

MATERIAL SCIENCE
(CHE2106)

Time Allotted : 2½ hrs

Full Marks : 60

Figures out of the right margin indicate full marks.

*Candidates are required to answer Group A and
any 4 (four) from Group B to E, taking one from each group.*

Candidates are required to give answer in their own words as far as practicable.

Group – A

1. Answer any twelve:

12 × 1 = 12

Choose the correct alternative for the following

- (i) Net ionic energy (E) of an atom within a lattice is given by _____.
- (a) $E = -\frac{e^2}{4\pi\epsilon_0 r} + \frac{b}{4\pi\epsilon_0 r^n}$ (b) $E = -\frac{e^2}{4\pi\epsilon_0 r^2} + \frac{b}{4\pi\epsilon_0 r^n}$
- (c) $E = \frac{e^2}{4\pi\epsilon_0 r} - \frac{b}{4\pi\epsilon_0 r^n}$ (d) $E = \frac{e^2}{4\pi\epsilon_0 r^2} - \frac{b}{4\pi\epsilon_0 r^n}$
- (ii) Pitch is the measure between the layers comprising of _____ crystals in cholesteric liquid crystal.
- (a) 90° rotated (b) 180° rotated
(c) 270° rotated (d) 360° rotated
- (iii) Wridemann-Franz ratio is given by _____, where k_B is the Boltzmann constant and 'e' is electronic charge.
- (a) $\frac{\pi^2}{3} \left(\frac{k_B}{e} \right)^2$ (b) $\frac{\pi^2}{3} \left(\frac{k_B}{e} \right)$ (c) $\frac{\pi}{3} \left(\frac{k_B}{e} \right)^2$ (d) $\frac{\pi}{3} \left(\frac{k_B}{e} \right)$
- (iv) With the isotropic material the relationship between modulus of elasticity (E) and shear modulus (G) is given by _____, where γ is the shear strain.
- (a) $E = \frac{2(1+\gamma)}{G}$ (b) $E = 2G(1+\gamma)$
(c) $E = \frac{2G}{(1+\gamma)}$ (d) $E = \frac{G(1+\gamma)}{2}$
- (v) Leaching is a unit operation under _____.
- (a) Pyrometallurgy (b) Hydrometallurgy
(c) Electrometallurgy (d) Powder metallurgy
- (vi) Stainless steel is an alloy of _____.
- (a) Al (b) Cu (c) Fe (d) Sn

- (vii) During metal oxide formation the change in entropy is _____.
 (a) positive (b) negative
 (c) zero (d) depending on the temperature of the process
- (viii) The ratio of tensile stress to tensile strain within elastic limit is called _____.
 (a) bulk modulus (b) Poisson's ratio
 (c) modulus of rigidity (d) modulus of elasticity
- (ix) Poisson's ratio ν is defined as ratio of _____.
 (a) axial strain to transverse strain (b) transverse strain to axial strain
 (c) shear strain to axial strain (d) axial strain to shear strain
- (x) For a Poisson's ratio of 0.4 for a material, the ratio of the shear modulus to modulus of elasticity is _____.
 (a) 14/5 (b) 5/7 (c) 7/5 (d) 5/14

Fill in the blanks with the correct word

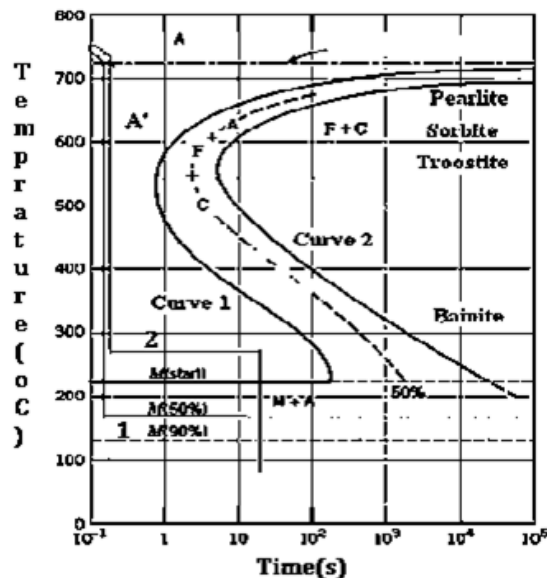
- (xi) The energy calculated among the atoms A and B because of London dispersion force is equal to _____, when ionisation energy for A and B are 502 kJ/mol and 418.8 kJ/mol respectively. The polarizability of A and B are 0.131 \AA^3 and 0.795 \AA^3 . The interatomic distance is 0.28 nm.
- (xii) S-N curve shows the variation of _____ with the number of cycles for applied force.
- (xiii) _____ is basically an amplitude of the scattered wave from each atom in an unit cell.
- (xiv) Materials which shown direction independent properties are called _____ materials.
- (xv) In an Open Hearth Process _____% of scrap and iron are mixed together respectively and given as a feed to the process.

