

04-BS-11 Properties of Materials

3 Hours DurationNotes:

- (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:(1) Atomic Masses (g.mol⁻¹)

H	1.01	C	12.01	N	14.01	O	16.00	S	32.1
Cl	35.5	Sn	118.7	Pb	207.2	Mo	95.94		

(2) Constants and Conversions

Avagadro's number, N_A	= 0.602 x 10 ²⁴ mol ⁻¹
Boltzmann's constant, k	= 13.8 x 10 ⁻²⁴ J. mol ⁻¹ .K ⁻¹
Universal gas constant, R	= 8.314 J. mol ⁻¹ .K ⁻¹
Angstrom, Å	= 1 x 10 ⁻¹⁰ m

(3) 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

(4) Useful formulae

Chvorinov's Rule, $t_s = B(V/A)^n$; (n is usually 2)

Questions:

1. Molybdenum has a body centered cubic structure and lattice parameter, a_0 , of 3.1468 Å. Calculate the atomic radius (Å) and density ($\text{g}\cdot\text{cm}^{-3}$) of molybdenum.

Sketch the unit cell. On your sketch show the (112) plane and [011] direction. What is the spacing (Å) between the (102) planes?

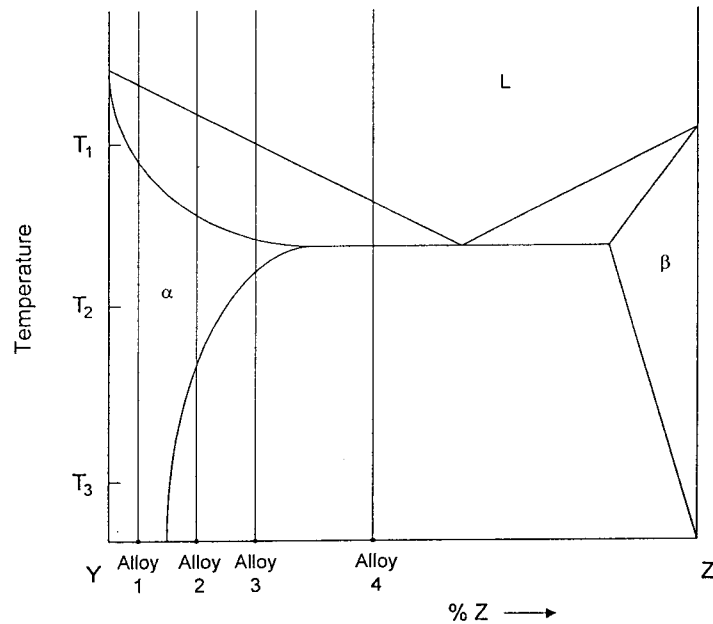
2. The following data were obtained from a tensile test of high strength aluminum (7075-T5) alloy. (Note: kip = 10^3 lb). All test samples had an initial diameter of 0.505 inch and an average final diameter of 0.390”.

<u>Load (kips)</u>	<u>Gauge Length (inches)</u>
0	2.0000
4	2.0041
8	2.0079
10	2.0103
12	2.0114
13	2.0142
14	2.0202
16	2.0503
16.1	2.0990
15.6 (fracture)	2.1340

Using the supplied graph paper plot the engineering stress – strain curve. Use your plot to determine the following:

- (i) Modulus of elasticity (psi)
- (ii) Yield strength at 0.2% offset (psi)
- (iii) Reduction in area (%)
- (iv) Elongation (%)
- (v) Tensile strength (psi)

3. (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.
4. (a) PVC (polyvinyl chloride) is usually used as a copolymer with PE (polyethylene) rather than as a homopolymer. Why? The copolymer is normally syndiotactic. Would you expect the copolymer to be crystalline? Thermoplastic or thermosetting? Explain your answers.
- (b) Name and describe the processing methods to make the following: polyethylene squeeze bottle, melamine dish, nylon fishing line, fibreglass boat hull.
- (c) A rubber contains 94% by weight polymerized chloroprene ($\text{CH}_2\text{CClCHCH}_2$) and 6% sulphur. What fraction of the chloroprene is crosslinked? Assume that all the sulphur is utilized in the crosslinking.

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 spheroidised
- (b) A piping system used to transport a corrosive liquid is fabricated from 304 stainless steel. Welding of the pipes is required to assemble the system. Unfortunately, corrosion occurs and the corrosive liquid leaks from the pipes near the weld. Identify the problem and state what steps you would take to prevent corrosion in the future, while still using a welded 304 stainless steel construction.
6. (a) Glass fibres in nylon provide reinforcement. If the nylon contains 10 vol% of E glass, what fraction of the applied force is carried by the glass fibres?
($E_{\text{glass}} = 10 \times 10^6$ psi, $E_{\text{nylon}} = 0.5 \times 10^6$ psi)
- (b) Using an appropriate sketch show that the minimum ionic radius ratio for 4-fold coordination is 0.225.
7. (a) Name and describe the two most common defects that occur during solidification of castings. In your discussion indicate the precautions that can be employed to minimize these defects.
- (b) Liquid bronze is cast into a mold to form a 2 inch cube. The solidification time is 8.2 minutes. What would be the solidification time for a 1 in x 1 in x 6 in bar that is cast under similar conditions?