **Characteristics:**
  - Definite shape and volume
  - Particles have strong intermolecular forces
  - Low energy level
- **Examples:** Ice, wood, metal

Liquid

- **Definition**: A **liquid** is a state of matter that has **a definite volume but no fixed shape**. Liquids take the shape of the container they are in but maintain their own fixed volume.
- **Particle Arrangement**: Particles are close together but can slide past each other, allowing the liquid to flow.
- **Characteristics**:
    - No fixed shape (takes the shape of the container)
    - Fixed volume
    - Particles have weaker intermolecular forces compared to solids
- **Examples**: Water, milk, juice, oil

Gas

- **Definition**: A **gas** is a state of matter that has **no fixed shape or volume**. Gases expand to fill any container they are placed in and are highly compressible.
- **Particle Arrangement**: Particles are far apart, move freely, and have high kinetic energy.
- **Characteristics**:
    - No fixed shape or volume
    - Particles move quickly and spread out
    - Low intermolecular forces
- **Examples**: Air, oxygen, carbon dioxide, steam

Comparison of States of Matter

Property	Solid	Liquid	Gas
Shape	Fixed	Takes the shape of the container	No fixed shape
Volume	Fixed	Fixed	No fixed volume
Particle Arrangement	Closely packed in a regular pattern	Close together but can slide	Far apart and move freely
Intermolecular Forces	Strongest	Moderate	Weakest
Energy Level	Low	Medium	High