DEC 2017 **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:

(1) Atomic Masses (g.mol^{-1})

H	1.0	C	12.0	O	16.0	F	19.0
Fe	55.85	Cu	63.54	Sn	118.7	Pb	207.2

(2) Constants and Conversions

Avagadro’s number, N_A = 0.602×10^{24} mol^{-1}
Boltzmann’s constant, k = 13.8×10^{-24} J/atom·K
Calorie = 4.18 J
Kelvin, K = °C + 273
Electron volt, eV = 0.16×10^{-18} J

(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 equations

Diffusion, $J = -D\,\frac{\Delta c}{\Delta x}$ $D = D_0 \exp\left(\frac{-Q}{RT}\right)$ $\frac{dc}{dt} = D\,\frac{d^2c}{dx^2}$

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

Questions:

1. (a) Explain why you would expect iron oxide FeO to have the rock salt structure. Calculate the atomic packing factor and density of FeO. (The ionic radii for Fe^{2+} and O^{2-} are 0.074 nm and 0.140 nm respectively).

   (b) Wüstite is a non-stoichiometric form of iron oxide having the general formula $Fe_{1-x}O$. Explain why this material is a semiconductor.

   (c) Assuming one charge carrier per vacancy, calculate the number of charge carriers per cm^3 for a wüstite sample where $x = 0.5$.

2. At 500°C, a diffusion experiment indicates that 1 in 10^{10} atoms has enough activation energy to jump out of its lattice position into an interstitial site. At 600 °C, this fraction increases to 1 in 10^9 atoms.

   (a) Calculate the activation energy required for the jump. Give your answer in eV/atom and also in cal/mole.

   (b) What fraction of the atoms has enough energy at 700 °C?

3. (a) The melt index is the rate at which a polymer is extruded under prescribed conditions through a die of specified length and diameter (ASTM-D-1238). The units are grams of polymer extruded in 10 minutes.

   (i) How does the melt index vary with molecular weight of the polymer?

   (ii) Explain why the weight average molecular weight would be more important as a measure of the melt index than would the number average molecular weight.

   (b) The degree of polymerization of polytetrafluorethylene (PTFE or Teflon) is 8000. If all the polymer chains are of the same length, calculate:

   (i) The molecular weight of the chains.

   (ii) The total number of chains in 1200 g of the polymer.

4. 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 inch.

Load (kips)	Gauge Length (inches)
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)

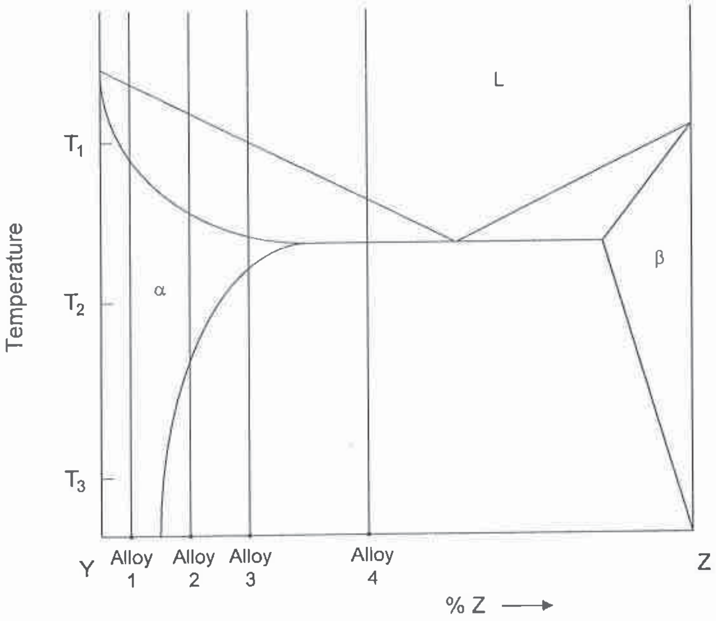
5. (a) Indicate whether the following statements about a 1080 steel are correct or incorrect and justify your answer.

(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 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) 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.

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 1in x 1in x 6in bar that is cast under similar conditions?