

BITS, PILANI - DUBAI CAMPUS
STRUCTURE & PROPERTIES OF MATERIALS (ES UC242)
II SEMESTER 2005-2006
COMPREHENSIVE EXAMINATION (Regular)
Part A - Closed book

Max. Marks: 40
Date: 28/05/06

Duration: 60 Min.

- Answer all the questions.
- Assume any missing data.
- Answer Part A in the answer sheet provided.
- Answer Part B only after returning Part A answer sheet.
- Mention the version of question paper.
- Each correct answer carries 1 mark in Part A.
- For each wrong answer 0.25 marks will be deducted in Part A.

VERSION B

1. Which statement is true for eutectic point?
 - (a) It is a point in the phase diagram at which the liquidus and the solidus line meet.
 - (b) It is the point at which 3 phases coexist.
 - (c) Number of degrees of freedom is zero.
 - (d) All of the above.

2. Which is an example of line defect?
 - (a) Edge dislocation
 - (b) Screw dislocation
 - (c) Both (a) and (b)
 - (d) Neither (a) nor (b)

3. In edge dislocation burger's vector is -----to dislocation line.
 - (a) Parallel
 - (b) At 30°
 - (c) Perpendicular
 - (d) At 60°

4. Degree to which solute and solvent dissolves in one another depends upon
 - (a) Atomic size factor
 - (b) Crystal structure
 - (c) Valences
 - (d) All of the above

5. If D_0 is a temperature independent preexponential, Q_d is the activation energy, R is a gas constant and T is the absolute temperature. Temperature dependence of diffusion coefficient is given by
 - (a) $D = D_0 \exp\left(\frac{-Q_d}{RT}\right)$
 - (b) $D = D_0 \exp\left(\frac{-RT}{Q_d}\right)$
 - (c) $D = Q_d \exp\left(\frac{-D_0}{RT}\right)$
 - (d) None of the above

6. For isotropic materials, shear (G) and elastic moduli (E) are related to each other and to poisson ratio (ν) according to

(a) $E = G(1 + \nu)$

(b) $E = G(1 - \nu)$

(c) $E = 2G(1 + \nu)$

(d) None of the above

7. If d is the average grain diameter, σ_0 , k_y are constants for a particular material than yield strength σ_y varies with grain size according to

(a) $\sigma_y = \sigma_0 + k_y d^{-0.5}$

(b) $\sigma_y = \sigma_0 + k_y d$

(c) $\sigma_y = \sigma_0 - k_y d^{-0.5}$

(d) None of the above

8. True and engineering stress and strain are related according to

(a) $\sigma_T = \sigma(1 - \epsilon)$

(b) $\epsilon_T = \ln(1 - \epsilon)$

(c) Both (a) and (b)

(d) Neither (a) nor (b)

9. If A is the atomic weight, ρ is the density, N_A is the Avogadro number, N_v is the number of vacancies, Q_v is the energy required for the formation of a vacancy, T is the absolute temperature in Kelvin, k is the boltzman constant, then the number of atomic sites N is given by

(a) $N = \frac{N_A \rho}{A}$

(b) $N = \frac{N_v \rho}{A}$

(c) $N = N_v \exp\left(\frac{-Q_v}{kT}\right)$

(d) $N = N_A \exp\left(\frac{-Q_v}{kT}\right)$

10. If r is the interatomic radius distance, A, B and n are constants. Net potential energy between adjacent ions is given by

(a) $E_N = \frac{B}{r} - \frac{A}{r^n}$

(b) $E_N = -\frac{B}{r^n} + \frac{A}{r}$

(c) $E_N = \frac{B}{r^n} - \frac{A}{r}$

(d) None of the above

11. Which of the following statements is true for a barium titanate crystal structure:

(a) Barium ion(s) occupy the face centers of the cube.

(b) Titanium ion(s) occupy the face centers of the cube.

(c) Barium ion is situated at the cube centre.

(d) Titanium ion is situated at the cube center.

