1

a) Show that electron does not exist inside the nucleus of the atom.

According to theory of relativity. the energy E of particle is expressed as.

$$E = mc^2 \rightarrow (1)$$

where m is the relativistic mass of a particle moveing the a velocity V and the expression for it in terms of rest mass can be written as

$$m = \frac{m_0}{\sqrt{1-\frac{V^2}{c^2}}} \rightarrow (2)$$

If P is a momentum of the particle. then the expression for kinetic energy of the particle in terms on momentum is given

$$E = \frac{p^2}{2m} \rightarrow (3)$$

According to Heisenberg's uncertainty principle. we have

$$\Delta x \, \Delta P_x \geq \frac{h}{4\pi} \quad \text{or} \quad \Delta P_x \geq \frac{h}{4\pi \Delta x} \rightarrow (5)$$

we know that the diameter of the nucleus is of the order of 10^{-14} m. If an electron is to exist inside the nucleus. then the uncertainty in its position Δx must not exceed the size of the nucleus. i.e $\Delta x \leq 10^{-14}$ m

using the Δx is equation (5) we have

$$\Delta P_x \geq \frac{h}{4\pi \Delta x} \geq \frac{6.63 \times 10^{-34}}{4\pi \times 10^{-14}} \geq 0.5 \times 10^{-20} \text{ Ns}$$

$$\therefore P_x \geq 0.5 \times 10^{-20} \text{ Ns}$$

This is the uncertainity in momentum of an electron and it is equal to the momentum of the electron inside the nucleus.

Using momentum value P_x in an equation (3) we get

$$E = \frac{p^2}{2m} = \frac{(0.2\times10^{-20})^2}{2\times9.1\times10^{-31}} = 1.5\times10^{-12}\,J$$

$$E = \frac{1.5\times10^{-12}}{1.602\times10^{-19}} = 9.36\times10^{6}\,eV \approx 9.4\,MeV$$

An electron may exist inside the nucleus if its energy is equal to or greater than 9.4 MeV. But the experimental investigations on β-decay say that kinetic energy of the β particle is 3 to 4 MeV. this clearly indicates that. electrons cannot exist within the nucleus.

$$n \rightarrow p + e^{-1} + \nu\,(\text{energy}) \quad \text{or} \quad p \rightarrow n + e^{+1} + \nu\,(\text{energy})$$

b) obtain the expression for time independent Schrodinger's wave equation

By de-Broglie idea of matter waves

$$\lambda = \frac{h}{mv} = \frac{h}{p}$$

p = momentum of the particle

Let the wave function

$$\psi = Ae^{i(kx-\omega t)} \rightarrow (1)$$

where ψ is total wave function

Let differentiate ψ by twice with respect to 'x'

$$\frac{d\psi}{dx} = A(ik)e^{i(kx-\omega t)}$$

$$\frac{d^2\psi}{dx^2} = A(ik)^2e^{i(kx-\omega t)}$$

$$\frac{d^2\psi}{dx^2} = -k^2\psi \quad \text{or} \quad \frac{d^2\psi}{dx^2} + k^2\psi = 0 \rightarrow (2) \quad \because i^2 = -1$$

But $k = \frac{2\pi}{\lambda}$ and $\lambda = \frac{h}{mv}$

$$k = \frac{2\pi mv}{h} \quad \text{or} \quad k^2 = \frac{4\pi^2m^2v^2}{h^2}$$

eq ② becoms $\frac{d^2\psi}{dx^2} + \frac{4\pi^2 m^2 v^2}{h^2}\psi = 0 \rightarrow ③$

total energy

$\therefore E = T + V$

$T = \frac{1}{2}mv^2 \therefore \frac{1}{2}mv^2 > mv^2$. or $mv^2 = 2(E-V)$

eq ③ we get

$$\frac{d^2\psi}{dx^2} + \frac{8\pi^2 m}{h^2}(E-V)\psi = 0 \rightarrow ⑤$$

this is time independent 1 - dimentional Schrodinger equation

⑤ extendend for 3-dimention

$$\frac{d^2\psi}{dx^2} + \frac{d^2\psi}{dy^2} + \frac{d^2\psi}{dz^2} + \frac{8\pi^2 m}{h^2}(E-V)\psi = 0 \rightarrow ⑥$$

