SCHOOL OF MINING, METALLURGY & CHEMICAL ENGINEERING

DEPARTMENT OF METALLURGY

BACHELOR OF ENGINEERING TECHNOLOGY: PHYSICAL METALLURGY

SUBJECT:	**Physical Metallurgy 2A**
CODE:	**PMTMTA2**
ASSESSMENT:	**Supplementary Exam**
WEIGHT:	**40:60**
EXAMINER:	**Mr TG Langa**
MODERATOR:	**Mr LG Juganan**
DATE:	**16 July 2019**
DURATION:	**3 hours**
TIME:	**11:30**
NUMBER OF PAGES:	**5 (Including Cover page and Appendices)**
TOTAL MARKS:	**90**

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Instructions:

- **Use the appendices provided at the end of the question paper to answer some of the questions**
- **Scientific Calculator**
- **Answer all the questions**

Question 1: (15 marks)

1.1 List four (4) classifications of engineering materials. **(4)**

1.2 What properties should an engineer consider for a dental implant when selecting the materials for this application? **(5)**

1.3 The relationship between structure and materials properties can be influenced by the service conditions (environmental conditions). Name two engineering disasters that have had tragic results and why they happened? **(6)**

Question 2: (16marks)

2.1 With the aid of a sketch, derive the Bragg's law equation.**(8)**

2.2 Describe the principle behind how an SEM reveals surface relief when a secondary electron (SE) and backscattered electron (BSE) detector is used **(8)**

Question 3: (33 marks)

3.1 Compare interstitial and vacancy atomic mechanisms for diffusion. Support with a schematic drawing. **(6)**

3.2 Cite two reasons why interstitial diffusion is normally more rapid than vacancy diffusion. **(4)**

3.3 A nitriding heat treatment of a BCC steel normally requires 1 h 45min at 680 °C. What temperature would be required to reduce the heat treatment time to 1 h? **(5)**

3.4 A carburizing process is done to a 0.15% C steel by introducing 1.1% C at the surface at 900°C, where the iron is FCC. Calculate the carbon content at 0.6 mm and 1.5 mm beneath the surface after 50min. **(10)**

3.5 A 0.5 mm thick wafer of MgO separates a gas containing 1 x 10^{26} O atoms/m^3 from another chamber containing 6 x 10^{22} O atoms/m^3. The system is operating at 1200°C,

a) Calculate concentration gradient of oxygen through the wafer and **(4)**

b) Calculate the oxygen atoms through the foil. **(4)**

Question 4: (20 marks)

4.1 Your company is currently producing a disk-shaped iron casting. 53.4 mm thick and 275 mm in diameter. You believe that by making the cast solidify 25% faster can improve the mechanical properties of the casting and will allow the casting to be lighter. Design the casting to allow this. Assume mold constant to be 3.014×10^6 s/m^2 for this process and n=2. **(20)**

Question 5: (6 marks)

5.1 Briefly cite the differences between recovery and recrystallization processes in annealing.**(6)**

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APPENDIX

Diffusing Species	*Host Metal*	$D_0(m^2/s)$	$Q_d(J/mol)$
		Interstitial Diffusion	
C^b	Fe (α or BCC)^a	1.1×10^{-6}	87,400
C^c	Fe (γ or FCC)^a	2.3×10^{-5}	148,000
N^b	Fe (α or BCC)^a	5.0×10^{-7}	77,000
N^c	Fe (γ or FCC)^a	9.1×10^{-5}	168,000
		Self-Diffusion	
Fe^c	Fe (α or BCC)^a	2.8×10^{-4}	251,000
Fe^c	Fe (γ or FCC)^a	5.0×10^{-5}	284,000
Cu^d	Cu (FCC)	2.5×10^{-5}	200,000
Al^c	Al (FCC)	2.3×10^{-4}	144,000
Mg^c	Mg (HCP)	1.5×10^{-4}	136,000
Zn^c	Zn (HCP)	1.5×10^{-5}	94,000
Mo^d	Mo (BCC)	1.8×10^{-4}	461,000
Ni^d	Ni (FCC)	1.9×10^{-4}	285,000
		Interdiffusion (Vacancy)	
Zn^c	Cu (FCC)	2.4×10^{-5}	189,000
Cu^c	Zn (HCP)	2.1×10^{-4}	124,000
Cu^c	Al (FCC)	6.5×10^{-5}	136,000
Mg^c	Al (FCC)	1.2×10^{-4}	130,000
Cu^c	Ni (FCC)	2.7×10^{-5}	256,000
Ni^d	Cu (FCC)	1.9×10^{-4}	230,000

Argument of the Error Function $\frac{x}{2\sqrt{Dt}}$	Value of the Error Function erf $\frac{x}{2\sqrt{Dt}}$
0	0
0.10	0.1125
0.20	0.2227
0.30	0.3286
0.40	0.4284
0.50	0.5205
0.60	0.6039
0.70	0.6778
0.80	0.7421
0.90	0.7969
1.00	0.8427
1.50	0.9661
2.00	0.9953

Avogadro's number = 6.022 x 10^{23} atoms/mol

1 nanometer (nm) = 10^{-9} m = 10^{-7} cm = 10 Å
1 angstrom (Å) = 0.1 nm = 10^{-10} m = 10^{-8} cm

$$r^* = \frac{2\sigma_{sl}T_m}{\Delta H_f \Delta T}$$

Table 9-1 Values for freezing temperature, latent heat of fusion, surface energy, and maximum undercooling for selected materials

Material	Freezing Temperature (T_m) (°C)	Heat of Fusion (ΔH_f) (MJ/m³)	Solid-Liquid Interfacial Energy (σ_{sl}) (J/m²)	Typical Undercooling for Homogeneous Nucleation (ΔT) (°C)
Ga	30	488	56×10^{-3}	76
Bi	271	543	54×10^{-3}	90
Pb	327	237	33×10^{-3}	80
Ag	962	965	126×10^{-3}	250
Cu	1085	1628	177×10^{-3}	236
Ni	1453	2756	255×10^{-3}	480
Fe	1538	1737	204×10^{-3}	420
NaCl	801			169
CsCl	645			152
H_2O	0			40