Al-Mustaqbal University Collage

Medical physics Department

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Out lines:-

Free electrons theory metal:-

1- Classical Theory for Free electrons.

2- Drude Theory.

Introduction:-

♦ In solid state physics, the free electron model is a model that studies the behavior of valence electrons in crystals.

♦ The electron theory of solids aims to explain the structures and properties of solids through their electronic structure.

♦ Conduction electrons are the valence electrons in metals.

♦ To understand the origin of free electrons in metals, we take the sodium atom for example:

The sodium atom contains 11 electrons distributed around the nucleus in energy levels, the last orbital contains one electron called the valence electron.

When sodium atoms converge to form a crystal, the orbitals of the valence electrons in the different atoms overlap and the valence electrons become more free and move inside the crystal, and therefore they can be considered as free electrons.

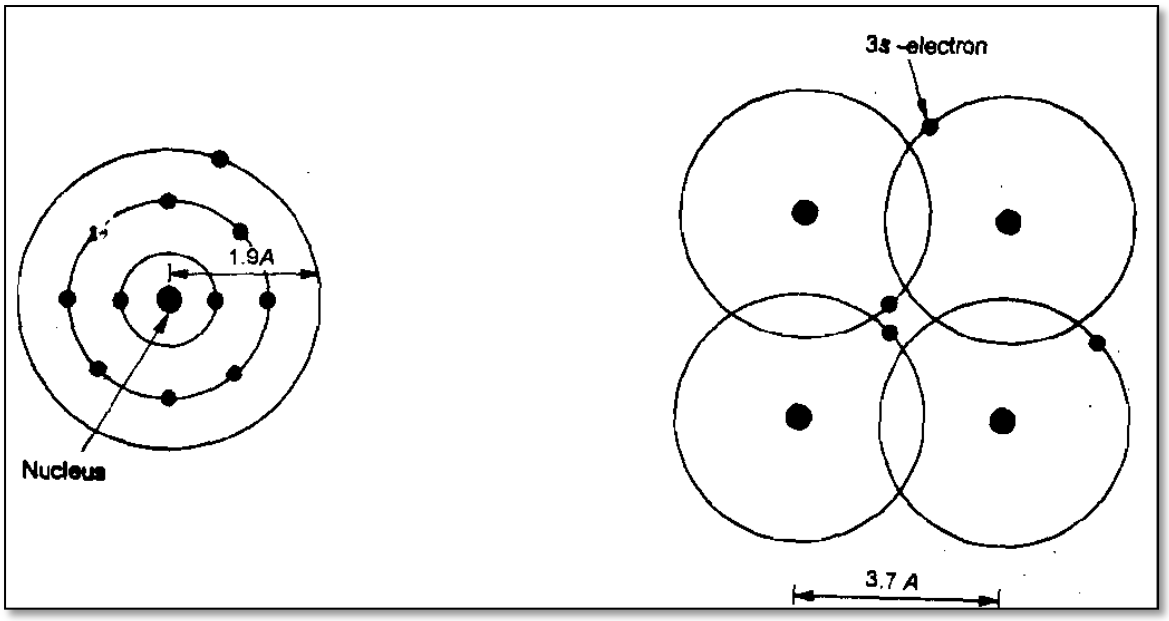

Fig.1: sodium atoms arranged in a crystal lattice forming sodium metal

1- Classical Theory for Free electrons:-

- This model appeared in the nineteenth century to visualize the shape of conduction electrons in a metal material.

- The valence electrons of atoms are free to move about the whole volume of the metals like the molecules of a perfect gas.

- These free electrons move in random directions and collide with either positive ions fixed to the lattice or other free electrons. All the collisions are elastic, there is no loss of energy.

- The movements of free electrons obey the laws of the classical kinetic theory of gases.

● The electron velocities in a metal obey the classical Maxwell – Boltzmann distribution of velocities.

● When an electric field is applied to the metal, the free electrons are accelerated in the direction opposite to the direction of applied electric field.

Drawbacks of classical free electron theory:

1. The phenomena such a photoelectric effect, Compton effect and the black body radiation couldn't be explained by classical free electron theory.

2.According to the classical free electron theory the value of specific heat of metals is given by 4.5***R*** is the Universal gas constant whereas the experimental value is nearly equal to 3***R***.

3. Electrical conductivity of semiconductor or insulators couldn't be explained using this model.

2- Drude Theory:-

• Drude proposed that the physical properties of metals can be understood in terms of the free electron model. According to this model, a metal consists of positive ions and valence electrons.

● Drude attempted to explain the properties like electrical conduction and heat capacity of metals in terms of the parameters such as charge, mass, and momentum of free electrons.

● Lorentz contributed significantly to the development of Drude's model by applying the laws of statistical mechanics (Maxwell-Boltzaman distribution). Therefore, the microscopic theory developed on the basis of Drude model is called the ***Drude-Lorentz theory*** .

● For mathematical ease, following simplifying assumptions about metals are made in Drude - Lorentz theory:

1. Valence electrons behave as free electrons and can move all around the volume of the metal.
2. The interaction between free electrons themselves is too small and can be ignored. therefore, the free electrons move randomely inside the metal specimen without any change in their energy.
3. Free electrons behave as molecules of an ideal gas and obey kinetic theory of gases.

You will now learn how this model helped in developing an understanding of electrical conductivity.

We know that electrical conduction is the flow of electric current in a solid specimen. The relation between current I and potential difference V is governed by Ohm's law:

$$V = I R$$

Also, Ohm's law can be written in the following form:

$$J = \sigma \varepsilon$$

where is σ electrical conductivity of the material. Electrical conductivity is one of the important parameters that enable us to differentiate a metal from an insulator.

Suppose that we have a metal sample in thermal equilibrium at a temperature T , in the absence of an electric field, the free electrons move randomly. When an electric field is applied the electrons will acquire a drift velocity that is responsible for the flow of electric current.

How did Drood's theory overcome this problem?

It has been suggested that the accelerated electrons collide with the ions inside the sample as a result, upon collision, the electron loses the drift velocity and is left only at a random speed, After getting out of the collision, the electron begins to accelerate in the electric field again and acquires a drift velocity, and at the next collision it loses its drift velocity completely again and so this process continues.