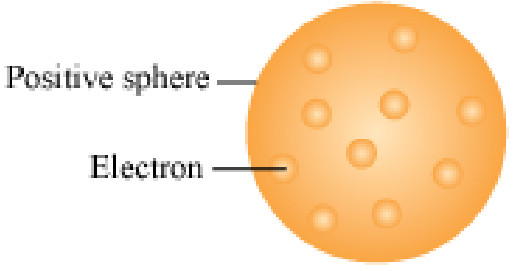
Atomic Structure and Chemical Bonding

- Atoms are not indivisible and are composed of three fundamental particles. These particles are electrons, protons, and neutrons.

- **Charged particles in Matter**
  - Electrons are negatively-charged particles. They were discovered by J. J. Thomson, by cathode ray experiment.
  - Canal rays are positively charged radiation consisting of protons. Protons are positively-charged particles and were discovered by E. Goldstein.
  - The third fundamental particles present in an atom are neutrons. They are electrically-neutral and were discovered by J. Chadwick.
  - Various models were given to explain the structure of atom.

- **Thomson's atomic model**:
  - Thomson thought that an atom is a sphere of positive charge in which electrons are embedded.
  - An atom as a whole is electrically neutral because the negative and positive charges are equal in magnitude.



- **Rutherford's atomic model**:
    - On the basis of his experiments with alpha rays and gold foil, Rutherford concluded that Thomson's atomic model was incorrect.
    - He proposed an atomic model based on the results of his experiments.
    - In this model, all the positive charges (i.e., protons) were present at the centre of the atom, inside the nucleus, and the electrons were present in circular orbits around the nucleus.
    - He said that the electrons are not at rest and keep moving continuously in these circular orbits.
    - He also said that the size of the nucleus is very small as compared to that of the atom.

- **Drawbacks of Rutherford's Model**

    - It cannot explain the stability of an atom on the basis of classical mechanics and electromagnetic theory.

    - If the electrons were stationary, then the strong electrostatic force of attraction between the dense nucleus and the electrons would pull the electrons towards the nucleus. Thus, it cannot explain the stability of an atom.

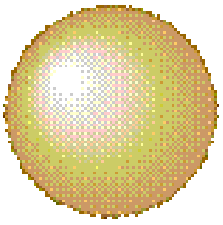
    - Rutherford's model does not give any idea about the distribution of electrons around the nucleus (i.e., the electronic structure of the atom), and about their energy.

    - It cannot explain the atomic spectra.

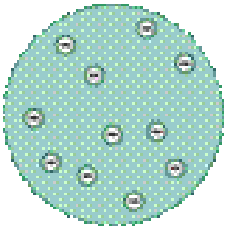
- **Bohr's atomic model**:
    - Neils Bohr proposed that the electrons present around the nucleus revolve in specific orbits called energy levels.

- He also stated that the electrons do not release energy while revolving. Thus, the resulting atom is a stable one.
- The shells in which the electrons are present are known as K, L, M, N, and so on (or 1, 2, 3, 4, and so on), as proposed by Bohr and Bury.
- Each shell contains a specific number of electrons, which can be calculated using the formula $2n^2$.

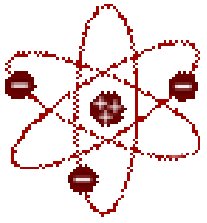
Atomic Models



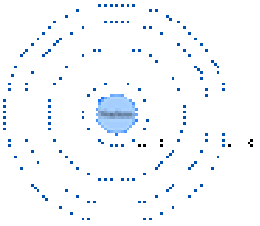
Dalton's atomic model



Thomson's atomic model



Rutherford's atomic model



Bohr's atomic model

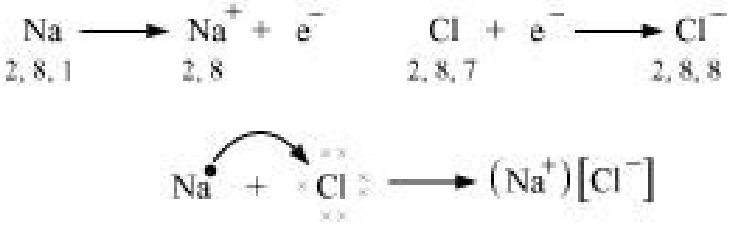
- Valency is defined as the combining capacity of the atom of an element. Valency of an element depends upon the number of electrons present in the outermost shell of its atom.

