Normal, Excited and Ionized Atoms

- Hydrogen atom has a single electron.
- When this electron lies in the innermost K orbit ($n = 1$), the atom is said to be in normal state.
- Normal state is also called ground state.
- The electron in normal state remains stable.
- The atom is said to be excited if its electron is forced into an outer orbit.
- The electron absorbs energy in this case.
- The atom is said to be ionized when its electron is removed out from the atom completely.
- The electron emits energy in ionized state.
- The radius r_o, velocity v_o and frequency f_o of hydrogen atom in ground state ($n = 1$) are obtained using Eqs. 2.4, 2.5 and 2.7
- These values are $r_o = 0.53$ Å, $v_o = 2.2 \times l06$ m/s and
- $f_o = 0.66 \times 10$ m/s^2

Modern Concept of Atomic Model

- **De Broglie Wave:**
- The modern concept of atom also considers the concept of wave nature of electron.
- According to this concept a particle (say electron) of mass m moving with velocity v is associated with a wave propagating in the direction of moving particle.
- This wave is known as de Broglie wave or matter wave.
- Wavelength λ of such a wave associated with the particle is given by

$$\lambda = \frac{h}{mv} \qquad (2.11)$$

- Velocity of electron accelerated by a potential difference of V volts can be obtained from

$$\mathrm{eV} = \frac{1}{2}\mathrm{mv}^2, \mathrm{or}\ \mathrm{v} = \frac{\sqrt{2eV}}{m}$$

$$\mathrm{mv} = \sqrt{2meV} \qquad (2.12)$$

Modern Concept of Atomic Model

- **Wavelength of Electron Wave:**
- Therefore, wavelength of electron wave in Eq. 2.11 becomes

$$\lambda = \frac{h}{\sqrt{2meV}}$$

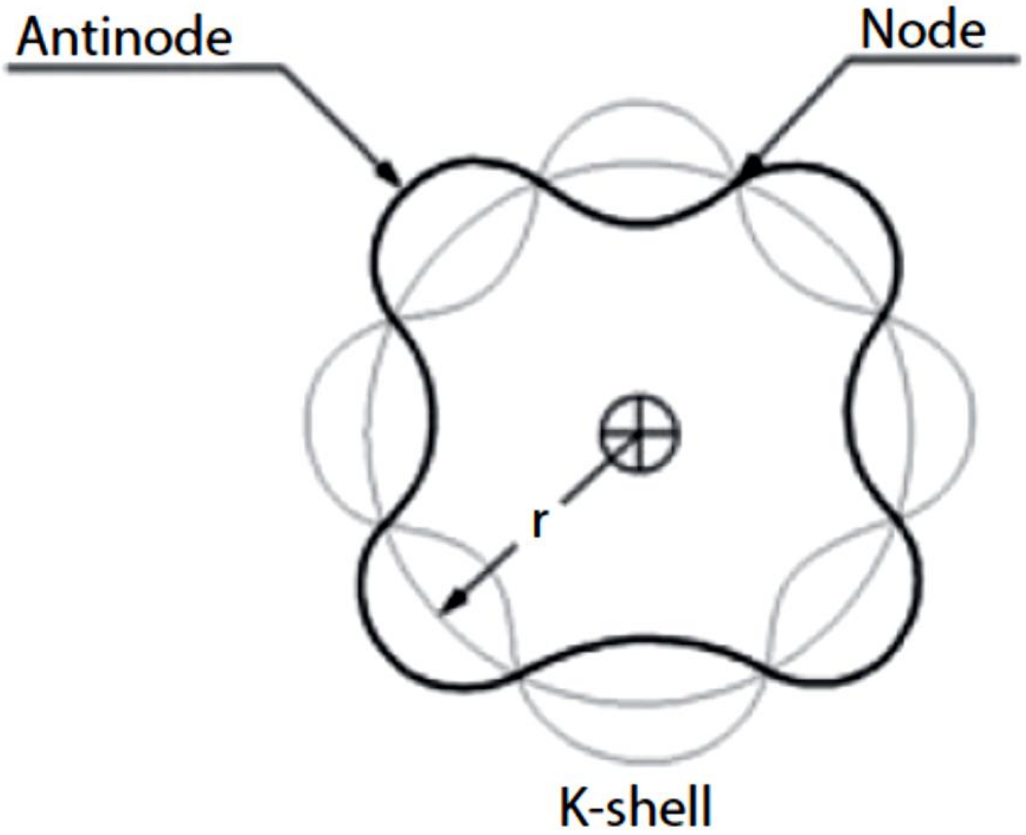
- On substituting h = 6.62 × 10^{-34} Js, m = 9.1 × 10^{-31} kg, and e = 1.602 × 10^{-19} C, we get