Group - B

2. (a) Consider a gaseous molecule A^+B^- , where the first ionization energy of A is 220 kJ/mol and electron affinity for B is 110 kJ/mol. The interionic separation is 4 \AA . Find the bond dissociation energy and comment on the stability of the molecule. [[CO1](Analyse/HOCQ)]
- (b) Cite one example of material that is taking lattice form from each of FCC and BCC crystal. [[CO1](Remember/LOCQ)]
- (c) Show that the atomic packing factor for hexagonal closed-pack (HCP) crystal is 0.74. [[CO1](Estimate/HOCQ)]
(4 + 2) + 2 + 4 = 12
3. (a) Find out the mole fraction of Schottky defect in NaCl crystal at 2900 K, when ΔH for Schottky is 2 eV, $1 \text{ eV} = 1.608 \times 10^{-19} \text{ J}$ and $k_B = 1.38 \times 10^{-23} \text{ J/K}$ [[CO1](Apply/IOCQ)]
- (b) Why the conduction band and valence band appear in a compound? Elaborate with proper diagram. [[CO2](Remember/LOCQ)]
- (c) A semiconductor diode laser has a peak emission wavelength of $1.55 \mu\text{m}$. Find its band gap in eV. The velocity of light is $3 \times 10^8 \text{ m/s}$, $h = 6.63 \times 10^{-34} \text{ J-s}$. [[CO2](Apply/IOCQ)]
5 + 4 + 3 = 12

Group - C

4. (a) A hexagonal close-packed cell is known to contain two atoms of the same type located at the positions of (000) and $(\frac{1}{3}, \frac{2}{3}, \frac{1}{2})$. Compute the structure factor F_{hkl} , when $h+2k$ is a multiple of 3 and l is even. [[CO6](Apply/IOCQ)]
- (b) What is eutectic point? In Fe-C phase diagram, write down the eutectic equations at C weight percentage of 0.8 and 4.3. [[CO3](Remember/LOCQ)]
- (c) Show the microstructure of allow in Fe-C diagram when C weight percentage is 0.8. Also label a sketch of the microstructure. [[CO3](Remember/LOCQ)]
- 6 + (2 + 2) + 2 = 12**
5. (a) In XRD spectrum for an anhydrous salt sample the signature peak shows at (003) with d-spacing 5.9\AA . Further with the hexahydrate of the salt sample the signature peak is seen at (111) with d-spacing 4.1\AA . The hydrated sample is monoclinic. Show an approximate schematic of the water attachment in the sample considering the interstitial site as tetrahedral. What is the ratio of the glancing angle? Why the peaks appear for two cases with different glancing angle? [[CO1](Analyse/HOCQ)]
- (b) From the following figure describe what transformation happens in for the path 1 and path 2. [[CO3](Apply/IOCQ)]



(6 + 2) + (2 + 2) = 12

Group - D

6. (a) What is predominance area diagram? Construct the predominance area diagram for any metal (M) along with metal sulphide (MS). The roasted product comprises of MO , M , MS , MSO_4 , SO_2 and O_2 primarily. [[CO4](Apply/IOCQ)]
- (b) In one roasting unit, an ore concentrate of the composition 21% Cu_2S , 40% FeS_2 , 31% SiO_2 and 8% H_2O is roasted using air. The roasting unit is heated by oil of composition 85% C and 15% H, when the amount of oil is 5.2% of the weight of the ore. Air for combustion and roasting is 110% in excess of the theoretical requirement. The gases from combustion and roasting mix together and are carried through a flue. S passes as SO_2 . The roasted product consists of CuO , Fe_2O_3 and SiO_2 .

Calculate the weight of the roasted product and amount of H₂O per cubic meter of the flue gas at STP.

[[CO4](Apply/IOCQ)]
(2 + 5) + 5 = 12

7. (a) What are the stages involved in hydrometallurgy? [[CO4](Remember/LOCQ)]
 (b) In case with the oxidative leaching process during metal extraction, why Fe⁺³ is used? [[CO4](Remember/LOCQ)]
 What are the disadvantages one has with the usage of Fe⁺³? [[CO4](Remember/LOCQ)]
 (c) What is electrowinning? Elaborate with a neat sketch. [[CO4](Remember/LOCQ)]
3 + (3 + 2) + 4 = 12

Group - E

8. At a point on the surface of a generator shaft the stresses are $\sigma_x = 50$ MPa, $\sigma_y = 10$ MPa, and $\tau_{xy} = 40$ MPa, as shown in Fig. 1. Using Mohr's circle, determine the following quantities:
 (i) the principal stresses
 (ii) principal planes
 (iii) the maximum shear stresses
 (iv) plane of maximum shear

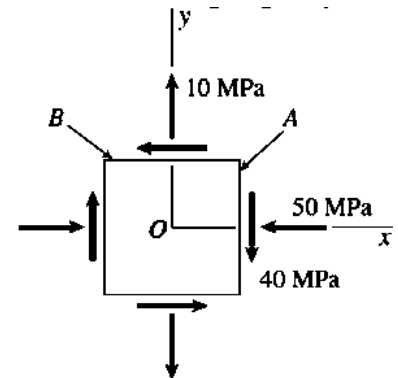


Fig. 1 [[CO5](Analyse/HOCQ)]
(3 + 3 + 3 + 3) = 12

9. (a) Define Bulk Modulus. Deduce the relation between Young's Modulus, Bulk Modulus and Poisson's ratio. [[CO5](Remember/LOCQ)]
 (b) An aluminium specimen shown in Fig. 2 has a diameter of $d_0 = 25$ mm and a gauge length of $L_0 = 250$ mm. If a force of 150 kN elongates the gauge length 1.20 mm, determine the modulus of elasticity. Also, determine by how much the force causes the diameter of the specimen to contract. Take $G_{al} = 26$ GPa and $\sigma_y = 440$ MPa. [[CO5](Apply/IOCQ)]

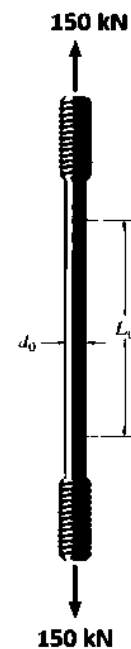


Fig. 2
(3 + 3) + (3 + 3) = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	25	43.75	31.25