12. On the basis of ionic radii ($\text{Si}^{4+} = 0.040\text{nm}$, $\text{O}^{2-} = 0.140\text{nm}$), what will be the coordination number for SiO_2 ?

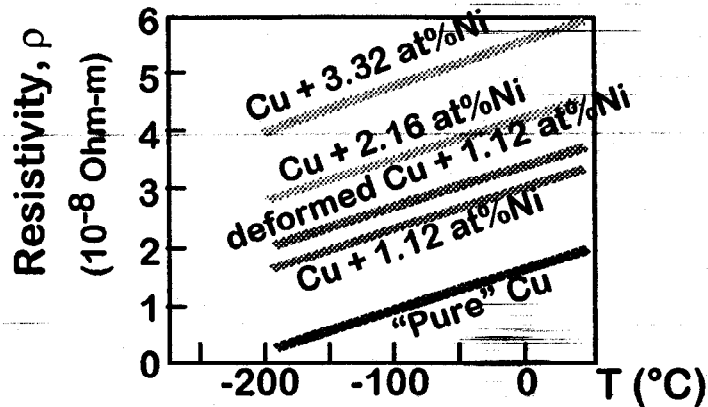
(a) 3

(b) 4

(c) 6

(d) 8

13. Given that the atomic weight of C = 12.01g/mol, H = 1.008g/mol, Cl = 35.45g/mol, F = 19g/mol and O = 16g/mol, what is the approximate number average degree of polymerization of polypropylene if the number average molecular weight is 125,575 g/mol?



- (a) $3.0 \times 10^{-8} \Omega^{-1}\text{m}^{-1}$
 (c) $33.33 \times 10^6 \Omega^{-1}\text{m}^{-1}$

- (b) $3.5 \times 10^{-8} \Omega^{-1}\text{m}^{-1}$
 (d) $28.57 \times 10^6 \Omega^{-1}\text{m}^{-1}$

19. Dezincification of brass is an example of
 (a) Uniform corrosion
 (b) Galvanic corrosion
 (c) Selective leaching
 (d) Hydrogen embrittlement
20. Weld decay is a form of
 (a) Erosion corrosion
 (b) Stress corrosion
 (c) Crevice corrosion
 (d) Intergranular corrosion
21. The properties of materials are highly anisotropic when they are in the form of
 (a) Polycrystalline
 (b) Single Crystalline
 (c) Liquid
 (d) Solid
22. Van der Waals bond is formed due to
 (a) Electrons and ion cores interaction
 (b) Coulomb interaction
 (c) Dipole-dipole interaction
 (d) Sharing of electrons
23. How many atoms per unit cell are there in diamond cubic structure?
 (a) 4
 (b) 6
 (c) 8
 (d) 12
24. The coordination number of FCC structure is
 (a) 4
 (b) 6
 (c) 8
 (d) 12
25. Which one of the following structures has the highest packing factor?
 (a) FCC
 (b) Simple cubic
 (c) BCC
 (d) All have same
26. A crystal will be mechanically weak if
 a. ~~All dislocations~~ are removed and crystal is made perfect.
 b. ~~There are few dislocations~~ in the crystal.

- (a) 40,125
- (c) 26,750

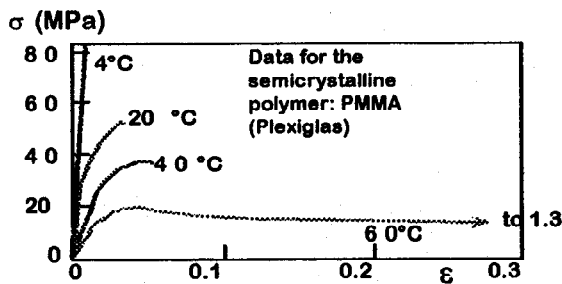
- (b) 11,255
- (d) 18,010

14. Sphalerite crystal structure has a
- (a) FCC atomic packing for anions
 - (b) Simple cubic atomic packing for anions
 - (c) BCC atomic packing for anions
 - (d) HCP atomic packing for anions

