INDIAN INSTITUTE OF SCIENCE
BANGALORE - 560012

ENTRANCE TEST FOR ADMISSIONS - 2010

Program : Research
Entrance Paper : Materials Science
Paper Code : MR

Day & Date
SUNDAY, 25TH APRIL 2010

Time
9.00 A.M. TO 12.00 NOON

General Instructions

1. This question paper has two parts (A&B). Answer all the questions from part A. Each question carries one mark. Answer any 5 questions from part B. Each question carries 10 marks.
2. Answers for part A have to be marked in the OMR sheet, while part B should be answered in the answer book provided.
3. For each question, darken the appropriate bubble in the OMR to indicate your answer.
4. Use only HB pencils for darkening the bubble.
5. Darken only one bubble per question. If you darken more than one, the answer will be evaluated as incorrect.
6. In case you wish to change your answer, erase the existing one completely before darkening another bubble.
7. There is no negative marking.

The following physical constants and conversion factors may be of some use:

Planck's constant (h),	=	6.626×10^{-34}	J.s
Electron rest mass (m_e),	=	9.108×10^{-31}	kg
Proton rest mass (m_p),	=	1.673×10^{-27}	kg
Electronic charge (e),	=	1.602×10^{-19}	C
Boltzmann's constant (k_B),	=	1.380×10^{-23}	J/K
Avagadro's number (N_A),	=	6.022×10^{23}	mol^{-1}
Speed of light in vacuum (c),	=	2.998×10^{8}	m/s
Permittivity of free space (ε_o),	=	8.854×10^{-12}	F/m
Permeability of free space (μ_o)	=	$4\pi\times10^{-7}$	H/m
Bohr Magneton (μ_B)	=	9.274×10^{-24}	J/T
1 eV	=	1.602×10^{-19}	J

MATERIALS SCIENCE
PART A

Q.1. The equilibrium concentration of vacancies in a metal at a given temperature depends on its

(a) crystal structure (b) melting point

(c) density (d) degree of cold-working

Q.2. Possible Burgers vector of a perfect dislocation in an *FCC* structure is

(a) [100] (b) 1/3 [111] (c) 1/2 [110] (d) 1/6 [122]

Q.3. Which of these statements about a perfect edge dislocation in an *FCC* crystal is false?

(a) Line direction is perpendicular to the Burgers vector

(b) The dislocation can cross-slip

(c) The dislocation can dissociate into partial dislocations

(d) The dislocation can move by a climb process

Q.4 A low angle tilt grain boundary consists of

(a) an array of screw dislocations (b) an array of edge dislocations

(c) an ordered array of vacancy clusters (d) parallel sets of stacking faults

Q.5. Surface energy of metal

(a) is independent of the orientation of the surface

(b) is generally lower for close-packed surfaces

(c) is not affected by the presence of adsorbed molecules

(d) does not vary with temperature

Q.6. The equilibrium shape of a material

(a) consists of only the lowest energy facets

(b) has the lowest surface area for a given volume

(c) is independent of temperature

(d) can include high energy facets

Q.7. The enthalpy of melting of water is 80cal/gm at 0^oC (liquid-solid equilibrium temperature at pressure invoved). The entropy change associated with melting is

(a) ∞ cal/gmK (b) 0 cal/gm K (c) +0.3 cal/gm K (d) -0.3 cal/gm K

Q8. The standard Gibbs free energy change for the reaction H_2O (liquid) = H_2O (vapour) is equal to 2 kcal/mol at 25^oC. The equilibrium vapour pressure of water at 25^oC is

(a) 2500 T_{orr} (b) 250 T_{orr} (c) 25 T_{orr} (d) 2.5 T_{orr}

Q.9. A H_2O molecule contains 2 hydrogen atoms and 1 oxygen atom. For applying the phase rule to the water phase diagram, the number of components to be considered is

(a) 1 (b) 2 (c) 3 (d) 1.5

Q.10. Mild steel is

(a) a compound of *Fe* and *C*

(b) a substitutional solid solution of *Fe* and *C*

(c) an interstitial solid solution of *Fe* and *C*

(d) an ordered solution of *Fe* and *C*

Q. 11. In a binary phase diagram, the number of degree of freedom at the eutectic point is

(a) 0 (b) 1 (c) 2 (d) 3

Q.12. Inhomogeneity in solid composition during alloy solidification is because of