$$\lambda = \frac{12.25}{\sqrt{V}} \mathring{A} \qquad (2.13)$$

Modern Concept of Atomic Model

- **Concept of Standing Wave:**
- Modern concept of atomic model, also known as wave-mechanical model, assumes behaviour of electron as a standing or stationary wave.
- Such a wave will establish when the length of orbit is a whole number multiple of electron wavelength as shown in Fig.
- Hence $2\pi r = n\lambda = nh/mv$
- Or $mvr = nh/2\pi$ for $n = 1, 2, 3, \ldots$ etc. (2.14)
- Here r is radius of the circular orbit, mvr is angular momentum of electron as a particle.

Modern Concept of Atomic Model



Wave nature of electron in K-shell of an atom showing stationary wave

Modern Concept of Atomic Model

✓ **Characteristics of standing waves.**

- The stationary waves have their nodes and antinodes.
- Motion is practically zero at nodes, and there are almost no charge on them at these points.
- The amount of charge is maximum at antinodes.
- Whole of electron charge and mass is uniformly distributed around nucleus of the atom.
- The wavelength of electron is of the order of interatomic spacing in the crystals.
- A beam of electron incident on a crystal shows diffraction pattern thus depicting concept of wave nature of electron.

Modern Concept of Atomic Model

- ✓ **Example:** Calculate the minimum uncertainty in determining the position of a particle when the uncertainty in its momentum does not exceed 10^{-27} kg ms^{-1}.
- ✓ ***Solution***: From Eq. 2.11,
- ✓ $(\Delta p)(\Delta x) > h/2\pi$
- ✓ Given is the value of $(\Delta p) \le 10^{-27}$ kg ms^{-1}, and taking $h = 6.626 \times 10^{-34}$ Js, the uncertainty in position (displacement) of the particle will be obtained from

$$\Delta x \ge \frac{h}{2\pi.(\Delta p)}$$

$$\ge \frac{6.626 \times 10^{-34}}{2\pi\left(10^{-27}\right)}$$

$$\ge 1.054 \times 10^{-7} \text{ metre}$$

Thus the minimum uncertainty = 1.054×10^{-7} m.

