UNIVERSITY OF EMBU

2017/2018 ACADEMIC YEAR

SECOND SEMESTER EXAMINATIONS

THIRD YEAR EXAMINATION FOR THE DEGREE OF BACHELOR OF SCIENCE AND BACHELOR OF EDUCATION,

SCH 303: THERMODYNAMICS II AND PHASE EQUILIBRIA

DATE: APRIL 4, 2018 **TIME: 2:00-4:00PM**

INSTRUCTIONS:

Answer Question ONE and any other TWO Questions

QUESTION ONE (30 MARKS)

a) differentiate between the following terms:

i) Spontaneous reaction and Non-spontaneous reaction (2 marks)

ii) Phase diagram and Phase boundary (2 marks)

iii) ΔS and $\Delta S°$ (2 marks)

iv) Intensive property and Extensive property (2 marks)

v) Path function and State function (2 marks)

b) i) With examples, state processes that are accompanied by an increase or decrease entropy (two for each process) (2 marks)

ii) What is the property of a system described by entropy? (2 marks)

iii) What is the importance of Maxwell relations? (2 marks)

c) i) Estimate the boiling point of bromine. (4 marks)

$$Br_{2(l)} \rightarrow Br_{2(g)} \qquad \Delta H_{vap} = 30.91 \text{ kj /mol}$$

ii) Calculate ΔG° at 25°C for the following reaction.

$$2NO_{2(g)} \rightarrow N_2O_{4(g)}$$

Given: ΔH° = - 57.20 kJ/mol and ΔS° = 137.55 J/mol · K.
Is this reaction spontaneous? (4 marks)

d) i) Calculate the entropy change at 25°C of the following reaction. Is the reaction spontaneous? (4 marks)

$$N_2H_{4(l)} + 2H_2O_{2(g)} \rightarrow N_{2(g)} + 4H_2O_{(g)} \quad \Delta H° = -642.2kJ/mol$$

ii) Water can exist as solid, liquid or vapour. How many components does a water system have? (2 marks)

QUESTION TWO (20 MARKS)

a) i) State Clausius–Clapeyron Equation (2 marks)

ii) The vapor pressure of 1-propanol is 10.0 torr at 14.7 °C. Calculate the vapor pressure at 52.8 °C.
Given:
Heat of vaporization of 1-propanol = 47.2 kJ/mol (4 marks)

iii) Discuss the advantages of phase rule. (6 marks)

b) i) Explain how signs and magnitude of ΔH, ΔS and Temperature affect spontaneity of a process. (4 marks)

ii) Given ΔH° = -98.2 kJ, ΔS° = 70.1J/K. Calculate the value of k_p for this reaction at 25°C is this reaction spontaneous? (4 marks)

QUESTION THREE (20 MARKS)

a) Given $\partial U = T\partial S - P\partial V$ derive the following $(\frac{dS}{dV})_s = -(\frac{dP}{dS})_T$ (4 marks)

b) Most spontaneous reactions are exothermic, but some are not. Explain. (5 marks)

c) i)Illustrate Gibb's phase rule (5 marks)

ii) Calculate f (degree of freedom) of water at triple point. (3 marks)

iii) Distinguish between Bivariant and Trivariant systems (3 marks)

QUESTION FOUR (20 MARKS)

a) Justify $\frac{q_h}{q_c} = \frac{T_h}{T_c}$ (6 marks)

b) i) Draw and label a basic structure of carnot cycle (5 marks)

ii) Give the Maxwell relation for U, H, A, and G (4 marks)

c) When liquid water vapourizes spontaneously at 25°C, what is the sign of ΔG. Under what conditions would ΔG=0 at 25°C, if any? (5 marks)

QUESTION FIVE (20 MARKS)

a) Estimate the temperature range for which the following reaction is spontaneous.

$$SiO_{2(g)} + 2C_{graphite} + Cl_{2(g)} \rightarrow SiCl_{4(g)} + 2CO_{(g)}$$

(6 marks)

b) i) Will a spontaneous process always occur rapidly? (5 marks)

ii) At the boiling point, 35°C, the heat of vaporization of MoF_6 is 25Kj/mol.