(a) slow diffusion in the solid phase

(b) fast diffusion in the solid phase

(c) slow diffusion in the liquid phase

(d) fast diffusion in the liquid phase

Q.13. The requirement for cooling below the thermodynamically predicted phase transformation temperatures to start solidification is because of

(a) surface energy (b) presence of impurities

(c) adsorbed species (d) bulk free energy

Q.14. The unit for viscosity is

(a) Pa.sec (b) Pa/sec (c) Kg.m/sec (d) $Kg.m/s^2$

Q.15. Aluminum is more corrosion resistant than iron because

(a) the free energy of formation of alumina is higher than that of iron oxide

(b) the free energy of formation of alumina is less than that of iron oxide

(c) iron oxide has more point defects than alumina

(d) alumina is more adherent than iron oxide

Q.16. A doubling of temperature causes a doubling of the diffusion coefficient. The activation energy of this diffusion process is

(a) 0.14 kcal/mol (b) 1.4 kcal/mol (c) 14 kcal/mol (d) 140 kcal/mol

Q.17. In materials with solid state phase transitions, the strain induced by the phase change may be used to drive the crystallization in specimens that are

(a) heated above the transition temperature

(b) heated well below the transition temperature

(c) annealed alternately above and below the transition temperature

(d) annealed well above the phase transition temperature

Q.18. If the change from solid to liquid occurs discontinuously at atomic scale over one atomic plane, the interface is called

(a) sharp (b) diffuse (c) singular (d) rough

Q.19. Zone-melting process is very effective in purifying silcon as its segregation coefficient is less than one in which

(a) the impurities segregate to the solid

(b) the impurities segregate to the liquid

(c) its semiconducting characteristic is exploited

(d) most impurities are leveled over the entire sample

Q.20. The extent of short medium and local long range order in glasses is assessed by the

(a) radial distribution function (b) structure factor

(c) atomic scattering factor (d) glass transition temperature

Q.21. For an impure superconductor, the penetration depth λ and coherence length ξ is related to the mean free path l of electrons in normal state by

(a) $\xi^2 = \xi_0^2 \lambda_L^{\,2} / l$ *and* $\lambda^2 = \lambda_L^2 \xi_0 / l$ (b) $\xi^2 = \xi_0 l$ *and* $\lambda^2 = \lambda_L l$

(c) $\xi^2 / l = \xi_0$ *and* $\lambda^2 / l = \lambda_L$ (d) $\xi^2 = \xi_0 l$ *and* $\lambda^2 = \lambda_L^2 \xi_0 / l$

Q.22. The free energy of superconductors

(a) is always positive

(b) is always negative

(c) can be changed from negative to positive by applying magnetic field

(d) can be changed from positive to negative by applying magnetic field

Q.23. Typical force constant of the cantilever used in Atomic Force Microscopy is

(a) 1 N/m (b) 1 mN/m (c) 1nN/m (d) 1pN/m

Q.24. Which one of the properties of nanomaterial cannot be related to the quantum size effect?

(a) Optical (b) Electrical (c) Optoelectronic (d) Magnetic

Q.25. The value of Poisson's ratio for most materials is typically between

(a) 0 and 0.25 (b) 0.25 and 0.5 (c) 0.5 and 0.75 (d) 0.75 and 1.0

Q.26. The kinetic energy associated with a plane electron wave is as follows where h is the Plank's constant, k is the magnitude of the wave vector of the electron and m is the mass of the electron.

(a) hk (b) $(mk^2)/2$ (c) $(h^2k^2)/(8\pi^2m)$ (d) $(hk^2)/2$

Q.27. The characteristic feature of the transition elements is

(a) a partially filled inner shell (b) an empty inner shell

(c) a partially filled valence shell (d) an unfilled outer shell

Q.28. The outer electronic configuration which gives the noble gases their extreme chemical inertness is

(a) s^2p^4 (b) s^2p^6 (c) p^2d^6 (d) s^4p^4

Q.29. Chlorine gas solidifies at the relatively low temperature of about 170 K, because of the presence of

(a) ionic bonds (b) mixed ionic-covalent bonds

(c) covalent bonds (d) van der Walls bonds

Q.30. The electro negativity of an element is a measure of the

(a) excess of electrons over the protons

(b) number of electrons in the valence shell

(c) strength with which electrons are attracted to the atoms

(d) strength of electrostatic repulsion of one electrons by others in the atoms of the element

