DEC 2018 **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	12.01	N	14.01	O	16.0	Mg	24.31	Si	28.09	P	31.98
S	32.06	Cl	35.45	Ca	40.08	V	50.94	Ni	58.71	Ge	72.59		

(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/atom·K
Calorie	= 4.18 J
Kelvin, K	= °C + 273
Electron volt, eV	$= 0.16 \times 10^{-18}$ 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

Interplanar spacing, $d_{(hkl)} = \dfrac{a_o}{\sqrt{h^2 + k^2 + l^2}}$

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

Questions:

1. (a) X-Ray crystallography studies of the metal vanadium show that it has a body centred cubic structure with a d_{110} interplanar spacing of 0.215 nm. Calculate the lattice constant and density of this metal. Marks will be awarded for a diagram supporting your calculations.

   (b) Compare and contrast: twin boundary, tilt boundary, and twist boundary.

2. (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 ($CH_2CClCHCH_2$) and 6% sulphur. What fraction of the chloroprene is crosslinked? Assume that all the sulphur is utilized in the crosslinking.

3. The following data were collected from a tensile test of a 12 mm diameter magnesium alloy sample.

Load (kN)	Gauge Length (mm)
0	30.00
5	30.0296
10	30.0592
15	30.0888
20	30.15
25	30.51
26.5	30.90
27	31.50 (maximum load)
26.5	32.10
25	32.79 (fracture)

After fracture, the gauge length was 32.61 mm and the diameter 11.74 mm. Plot the data and calculate the:

(i) 0.2% offset yield strength
(ii) tensile strength
(iii) modulus of elasticity
(iv) % elongation
(v) % reduction in area
(vi) engineering stress at fracture
(vii) true stress at fracture

4. (a) Explain how you would obtain the following microstructures in a 0.45% plain carbon steel: ferrite and pearlite; all martensite; all spherodite; all bainite.

(b) Cartridge brass CA260 (70Cu30Zn) is one of the most formable engineering alloys, making it ideal for deep drawing applications. Unfortunately, it is prone to corrosion due to "season cracking" (stress corrosion cracking) and "dezincification" (selective leaching). Describe these two types of corrosion and indicate how they can be minimized.

(c) "Weld decay" is commonly observed in austenitic stainless steels. It is intergranular corrosion. Describe why it occurs and how it can be minimised in these materials.

5. (a) Predict the coordination number for CaO given that the ionic radii are $Ca^{2+} = 0.100$ nm, $O^{2-} = 0.140$ nm.

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

(c) Explain why statistical methods are often used to predict failure in ceramic materials. In particular, discuss how the Weibull distribution is employed.

6. (a) Name and briefly describe some nondestructive testing methods that might be helpful in detecting cracks parallel to the surface of welded stainless steel pipe?

(b) In an investigation of a traffic accident, one of the drivers claimed that the headlights were not working in the other vehicle. Laboratory examination of the lamp filament showed that this was not the case. Explain what test(s) were done and the general nature of the results obtained. How would the results differ if the headlights had been off?

(c) In another traffic accident the teeth on a gear in the transmission were found to be badly worn. The gear made of a carburized alloy steel should have a surface hardness of 61 R_C. The hardness measured on a tooth of another gear that was intact was found to be 31 R_C. Suggest possible sources for the failure and the laboratory steps you would take for confirmation.

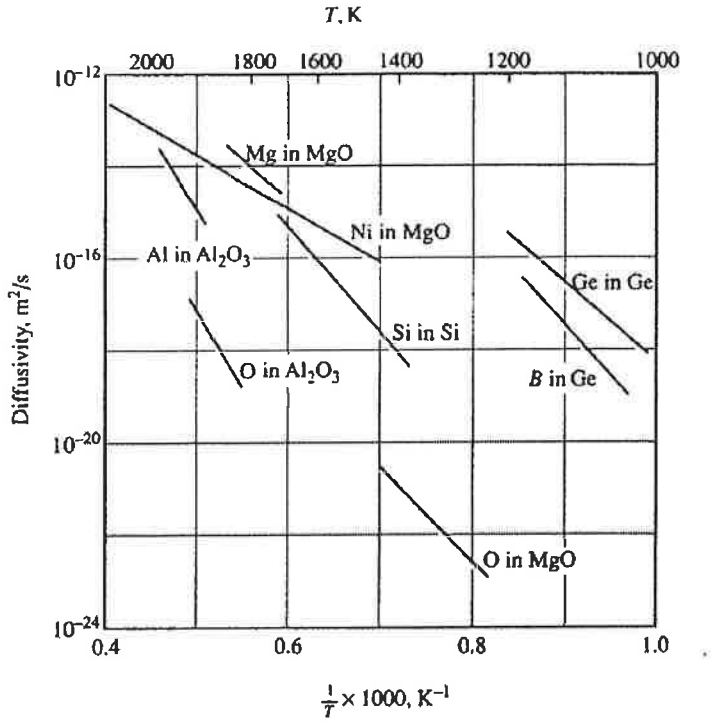

Fig 1 Diffusivity data for some non-metallic systems

7. (a) Refer to Fig 1 above.

(i) Show that the units of diffusivity (diffusion constant) are m^2/s

(ii) Explain the general nature of the data i.e. straight lines with negative slopes.

(iii) At a given temperature, why would you expect the diffusivity of oxygen in MgO to be less than that of Mg in MgO? Explain.

(iv) Similarly, at a given temperature, why does the diffusivity of Mg in MgO lie close to, but higher than that of Ni in MgO?

(v) Si and Ge are both semiconductors. Compare the diffusion data for both materials. What, if any, is the significance of this?

(b) In order to make n-type extrinsic semiconductor material for a transistor, phosphorus is to be diffused into pure silicon. The silicon is in the form of a 1mm thick wafer. The original concentration of phosphorus is one atom per for every 10 million Si atoms. The concentration is to be increased by a factor of 500. Calculate the diffusion flux for phosphorus in silicon, expressing your answer as the number of phosphorus atoms passing through a unit cell of silicon per minute. For the conditions employed, the diffusivity of P in Si is 10.5×10^{-10} m^2/s.

Note: silicon is diamond cubic (8 atoms/unit cell), lattice constant 0.5431 nm