CL25_Q1. Mention the postulates of quantum free electron theory of metals.

Answer

1.   The valence electrons in the metal are arranged in discrete energy states following Pauli's exclusion principle. Only electrons close to the Fermi level participate in the conduction process

2.   The occupation probability of the electron states is described by the Fermi Dirac distribution function applicable to fermions.

3.   The conduction electrons in a metal move in an array of positive ions, colliding with the ionic centers and other electrons resulting in the resistance of the material.

4.   The electrostatic interactions, namely the electron – electron interaction and the electron – ion interactions are negligible.

5.   The electrons undergo random scattering due to the vibrating ionic centers, giving rise to resistance to flow of electrons.

CL25_Q2. Explain the distribution of electrons at 0K based on the quantum theory.

Answer

We know that for a metal containing N atoms there will be N allowed energy levels in each band. As per the Pauli's exclusion principle, each energy level can accommodate a maximum of two electrons, one with spin up and the other one with spin down. When the filling up of the energy levels is undertaken, the universal rule is that, any system which is free tends to go to the state of lowest energy. Thus, a pair of electrons- one with spin up and the other with spin down occupy the lowest level. The next pair of electrons occupy the next higher level, and so on. In this way when all the electrons are accommodated in the permitted

energy levels, we see that all the energy levels in all the bands below the valence band will be completely filled. The valence band for a metal, however, will be partially filled i.e. below a particular filled energy level all the energy levels are completely filled and the ones above it will remain completely vacant. This is the picture when there is no external energy supply for the electrons, such as thermal energy or electrical energy, i.e. at the temperature of absolute zero, and when the metal is not under the influence of any external field.

CL25_Q3. Describe the Matthiessen's rule. Discuss how temperature and impurities affect the resistivity of metals?

Answer

Matthiessen's rule states that the total resistivity of a metal is the sum of the ideal resistivity due to phonon scattering, which is temperature dependent and the residual resistivity due to scattering by impurities which is temperature independent.

With increase in temperature, the lattice vibrations also increase and the resistivity due to scattering of electrons by lattice vibrations also increases. The impurities in a metal act as scattering centers for electrons. Thus the electrons in an impure metal are scattered by impurity atoms and contribute to the resistivity even at absolute zero temperature.