(or) $$\nabla^2\psi + \frac{8\pi^2 m}{h^2}(E-V)\psi = 0 \rightarrow ⑦$$

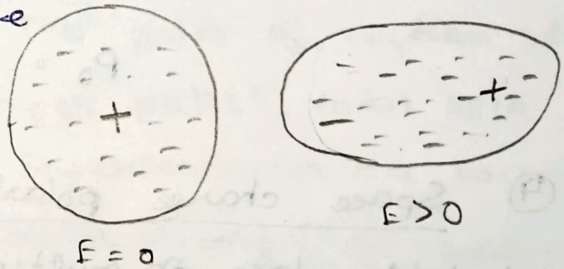
where $\nabla^2 = \frac{d^2}{dx^2} + \frac{d^2}{dy^2} + \frac{d^2}{dz^2}$

where ψ is $\psi(x, y, z)$

2 a) Describe in brief the various types of mechanism of polarization.

1) Electronic (induced polarization:

It occurs in mono atomic gases like Hg, Ne, Ar .etc. Before the applicat-ion of EF the +'ve charge will be surrended by "-'ve charge

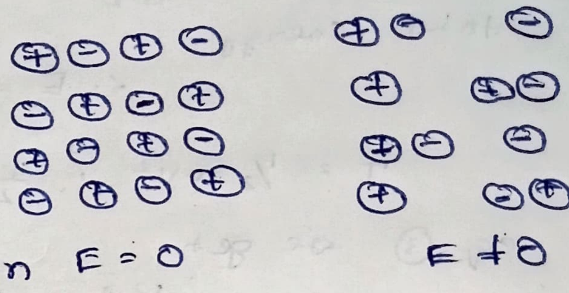


After the Application of EF & the +'ve charge move in the direction of applied EF. so they create dipole moment they are independent of temp. the time taken for complet-n ε_p is 10^{-15} sec.

$P = N\alpha E$, $P = \varepsilon_0(\varepsilon_r - 1)E$ $\alpha_e = \frac{P_e}{NE} = \frac{\varepsilon_0(\varepsilon_r - 1)\cancel{E}}{N\cancel{E}} = \frac{\varepsilon_0(\varepsilon_r - 1)}{N}$

② Ionic polarization

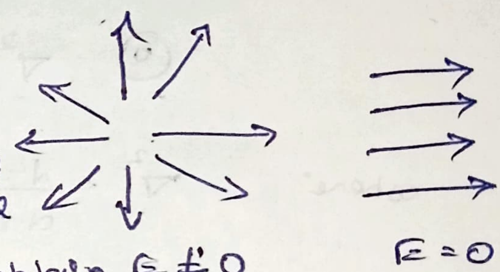
It occurs in the dielectric material which posses ionic bond such as NaCl. Before EF +ve & -ve charge are mixed together. After EF the -ve charge in the direction of EF & the +ve charge move on the direction of opp to the E.F. It doesnot depend on temp time to polarization 10^{-13} to 10^{-12} s.



$$P_e = N\alpha_e E \qquad \alpha_e = \frac{\varepsilon_0(\varepsilon_r - 1)}{N}$$

③ Orientational polarization

It occurs in DM's which has a molecules with parmenent dipole movement. Before it molecules moving random direction because of thermal energy. After EF molecules with obtain & reorient with the direction of EF and the dipole will get concled therefore net dipole movement is zero temp dependent. time to polarization is 10^{-15} s.