Q.31. Two bodies in contacts are said to be in thermal equilibrium when

(a) there is no exchange of energy between their atoms

(b) the distribution of energy among the atoms is the same in both

(c) the probabilities of atomic collisions at the interface are the same in both the bodies

(d) the two bodies have the same Helmholtz free energy

Q.32. To increase the permeability of iron, it is necessary to

(a) add carbon to it (b) purify it

(c) add cobalt to it (d) add nickel to it

Q.33. The Fermi energy of metals is of the order of

(a) 3 eV (b) 30 eV (c) 0.03 eV (d) 0.003 eV

Q.34. The Hall coefficient of an elemental metal at two temperatures, T_1 and T_2, is R_1 and R_2, respectively. Given that $T_1 > T_2$, and both are less than300 K,

(a) $R_1 > R_2$, (b) $R_1 < R_2$, (c) $R_1 >> R_2$, (d) $R_1 = R_2$,

Q.35. Some metals become superconductors at a sufficiently low temperature, such a change is an example of a

(a) zeroth order phase transition (b) first order phase transition

(c) second order phase transition (d) metallic glass transition

Q.36. If the domain walls in a magnetic material can be moved easily, the material may be said to display

(a) high permeability (b) high flux density

(c) paramagnetism (d) magnetic anisotropy

Q.37. Electronic devices can be fabricated using either of the semiconductors, Ge or Si. Given that the band gap of Ge is 0.67 eV and that of Si is 1.1 eV,

(a) The highest possible operating temperature of Si devices is greater than that of Ge devices

(b) The highest possible operating temperature of Ge devices is greater than that of Si devices

(c) The highest operating temperature is the same for both Ge and Si devices

(d) Operating temperature of semiconductor devices is unrelated to the bandgap

Q.38. The number of roots of the equation $f(x) = ax^3 - bx^2 + cx - d$ are

(a) 0 (b) 4 real roots

(c) 3 real roots (d) insufficient information

Q.39. A diffusion process is invariant under the scale transformation

(a) $x \to \lambda x, t \to \lambda t$ (b) $x \to \lambda x, t \to \lambda^{0.5} t$

(c) $x \to \lambda^{0.5} x, t \to \lambda t$ (d) $x \to x, t \to \lambda^{0.5} t$

Q.40. The eigenvalues of 2x2 matrixes with unit entries are

(a) 0,1 (b) 0,0 (c) 0,-2 (d) 0,2

Q.41. Given $f(x) = x/(1-x)$, $f(f(x))$ is

(a) x (b) $x/(1 - 2x)$ (c) $x/(1 + 2x)$ (d) $1/(1-x)$

Q.42. If A and B are Hermitian operators, then $C = \alpha A + \beta B$ is Hermitian if and only if

(a) α and β are real (b) α is real and β is imaginary

(c) α and β are imaginary (d) α and β are complex

Q.43. The Bravais lattice symbol used to represent base centered unit cell is

(a) P (b) R (c) I (d) C

Q.44. The number that uniquely identifies the ionic or neutral form of an atom is the

(a) number of protons (b) number of neutrons

(c) number of electrons (d) atomic mass

Q.45. For the hexagonal unit cell the Miller-Bravais index i is given by

(a) $h + k = i$ (b) $h + k = -i$ (c) $h - k = i$ (d) $h - k = -i$

Q.46. When a material sustains steady loads for long periods of time, it may continue to deform until fracture. The phenomenon is known as

(a) Creep (b) fatigue (c) malleability (d) impact failure

Q.47. Which of the following point groups would exhibit ferroelectric property

(a) mm2 (b) 222 (c) 4/mmm (d) 4/m

Q.48. Materials that crystallize in $\bar{4}3m$ class have

(a) two independent piezoelectric coefficients

(b) four independent piezoelectric coefficients

(c) only one independent piezoelectric coefficient

(d) no piezoelectric coefficients

Q.49. In a certain class of materials, ferroelectricity results from piezoelectric coupling to an elastic instability. Such materials are known as

