UES-022 (Quantum Materials)
Department of Physics and Material Science, TIET
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Tutorial Sheet 4-5

Introduction to solids & Free electron theory (classical & quantum electron gas)

1. Which of the following electron configurations is for an inert gas?
   a) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$
   b) $1s^2\ 2s^2\ 2p^6\ 3s^2$
   c) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1$
   d) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^2\ 4s^2$

2. Potential energy W for the formation of a bond between two univalent ions is given by $W = -(AZ_1Z_2e^2)/r + B/r^m$. The equilibrium spacing is $r_0 = 0.25$ nm. Find the value of the constant B, given m = 9.

3. If the attractive force between a pair of Mg^{2+} and S^{2-} ions is 1.49×10^{-8} N and if the S^{2-} ion has a radius of 0.184nm, calculate a value for the ionic radius of Mg^{2+} ion in nm.

4. Covalent-Metallivity number for Tungsten is 3.86. What is the percentage of metallic character for it?

5. Compute the percentage of ionic character of the interatomic bonds for the following compounds: TiO_2, ZnTe, CsCl, InSb and $MgCl_2$.
   (electronegativities are: Ti:1.8, Te:2.1, Zn:1.6, O:3.5, Cs:0.7, Cl:3.82, In:1.7, Sb:1.9, Mg:1.2)

6. List the types of bonds present in solids. Categorize them based on:
   a) Conduction
   b) Directionality
   c) Electronegativity

7. Explain (with a drawing) why a base-centered tetragonal lattice is not possible.

8. Which is the most symmetrical and least symmetric crystal structure? Why?

9. Calculate APF for:
   a) FCC unit cell.
   b) Simple hexagonal unit cell

10. Cu (At mass = 63.546 g/mole, Density = 8.96 g/cm^3) has FCC structure. Determine its atomic size.

11. What is the applied electric field that will impose a drift velocity equal to 0.10% of the mean speed, $u = 1.2 \times 10^6$ m/s, of the conduction electrons in copper. The drift mobility of the electron is 32 cm^2/Vs.

12. Calculate the number density (N_d, number of atoms/volume) and n (number of valence electrons/volume) for iron. (At. Mass: 56g/mol, density 7.8g/cm^3)

13. List 3 main assumptions for the classical theory of electrons in a solid.

14. For a perfect crystal of potassium (At mass = 39.10 g/mole, Density = 0.86 g/cm^3) the relaxation time for electrons is 4.3 x 10-14 s at room temperature. Determine:
    i) electron mobility
    ii) conductivity

15. Define: Van der Waals Bond, Bond length, tetragonal crystal class, electron mobility(for solids), electron relaxation time (for solids), Fermi energy, Fermi sphere

16. In Al the Fermi energy of the conduction electron is 5.9 eV. What are the energy, speed and momentum of the conduction electrons?

17. For a perfect crystal of potassium (At mass = 39.10 g/mole, Density = 0.86 g/cm^3) what is the value of Fermi level (in eV)?

18. Calculate density of states ($g(E_f)$) for potassium at Fermi level.

19. What is the fermi temperature of Sodium? (E_f = 3.24 eV)

20. Determine the fraction of electrons affected at Room temperature for Na.