UNIVERSITY OF MINES AND TECHNOLOGY, TARKWA

FIRST SEMESTER EXAMINATIONS, NOV/DEC 2018

COURSE NO: MR 275
COURSE NAME: METALLURGICAL THERMODYNAMICS
CLASS: BSc II, MR **TIME:** 3 HOURS

Name**:** _____Index Number: _____

ANSWER ALL QUESTIONS

Q1. An innovative way for the 'safe' disposal of samples of methanol (CH_3OH) is to convert it to the gaseous reductants carbon monoxide (CO) and hydrogen (H_2) at suitable temperatures for use as reductants in ironmaking:

$$CH_3OH_{(g)} \rightleftharpoons CO_{(g)} + 2H_{2(g)}$$

a) Using the law of mass action, write an expression for the equilibrium constant K_p for this reaction. **(4 marks)**

b) Calculate ΔH_r^o and ΔS_r^o for the reaction at 25 °C. **(6 marks)**

c) Discuss the effect of i) an *increase* in *temperature* and ii) a *decrease* in *volume* of the container on the production of H_2 **(6 marks)**

d) Determine the temperature required to achieve 99% recovery at a total pressure of 1.0 bar. **(9 marks)**

Substance	ΔH_f^o (kJ mol^{-1})	S^o (J K^{-1} mol^{-1})
$CH_3OH_{(g)}$	-201	240
$CO_{(g)}$	-111	198
$H_{2(g)}$	0	131

Q2. a) Explain the terms: i) oxidation ii) reduction iii) disproportionation **(6 marks)**

b) The overall reaction in the lead storage battery is

$$Pb_{(s)} + PbO_{2(s)} + 2H^+_{(aq)} + 2HSO_4^-{}_{(aq)} \rightarrow 2PbSO_{4(s)} + 2H_2O_{(l)}$$

i) Calculate E^{rev} at 25 °C for this battery when $[H_2SO_4] = 4.5$ M; that is $[H^+] = [HSO_4^-] = 4.5$ M. At 25 °C, E° = 2.04 V for the lead storage battery **(5 marks)**

ii) For the cell reaction ΔH° = -315.9 kJ and ΔS° = 263.5 J/K. Calculate E° at -20 °C. **(5 marks)**

iii) Calculate E^{rev} at -20 °C when $[HSO_4^-] = 4.5$ M. **(5 marks)**

iv) Based on your previous answers, why does it seem that batteries fail more often on cold days than on warm days? **(4 marks)**

Q3 a) State the first, second and third laws of thermodynamics **(6 marks)**

b) In the production of compact discs, phosgene ($COCl_2$) is synthesized by reacting gaseous carbon monoxide with gaseous chlorine as follows:

$$CO_{(g)} + Cl_{2(g)} \rightarrow COCl_{2(g)}$$

Calculate ΔG at 25 °C for this reaction if 4.82 atm of carbon monoxide are made to react with 2.97 atm of chlorine to form phosgene. Comment on the spontaneity of the process. **(7 marks)**

Substance	ΔH_f^o (kJ mol^{-1})	S^o (J K^{-1} mol^{-1})
$COCl_{2\,(g)}$	-219	284
$CO_{(g)}$	-111	198
$Cl_{2\,(g)}$	0	223

c) One of the reactions that occur in the exhaust pipe of 'katalysator' engines is the catalytic decomposition of toxic nitrogen (II) oxide (NO) into nitrogen (N_2) and oxygen (O_2).

$$NO_{(g)} = ½\ O_{2(g)} + ½\ N_{2(g)}$$

i) Calculate ΔH°, ΔG° and K (at 25°C) for this reaction using the data below. **(6 marks)**
ii) Discuss the effect of temperature on the destruction of NO **(3 marks)**
iii) The reaction is allowed to occur in reactor of variable volume V. Discuss the effect of a decrease in the volume of the reactor on the destruction of NO. **(3 marks)**

Substance	ΔH_f^o (kJ mol^{-1})	S^o (J K^{-1} mol^{-1})
$NO_{(g)}$	90	211
$N_{2(g)}$	0	192
$O_{2(g)}$	0	205

Q4 a) 'G-tablets', *Aluminium hydroxide, Al(OH)$_3$,* can establish an important equilibrium reaction in the stomach, when chewed. Write down this equilibrium reaction and explain why 'G-tablets' are able to combat excess acidity to bring about a refreshing relief stomach. **(5 ½ marks)**

b) The following reaction is exothermic from left to right with equilibrium constant $K = 8.0 \times 10^{-2}$ M at a given temperature:

$$CH_{4(g)} + 2H_2S_{(g)} \rightleftharpoons 4H_{2(g)} + CS_{2(g)}$$

How will the amount of H_2 change in each of the following situations?

i) adding more $H_{2(g)}$ ii) decreasing the volume iii) decreasing the temperature **(4 ½ marks)**

ii) The following equilibrium amounts were measured for the reaction in a reaction chamber of volume V: 0.10 mol CS_2, 0.20 mol H_2, 0.05 mol H_2S and 0.15 mol CH_4. Determine the volume, V of the reaction chamber. **(5 marks)**

c) The pH of a solution is 6.4. Determine the exact concentration of Al^{3+} required to precipitate $Al(OH)_3$ from the solution. $K_{sp}(Al(OH)_3) = 2.0 \times 10^{-32}$ M^4 **(5 marks)**

d) The pH of a saturated solution of $Ca(OH)_2$ is 12.2. Determine the solubility product of $Ca(OH)_2$

(5 marks)

ASSOC PROF JAMES R. DANKWAH

Periodic Table of the Elements

1 H 1.008																	2 He 4.003
3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.30											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.88	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.61	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
55 Cs 132.9	56 Ba 137.3	57 *La 138.9	72 Hf 178.5	73 Ta 180.9	74 W 183.8	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 #Ac 227.0															

* Lanthanide Series	57 La 138.9	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (145)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.2	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
# Actinide Series	89 Ac 227.0	90 Th 232.0	91 Pa 231.0	92 U 238.0	93 Np 237.0	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (260)

6 C 12.00	<-- Atomic Number <-- Symbol <-- Atomic Weight (Relative Atomic Mass)

Volumes are given in the units of litres (L), or millilitres (mL)

Temperatures are given in the units of degrees Celsius (°C) or Kelvin (K).

It may be assumed that 0.0°C = 273.1 K

Energy changes are given in the SI unit kilojoule (kJ)

Pressures are given in the SI unit kilopascal (kPa), in atmospheres (atm), or in millimetres of mercury (mmHg)

1.000 atm = 101.3 kPa = 760.0 mmHg

Solution concentrations are given in the unit moles per litre (mol L^{-1})

Relating commonly used symbolism, 1 mol L^{-1} = 1 M

Universal Gas Constant, R = 8.315 J K^{-1} mol^{-1} or 0.08206 L atm K^{-1} mol^{-1}

Avogadro Constant, N = 6.022 x 10^{23} mol^{-1}

Magnitude of the electronic charge, q_e = 1.602 x 10^{-19} coulomb (C)

Magnitude of the charge carried by one mole of electrons = 1 faraday (F) = 9.649 x 10^4 C

Volume of 1.000 mol of an ideal gas at 0.0°C and 101.3 kPa is 22.41 L and at 25.0°C and 101.3 kPa is 24.47 L

S.T.P. is 0.0°C and 101.3 kPa