UNIVERSITY OF GHANA

FACULTY OF ENGINEERING SCIENCES

BSc. (ENG) SECOND SEMESTER EXAMINATIONS: 2011/2012

MTEN 202 Kinetics and Surface Phenomena (2 Credits)

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

Section A

1. Compare the activation energies of interstitial and vacancy diffusion as well as the activation energy of low and high melting point materials

2. What is self diffusion and how will you experimentally measure self diffusion in a normal material like Ni.

3. Both the atomic and statistical aspect of Diffusion may be summed up by diffusion equations called Fick's Laws. State these laws and interpret them and then give the conditions under which these laws apply respectively.

4. Using a sketch diagram, state Young's equation of a wetting surface

5. Rewrite the expression for the total free energy change for nucleation for the case of a cube nucleus of edge 'a' (instead of 'r' for a sphere). Is ΔG^* greater for a cube or a sphere.

6. What is the difference between homogenous and heterogeneous nucleation and why is the activation energy for nucleation lower in heterogeneous nucleation.

7. Sketch the concentration profile for nonsteady state diffusion taken at three different times.

8. Define a surface and name three different surfaces as applied in surface science.

9. Differentiate between cohesive and adhesive force

10. Using a sketch diagram differentiate between a wetting and dewetting surface.

Section B

1. **(a)** For the solidification of pure gold, calculate the critical radius and the activation free energy if nucleation is homogeneous.Values for the latent heat of fusion and surface free energy are J/m3 and 0.132 J/m2, respectively. Use the supercooling value (ΔT) of 230°C.

   (b) For some transformation having kinetics that obey the Avrami equation, the parameter *n* is known to have a value of 1.5. If, after 125 s, the reaction is 25% complete, how long (total time) will it take the transformation to go to 90% completion?

   (c) It is known that the kinetics of recrystallization for some alloy obey the Avrami equation, and that the value of *n* in the exponential is 5.0. If, at some temperature, the fraction recrystallized is 0.30 after 100 min, determine the rate of recrystallization at this temperature.

2. **(a)** A sheet of steel 2.5mm thick has nitrogen atmospheres on both sides at 900°C and is permitted to achieve a steady-state diffusion condition. The diffusion coefficient for nitrogen in steel at this temperature is $1.2*10^{-10}$ m^2/s, and the diffusion flux is found to be $1.0*10^{-7}$ kg/m^2-s. Also, it is known that the concentration of nitrogen in the steel at the high-pressure surface is 2 kg/m^3. How far into the sheet from this high pressure side will the concentration be 0.5kg/m^3? Assume a linear concentration profile.

   (b) Determine the carburizing time necessary to achieve a carbon concentration of 0.30 wt% at a position 4 mm into an iron–carbon alloy that initially contains 0.10 wt% C.The surface concentration is to be maintained at 0.90 wt%C, and the treatment is to be conducted at 1100°C. Use the diffusion data for γ-Fe in Figure 1.

Diffusing Species	*Host Metal*	*$D_0(m^2/s)$*	*Activation Energy Q_d*		*Calculated Values*	
			kJ/mol	*eV/atom*	*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}

Figure 1: Some Diffusing Tabulation Data for some Species