Calculate ΔS for vaporization of MoF_6 (4 marks)

c) Calculate ΔG at 700K for the following reaction mixture that consist 30.0 atm of H_2, 20.0 atm of N_2, and 0.5 atm of NH_3. $\Delta G°_{rxn} = 26.9$ Kj/mol (5 marks)

$$\frac{1}{2}N_{2(g)} + \frac{3}{2}H_{2(g)} \leftrightarrow NH_{3(g)}$$

Substance and State	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J K^{-1} mol^{-1})
$CaCO_3(s)$	−1207	−1129	93
$CaO(s)$	−635	−604	40.
$Ca(OH)_2(s)$	−987	−899	83
$Ca_3(PO_4)_2(s)$	−4126	−3890.	241
$CaSO_4(s)$	−1433	−1320.	107
$CaSiO_3(s)$	−1630.	−1550.	84
Carbon			
$C(s)$ (graphite)	0	0	6
$C(s)$ (diamond)	2	3	2
$CO(g)$	−110.5	−137	198
$CO_2(g)$	−393.5	−394	214
$CH_4(g)$	−75	−51	186
$CH_3OH(g)$	−201	−163	240.
$CH_3OH(l)$	−239	−166	127
$H_2CO(g)$	−116	−110.	219
$HCOOH(g)$	−363	−351	249
$HCN(g)$	135.1	125	202
$C_2H_2(g)$	227	209	201
$C_2H_4(g)$	52	68	219
$CH_3CHO(g)$	−166	−129	250.
$C_2H_5OH(l)$	−278	−175	161
$C_2H_6(g)$	−84.7	−32.9	229.5
$C_3H_6(g)$	20.9	62.7	266.9
$C_3H_8(g)$	−104	−24	270.
$C_2H_4O(g)$ (ethylene oxide)	−53	−13	242
$CH_2=CHCN(g)$	185.0	195.4	274
$CH_3COOH(l)$	−484	−389	160.
$C_6H_{12}O_6(s)$	−1275	−911	212
$CCl_4(l)$	−135	−65	216
Chlorine			
$Cl_2(g)$	0	0	223
$Cl_2(aq)$	−23	7	121
$Cl^-(aq)$	−167	−131	57
$HCl(g)$	−92	−95	187
Chromium			
$Cr(s)$	0	0	24
$Cr_2O_3(s)$	−1128	−1047	81
$CrO_3(s)$	−579	−502	72
Copper			
$Cu(s)$	0	0	33
$CuCO_3(s)$	−595	−518	88
$Cu_2O(s)$	−170.	−148	93
$CuO(s)$	−156	−128	43
$Cu(OH)_2(s)$	−450.	−372	108
$CuS(s)$	−49	−49	67
Fluorine			
$F_2(g)$	0	0	203
$F^-(aq)$	−333	−279	−14
$HF(g)$	−271	−273	174
Hydrogen			
$H_2(g)$	0	0	131
$H(g)$	217	203	115
$H^+(aq)$	0	0	0
$OH^-(aq)$	−230.	−157	−11
$H_2O(l)$	−286	−237	70.
$H_2O(g)$	−242	−229	189
Iodine			
$I_2(s)$	0	0	116
$I_2(g)$	62	19	261
$I_2(aq)$	23	16	137
$I^-(aq)$	−55	−52	106
Iron			
$Fe(s)$	0	0	27
$Fe_3C(s)$	21	15	108
$Fe_{0.95}O(s)$ (wustite)	−264	−240.	59
$FeO(s)$	−272	−255	61
$Fe_3O_4(s)$ (magnetite)	−1117	−1013	146
$Fe_2O_3(s)$ (hematite)	−826	−740.	90.
$FeS(s)$	−95	−97	67
$FeS_2(s)$	−178	−166	53
$FeSO_4(s)$	−929	−825	121
Lead			
$Pb(s)$	0	0	65
$PbO_2(s)$	−277	−217	69
$PbS(s)$	−100.	−99	91
$PbSO_4(s)$	−920.	−813	149
Magnesium			
$Mg(s)$	0	0	33
$MgCO_3(s)$	−1113	−1029	66
$MgO(s)$	−602	−569	27
$Mg(OH)_2(s)$	−925	−834	64
Manganese			
$Mn(s)$	0	0	32
$MnO(s)$	−385	−363	60.
$Mn_3O_4(s)$	−1387	−1280.	149
$Mn_2O_3(s)$	−971	−893	110.
$MnO_2(s)$	−521	−466	53
$MnO_4^-(aq)$	−543	−449	190.
Mercury			
$Hg(l)$	0	0	76
$Hg_2Cl_2(s)$	−265	−211	196
$HgCl_2(s)$	−230.	−184	144
$HgO(s)$	−90.	−59	70.
$HgS(s)$	−58	−49	78
Nickel			
$Ni(s)$	0	0	30.
$NiCl_2(s)$	−316	−272	107
$NiO(s)$	−241	−213	38
$Ni(OH)_2(s)$	−538	−453	79
$NiS(s)$	−93	−90.	53
Nitrogen			
$N_2(g)$	0	0	192
$NH_3(g)$	−46	−17	193
$NH_3(aq)$	−80.	−27	111
$NH_4^+(aq)$	−132	−79	113
$NO(g)$	90.	87	211