15. If the tensile strengths and number average molecular weights of two low density polyethylene materials is $TS_1=22\text{MPa}$, $TS_2=30\text{MPa}$, $M_{n1}=4000\text{g/mol}$, $M_{n2}=6000\text{g/mol}$, the values of the constants will be:

- (a) $TS_\infty=46\text{ GPa}$, $A=96038\text{ GPa}$
- (b) $TS_\infty=46\text{ MPa}$, $A=96038\text{ MPa}$
- (c) $TS_\infty=46\text{ MPa}$, $A=96.038\text{ GPa}$
- (d) $TS_\infty=46\text{ GPa}$, $A=96038\text{ MPa}$

16. The tensile strength of the polymer PMMA at 20°C from the graph below is

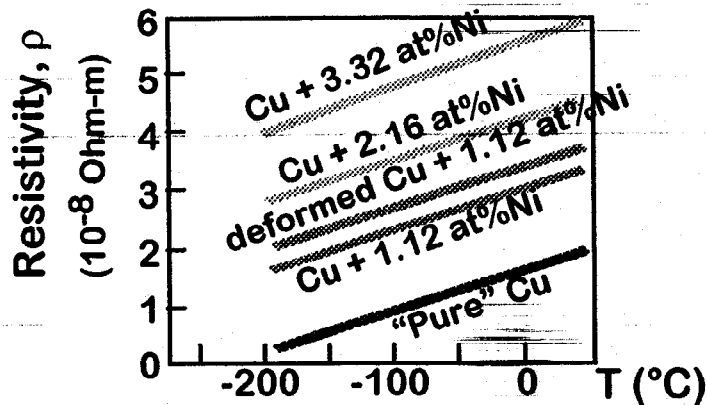


- (a) 52 MPa
- (c) 82 MPa

- (b) 42 MPa
- (d) 62 MPa

17. Polyvinyl chloride belongs to which of the following structure of molecular chain?
- (a) linear
 - (b) crosslinked
 - (c) alternating
 - (d) graft

18. From the graph given below, what is the total electrical conductivity of Cu-Ni alloy at 0°C and 1.12 wt% of Ni?



- (a) $3.0 \times 10^{-8} \Omega^{-1}m^{-1}$
 (c) $33.33 \times 10^6 \Omega^{-1}m^{-1}$

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 (d) $28.57 \times 10^6 \Omega^{-1}m^{-1}$

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26. A crystal will be mechanically weak if
 a. ~~All dislocations~~ are removed and crystal is made perfect.
 b. ~~There are few dislocations~~ in the crystal.

- c. Dislocation density in the crystal is very high.
 d. Small tiny particles of a second phase are present in the crystal.
27. Schottky defects normally occur
 (a) Only in ionic crystals (b) Covalent crystals
 (c) Non metallic crystals (d) Metallic and ionic crystals.
28. Carburization of steel
 (a) Improves fatigue resistance (b) Makes it less brittle
 (c) Makes it corrosion resistant (d) Decreases its strength.
29. Decarburization of steel occurs when steel is exposed to the atmosphere of
 (a) Carbon (b) Inert
 (c) Oxygen (d) Moisture.
30. Fick's law describe the flow of atoms caused by
 (a) Temperature gradient (b) Electric potential gradient
 (c) Concentration gradient (d) Electric field gradient.
31. A tie line is used for finding
 a. Solubility limit of the solute component of the alloy.
 b. Melting point of the alloy.
 c. Composition of the alloy in the two phases in equilibrium.
 d. Proportions of the two phases in the alloy.
32. Which of the following is a eutectoid reaction?
 (a) $L \xrightleftharpoons[\text{heating}]{\text{cooling}} \alpha + \beta$
 (b) $\delta \xrightleftharpoons[\text{heating}]{\text{cooling}} \gamma + \epsilon$
 (c) $\delta + L \xrightleftharpoons[\text{heating}]{\text{cooling}} \epsilon$
 (d) none of the above
33. Iron carbon alloy is ferromagnetic at room temperature
 (a) For all compositions.
 (b) For compositions above 0.022 wt% of carbon.
 (c) For compositions below 0.022 wt% of carbon.
 (d) For compositions above 6.7 wt% of carbon.

