UNIVERSITY OF GHANA

SCHOOL OF ENGINEERING SCIENCES

BSc. (ENG) MATERIALS SCIENCE & ENGINNERING

SECOND SEMESTER EXAMINATIONS: 2014/2015

MTEN 202 Kinetics and Surface Phenomena (2 Credits)

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

1. (a) 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? *10marks*

   (b) 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 -1.16×10^9 J/m^3 and 0.132 J/m^2, respectively. Use the supercooling value (ΔT) of 230°C. *6marks*

   (c) The kinetics of the austenite-to-pearlite transformation obey the Avrami relationship. Using the fraction transformed–time data given below, determine the total time required for 95% of the austenite to transform to pearlite: *4marks*

Fraction Transformed	Time (s)
0.2	12.6
0.8	28.2

2. Figure1 shows how a zinc anode connected by a salt bridge to a copper cathode will convert chemical energy to electrical energy and allow the light bulb to light up. Look at the electrochemistry involved by considering the two redox reactions of Zn and Cu below:
   $Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$ is –0.76 V
   $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$ is 0.34 V.

(a) Using these reduction potentials, calculate the standard cell potential and describe the practical significance of your answer *10marks*

(b) Using your answer in (2a) calculate the EMF of the cell under nonstandard conditions at 298K with the following cell concentrations. *10marks*

$Zn(s) \mid Zn^{2+}(aq), 3.00M; SO_4^{2-}(3.00M) \parallel Cu^{2+}(aq), 0.0015M; SO_4^{2-}(0.0015M) \mid Cu(s)$

(c) Show that the reaction processes in (2b) is spontaneous. Take Faraday's constant to be 98485 C/mol e *10marks*

(d) Describe in your own words the practical significance of electrochemistry in terms materials purification and coating. *10marks*

Examiner: Dr. Johnson Kwame Efavi

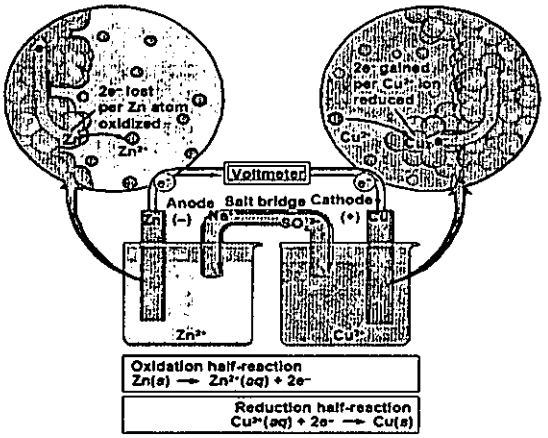

Figure1: Zn/Cu Galvanic Cell

3. Nitrogen from a gaseous phase is to be diffused into pure iron at 700°C. If the surface concentration is maintained at 0.1 wt% N, what will be the concentration 1 mm from the surface after 10 h? The diffusion coefficient for nitrogen in iron at 700°C is 2.5×10^{-11} m^2/s. Use data from the error function table below:

20marks

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

4. Fuel cells 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 the Gemini, Apollo and Space Shuttle program.
   (a) Sketch schematically and label a fuel cell with a solid oxide electrolyte

   5marks

   (b) Write the half reactions of the cell and describe the fundamental principle behind the operation of a solid oxide fuel cell with reference to the fuel and air transport mechanism. *15marks*