INDIAN INSTITUTE OF SCIENCE
BANGALORE - 560012

ENTRANCE TEST FOR ADMISSIONS - 2009

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

Day & Date
SUNDAY, 26TH APRIL 2009

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 10 questions from part B. Each question carries 5 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)	=	$4\pi \times 10^{-7}$	H/m
Bohr Magneton (μ_B)	=	9.274×10^{-24}	J/T
1 eV	=	1.602×10^{-19}	J

MATERIALS SCIENCE
PART A

1. Consider a particle in a potential well of height h and width w. When the width w is reduced and height h is increased, the eigenvalues of the energy of the particle in the box change in accordance with the

   (A) Pauli exclusion principle.
   (B) Heisenberg uncertainty principle.
   (C) Fermi Golden Rule.
   (D) Correspondence principle.

2. Which of the following best describes Hund's rule?

   (A) When atomic orbitals of equal energy are filled, the ground state electronic configuration is that with the most unoccupied orbitals.
   (B) Atomic orbitals should be filled from the lowest energy to the highest energy.
   (C) When atomic orbitals of equal energy are filled, the ground state electronic configuration is that with the most unpaired electrons.
   (D) Electrons in the same orbital must not have the same spin.

3. Packing in FCC solids is ABCABC... along

   (A) (100) direction.
   (B) (110) direction.
   (C) (111) direction.
   (D) (123) direction.

4. In the CaF_2 structure the coordination number of anion and cation is

   (A) 4 and 4.
   (B) 8 and 4.
   (C) 8 and 8.
   (D) 4 and 8.

5. A transmission electron microscope is used to produce a diffraction ring for the polycrystalline sample of copper. The (111) ring is 12 nm from the centre. How far would (200) ring be from the centre?

   (A) 9.0
   (B) 10.4
   (C) 12.9
   (D) 16.0

6. Two waves with same wavelength can interfere constructively if

(A) they are in phase.
(B) they have the same amplitude.
(C) the wavelength is small.
(D) the amplitudes are related by integral multiples.

7. In rock-salt type structure, the large anions are arranged in cubic close packing and the cations occupy

(A) all the octahedral interstitial positions.
(B) only the ten percent of the octahedral interstitial positions.
(C) all the tetrahedral interstitial positions.
(D) 50% of the tetrahedral interstitial positions.

8. Crystalline solids with well defined cleavage planes have

(A) lower fracture velocities.
(B) high hardness.
(C) lower toughness.
(D) high fracture velocities.

9. The structure of an ionic crystal is decided mainly by the

(A) nature of the chemical bonds.
(B) valence of the ions.
(C) relative diameters of the constituent ions.
(D) co-ordination number.

10. Compared to a strain free sample, the Bragg peaks in the powder diffraction pattern of uniformly strained Cu will be

(A) more intense.
(B) less intense.
(C) broader.
(D) shifted to a different Bragg angle.

11. A plane in a cubic crystal intersects the a-axis at 1, b-axis at 2 and the c-axis at infinity. The Miller indices of the plane are

(A) (1 2 0).
(B) (2 1 0).
(C) (1 2 ∞).
(D) (2 1 ∞).

12. Given the table below,

Characterization technique	Problem
i. Energy Dispersive Analysis by X-rays	a. Studying surface topography
ii. Scanning electron microscopy	b. Obtaining the orientation of a single crystal.
iii. Transmission electron microscopy	c. Understanding qualitative chemical composition
iv. X-ray diffraction	d. Studying the structure of grain boundaries

which one of the following sets best matches the characterization technique with the problem to be tackled?

(A) i-a, ii-b, iii-c, iv-d.
(B) i-c, ii-b, iii-d, iv-a
(C) i-c, ii-a, iii-d, iv-b.
(D) i-d, ii-a, iii-b, iv-d

13. In metals with hexagonal close packed crystal structures the Miller indices of planes on which easy slip can take place are

(A) (100).
(B) (010).
(C) (001).
(D) (110).

14. According to Wulff construction of equilibrium shape for anisotropic crystal, the surface energy of a surface (γ_i) is related to the distance from the centre to the surface (h_i) as

(A) γ_i/h_i=constant.
(B) $\gamma_i h_i$=constant.
(C) $\gamma_i h_i^2$=constant.
(D) h_i is independent of γ_i.