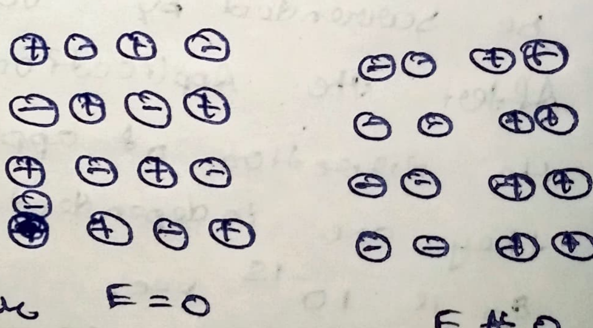


$$P = N\alpha_e E. \qquad \alpha_o = \frac{\mu^2}{3KT}$$

$$P_o = \frac{N\mu^2 E}{3KT}$$

④ Space charge polarization

It takes place in multiphase DM's in which the resistivity changes for different phases. before EF ⊕ ve & ⊖ ve charge will be mixed together. After E.F high temperature ⊕ ve & ⊖ ve charge will occupies in opp part of at



low resistivity phase. It is strongly dependent on high temperature

Explain in brief the BCS theory of superconductivity.

BCS theory is based upon the formation of cooper pairs. During the flow of current in a superconductor. when a electron comes near a positive ion core of the lattice it experiences an attractive force because of the opposite charge polarity between electron and ion core. the ion core will be displaced from its position due to this interaction which is called 'lattice distortion'.

Now an electron which comes near that place will also interact with the distorted lattice. which tends to reduce the energy of electron. the interaction is called 'electron - lattice - electron' interaction via the phonon field. Because of the reduction of energy during the interaction. it is treated as equivalent to establishing an attractive force between the two electron. becomes cooper.

Below critical temperature attraction reaches a maximum value of any two electrons of equal and opposite spins & opposite momentum. This force of attraction exceeds the columbian force for repulsion between two electron stick together and move as pairs. the pairs of electron of opposite moment are called 'cooper pairs'. total spin of zero. the electron pairs in a superconductor are bosons.

$T < T_c$ lattice electron interaction is stronger of coulomb pair encompanies as many as 10^6 other pairs.

when the electron flow in the form of cooper pairs in materials. they do not encounter any scattering and thereby resistance reduces to zero or conductivity becomes infinity which is known as 'superconductivity'

3

a) Derive the expression for density of states of Metal

$$g(E)\,dE = \frac{\text{No. of energy states available b/w } E \text{ and } E + dE}{\text{Volume of that metal}}$$

Energy $E_n = \frac{n^2 h^2}{8mL^2} \rightarrow (1)$

In three dimension

$$E = \frac{h^2}{8mL^2}(n_x^2 + n_y^2 + n_z^2) \rightarrow (2)$$

n_x, n_y & n_z are non zero positive integers

$$E_0 = \frac{h^2}{8mL^2} \quad \& \quad R^2 = n_x^2 + n_y^2 + n_z^2$$

$$E = E_0 R^2$$

The number of allowed energy values $N(E)\,dE$

$$N(E)\,dE = \frac{1}{8} \times 4\pi R^2 dR \times 1$$

$$N(E)\,dE = \frac{1}{2}\pi R^2 dR \rightarrow (4)$$

$$Z(E)\,dE = 2 \times \frac{1}{2}\pi R^2 dR = \pi R^2 dR \rightarrow (5)$$

$$E = E_0 R^2$$

$$R = \sqrt{\frac{E}{E_0}} \quad \& \quad dE = E_0 2R\,dR \quad \text{or} \quad R\,dR = \frac{dE}{2E_0}$$

$$R^2 dR = R\,R\,dR = \sqrt{\frac{E}{E_0}}\,\frac{dE}{2E_0} = \frac{1}{2}\frac{\sqrt{E}\,dE}{\sqrt{E_0^3}} \rightarrow (6)$$

