



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:

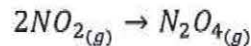
Answer Question ONE and any other TWO Questions

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 ΔS° (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)



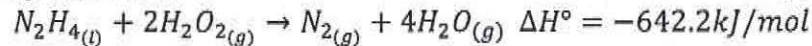
ii) Calculate ΔG° at 25°C for the following reaction.



Given: $\Delta H^\circ = -57.20 \text{ kJ/mol}$ and $\Delta S^\circ = 137.55 \text{ J/mol} \cdot \text{K}$.

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)



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 $\Delta H^\circ = -98.2 \text{ kJ}$, $\Delta S^\circ = 70.1 \text{ J/K}$. 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 $\left(\frac{dS}{dV}\right)_T = -\left(\frac{dP}{dT}\right)_V$ (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)

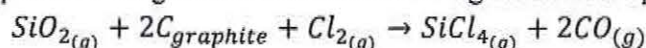
b) i) Draw and label a basic structure of carnot cycle (5 marks)

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 $\Delta G=0$ at 25°C, if any? (5 marks)

QUESTION FIVE (20 MARKS)

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



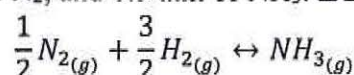
(6 marks)

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

ii) At the boiling point, 35°C, the heat of vaporization of MoF₆ is 25Kj/mol.

Calculate ΔS for vaporization of MoF₆ (4 marks)

- c) Calculate ΔG at 700K for the following reaction mixture that consist 30.0 atm of H₂, 20.0 atm of N₂, and 0.5 atm of NH₃. ΔG°_{rxn} = 26.9 Kj/mol (5 marks)



