M. Sc. Physics Semester-IV

Examination May-2018

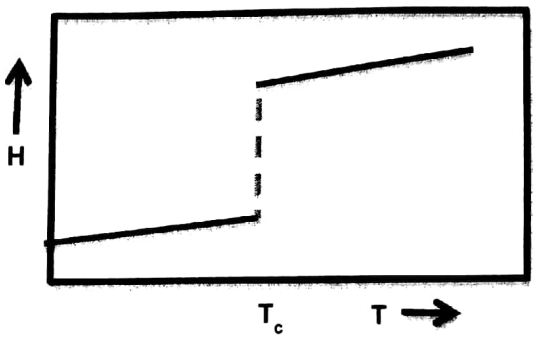
Paper: PHYS 531- Physics at Nanoscale (Part-II)

Time: 3 Hours **Total Marks: 70**

Attempt all the questions as directed

Q1: Answer **all** the questions 1x8=8

i. A system represents the variation of enthalpy (H) with temperature (T) plotted in the figure. What would be the order of transition?



a. Zero

b. First

c. Second

d. Third

ii. Which pump(s) is (are) the basic pump(s) necessary for all kinds of vacuum?

a. Rotary pump

b. Diffusion pump

c. Turbo molecular pump

d. Ion pump

iii. In a quantized system, the one electron charging energy and energy gap are

a. e^2/C and $e^2/2C$

b. $e^2/2C$ and $e^2/2C$

c. $e^2/4C$ and e^2/C

d. e^2/C and e^2/C

where, 'e' is the electronic charge and 'C' is the capacitance

Contd...

iv. Calculate the time (τ) for an electron to escape from a metal contact to nanostructure with the energy broadening (Γ) at the interface of 100 meV.

v. When does the electron exhibit ballistic transfer? Calculate the minimum resistance for this system.

vi. Which techniques could estimate the composition of nanostructure materials?

vii. In ball milling technique, how would you choose the quantity of beads to be utilized for nanostructuring 'm' amount of ~100 μm sized particles?

viii. What would be the kinetic energy of the photoelectrons emitted in a gas and a solid?

Q2: Answer **all** the questions 2×10=20

i. Between nucleation growth and spinodal decomposition, which one provide uniform distribution of compositions in the final alloy and why?

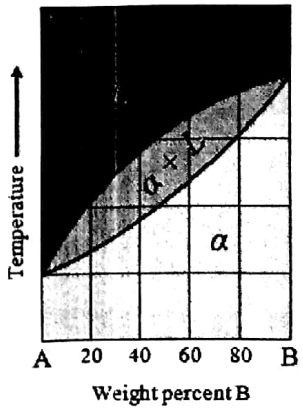
ii. For a component A of a mixture, concentration as a function of distance (x) is given by $C_A=5e^{-10x}$ (x is in cm and C_A in mol/liter). Calculate the value of diffusion velocity (m/s) of the component A at the point x=0, if diffusivity of A in the mixture is 2.567×10^{-5} m^2/s.

iii. What are the advantages and disadvantages of the MOCVD technique for ultra-thin film growth?

iv. Plot the current - voltage and conductance-voltage characteristics for a metal-nanoparticle-metal structure at absolute zero temperature.

v. How many degrees of freedom are available for the system with 3 phases, each having 2 components.

vi. Draw the Gibbs' free energy diagram at various critical temperatures for the isomorphous binary phase diagram:



vii. A certain liquid has a vapor pressure of 6.91 mmHg at 0 °C. If this liquid has a normal boiling point of 105 °C, what is the liquid's heat of vaporization in kJ/mol?

viii. What is the packing parameter of a Micelle structure formed with surfactant consisting of 0.7 nm diameter head group and 2 nm chain length.

ix. Write down the steps to functionalize a biomolecule on a gold nanoparticle.

x. A liquid is allowed to cool below the freezing temperature. Find the driving force for solidification as the change in Gibb's free energy.

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Q3: Answer any **SIX** questions 7×6=42

i. Derive the critical temperature (T_c) at which the miscibility gap vanishes in the phase diagram. For a binary alloy $A_{0.3}$ $B_{0.7}$ with compositional interaction (Ω) of 0.6, what would be T_c?

ii. Plot and discuss the locus of points for conductivity peaks in differential conductance [$\delta G = \delta I/\delta V_{sd}$] by applying minimal source-drain voltage (V_{sd}) and changing the gate voltage (V_g). Discuss the appearance of different sized conductance diamonds in V_{sd} - V_g graph.

iii. Carbon (C) is diffused in titanium (Ti) at a rate of 1.27 x 10^{-9}kg/m^2.s. The concentration of C at a distance 1 mm from the surface is 0.25 kg/m^3 and at 3 mm the concentration is 0.68 kg/m^3. In this scenario, what would be the diffusion coefficient for C.

iv. Explain the working principle of X-ray photoelecron spectroscopy including the function of each parts.

v. X-ray Photoelectron Spectroscopy (XPS) using Al $K\alpha_1$ radiation of energy 1486.29 eV liberates photo-emitted electrons. In this process, the speeds of the electrons from F 1s core and F 2p valence levels are 16.75 x 10^6 m/s and 22.85 x 10^6 m/s, respectively. Find the location of binding energies for both the levels. Work function of the spectrometer (Φ) = 1.1 eV
Mass of electron (m_e) = 9.11 x 10^{-31} kg
Charge of electron (e) = 1.602 x 10^{-19} C $\Rightarrow$ 1 eV = 1.6021892 x 10^{-19} J

vi. Explain two methods of separation for colloidal particles of different sizes from a solution. Provide details for the biological process that purifies the colloidal solution in the human body.

vii. Estimate the changes in enthalpy (ΔH) and entropy(ΔS) for the following reaction and decide in which direction each of these factors will drive the reaction: $N_2(g) + 3\ H_2(g) \rightleftharpoons 2\ NH_3(g)$

Compound	**$\Delta H_f°$(kJ/mol)**	**ΔS(J/mol-K)**
$N_2(g)$	0	191.61
$H_2(g)$	0	130.68
$NH_3(g)$	-46.11	192.45