



# UNIVERSITY OF MINES AND TECHNOLOGY, TARKWA

FIRST SEMESTER EXAMINATIONS, NOV/DEC 2018

**COURSE NO:** MR 275

**COURSE NAME:** METALLURGICAL THERMODYNAMICS

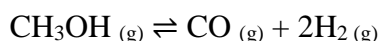
**CLASS:** BSc II, MR

**TIME:** 3 HOURS

Name: \_\_\_\_\_ Index Number: \_\_\_\_\_

## ANSWER ALL QUESTIONS

**Q1.** An innovative way for the 'safe' disposal of samples of methanol ( $\text{CH}_3\text{OH}$ ) is to convert it to the gaseous reductants carbon monoxide ( $\text{CO}$ ) and hydrogen ( $\text{H}_2$ ) at suitable temperatures for use as reductants in ironmaking:



- Using the law of mass action, write an expression for the equilibrium constant  $K_p$  for this reaction. **(4 marks)**
- Calculate  $\Delta H_r^\circ$  and  $\Delta S_r^\circ$  for the reaction at  $25^\circ\text{C}$ . **(6 marks)**
- Discuss the effect of i) an *increase* in *temperature* and ii) a *decrease* in *volume* of the container on the production of  $\text{H}_2$  **(6 marks)**
- Determine the temperature required to achieve 99% recovery at a total pressure of 1.0 bar. **(9 marks)**

Substance	$\Delta H_f^\circ$ (kJ mol <sup>-1</sup> )	$S^\circ$ (J K <sup>-1</sup> mol <sup>-1</sup> )
$\text{CH}_3\text{OH}_{(g)}$	-201	240
$\text{CO}_{(g)}$	-111	198
$\text{H}_2_{(g)}$	0	131

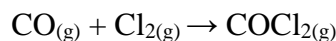
- Q2.** a) Explain the terms: i) oxidation ii) reduction iii) disproportionation **(6 marks)**
- b) The overall reaction in the lead storage battery is



- Calculate  $E^{\text{rev}}$  at  $25^\circ\text{C}$  for this battery when  $[\text{H}_2\text{SO}_4] = 4.5\text{ M}$ ; that is  $[\text{H}^+] = [\text{HSO}_4^-] = 4.5\text{ M}$ . At  $25^\circ\text{C}$ ,  $E^\circ = 2.04\text{ V}$  for the lead storage battery **(5 marks)**
- For the cell reaction  $\Delta H^\circ = -315.9\text{ kJ}$  and  $\Delta S^\circ = 263.5\text{ J/K}$ . Calculate  $E^\circ$  at  $-20^\circ\text{C}$ . **(5 marks)**
- Calculate  $E^{\text{rev}}$  at  $-20^\circ\text{C}$  when  $[\text{HSO}_4^-] = 4.5\text{ M}$ . **(5 marks)**
- 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)**

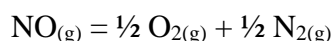
b) In the production of compact discs, phosgene ( $\text{COCl}_2$ ) is synthesized by reacting gaseous carbon monoxide with gaseous chlorine as follows:



Calculate  $\Delta G$  at  $25^\circ\text{C}$  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	$\Delta H_f^\circ$ (kJ mol <sup>-1</sup> )	$S^\circ$ (J K <sup>-1</sup> mol <sup>-1</sup> )
$\text{COCl}_{2(g)}$	-219	284
$\text{CO}_{(g)}$	-111	198
$\text{Cl}_{2(g)}$	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 ( $\text{N}_2$ ) and oxygen ( $\text{O}_2$ ).



i) Calculate  $\Delta H^\circ$ ,  $\Delta G^\circ$  and  $K$  (at  $25^\circ\text{C}$ ) for this reaction using the data below. **(6 marks)**

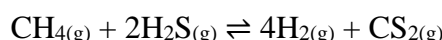
ii) Discuss the effect of temperature on the destruction of NO **(3 marks)**

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	$\Delta H_f^\circ$ (kJ mol <sup>-1</sup> )	$S^\circ$ (J K <sup>-1</sup> mol <sup>-1</sup> )
$\text{NO}_{(g)}$	90	211
$\text{N}_{2(g)}$	0	192
$\text{O}_{2(g)}$	0	205

**Q4** a) 'G-tablets', *Aluminium hydroxide*,  $\text{Al}(\text{OH})_3$ , 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 1/2 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:



How will the amount of  $\text{H}_2$  change in each of the following situations?

i) adding more  $\text{H}_{2(g)}$     ii) decreasing the volume    iii) decreasing the temperature **(4 1/2 marks)**

ii) The following equilibrium amounts were measured for the reaction in a reaction chamber of volume  $V$ : 0.10 mol  $\text{CS}_2$ , 0.20 mol  $\text{H}_2$ , 0.05 mol  $\text{H}_2\text{S}$  and 0.15 mol  $\text{CH}_4$ . Determine the volume,  $V$  of the reaction chamber. **(5 marks)**

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

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

**(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	<-- Atomic Number
C	<-- Symbol
12.00	<-- 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)

$$1.000 \text{ atm} = 101.3 \text{ kPa} = 760.0 \text{ mmHg}$$

**Solution concentrations** are given in the unit moles per litre (mol L<sup>-1</sup>)

Relating commonly used symbolism, 1 mol L<sup>-1</sup> = 1 M

Universal Gas Constant, R = 8.315 J K<sup>-1</sup> mol<sup>-1</sup> or 0.08206 L atm K<sup>-1</sup> mol<sup>-1</sup>

Avogadro Constant, N = 6.022 x 10<sup>23</sup> mol<sup>-1</sup>

Magnitude of the electronic charge, q<sub>e</sub> = 1.602 x 10<sup>-19</sup> coulomb (C)

Magnitude of the charge carried by one mole of electrons = 1 faraday (F) = 9.649 x 10<sup>4</sup> 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