UNIVERSITY OF GHANA

All Rights Reserved

FACULTY OF ENGINEERING SCIENCES LIBRARY UNIVERSITY OF GHANA

SCHOOL OF ENGINEERING SCIENCES

BSc. (ENG) MATERIALS SCIENCE & ENGINNERING

SECOND SEMESTER EXAMINATIONS: 2015/2016

MTEN 202 Kinetics and Surface Phenomena (2 Credits)

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

1. (a) Describe how you will experimentally measure self-diffusion in a metallic material like Ni and how different is self-diffusion from Kirkendall Effect? ***5marks***

   (b) 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. ***10marks***

   (c) 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 Table 1. ***10marks***

2. (a) As a Materials Scientist, why is it important to study surfaces and interfaces of materials? ***4marks***

   (b) Discontinuity in a surface creates an interface. What are the consequences of discontinuities? ***4marks***

   (c) For the solidification of nickel, calculate the critical radius r^* and the activation free energy G^* if nucleation is homogeneous. Values for the latent heat of fusion and surface free energy are -2.53×10^9 J/m^3 and 0.255 J/m^2, respectively. Use the supercooling value of 319°C and equilibrium melting temperature of 1,455 °C ***10marks***

   (d) Name the two ways in which crystals grow and explain the modes of heat dissipation ***4marks***

3. (a) Describe the basis for an electrochemical cell and state the equation relating Gibbs free energy to electrical work defining all variables. *5marks*

   (b) State the Nernst Equation and explain how useful the Nernst Equation is to you as a materials scientist. ***3marks***

   (c) Find the standard potential of the cell Cu(s) | Cu^{2+}(aq) ||Cl^- | AgCl(s) | Ag (s) and predict the direction of electron flow when the two electrodes are connected. The Cu/ Cu^{2+} half-cell potential is -0.34V and AgCl(s)+ e^- ----> Ag(s) + Cl^- (aq) is +0.22V ***5marks***

4. Batteries directly convert stored chemical energy of fuels into electrical energy without combustion, and are capable of overcoming the combustion efficiency limitation as

imposed by the Carnot cycle. This technology has been used in a number of electronic gadgets.

(a) Explain using schematic sketches and label clearly the principle governing the operation of a battery. *5marks*

(b) Describe the fundamental principle behind the operation of a solid oxide fuel cell with reference to the fuel and air transport mechanism *5marks*

Table 1: Some Diffusing Tabulation Data for some Species

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	500 900	3.0×10^{-21} 1.8×10^{-15}
Fe	γ-Fe (FCC)	5.0×10^{-5}	284	2.94	900 1100	1.1×10^{-17} 7.8×10^{-16}
C	α-Fe	6.2×10^{-7}	80	0.83	500 900	2.4×10^{-12} 1.7×10^{-10}
C	γ-Fe	2.3×10^{-5}	148	1.53	900 1100	5.9×10^{-12} 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 2: Tabulation of Error Function Values

z	*erf(z)*	*z*	*erf(z)*	*z*	*erf(z)*
0	0	0.55	0.5633	1.3	0.9340
0.025	0.0282	0.60	0.6039	1.4	0.9523
0.05	0.0564	0.65	0.6420	1.5	0.9661
0.10	0.1125	0.70	0.6778	1.6	0.9763
0.15	0.1680	0.75	0.7112	1.7	0.9838
0.20	0.2227	0.80	0.7421	1.8	0.9891
0.25	0.2763	0.85	0.7707	1.9	0.9928
0.30	0.3286	0.90	0.7970	2.0	0.9953
0.35	0.3794	0.95	0.8209	2.2	0.9981
0.40	0.4284	1.0	0.8427	2.4	0.9993
0.45	0.4755	1.1	0.8802	2.6	0.9998
0.50	0.5205	1.2	0.9103	2.8	0.9999

z	$erf(z)$	z	$erf(z)$	z	$erf(z)$
0	0	0.55	0.5633	1.3	0.9340
0.025	0.0282	0.60	0.6039	1.4	0.9523
0.05	0.0564	0.65	0.6420	1.5	0.9661
0.10	0.1125	0.70	0.6778	1.6	0.9763
0.15	0.1680	0.75	0.7112	1.7	0.9838
0.20	0.2227	0.80	0.7421	1.8	0.9891
0.25	0.2763	0.85	0.7707	1.9	0.9928
0.30	0.3286	0.90	0.7970	2.0	0.9953
0.35	0.3794	0.95	0.8209	2.2	0.9981
0.40	0.4284	1.0	0.8427	2.4	0.9993
0.45	0.4755	1.1	0.8802	2.6	0.9998
0.50	0.5205	1.2	0.9103	2.8	0.9999

Figure 2: Tabulation of Error Function Values