Substance and State	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J K^{-1} mol^{-1})	Substance and State	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J K^{-1} mol^{-1})
Aluminum				Bromine			
$Al(s)$	0	0	28	$Br_2(l)$	0	0	152
$Al_2O_3(s)$	−1676	−1582	51	$Br_2(g)$	31	3	245
$Al(OH)_3(s)$	−1277	—	—	$Br_2(aq)$	−3	4	130.
$AlCl_3(s)$	−704	−629	111	$Br^-(aq)$	−121	−104	82
Barium				$HBr(g)$	−36	−53	199
$Ba(s)$	0	0	67	Cadmium			
$BaCO_3(s)$	−1219	−1139	112	$Cd(s)$	0	0	52
$BaO(s)$	−582	−552	70.	$CdO(s)$	−258	−228	55
$Ba(OH)_2(s)$	−946	—	—	$Cd(OH)_2(s)$	−561	−474	96
$BaSO_4(s)$	−1465	−1353	132	$CdS(s)$	−162	−156	65
Beryllium				$CdSO_4(s)$	−935	−823	123
$Be(s)$	0	0	10.	Calcium			
$BeO(s)$	−599	−569	14	$Ca(s)$	0	0	41
$Be(OH)_2(s)$	−904	−815	47	$CaC_2(s)$	−63	−68	70.