34. Among the following types of materials which one has the highest modulus of elasticity?

- (a) Metals
- (b) Polymers
- (c) Ceramics
- (d) Semiconductors.

35. Yield strength of the material is the stress at which the material

- (a) Fractures
- (b) Becomes plastic
- (c) Develop cracks
- (d) Ruptures

36. Materials that normally undergo creep are

- (a) Low melting point metals
- (b) Metals at high temperature
- (c) Both (a) and (b)
- (d) Neither (a) nor (b)

37. Among the following materials, which one has the highest hardness?

- (a) Steel
- (b) Copper
- (c) Cast iron
- (d) Silicon carbide

38. Experimental value of the critical resolved shear stress is -----than the theoretically predicted value.

- (a) Much smaller
- (b) Equal
- (c) Much higher
- (d) We can't say.

39. Resilience of a material is defined as the measure of the

- (a) Degree of plastic deformation that has been sustained at fracture
- (b) Capacity to absorb energy when it is deformed elastically and recover the same on unloading
- (c) Ability to absorb energy up to fracture
- (d) Resistance to localized plastic deformation

40. Slip takes place when the stress resolved in the slip direction

- (a) Exceeds a certain critical shear stress
- (b) Below critical shear stress
- (c) Equal to critical shear stress.
- (d) It can happen at any value.

BITS, PILANI - DUBAI CAMPUS
STRUCTURE & PROPERTIES OF MATERIALS (ES UC242)
II SEMESTER 2005-2006
COMPREHENSIVE EXAMINATION (Regular)

Part B - open book

Max. Marks: 80

Duration: 120 Min.

Date: 28/05/06

- Answer all the questions.
- Assume any missing data.

1. Copper and platinum both have FCC crystal structure and copper forms a substitutional solid solution for concentrations up to 6 wt% of Cu at room temperature. Compute the unit cell length edge for a 95 wt% Pt and 5 wt% Cu alloy. **(10 M)**
2. The wear resistance of steel shaft is to be improved by hardening its surface. This is to be accomplished by increasing the nitrogen content within an outer surface layer as a result of nitrogen diffusion into the steel; the nitrogen is to be supplied from an external nitrogen rich gas at an elevated and constant temperature. The initial nitrogen content of the steel is 0.0025 wt% and the surface concentration is to be maintained at 0.45 wt%. For this treatment to be effective, a nitrogen content of 0.12 wt% must be established at a position 0.45 mm below the surface. Specify an appropriate heat treatment in terms of temperature and time for a temperature of 500°C. The preexponential and activation energy for the diffusion of nitrogen in iron are $3 \times 10^{-7} \text{ m}^2/\text{s}$ and 76,150 J/mol respectively for this temperature. **(12 M)**
3. A specimen of some hypothetical metal is deformed in tension. Given below is the load-elongation data:

Load (N)	Length (mm)
0	63.50
1380	63.53
2780	63.56
5630	63.62
7430	63.70
8140	63.75
9870	64.14
12850	65.41
14100	66.68
14340	67.95
13830	69.22
12500	70.49
Fracture	