15. At equilibrium, the concentration of intrinsic vacancies in crystalline solids will be determined by the

(A) minimum in enthalpy.
(B) minimum in free energy.
(C) maximum in configurational entropy.
(D) maximum in vibrational entropy.

16. The unit for the diffusion coefficient is

(A) cm/sec.
(B) cm^2/sec.
(C) cm^3/sec.
(D) mol/cm^2/sec.

17. The number of components in C_2H_5OH for the purpose of applying the phase rule is

(A) 1.
(B) 3.
(C) 4.
(D) 9.

18. Average molecular weight of polyethylene is 2500 amu. The degree of polymerization is

(A) 6220.
(B) 1558.
(C) 1040.
(D) 891.

19. The pearlitic transformation is an example of a

(A) massive phase transformation.
(B) peritectic reaction.
(C) eutectic reaction.
(D) diffusive phase transformation.

20. Heterogenous nucleation involves

(A) lower energy barrier than homogenous nucleation.
(B) higher energy barrier than homogenous nucleation.
(C) lower critical radius than homogenous nucleation.
(D) higher critical radius than homogenous nucleation.

21. Silicon could be purified successfully using zone-melting process because

(A) the impurities segregate to the solid.
(B) the impurities segregate to the liquid.
(C) of its semiconducting nature.
(D) of its high segregation coefficient.

22. The external shape of the grown crystal is fixed by the crucible geometry in one of the following techniques

(A) Czochralski
(B) Flame-fusion
(C) Bridgman-Stockbarger
(D) Float-zone

23. Bulk diffusion in solids would be slowest by which one of the following mechanisms?

(A) Diffusion through dislocations
(B) Diffusion through grain boundaries
(C) Diffusion through interphase boundaries
(D) Diffusion through vacancies

24. The refractive index of a material is related to the polarization of the following kind

(A) Dipolar
(B) Electronic
(C) Ionic
(D) Space charge

25. What holds an inert gas crystal together?

(A) Electrostatic interaction between the atoms
(B) Participation of electrons from each atom
(C) Exchange interaction between the atoms
(D) Induced dipole moments between the atoms

26. The semiconductor used in the fabrication of the CPU of a laptop computer today is

(A) Ge.
(B) Si.
(C) GaAs.
(D) SiC.

27. If the domain walls in a magnetic material can be moved easily, the material displays

(A) high flux density.
(B) paramagnetic behavior.
(C) high permeability.
(D) high Neel temperature.

28. The paramagnetic-ferromagnetic transition in iron as a function of temperature is a

(A) second-order phase transition.
(B) first-order phase transition.
(C) zeroth-order phase transition.
(D) metallic glass transition.

29. Which element can be doped to obtain n-type GaAs semiconductor?

(A) Zn .
(B) In.
(C) Si
(D) Al

30. The band gap of Si is 1.1 eV. It can absorb in the following region(s) of electromagnetic radiation:

(A) only ultra violet light.
(B) only visible light.
(C) only infra red light.
(D) both ultra violet and visible light.

31. The platinum resistance thermometer is used to measure the temperature below 660 ^{0}C. This is because above 660 ^{0}C

(A) resistance is not linear with temperature.
(B) resistance is independent of temperature.
(C) platinum is contaminated.
(D) platinum melts.

32. The heat capacity of a superconductor (C_p) has been measured as a function of temperature in the vicinity of the transition temperature (T_C). We may expect that

(A) C_p is constant near T_C.
(B) C_p reaches a minimum near T_C.
(C) C_p reaches a maximum near T_C.
(D) C_p increases linearly with temperature near T_C.

33. The presence of dislocations in crystalline solids reduces their

(A) theoretical fracture strength.
(B) theoretical shear strength.
(C) free energy.
(D) configurational entropy.

34. The ratio of the resistivity R_t of a metal at room temperature to its resistivity R_0 extrapolated to zero temperature is called residual resistivity ratio (RRR). That is, $RRR \equiv R_t/R_0$. When a metal is extremely pure, its RRR is

(A) very large.
(B) very small.
(C) approximately equal to unity.
(D) approximately equal to 10.