Substance and State	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J K^{-1} mol^{-1})
$NO_2(g)$	34	52	240.
$N_2O(g)$	82	104	220.
$N_2O_4(g)$	10.	98	304
$N_2O_4(l)$	−20.	97	209
$N_2O_5(s)$	−42	134	178
$N_2H_4(l)$	51	149	121
$N_2H_3CH_3(l)$	54	180.	166
$HNO_3(aq)$	−207	−111	146
$HNO_3(l)$	−174	−81	156
$NH_4ClO_4(s)$	−295	−89	186
$NH_4Cl(s)$	−314	−203	96
Oxygen			
$O_2(g)$	0	0	205
$O(g)$	249	232	161
$O_3(g)$	143	163	239
Phosphorus			
$P(s)$ (white)	0	0	41
$P(s)$ (red)	−18	−12	23
$P(s)$ (black)	−39	−33	23
$P_4(g)$	59	24	280.
$PF_5(g)$	−1578	−1509	296
$PH_3(g)$	5	13	210.
$H_3PO_4(s)$	−1279	−1119	110.
$H_3PO_4(l)$	−1267	—	—
$H_3PO_4(aq)$	−1288	−1143	158
$P_4O_{10}(s)$	−2984	−2698	229
Potassium			
$K(s)$	0	0	64
$KCl(s)$	−436	−408	83
$KClO_3(s)$	−391	−290.	143
$KClO_4(s)$	−433	−304	151
$K_2O(s)$	−361	−322	98
$K_2O_2(s)$	−496	−430.	113
$KO_2(s)$	−283	−238	117
$KOH(s)$	−425	−379	79
$KOH(aq)$	−481	−440.	9.20
Silicon			
$SiO_2(s)$ (quartz)	−911	−856	42
$SiCl_4(l)$	−687	−620.	240.
Silver			
$Ag(s)$	0	0	43
$Ag^+(aq)$	105	77	73
$AgBr(s)$	−100.	−97	107
$AgCN(s)$	146	164	84
$AgCl(s)$	−127	−110.	96
$Ag_2CrO_4(s)$	−712	−622	217
$AgI(s)$	−62	−66	115
$Ag_2O(s)$	−31	−11	122
$Ag_2S(s)$	−32	−40.	146
Sodium			
$Na(s)$	0	0	51
$Na^+(aq)$	−240.	−262	59
$NaBr(s)$	−360.	−347	84
$Na_2CO_3(s)$	−1131	−1048	136
$NaHCO_3(s)$	−948	−852	102
$NaCl(s)$	−411	−384	72
$NaH(s)$	−56	−33	40.
$NaI(s)$	−288	−282	91
$NaNO_2(s)$	−359	—	—
$NaNO_3(s)$	−467	−366	116
$Na_2O(s)$	−416	−377	73
$Na_2O_2(s)$	−515	−451	95
$NaOH(s)$	−427	−381	64
$NaOH(aq)$	−470.	−419	50.
Sulfur			
$S(s)$ (rhombic)	0	0	32
$S(s)$ (monoclinic)	0.3	0.1	33
$S^{2-}(aq)$	33	86	−15
$S_8(g)$	102	50.	431
$SF_6(g)$	−1209	−1105	292
$H_2S(g)$	−21	−34	206
$SO_2(g)$	−297	−300.	248
$SO_3(g)$	−396	−371	257
$SO_4^{2-}(aq)$	−909	−745	20.
$H_2SO_4(l)$	−814	−690.	157
$H_2SO_4(aq)$	−909	−745	20.
Tin			
$Sn(s)$ (white)	0	0	52
$Sn(s)$ (gray)	−2	0.1	44
$SnO(s)$	−285	−257	56
$SnO_2(s)$	−581	−520.	52
$Sn(OH)_2(s)$	−561	−492	155
Titanium			
$TiCl_4(g)$	−763	−727	355
$TiO_2(s)$	−945	−890.	50.
Uranium			
$U(s)$	0	0	50.
$UF_6(s)$	−2137	−2008	228
$UF_6(g)$	−2113	−2029	380.
$UO_2(s)$	−1084	−1029	78
$U_3O_8(s)$	−3575	−3393	282
$UO_3(s)$	−1230.	−1150.	99
Xenon			
$Xe(g)$	0	0	170.
$XeF_2(g)$	−108	−48	254
$XeF_4(s)$	−251	−121	146
$XeF_6(g)$	−294	—	—
$XeO_3(s)$	402	—	—
Zinc			
$Zn(s)$	0	0	42
$ZnO(s)$	−348	−318	44
$Zn(OH)_2(s)$	−642	—	—
$ZnS(s)$ (wurtzite)	−193	—	—
$ZnS(s)$ (zinc blende)	−206	−201	58
$ZnSO_4(s)$	−983	−874	120.

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