UNIVERSITY OF GHANA

FACULTY OF ENGINEERING SCIENCES

BSc. (ENG) SECOND SEMESTER EXAMINATIONS: 2012/2013

MTEN 202 Kinetics and Surface Phenomena (2 Credits)

Answer All Questions **Time Allowed: 2hours**

Section A: 40MARKS

1. Why is the study of diffusion so important to the Material Scientist?

2. The values of the diffusion coefficients for the interdiffusion of carbon in both α-iron (BCC) and γ-iron (FCC) at 900°C are in Table 1. Explain the difference in values as observed.

3. (a)Sketch the schematic curves for volume free energy and surface free energy contributions to the total free energy change attending the formation of a spherical embryo/nucleus during solidification.

   (*b*) Sketch the schematic plot of free energy versus embryo/nucleus radius, on which is shown the critical free energy change (ΔG^*) and the critical nucleus radius (r^*).

4. (a)Rewrite the expression for the total free energy change for nucleation for the case of a cubic nucleus of edge length a (instead of a sphere of radius r). Now differentiate this expression with respect to a and solve for both the critical cube edge length, a^*, and also ΔG^*

   (b) Is ΔG^* greater for a cube or a sphere? Why?

5. Sketch the schematic free energy- versus-embryo/nucleus radius plot on which curves for both homogeneous and heterogeneous nucleation are presented. Show also the critical free energies and the critical radius.

6. As a Materials Scientist, why is it important to study surfaces and interfaces of materials? State five discontinuities between material phases

7. Discontinuity in a surface creates an interface. What are the consequences of discontinuities?

8. Name the two ways in which crystals grow and explain the modes of heat dissipation

9. Differentiate between homogenous and heterogeneous nucleation

10. Name five sources of nucleation sites

Section B: 30MARKS

1. The outer surface of a steel gear is to be hardened by increasing its carbon content; the carbon is to be supplied from an external carbon-rich atmosphere that is maintained at an elevated temperature. A diffusion heat treatment at 873K for 100 min increases the carbon concentration to 0.75 wt% at a position 0.5 mm below the surface. Estimate the diffusion time required at 900°C (1173 K) to achieve this same concentration also at a 0.5-mm position. Assume that the surface carbon content is the same for both heat treatments, which is maintained constant. Use the diffusion data in figure 1 for C diffusion in α-Fe.

2. Carbon is allowed to diffuse through a steel plate 10 mm thick. The concentrations of carbon at the two faces are 0.85 and 0.40 kg C/cm^3 Fe, which are maintained constant. If the pre-exponential and activation energy are $6.2\text{x}10^{-7}\text{m}^2/\text{s}$ and 80,000 J/mol, respectively, compute the temperature at which the diffusion flux is $6.3\text{x}10^{-10}\text{kg/m}^2\text{-s}$.

Diffusing Species	*Host Metal*	$D_0(m^2/s)$	*Activation Energy Q_d* kJ/mol	eV/atom	*Calculated Values* $T(°C)$	$D(m^2/s)$
Fe	α-Fe (BCC)	2.8×10^{-4}	251	2.60	500	3.0×10^{-21}
					900	1.8×10^{-15}
Fe	γ-Fe (FCC)	5.0×10^{-5}	284	2.94	900	1.1×10^{-17}
					1100	7.8×10^{-16}
C	α-Fe	6.2×10^{-7}	80	0.83	500	2.4×10^{-12}
					900	1.7×10^{-10}
C	γ-Fe	2.3×10^{-5}	148	1.53	900	5.9×10^{-12}
					1100	5.3×10^{-11}
Cu	Cu	7.8×10^{-5}	211	2.19	500	4.2×10^{-19}
Zn	Cu	2.4×10^{-5}	189	1.96	500	4.0×10^{-18}
Al	Al	2.3×10^{-4}	144	1.49	500	4.2×10^{-14}
Cu	Al	6.5×10^{-5}	136	1.41	500	4.1×10^{-14}
Mg	Al	1.2×10^{-4}	131	1.35	500	1.9×10^{-13}
Cu	Ni	2.7×10^{-5}	256	2.65	500	1.3×10^{-22}

Table 1: Some Diffusing Tabulation Data for some Species