- i. Plot the data as engineering stress versus engineering strain if the cross section of the specimen is rectangular of dimensions 3.2 mm x 19.1 mm.
 - ii. Compute the modulus of elasticity.
 - iii. Determine the yield strength at a strain offset of 0.002.
 - iv. Determine the tensile strength of this metal.
 - v. What is the ductility in % EL? (10 M)
4. a) The mass fraction of eutectoid ferrite in an iron-carbon alloy is 0.71. On the basis of this information, is it possible to determine the composition of the alloy? If so, what is its composition? If this is not possible, explain why. (10 M)
- b) Estimate the Rockwell hardness for specimens of an iron-carbon alloy of eutectoid composition that have been subjected to the following heat treatments:
- (i) Cool rapidly to 420°C, hold for 200s, and then quench to room temperature.
 - (ii) Rapidly cool to 275°C, hold for 100s, and then quench to room temperature in water. Reheat to 315°C for 1 hour and slowly cool to room temperature. (10 M)
5. High-density polyethylene may be fluorinated by inducing the random substitution of fluorine atoms for hydrogen.
- i. Determine the concentration of fluorine (in wt%) that must be added if this substitution occurs for 5% of all the original hydrogen atoms.
 - ii. Does this fluorinated polyethylene differ from polyvinyl fluoride? If so in what ways? If not, why? (14 M)
6. The corrosion rate is to be determined for some divalent metal M in a solution containing hydrogen ions. The following corrosion data are known about the metal and solution:
- | Metal M | Hydrogen |
|------------------------------------|---------------------------------|
| $V_{(M/M^{2+})} = -0.90 \text{ V}$ | $V_{(H^+/H_2)} = 0 \text{ V}$ |
| $i_0 = 10^{-12} \text{ A/cm}^2$ | $i_0 = 10^{-10} \text{ A/cm}^2$ |
| $\beta = +0.10$ | $\beta = -0.15$ |
- a) Assuming that activation polarization controls both the oxidation and reduction reactions, determine the rate of corrosion of metal M (in mol/cm²-s).
 - b) Compute the corrosion potential for this reaction. (14 M)

BITS, PILANI - DUBAI CAMPUS
STRUCTURE & PROPERTIES OF MATERIALS (ES UC242)

II SEMESTER 2005-2006 TEST-III (Regular) – Open Book

Max. Marks: 60 (20%)

Duration: 50 Min.

Open book

Date: 26/04/06

- Answer all the questions. Justify all answers.
- Assume any missing data.
- Answer all the questions sequentially. Avoid elaborate answers.
- Only the prescribed text book is allowed for the open book test.

Q1. Which of the following cations would you predict to form fluorides having the cesium chloride structure? Justify your choices.

Cations: Al^{3+} , Ba^{2+} , Ca^{2+} , Cs^+ , Fe^{2+} , Fe^{3+} , K^+ , Mg^{2+} , Mn^{2+} , Na^+ , Ni^{2+} , Si^{2+} , Ti^{4+}

[14]

Q2. The kinetics of austenite to pearlite transformation obey the Avrami relationship. Using the fraction transformed time data given below, determine the total time required for 95% of the austenite to transform to pearlite.

Fraction transformed	Time (s)
0.2	280
0.6	425

[16]

Q3. Is it possible to produce an oil-quenched and tempered 4340 steel that has a minimum yield strength of 1240 MPa and a ductility of at least 50% RA? If this is possible, describe the tempering heat treatment. If it is not possible, then explain why.

[12]

Q4. Molecular weight data for some polymer is tabulated in the table given below.

Molecular weight Range (g/mol)	x_i	w_i
8,000-20,000	0.05	0.02
20,000-32,000	0.15	0.08
32,000-44,000	0.21	0.17
44,000-56,000	0.28	0.29
56,000-68,000	0.18	0.23
68,000-80,000	0.10	0.16
80,000-92,000	0.03	0.05

If it is known that this polymer's number average degree of polymerization is 477, which of the polymers listed below is this polymer? Why?

(i) polypropylene, (ii) polytetrafluoroethylene, (iii) phenol formaldehyde

[18]

BITS, PILANI - DUBAI CAMPUS
STRUCTURE & PROPERTIES OF MATERIALS (ES UC242)
II SEMESTER 2005-2006 TEST-II (Regular) – Open Book

Max. Marks: 60 (20%)

Duration: 50 Min.