- **Atomic number** of an element is equal to the number of protons present in the atom and atomic mass is equal to the sum of the number of protons and neutrons present in it.

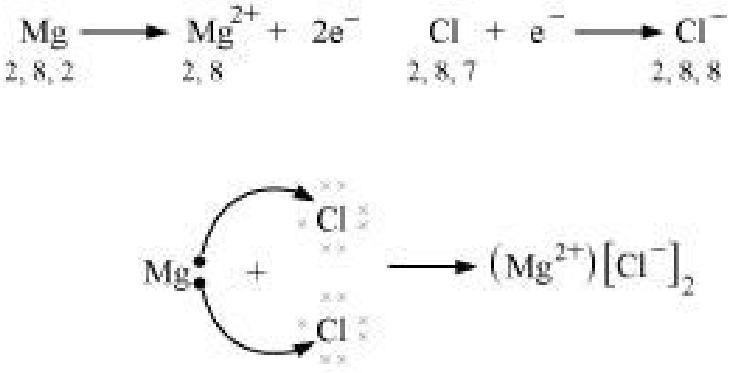
- **Isotopes** are atoms having the same atomic number and different atomic masses.

- **Isobars** are atoms having the same atomic mass and different atomic numbers.

- **Metals + Non-metals**
  - **1)**



  - **2)**



- **Physical Properties of Ionic compounds**

1. Solid

2. Hard [because of strong attraction force]

3. Brittle

4. High melting and boiling points

5. Soluble in H_2O; insoluble in kerosene, petrol

6. Conduct electricity in H_2O solution

Chemical bond:

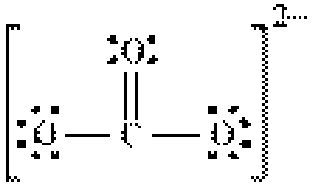
Chemical bond is the attractive force, which holds various constituents (such as atoms, ions) together in different chemical species.

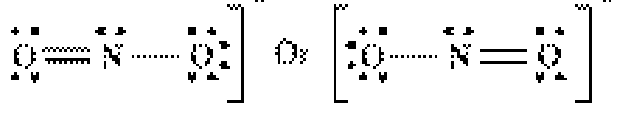
Octet rule:

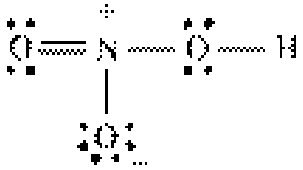
Atoms tend to gain, lose, or share electrons so as to have eight electrons in their valence shells.

Lewis dot Structure:

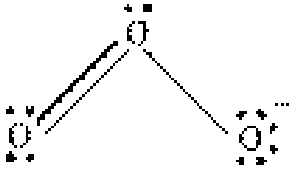
Representation of molecules and ions in terms of the shared pairs of electrons and the octet rule

$CO_3^{2-} \rightarrow$ 

$NO_2^- \rightarrow$ 

$HNO_3 \rightarrow$ 

Formal charge:

Lewis structure of $O_3 \rightarrow$ 

$$\begin{bmatrix}\text{Formal charge (F.C)}\\ \text{on an atom in a}\\ \text{Lewis structure}\end{bmatrix} = \begin{bmatrix}\text{Total number of}\\ \text{valence electrons}\\ \text{in the free atom}\end{bmatrix} - \begin{bmatrix}\text{Total number of}\\ \text{nonbonding (lone}\\ \text{pair electrons)}\end{bmatrix} - \frac{1}{2}\begin{bmatrix}\text{Total number of}\\ \text{bonding (shared}\\ \text{electrons)}\end{bmatrix}$$

F.C. on the $O^{-1} = 6 - 2 - \frac{1}{2}(6) = +1$

F.C. on the $O^{-2} = 6 - 4 - \frac{1}{2}(4) = 0$

F.C. on the $O^{-3} = 6 - 6 - \frac{1}{2}(2) = -1$

Limitations of the octet rule:

- Incomplete octet of the central atom

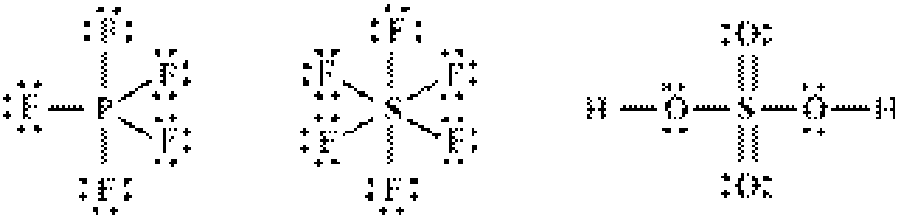
E.g. BeH_2, LiCl, BCl_3

- Odd electron molecules

E.g. NO, NO_2

- Expanded octet

E.g. PF_5, SF_6, H_2SO_4



- Some other drawbacks:

1. It is based upon chemical inertness of noble gases. However, some noble gases can combine to form compounds such as XeF_2, KrF_2, $XeOF_2$, etc.
2. Does not account for the shape of molecules
3. Does not explain the relative stability of molecules

Conditions for Formation of Covalent Bond

- Presence of four or more electrons in the outermost shell of an atom (exception H, Be, B and Al)
- High electronegativity of both the atoms
- High electron affinity for both the atoms
- High ionisation energy of both the atoms
- Electronegativity difference between combining atoms should be zero or very low

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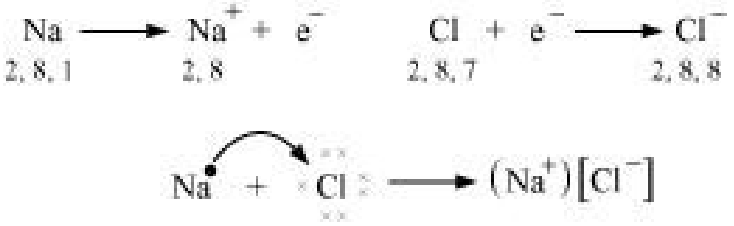
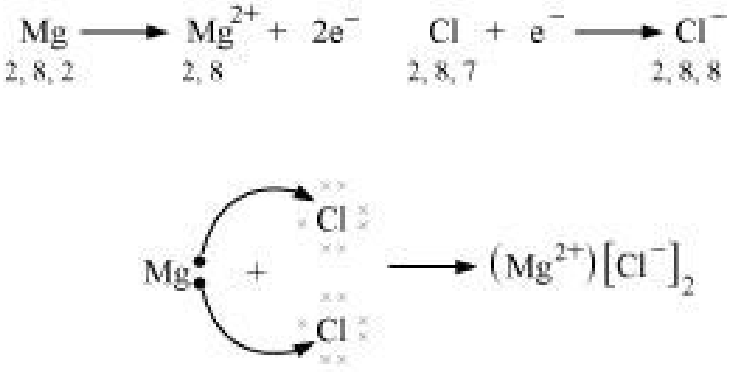
  - **1)**



  - **2)**



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- The bonds that are formed by sharing electrons are known as **covalent bonds**. Covalently bonded molecules have strong intermolecular forces, but intramolecular forces are weak.
- Carbon has four valence electrons and requires four more electrons to complete its octet. Therefore, it is capable of bonding with four other atoms of carbon or atoms of other elements having a valency of 1.
- Some properties of covalent compounds are:
    - Covalent compounds are non- conductors of electricity.
    - They also have low melting and boiling points.
    - These compounds mostly exist as liquids or gases at room temperature.
- Polar covalent compounds: A covalent bond formed between two different atoms, with different electronegativities is known as **polar covalent bond.** For example, hydrogen chloride molecule
- **$H^{\delta+}$----$Cl^{\delta-}$**
- Non-polar covalent compounds: A covalent bond formed between two like atoms, is known as **Non-polar bond**. For example, hydrogen molecule
- **H------H**
- **Cordinate bond**: It is formed when the shared pair of electrons is provided by one of the two atoms and shared by both.
- Conditions for formation of cordinate bond:
    - Presence of at least one lone pair of electrons on any of the two atoms. This atom acts like a donor.
    - Shortage of a lone pair of electron on the second atom. This atom acts like an acceptor.