DEC 2011 **NATIONAL EXAMINATIONS**

04-BS-11 Properties of Materials

3 Hours Duration

Notes:

(i) If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumption made.

(ii) Candidates may use one of two calculators, the Casio or Sharp approved models. This is a "closed book" examination.

(iii) Any five questions constitute a complete paper. Only the first five questions as they appear in your answer book will be marked.

(iv) All questions are of equal value.

Information:

Atomic Weights ($g.mol^{-1}$)

H	1.01	C	12.01	O	16.00
S	32.1	Cl	35.5	Cu	63.54
Ag	107.9	Sn	118.7	Pb	207.2

Constants and Conversions

Avagadro's number, N_A	=	$0.602 \times 10^{24}\ mol^{-1}$
Boltzmann's constant, k	=	$13.8 \times 10^{-24}\ J.K^{-1}$
Universal gas constant, R	=	$8.314\ J.\ mol^{-1}.K^{-1}$
1 eV	=	0.16×10^{-18} J
K	=	°C + 273
Cal	=	4.18 J

Prefixes

tera	T	10^{12}	milli	m	10^{-3}
giga	G	10^{9}	micro	μ	10^{-6}
mega	M	10^{6}	nano	n	10^{-9}
kilo	k	10^{3}	pico	p	10^{-12}

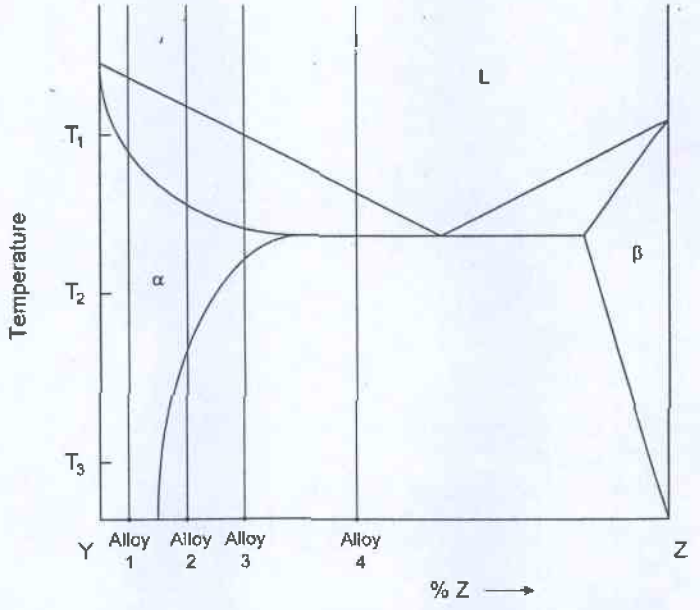
Questions:

1. (a) X-ray data gives the lattice constant of silver to be 0.4073 nm and its structure face centered cubic. Calculate the density ($g.cm^{-3}$) and atomic radius (nm) of silver.

   (b) An activation energy of 2.0 eV is required to form a vacancy in a metal. At 600°C there is one vacancy for every thousand atoms. At what temperature will there be one vacancy for every five hundred atoms?

2. (a) The solubility of tin in solid lead at 200°C is 18% Sn. The solubility of lead in the molten metal at the same temperature is 43% Pb. What is the *composition* of an alloy containing 60% liquid and 40% solid α at 200°C?

   (b) Distinguish between coherent and incoherent precipitates.



   (c) Which of the alloys (1,2,3, and/or 4) in the figure above could be strengthened by age hardening? (Assume that β forms a coherent precipitate in α). Outline the complete procedure for the age hardening process.

3. The selection of engineering materials for component design is done by matching engineering properties of the material to the service conditions required of the component. Using this criterion perform a materials selection for an 4 lb sledge hammer for driving steel fence posts into the ground.

4. (a) A neoprene rubber radiator hose contains 90 wt% polymerized chloroprene $(C_4H_5Cl)_n$ and 10 wt% sulphur. What fraction of the possible cross-links is joined by vulcanization? Assume that all the sulphur is used for cross-links. (Hint: there is one C=C site for each chloroprene mer).

(b) How do porosity and grain size affect the tensile strength of ceramic materials?

(c) What are glass network modifiers? How do they affect the silica-glass network? Why are they added to silica glass?

5. (a) Indicate whether the following statements about a 1080 steel are correct or incorrect and justify your answer.

(i) The hardness of pearlite is a fixed value.
(ii) Martensite is obtained by the isothermal transformation of austenite.
(iii) Retained austenite indicates the quench was too rapid.
(iv) For maximum machinability the steel should be spherodised

(b) A solid solution of copper in aluminum has 10^{26} atoms of copper per m^3 at point X, and 10^{24} copper atoms per m^3 at point Y. Points X and Y are 20 μm apart. What will be the diffusion flux of copper from X to Y at 500°C?

$[D_{Cu\ in\ Al} = 4 \times 10^{-14}\ m^2/sec\ @\ 500°C]$

6. (a) Predict the coordination number for CsCl given that the ionic radii are $Cs^+ = 0.167$ nm, $Cl^- = 0.181$ nm. Sketch the unit cell.

(b) Using a sketch show how the modulus varies with temperature for a partially crystalline nylon. How would the curve change if the degree of crystallinity increases? Decreases?

7. (a) A 3" x ¼" strip of annealed C26000 brass (70Cu-30Zn) is cut into nine 6" lengths. Each strip is put through a rolling mill with the distance between the rolls set from 0.250" down to 0.050" in intervals of 0.025". (Thus the first sample is rolled at 0.250", the second at 0.225", and so on). The hardness of each sample is then measured using a Rockwell superficial tester (similar to regular Rockwell except lighter loads are used, thus better for thinner materials). Sketch the graph of hardness vs cold work. Explain the nature of the graph.

(b) The sample that was rolled to 0.100" is now cut into seven (7) approximately equal pieces. Each piece is annealed for 10 minutes in a vacuum furnace. The temperature of the furnace is varied from 100°C to 700°C in intervals of 100°C. (Each piece is annealed at <u>one</u> temperature). After annealing the pieces are water quenched, dried and then their hardness measured using the same hardness tester. Sketch the graph of hardness vs annealing temperature and explain the nature of the graph.

8. (a) A composite is composed of glass fibres (E = 60 GPa) in a polymer matrix (E = 5 GPa).

(i) Determine the composite modulus for isostrain loading if the volume fraction of glass fibres is 0.25.

(ii) Using the modulus calculated in part (i) determine the volume fraction of glass fibres for isostress loading.

(b) A 2 inch inside diameter, 12 ft long copper distribution pipe in a plumbing system is accidentally connected to the power system of a manufacturing plant, causing a current of 65 mA to flow through the pipe. The wall thickness of the pipe is 0.125 inch. Estimate the time required before the pipe begins to leak, assuming a uniform rate of corrosion.
(Specific weight of copper = 8.93).