Open book

Date: 09/04/06

- Answer all the questions. Justify all answers.
- Assume any missing data.
- Answer all the questions sequentially. Avoid elaborate answers.
- Only the prescribed text book is allowed for the open book test.

Q1.

- a. Determine the magnitude of Burgers vector for Aluminum.

[8M]

- b. Determine the approximate temperature that a specimen of FCC iron has to be carburized for 5 hours that will produce the same result as at 900 °C for 10 hours.

[12M]

Q2.

A cylindrical rod 120 mm long and having a diameter of 15 mm is to be deformed using a tensile load of 35 kN. It must not experience either plastic deformation or a diameter reduction more than 0.012 mm. of the materials listed below, which are the possible candidates? Justify your choice(s).

Material	Modulus of Elasticity (GPa)	Yield strength (MPa)	Poisson's Ratio
Aluminum alloy	70	250	0.33
Titanium alloy	105	850	0.36
Steel alloy	205	550	0.27
Magnesium alloy	45	170	0.20

[14M]

Q3

- a. Consider a single crystal BCC iron oriented such that the tensile stress is applied in the [100] direction. (i) Show the diagram of unit cell with the slip direction and plane as well as the direction of applied stress. (ii) Compute the resolved shear stress along $(10\bar{1})$ plane in the $[\bar{1}\bar{1}1]$ direction when the tensile stress is 4 MPa.

[14M]

- b. Fig. 1 shows the tin-gold phase diagram. Specify temperature-composition points at which all (i) eutectic and (ii) eutectoid phase transformations occur, (if any) and (iii) write the reaction upon cooling.

[12M]