Modern Concept of Atomic Model

✓ **Electron Configuration:**

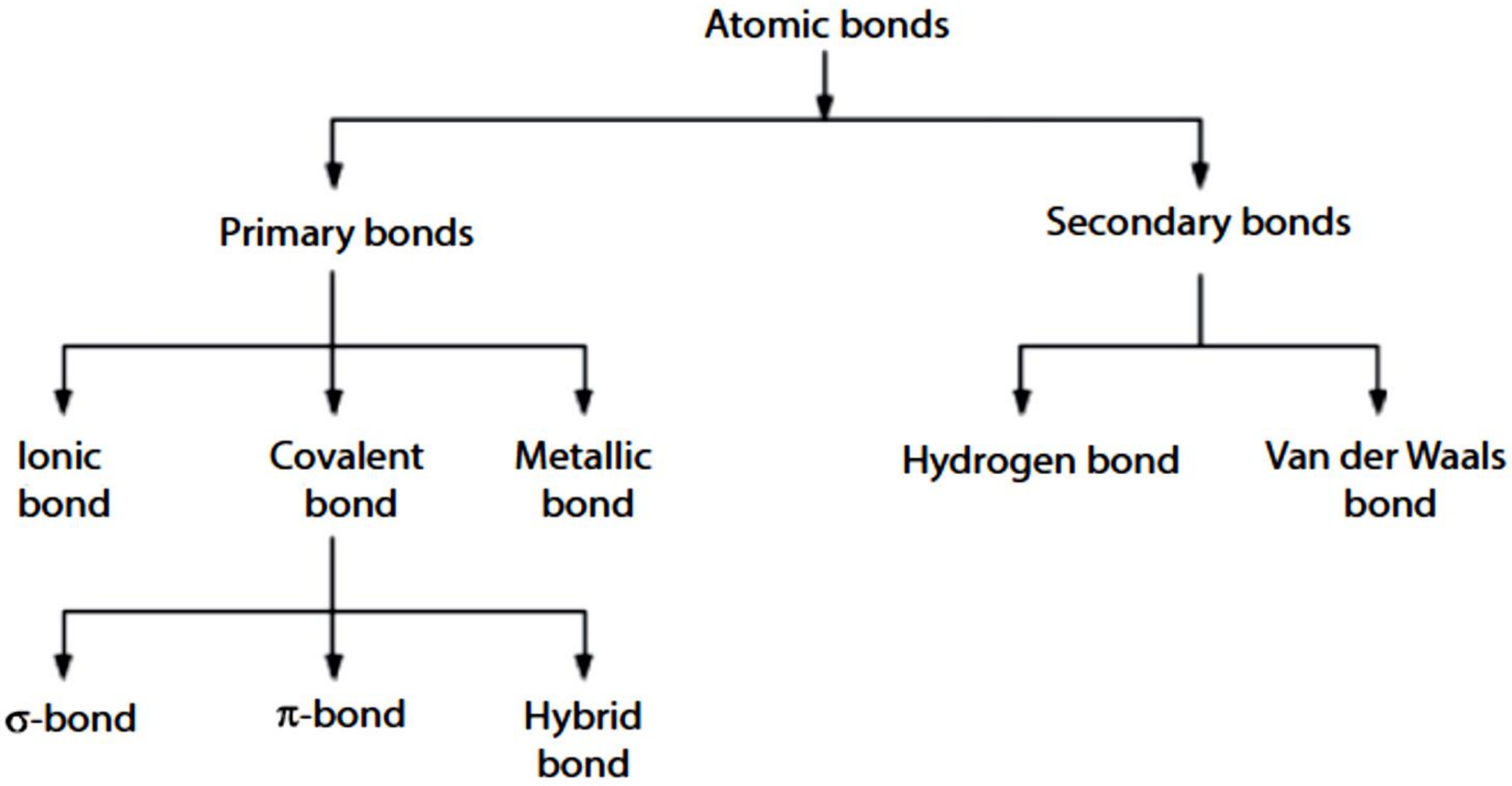
Element	Symbol	Configuration	Atomic Number
Hydrogen	H	$1s^1$	1
Nitrogen	N	$1s^2\ 2s^2\ 2p^3$	7
Silicon	Si	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^2$	14
Titanium	Ti	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^2\ 4s^2$	22
Copper	Cu	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^1$	29
Molybdenum	Mo	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^5\ 5s^1$	42
Antimony	Sb	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 5s^2\ 5p^3$	51
Neutral iron	Fe	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^6\ 4s^2$	26
Ferrous ion	Fe^{2+}	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^6$	24
Ferric ion	Fe^{3+}	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5$	23

BONDS IN SOLIDS

BONDS IN SOLIDS

- If we try to break a material, it requires application of some breaking force.
- The magnitude of applied force varies widely for different materials.
- A chalk may break by applying a small force; timber may require application of medium magnitude of force, but steel necessitates application of substantial external force.
- One may think as to why is it so?
- In fact, atoms in the solids are held together by internal forces.
- These forces are known as bonding forces or atomic bonding forces or chemical bonding forces.

