Maximum Marks : 60

Note : Answer any FOUR questions.

(M. Tech. students governed by the old ordinance and students of Advanced P.G. Diploma in Nanotechnology will be examined out of 75 marks and their obtained marks shall be proportionately raised.)

1. (a) Write in detail main features of the lecture ‘There is a plenty of room at the bottom’.

(b) Discuss the discovery and structure of C-60. How many hexagons shall be needed in going from C-60 to C-70 and C-80?

(c) Explain the formation of Ca-shells around C-60.

2. (a) Write a note on the discovery of CNT’s. Discuss the classification and structure of single wall carbon nanotubes.

(b) Describe the three methods of preparation of carbon nanotubes.

3. (a) Explain the process of self assembly and describe semiconductor islands.

(b) What is Langmuir-Blodgett technique of preparing monolayers? Explain the formation of self assembled monolayers of alkane thiol on gold substrate.

(c) Give two applications of SAMs.

4. (a) What are DNA double nanowires? Draw the structures of nucleotide bases.

(b) Give few examples of proteins.

(c) Sketch the structures formed by amphiphilic molecules at water-oil or water-air interfaces for various values of the packing parameter p.

5. (a) Distinguish between quantum wells, quantum wires and quantum dots. Give two examples of each structure.

(b) Write Schrödinger equation for bulk crystalline lattices and write the equation for eigen values for the parabolic band approximation. Explain the concept of quantum confinement in a three dimensional quantum dot and discuss the widening of the band gap as the size of the structure is reduced.
Attempt all questions.

Q No. 1(a) Calculate the lowest three energy levels in eV for an electron placed inside an infinite potential well of width $2a = 4\text{Å}$.

$$V(x) = \begin{cases} 0, & \text{if } -a \leq x \leq a \\ \infty, & \text{otherwise} \end{cases}$$

Determine also the normalized eigenfunctions. (5)

(b) Find the discrete energy levels of a particle in a one dimensional finite square well potential defined by

$$V(x) = \begin{cases} 0, & \text{if } -a \leq x \leq a \\ V_0, & \text{otherwise} \end{cases}$$

Show that in the limiting case of $V_0 \to \infty$, the energy levels correspond to that of an infinite square well. (6)

(c) The electron in a hydrogen atom may be thought of as confined to a nucleus of radius $5 \times 10^{11}$ meter. Calculate the minimum kinetic energy of the electron, given that, $m = 9 \times 10^{-28}$ gm and $h = 6.62 \times 10^{-27}$ erg-sec. (4)

Q No. 2 (a) Starting with the classical definition of angular momentum and using the commutation relations $[x, L_x] = [y, L_y] = [z, L_z] = i\hbar$, deduce the commutation relations between the components of angular momentum operator. (5)

(b) What are Pauli spin operators? Express Pauli spin functions in the form of $2 \times 2$ spin matrices. (10)

Q No. 3 (a) Show that the expectation values $\langle px \rangle$ and $\langle xp \rangle$ are related by, $\langle px \rangle - \langle xp \rangle = \hbar/i$. (5)

(b) The mean lifetimes of $\Sigma^+$ particle is 0.8 sec. What will be the uncertainty in the determination of its mass? (5)

(c) Find the probability that a particle trapped in a box L wide can be found between $0.45L$ and $0.55L$ for the ground and first excited states. (5)

OR

Q No. 3 (a) Outline the free electron theory of metals. (3)

(b) Write down the Schrödinger equation for a linear harmonic oscillator and find its eigen-values and eigen-functions. (6)

(c) Discuss the time independent perturbation theory for the non-degenerate stationary state. Obtain the corrected eigen-function and eigen-value. (6)

Q No. 4 (a) Obtain the WKB wave functions for the classical and non-classical regions. Explain the conditions under which the WKB approximation can be used. (10)

(b) Write short notes on quantum computation and quantum qubits (5)
Answer all questions. The symbols have their usual meaning.

1. (a) Explain the terms; Bravais and non-Bravais lattices, primitive and non-primitive unit cells, lattice constants and crystallographic directions.
    4

    (b) The Bragg angle for reflection from (110) planes in bcc iron is 22° for an X-ray wavelength of \( \lambda = 1.54 \) Å. Compute: cube edge for iron, Bragg angle for reflection from (111) planes and density of bcc iron if atomic wt. of Fe is 55.8.
    6

    (c) Write a brief note on single crystal and powder X-ray diffraction.
    5

2. (a) Explain van der Waals interaction. Apply it to explain formation of inert gas crystals. Show that interatomic force in such cases is proportional to \( r^{-7} \). Give \( U(r) \) vs. \( r \) and \( F(r) \) vs. \( r \) representations.
    8

    (b) Compute the cohesive energy per ion pair of LiCl structure from the data given below:
        \[ \alpha=1.748, \ r_0=0.257 \text{ nm}, \ n=8, \text{ The ionization energy of Li is 5.4 eV and electron affinity of Cl is 3.61 eV.} \]
        5

    (c) What is hydrogen bonding? Apply it to explain interaction between water molecules.
    2

    (c') Draw potential energy vs distance graph for bonding and antibonding molecular orbitals, showing all the details.