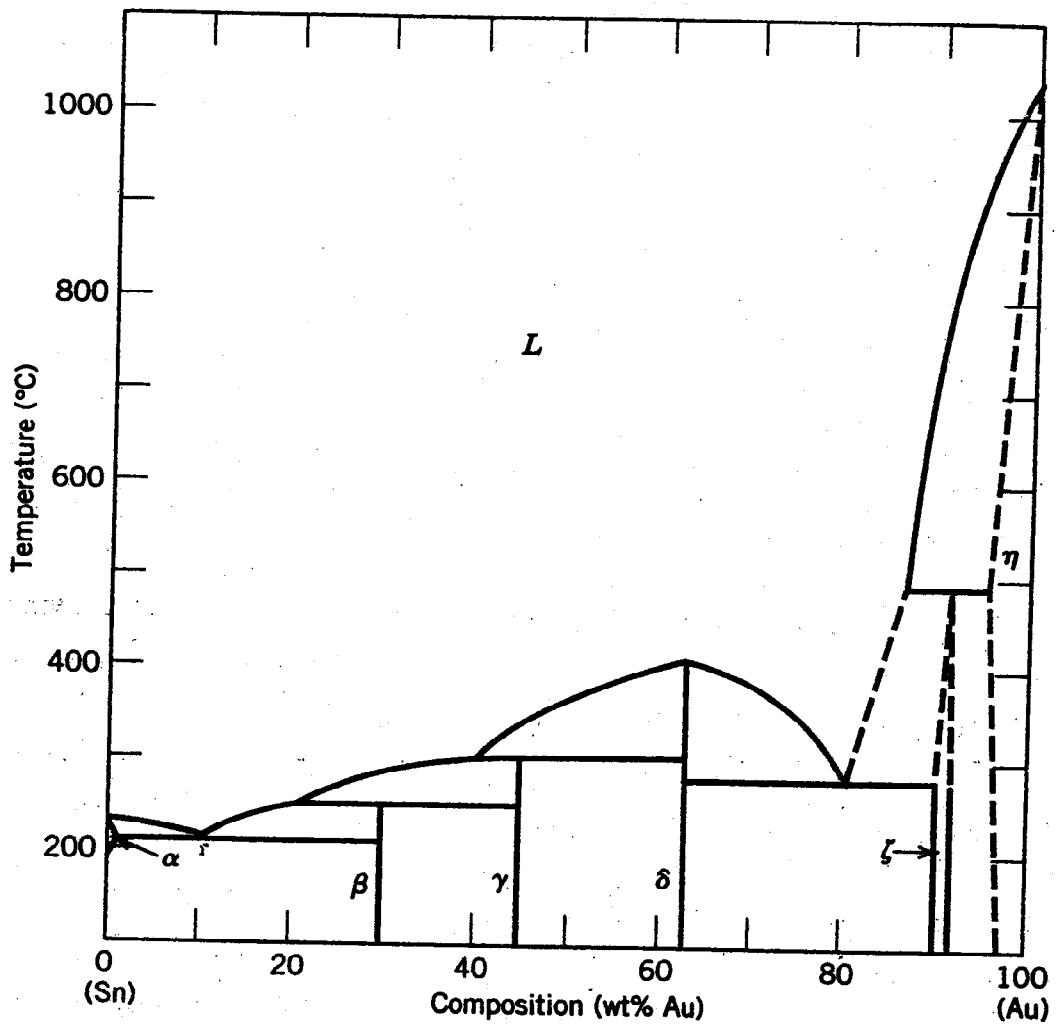


Fig. 1 (Figure for Q3b)

BITS, PILANI - DUBAI CAMPUS
STRUCTURES & PROPERTIES OF MATERIALS (ES UC242)
II SEMESTER 2005-2006 FIRST TEST (Regular)

Max. Marks: 60 (20%)

Duration: 50 Min.

Open book

Date: 22/02/06

- Answer all the questions.
- Assume any missing data.
- Answer all the questions sequentially. Avoid elaborate answers.
- Only the prescribed text book is allowed for the open book test.

1. It is required to manufacture gas cylinder. Given the choice between metals, ceramics, polymers and composites which one you are going to choose? Justify your selection. [12 M]
2. Figure 1 shows interstitial solution of carbon in α iron (at room temperature).
 - (a) How much oversize is the carbon atom? [14 M]
 - (b) Does the carbon atom have high solubility or low solubility? Justify your answer. [3 M]

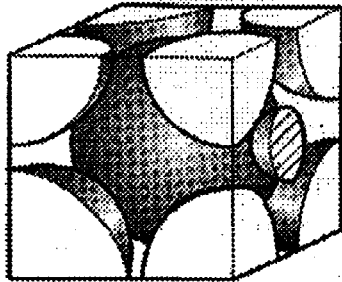


Figure 1 Figure for question 2

3. Do you agree with the statement *solid substances are formed for large bonding energy and typically have high melting temperatures whereas for small energies the gaseous state is favored. Liquids prevail when the bonding energy is of intermediate magnitude?* Justify your answer. [10 M]
4. Make a plot of bonding energy versus melting temperature for the hypothetical metals listed in the table given below. Using this plot, identify a metal having bonding energy corresponding to 6.1 eV (by approximating the melting temperature). [12 M]

Metal	A	B	C	D	E	F	G	H	I	J	K	L
eV	3.3	5.2	4.7	7.4	0.7	3.4	4.2	8.8	0.08	0.32	0.36	0.52
K	1074	3073	1683	3823	234	933	1811	3683	84	172	195	273

5. What type of bonding(s) is possible with the following materials? (a) Calcium bromide (b) Krypton (c) Bronze [9 M]

BITS, PILANI - DUBAI CAMPUS
STRUCTURES & PROPERTIES OF MATERIALS (ES UC242)
II SEMESTER 2005-2006 FIRST TEST (Regular)

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Open book

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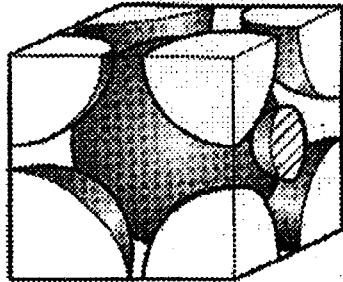


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