$R^2 dR$ in eq^n (5)

$$Z(E)\,dE = \frac{\pi}{2}\frac{\sqrt{E}\,dE}{\sqrt{E_0^3}} \quad \text{But } E_0 = \frac{h^2}{8mL^2} \rightarrow (7)$$

$$\therefore Z(E)\,dE = \frac{\pi}{2}\frac{\sqrt{E}\,dE}{\left(\frac{h^2}{8mL^2}\right)^3} = \frac{\pi}{2}\left(\frac{8mL^2}{h^2}\right)^{3/2} E^{1/2}\,dE$$

$$Z(E)\,dE = \frac{\pi}{2}\left(\frac{8m}{h^2}\right)^{3/2} L^3 E^{1/2}\, dE \rightarrow (8)$$

$$\therefore g(E)\,dE = \frac{Z(E)\,dE}{\text{Volume}\,(L^3)}$$

Hence $$g(E)\,dE = \frac{\pi}{2}\left(\frac{8m}{h^2}\right)^{3/2} E^{1/2}\, dE \rightarrow (9)$$

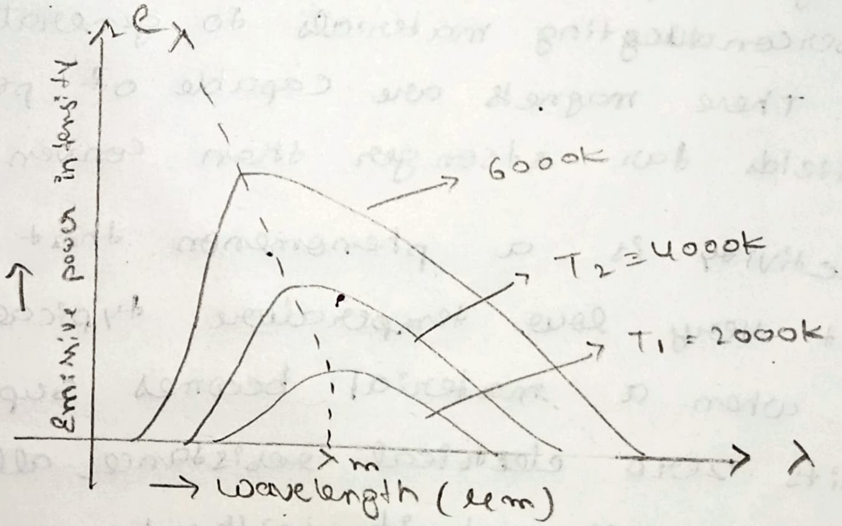
$$g(E)\,dE = \pi\,\frac{8\sqrt{2}\,m^{3/2}}{h^3}\, E^{1/2}\, dE \rightarrow (10)$$

equation 9 & 10 represent density of energy states

4

a) Explain the energy distribution in the spectrum of a black body.

The ~~above~~ curve in figure shows the variation of intensity of radiation with wavelength for different temperature of the black body ($T_1 < T_2 < T_3$).



1) At a given temperature, the energy distribution is not uniform in the spectrum of blackbody radiation

2) At a given temperature black body emits continuous range of wavelength of radiation As the wavelength

increases the intensity of radiation increases reaches a maximum value at a particular wavelength λ_m and then decreases with further increases in wavelength

3) As temperature increases, wavelength λ_m maximum energy density decreases, and vice versa

$$\lambda_m \propto 1/T$$

4) For all wavelength, an increase in temperature cause an increase in energy emission or intensity

5) the area under curve represent the total energy emitted for the complete spectrum. area under the curve increases with increase in temperature

$$E \propto T^4$$

b) Briefly explain about superconducting magnets

Superconducting magnets are a type of electromagnet that utilizes superconducting materials to generate strong magnetic fields. These magnets are capable of producing intense magnetic fields far stronger than conventional magnets

superconductivity is a phenomenon that occurs in certain materials at very low temperature, typically near absolute zero. when a material becomes superconducting it exhibits zero electrical resistance, allowing electric current to flow through it without any energy loss. This unique property makes superconductors ideal for creating powerful magnets.

To create a superconducting magnet, the supercondu

-ting wire is wound into a coil or solenoid configuration

-n. when a direct current (DC) is passed through the

coil, a strong magnetic field is generated. The magnetic

field strength of a superconducting magnet is directly

proportional to the current flowing through the coil