Classification of Chemical Bonds



Classification of Chemical Bonds

- ➢ Primary bonds are stronger and more stable than the secondary bonds.
- ➢ They are further classified into following types.

a. Ionic bond

b. Covalent bond

c. Metallic bond

- ✓ Out of these three bonds, the ionic bonds are strongest and the metallic bonds are weakest.
- ✓ The hardness, strength and other properties are imparted to the solids due to primary bonds.
- ✓ Mostly solids have primary bond of one kind or the other.
- ✓ Examples of primary bonded materials are ceramics (refractories) such as alumina (Al_2O_3) and magnesia (MgO); hydrogen, diamond, silicon, plastics etc; and ferrous and non-ferrous metals.
- ✓ Primary bonds are interatomic in nature.

Classification of Chemical Bonds

- The secondary bonds are further classified into two types.

a. Hydrogen bond

b. Van der Waals bond

- Secondary bonds are intermolecular.
- Gases and liquids, generally, form such bonds.
- They are feeble and less stable.
- Van der Waals bonds are the weakest amongst all known bonds.
- Secondary bonds may also be classified as follows.

a. Dipole bond

b. Dispersion bond

Classification of Chemical Bonds

- Both the hydrogen and Van der Waals bond, develop dipole in their formation.
- Hence they are also referred to as dipole bonds.
- Van der Waals bond is known as dispersion bond due to the dispersing nature of its dipoles.

Ionic Bond

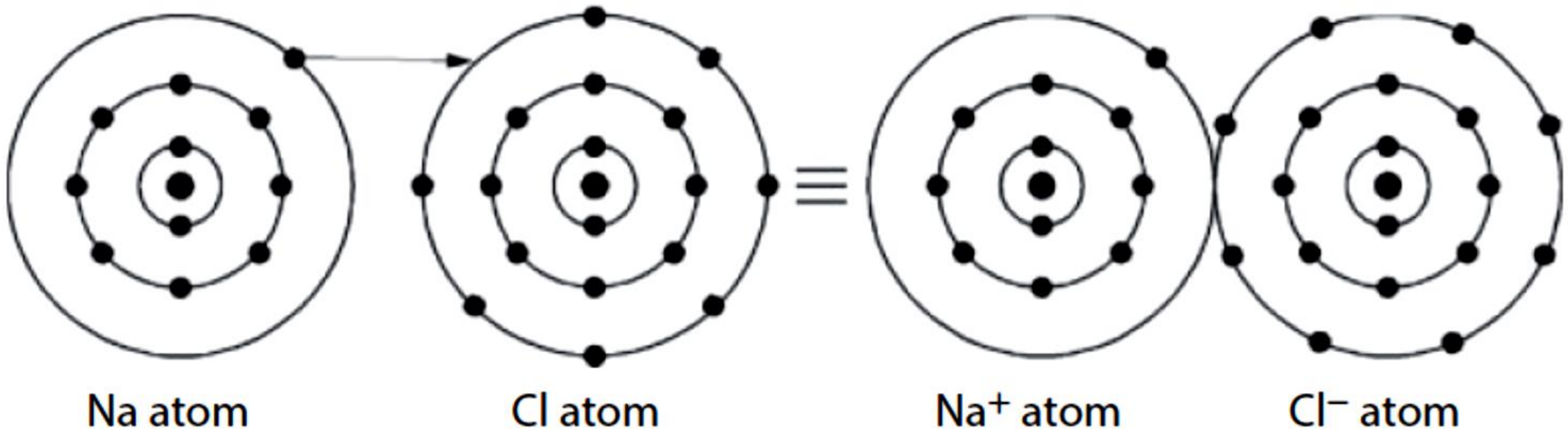
- Ionic bonds are formed between two oppositely charged ions.
- These are produced by transfer of electrons from one atom to another.
- An attractive force between a positive and a negative ion develops when they are brought in close proximity.
- These ions are formed when the atoms involved lose or gain electrons to stabilize their outer shell configurations.
- Let us consider the case of sodium chloride (NaCl) which is ionically bonded.