35. What is the probability of an electron being thermally promoted to the conduction band in diamond (band gap=5.6 eV) at room temperature (25 ^{0}C)?

(A) 1
(B) 4.39×10^{-10}
(C) 5.48×10^{-48}
(D) 2.09×10^{-95}

36. In 3*d* transition elements, the "crystal field" due to the charges on neighbouring ions in the solid causes

(A) the spin magnetic moment to become negligible.
(B) the spin magnetic moment to be a maximum
(C) the orbital magnetic moment to be negligible.
(D) the orbital magnetic moment to be a maximum.

37. Photoelastic effect can be observed in the materials of

(A) all symmetry classes.
(B) only centrosymmetric classes.
(C) non-centrosymmetric classes.
(D) only certain symmetry classes.

38. The Young's modulus of polyster is 6.9×10^3 MPa and that of glass is 72.4×10^3 MPa. The modulus of the polyster reinforced with 60 vol% glass under isostrain condition is

(A) 72.4×10^3 MPa.
(B) 46.2×10^3 MPa.
(C) 15.1×10^3 MPa.
(D) 33.1×10^3 MPa.

39. If a rod of steel is strained along the "z" axis by ε_z and ν is Poisson's ratio, the strain along the other two orthogonal directions "x" and "y" will be

(A) $-\varepsilon_z/\nu$.
(B) $\nu\ \varepsilon_z$.
(C) $\nu/\ \varepsilon_z$.
(D) $-\nu\ \varepsilon_z$.

40. Multiple layers of dielectric thin films of alternating high and low refractive indices would be ideal for

(A) achieving better reflectivity than that of metals.
(B) obtaining better transmission.
(C) absorbing all the light that is incident.
(D) reflecting a fraction of the incident light.

41. Detwinning in crystals is possible by subjecting them to

(A) an electric field.
(B) magnetic field.
(C) pressure.
(D) rapid annealing.

42. Materials belonging to the following crystal class would exhibit Pockels effect

(A) mmm
(B) 2/m
(C) 6/mmm
(D) mm2

43. Given the table below,

Processing method	**Product**
i. Sputtering	a. Aluminum foil
ii. Precipitation	b. Bulk single crystals
iii. Rolling	c. Thin films
iv. Float Zone Process	d. Ceramic Powders

which one of the following sets best matches the processing method with the product desired?

(A) i-c, ii-b, iii-a, iv-d.
(B) i-a, ii-d, iii-c, iv-b
(C) i-c, ii-d, iii-a, iv-b.
(D) i-c, ii-a, iii-b, iv-d

44. In an ionic concentration cell, the metals in

(A) low concentration environment are anodic and corrode.
(B) low concentration environment are cathodic and corrode.
(C) high concentration environment are anodic and corrode.
(D) high concentration environment are cathodic and corrode.

45. Reduction of metal complexes in solutions is the general method in the synthesis of metal colloids by chemical route. Finer colloidal particles can be obtained by the use of a

(A) strong reducing agent at high temperature.
(B) strong reducing agent at low temperature.
(C) weak reducing agent at low temperature.
(D) weak reducing agent at high temperature.

46. Which one of the following is *not* governed by the Kelvin equation for nanoparticles?

(A) Vapor pressure
(B) Gas adsorption
(C) Solubility
(D) Melting temperature

47. Band gap of a semiconductor nanoparticle

(A) increases with decreasing particle size.
(B) decreases with decreasing particle size.
(C) depends on the material.
(D) is same as that of bulk.

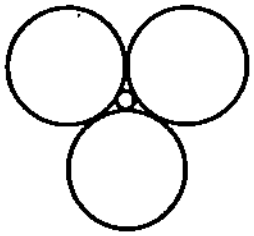
48. Which one of the statements is *not* appropriate for superconductors in the superconducitng state?

(A) They exhibit Meissner effect.
(B) The resistance is zero.
(C) They are perfect diamagnetic materials.
(D) They are paramagnetic materials.

49. Given the equation $9x^2-16y^2=144$, the x and y intercepts are

(A) 4 and 3.
(B) 4 and no y intercept.
(C) no x intercept and 3.
(D) no x intercept and no y intercept.