(a) Ferroelastic (b) Pyroelectric

(c) Piezoelectric (d) Paraelectic

Q.50. Phenol and formaldehyde are polymerized to produce

(a) Polyester (b) Bakelite (c) PVC (d) Nylon

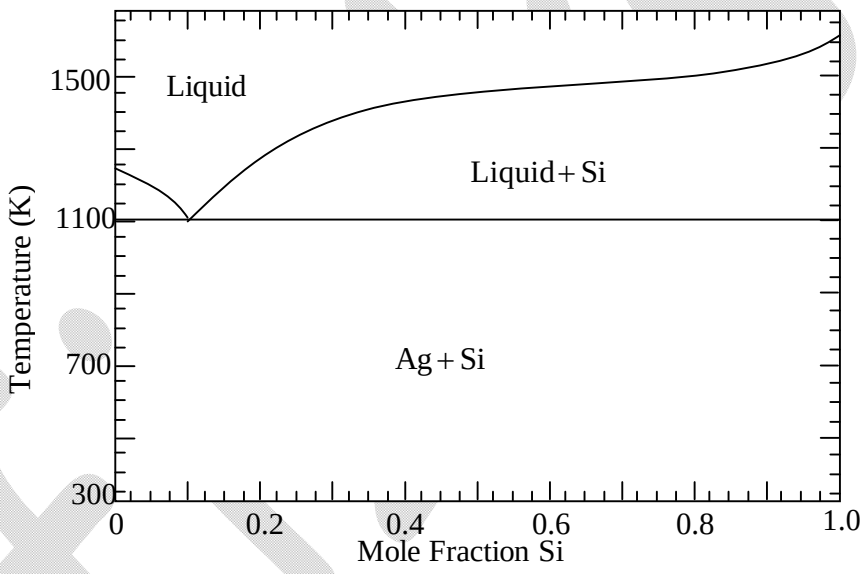
Part B: Answer any 5 questions. Each question carries 10 marks.

Q.51. The Ag-Si phase diagram is given below. Answer the following questions:

(a) Write down the invariant reaction that is shown in the diagram? What is this reaction called?

(b) What are the phases in equilibrium at 1150 K for compositions containing less than 0.1 mole fractions Si and more than 0.1 mole fractions Si? What are their compositions?

(c) Draw schematic room temperature microstructures based on lever rule calculations of alloys containing 0.40 and 0.8 mole fraction Si that have been cooled from temperatures above 1100°C.



Q.52. Explain in details the technique that you wish to employ to grow optically clear single crystals of oxides that are being used in the fabrication of solid-state lasers. Discuss about the thermal conditions that are required in Czochralski technique to grow large single crystals

Q.53. Write short notes on the following

(a) Linear electro-optic effect and its relation to the crystal structure

(b) Direct and indirect band gap semiconductor lasers

Q.54. (a) Calculate the diffraction angle (2θ) for the first three peaks in aluminum powder diffraction pattern. Note that the crystal structure of aluminum is *FCC* and the lattice constant is 0.404 nm,

(b) If the lattice constant of *Al* was larger than 0.404 nm, describe how the pattern would change.

(c) Outline the differences in the *x*-ray diffraction pattern of fullerenes and carbon nanotubes

Q.55. The magnetization density (M) and the heat capacity (C_p) of a ferromagnetic materials are found to vary with temperature (T) as it is raised from 0K to Curie temperature T_c and beyond. Draw a schematic diagram of (i) M *vs* T and (ii) C_p *vs* T, which show how each of these quantities varies with temperature. How does M vary with temperature in a ferimagnetic material?

Q.56. When electromagnetic radiation is incident on semiconductors and insulators, it may be transmitted, reflected, or absorbed, depending on the wavelength (λ) of the incident radiation. Draw a schematic diagram of the transmittance (T) versus λ for

(i) Silicon (*Si*), a semiconductor ith a bandgap of 1.1 eV

(ii) *Nacl*, an insulator with a bandgap of 7.7 eV

Can such a plot indicate that *Si* is an indirect bandgap semiconductor? If yes, how? If not, why not?

Q.57. An intrinsic semiconductor has a conductivity of 390 Ω^{-1} m^{-1} at 5^oC and $1010\Omega^{-1}$ m^{-1} at 25^oC.

(i) What is the bandgap (E_g) of the semiconductor?

(ii) What is its conductivity at 15^oC?

Q.58. (a) A composite material consists of particles of A in a matrix of B. Discuss the manner in which the Young's modulus of the composite materials will vary with the properties of the constituents and the distribution of particles of A.(b) A bimetallic strip is constructed from strip of two different metals are bonded together along their lengths. Explain how such device may be used in a thermostat to regulate temperature.