- The sodium atom has a single electron in its outer orbit.
- This electron transfers to join the seven electrons in the outer orbit of the chlorine atom.

Ionic Bond

•This atomic interaction involving transfer of electron from one atom to another leads to formation of ions which are held together by Coulomb's electrostatic attraction.

➢ The bonding process is shown in following fig.



Bonds in Solids

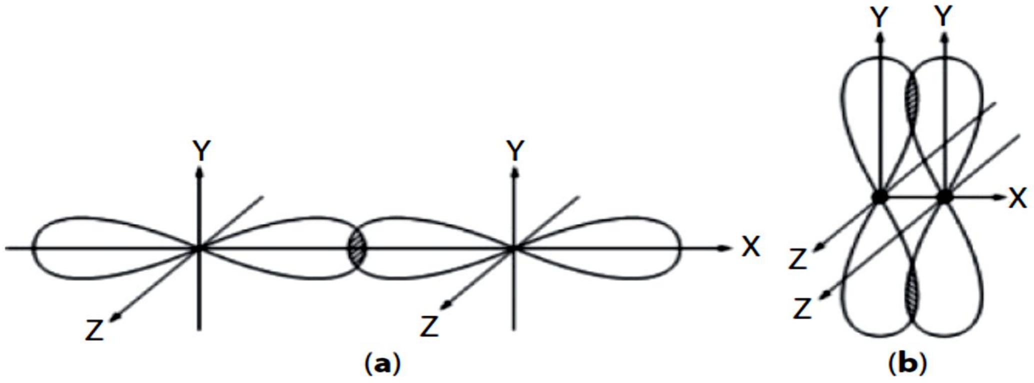
- **Covalent Bonds :**
- A covalent bond is formed when a pair of electrons are shared by several
- atoms.
- As a result of this sharing, their energies are lowered.
- Stable covalent bonds are formed between many non-metallic elements as the atoms of these elements usually posses half filled outer electron orbit.
- Such elements are hydrogen, carbon, nitrogen, oxygen and chlorine etc.
- **Examples**. Elements like silicon, germanium, arsenic and selenium etc. form partly covalent and partly metallic bond.
- Covalent bonds are also found in organic compounds such as alcohol, benzene, chloroform and turpentine etc.
- Polymers, rubbers, elastomers, glasses, potteries, brick, Mo, Ta and high strength fibers are also covalent bonded.

Bonds in Solids

- ✓ **Types of Covalent Bonds :**
- ✓ Covalent bonds may be further classified into following three kinds.

1. Sigma (σ) bond
2. Pi (π) bond
3. Hybrid bond

- ✓ End to end overlap of p sub-orbits gives rise to σ-bond.
- ✓ Bonding in Sulphur, selenium and tellurium are the examples.
- ✓ π-bonds are formed when overlap of p sub-orbits are lateral. Bond in oxygen molecule is the example of this kind.
- ✓ Schematic diagrams are shown in Fig



Covalent bond of type (a) σ-bond, and (b) π -bond.

Bonds in Solids

✓ **Comparison Between Sigma (σ) Bond and Pi (π) Bond**

S.No.	Characteristics	Sigma (σ) bond	Pi (π) bond
1.	Formation due to	Axial overlapping of orbitals	Lateral overlapping of orbitals
2.	Extent of overlapping	Greater	Smaller
3.	Orbitals involved and their axes	*p* along the same axis	*p* only at an angle
4.	Strength	Stronger	Comparatively weaker
5.	Rotation of atoms	Freely around the bond	No