50. As shown in the diagram below, the ratio between the diameter of the large circle and the small circle is

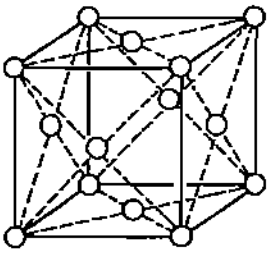


(A) 5.5.
(B) 6.5.
(C) 7.5.
(D) 10.

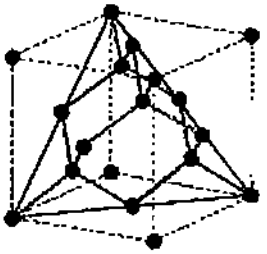
END OF PART A

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

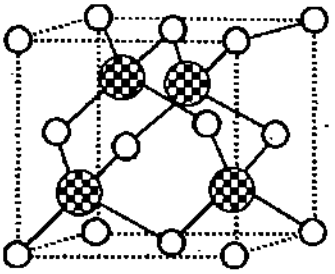
1. Shown below are the crystal structures of Aluminum , Silicon and GaAs (Zinc Blende structure).



Al



Si

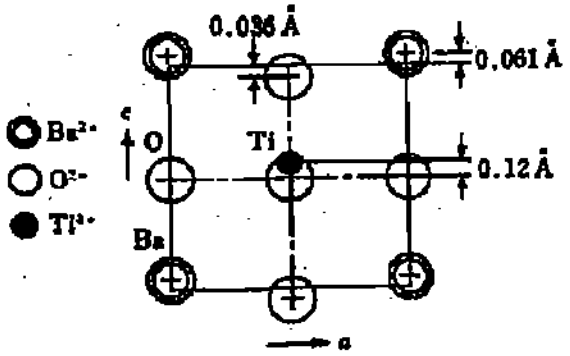


GaAs

   i. Determine the number of lattice points per FCC unit cell and the number of atoms per FCC unit cell in the three cases.
   ii. How do you generate these three crystal structures from the FCC lattice?

2. What is the Curie-Weiss relation? Explain what is the difference between the Curie Point (T_C) and the Curie-Weiss Temperature (T_0) in the Curie-Weiss relation?

3. $BaTiO_3$ exhibits ionic displacements as shown in the figure at room temperature. Calculate the magnitude of the spontaneous polarization. The lattice constants are a = 3.992 Å and c = 4.036 Å.



4. (a) Draw the schematic, complete B-H loop for (i) a hard magnet and (ii) a soft magnet, with appropriate arrows. (b) Describe BRIEFLY the connection between the B-H (hysteresis) loop and magnetic domains.

5. With a suitable diagram, explain briefly and clearly the meaning of the Hall effect. What is the utility of the experimental determination of the Hall co-efficient, R, in semiconductors? Is it easier to determine R in metals than in semiconductors? Why?

6. Write short notes on the following
   (a) diffuse interfaces
   (b) Holden's rotary crystallizer

7. Suggest a technique with details for each of the following to grow single crystals
   (a) XH_2PO_4 (where X= K or NH_4 ions) type
   (b) $LiNbO_3$

8. When a material A is deposited as a thin film on a single crystal of material B at 1000°C and cooled to room temperature, the thin film cracks. The relevant lattice parameters of materials A and B are 3.01 Å and 3.0 Å respectively and their relevant coefficients of thermal expansion are 4.00×10^{-5} and 3.60×10^{-5} /°C respectively. Can you explain why?

9. (a) Draw appropriate diagrams to show the difference between semiconductors with direct and indirect bandgaps. (b) Explain BRIEFLY, with a diagram, if needed, how these two types of semiconductors can be distinguished experimentally.

10. Discuss the temperature dependency of resistivity for a metal and a semiconductor. How does the resistivity vary for a CuAu alloy with composition?

11. Discuss the variation of heat capacity with temperature for a metal. What do you mean by thermal effective mass? Why is it different from electron mass?

12. Discuss Wiedemann-Franz law and its failure. What is Lorenz number and its value?

**************END OF QUESTION PAPER**************