OR

3. (a) Categorize different materials on the basis of electrical conductivity. Give experimental data in the support of your answer. Starting with the expressions of \( n_0 \) and \( p_0 \) obtain \( n_i \) and \( p_i \) in terms of intrinsic carrier concentration \( n_i \) and intrinsic energy \( E_i \) hence explain the shifting of Fermi level \( E_F \) with doping concentrations.
    7

    OR

    (a') Derive an expression for electrical conductivity in case of a semiconductor taking into consideration contribution of electrons and holes. Discuss its dependence on various terms.
    5

    (b) What are ceramics? Classify ceramic materials and discuss one of them in detail.

    (c) Calculate intrinsic carrier concentration for GaAs at 300 K and compare with the given \( n_i=2\times10^6 \text{ cm}^{-3} \). (Given: \( m_n^*=0.067m_0, \ m_p^*=0.48m_0, \ E_g=1.43 \text{ eV}, \ k_B=1.38\times10^{-23} \text{ J/K and } h=6.626\times10^{-34} \text{ J.sec})
    3

Continued............2
4(a) What are different defects in solids? Derive an expression for equilibrium concentration of Schottky defects and discuss its dependence on various terms.

(b) Define Burgers vector by using suitable diagram. Why do the single crystals show less strength as compared to theoretical strength? Give one example showing theoretical and observed strengths.

(c) Calculate the concentration of vacancies in Cu at 500 K. The energy needed to form a vacancy in Cu is 0.9 eV. Given: \( N_A = 6.023 \times 10^{23} \text{ atoms/mol} \), \( \rho = 8.4 \text{ g/cm}^3 \) and \( A_{cu} = 63.5 \text{ g/mol} \).
2011-2012
I SEMESTER EXAMINATION
(M. Tech. and Advanced P.G. Diploma in Nanotechnology)
Elements of Physical Chemistry
(AP-613)

Maximum Marks : 60
Duration : Three hours

Note : Answer all the questions.

(M. Tech. students governed by the old ordinance and students of Advanced P.G. Diploma in Nanotechnology will be examined out of 75 marks and their obtained marks shall be proportionately raised.)

1. (a) Discuss the limitations of the first law of thermodynamics and hence highlight the definition of the second law of thermodynamics in terms of adiabatic work between the two equilibrium states of a system having same kinetic and potential energies. (4)
   (b) With suitable examples establish the reaction kinetics for first and second order chemical reactions. (4)
   (c) State and prove Liouville’s theorem. (4)

2. (a) Mention various thermodynamic functions with their physical significance. (4)
   (b) What do you mean by micro- and macro-states of a system? Write the fundamental postulates of statistical mechanics? (4)
   (c) Write a short note on electrochemical processes. (4)

3. Derive an expression for the thermodynamical probability of a system obeying Bose-Einstein (BE) statistics. With the help of a box diagram show all the possible macrostates of a system consisting 6 particles of total energy 6E. (12)

   OR

3’ Discuss Maxwell-Boltzman statistics with suitable example for a system and also show all possible macrostates alongwith their thermodynamical probabilities for a system of your choice. (12)

4. (a) What are true solutions? Discuss the appropriate theory of solution. (4)
   (b) State the "Fick’s laws of diffusion. (4)
   (c) What do you mean by Kirkendall effect? (4)

5. (a) What do you mean by nucleation? Differentiate between homogenous and hetrogenous nucleation. (4)
   (b) Discuss Mertensitic transformation. (4)
   (c) Explain the term spinodal decomposition. (4)

*****
2011-2012
I SEMESTER EXAMINATION
(M. Tech. and Advanced P.G. Diploma in Nanotechnology)
Synthesis and Characterization of Nanomaterials
(AP-614)

Maximum Marks : 60

Duration : Three hours

Note : Answer all the questions.

(M. Tech. students governed by the old ordinance and students of Advanced P.G. Diploma in Nanotechnology will be examined out of 75 marks and their obtained marks shall be proportionately raised.)

1. (a) Explain the principle, working and advantages of sputtering technique to grow the nanostructure thin films.
   5
(b) Explain CVD method to prepare the nanoparticles.
   5
(c) Describe synthesis of nanostructure by chemical vapour deposition technique and give its limitations.
   5

OR

I'. Explain the following in detail.
   (i) AFM based nanolithography
   (ii) E-beam lithography
   (iii) Ion-beam lithography

2. Describe any three of the following methods of synthesis of nanoparticles.
   (i) Metal nanocrystals by reduction
   (ii) Electro-chemical synthesis
   (iii) Sol-gel method
   (iv) Thermolysis route

3. (a) Describe the advantages of the biosynthesis of nanoparticles.
   5
(b) Write the name of five fungi and bacteria commonly used for the synthesis of metal nanoparticles, respectively.
   5
(c) Explain any one mechanism used by the organism for the biosynthesis of metal nanoparticles.
   5

4. (a) What do you mean by characterization of nanomaterials? Describe in details the construction and working principle of a scanning electron microscope.
   8
(b) What is a spectrophotometer? How this equipment can be used to determine the band gap of a semiconductor?
   7

OR

Give a complete account of atomic force and scanning tunneling microscopic characterization techniques. Mention some salient features that make these techniques grossly different from each other.

*****