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)
CaCO ₃ (s)	-1207	-1129	93	H ₂ O(l)	-286	-237	70
CaO(s)	-635	-604	40	H ₂ O(g)	-242	-229	189
Ca(OH) ₂ (s)	-987	-899	83	Iodine			
Ca ₃ (PO ₄) ₂ (s)	-4126	-3890	241	I ₂ (s)	0	0	116
CaSO ₄ (s)	-1433	-1320	107	I ₂ (g)	62	19	261
CaSiO ₃ (s)	-1630	-1550	84	I ₂ (aq)	23	16	137
Carbon				I ⁻ (aq)	-55	-52	106
C(s) (graphite)	0	0	6	Iron			
C(s) (diamond)	2	3	2	Fe(s)	0	0	27
CO(g)	-110.5	-137	198	Fe ₃ C(s)	21	15	108
CO ₂ (g)	-393.5	-394	214	Fe ₃ O ₄ (s)			
CH ₄ (g)	-75	-51	186	(wustite)	-264	-240	59
CH ₃ OH(g)	-201	-163	240	FeO(s)	-272	-255	61
CH ₃ OH(l)	-239	-166	127	Fe ₂ O ₃ (s)			
H ₂ CO(g)	-116	-110	219	(magnetite)	-1117	-1013	146
HCOOH(g)	-363	-351	249	Fe ₂ O ₃ (s)			
HCN(g)	135.1	125	202	(hematite)	-826	-740	90
C ₂ H ₂ (g)	227	209	201	FeS(s)	-95	-97	67
C ₂ H ₄ (g)	52	68	219	FeS ₂ (s)	-178	-166	53
C ₂ H ₅ CHO(g)	-166	-129	250	FeSO ₄ (s)	-929	-825	121
C ₂ H ₅ OH(l)	-278	-175	161	Lead			
C ₂ H ₆ (g)	-84.7	-32.9	229.5	Pb(s)	0	0	65
C ₂ H ₆ (g)	20.9	62.7	266.9	PbO ₂ (s)	-277	-217	69
C ₂ H ₈ (g)	-104	-24	270	PbS(s)	-100	-99	91
C ₂ H ₄ O(g)				PbSO ₄ (s)	-920	-813	149
(ethylene oxide)	-53	-13	242	Magnesium			
CH ₂ = CHCN(g)	185.0	195.4	274	Mg(s)	0	0	33
CH ₃ COOH(l)	-484	-389	160	MgCO ₃ (s)	-1113	-1029	66
C ₆ H ₁₂ O ₆ (s)	-1275	-911	212	MgO(s)	-602	-569	27
CCl ₄ (l)	-135	-65	216	Mg(OH) ₂ (s)	-925	-834	64
Chlorine				Manganese			
Cl ₂ (g)	0	0	223	Mn(s)	0	0	32
Cl ₂ (aq)	-23	7	121	MnO(s)	-385	-363	60
Cl ⁻ (aq)	-167	-131	57	Mn ₂ O ₃ (s)	-1387	-1280	149
HCl(g)	-92	-95	187	Mn ₂ O ₄ (s)	-971	-893	110
Chromium				MnO ₂ (s)	-521	-466	53
Cr(s)	0	0	24	MnO ₄ ⁻ (aq)	-543	-449	190
Cr ₂ O ₃ (s)	-1128	-1047	81	Mercury			
CrO ₃ (s)	-579	-502	72	Hg(l)	0	0	76
Copper				Hg ₂ Cl ₂ (s)	-265	-211	196
Cu(s)	0	0	33	HgCl ₂ (s)	-230	-184	144
CuCO ₃ (s)	-595	-518	88	HgO(s)	-90	-59	70
Cu ₂ O(s)	-170	-148	93	HgS(s)	-58	-49	78
CuO(s)	-156	-128	43	Nickel			
Cu(OH) ₂ (s)	-450	-372	108	Ni(s)	0	0	30
CuS(s)	-49	-49	67	NiCl ₂ (s)	-316	-272	107
Fluorine				NiO(s)	-241	-213	38
F ₂ (g)	0	0	203	Ni(OH) ₂ (s)	-538	-453	79
F ⁻ (aq)	-333	-279	-14	NiS(s)	-93	-90	53
HF(g)	-271	-273	174	Nitrogen			
Hydrogen				N ₂ (g)	0	0	192
H ₂ (g)	0	0	131	NH ₃ (g)	-46	-17	193
H(g)	217	203	115	NH ₃ (aq)	-80	-27	111
H ⁺ (aq)	0	0	0	NH ₄ ⁺ (aq)	-132	-79	113
OH ⁻ (aq)	-230	-157	-11	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 ₂ O 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)	Substance and State	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J K ⁻¹ mol ⁻¹)
NO ₂ (g)	34	52	240.	NaHCO ₃ (s)	-948	-852	102
N ₂ O(g)	82	104	220.	NaCl(s)	-411	-384	72
N ₂ O ₄ (g)	10.	98	304	NaH(s)	-56	-33	40.
N ₂ O ₄ (l)	-20.	97	209	NaI(s)	-288	-282	91
N ₂ O ₅ (s)	-42	134	178	NaNO ₂ (s)	-359	—	—
N ₂ H ₄ (l)	51	149	121	NaNO ₃ (s)	-467	-366	116
N ₂ H ₃ CH ₃ (l)	54	180.	166	Na ₂ O(s)	-416	-377	73
HNO ₃ (aq)	-207	-111	146	Na ₂ O ₂ (s)	-515	-451	95
HNO ₃ (l)	-174	-81	156	NaOH(s)	-427	-381	64
NH ₄ ClO ₄ (s)	-295	-89	186	NaOH(aq)	-470.	-419	50.
NH ₄ Cl(s)	-314	-203	96	Sulfur			
Oxygen				S(s) (rhombic)	0	0	32
O ₂ (g)	0	0	205	S(s) (monoclinic)	0.3	0.1	33
O(g)	249	232	161	S ²⁻ (aq)	33	86	-15
O ₃ (g)	143	163	239	S ₈ (g)	102	50.	431
Phosphorus				SF ₆ (g)	-1209	-1105	292
P(s) (white)	0	0	41	H ₂ S(g)	-21	-34	206
P(s) (red)	-18	-12	23	SO ₂ (g)	-297	-300.	248
P(s) (black)	-39	-33	23	SO ₃ (g)	-396	-371	257
P ₄ (g)	59	24	280.	SO ₄ ²⁻ (aq)	-909	-745	20.
PF ₅ (g)	-1578	-1509	296	H ₂ SO ₄ (l)	-814	-690.	157
PH ₃ (g)	5	13	210.	H ₂ SO ₄ (aq)	-909	-745	20.
H ₃ PO ₄ (s)	-1279	-1119	110.	Tin			
H ₃ PO ₄ (l)	-1267	—	—	Sn(s) (white)	0	0	52
H ₃ PO ₄ (aq)	-1288	-1143	158	Sn(s) (gray)	-2	0.1	44
P ₄ O ₁₀ (s)	-2984	-2698	229	SnO(s)	-285	-257	56
Potassium				SnO ₂ (s)	-581	-520.	52
K(s)	0	0	64	Sn(OH) ₂ (s)	-561	-492	155
KCl(s)	-436	-408	83	Titanium			
KClO ₃ (s)	-391	-290.	143	TiCl ₄ (g)	-763	-727	355
KClO ₄ (s)	-433	-304	151	TiO ₂ (s)	-945	-890.	50.
K ₂ O(s)	-361	-322	98	Uranium			
K ₂ O ₂ (s)	-496	-430.	113	U(s)	0	0	50.
KO ₂ (s)	-283	-238	117	UF ₆ (s)	-2137	-2008	228
KOH(s)	-425	-379	79	UF ₆ (g)	-2113	-2029	380.
KOH(aq)	-481	-440.	9.20	UO ₂ (s)	-1084	-1029	78
Silicon				U ₃ O ₈ (s)	-3575	-3393	282
SiO ₂ (s) (quartz)	-911	-856	42	UO ₃ (s)	-1230.	-1150.	99
SiCl ₄ (l)	-687	-620.	240.	Xenon			
Silver				Xe(g)	0	0	170.
Ag(s)	0	0	43	XeF ₂ (g)	-108	-48	254
Ag ⁺ (aq)	105	77	73	XeF ₄ (s)	-251	-121	146
AgBr(s)	-100.	-97	107	XeF ₆ (g)	-294	—	—
AgCN(s)	146	164	84	XeO ₃ (s)	402	—	—
AgCl(s)	-127	-110.	96	Zinc			
Ag ₂ CrO ₄ (s)	-712	-622	217	Zn(s)	0	0	42
AgI(s)	-62	-66	115	ZnO(s)	-348	-318	44
Ag ₂ O(s)	-31	-11	122	Zn(OH) ₂ (s)	-642	—	—
Ag ₂ S(s)	-32	-40.	146	ZnS(s)			
Sodium				(wurtzite)	-193	—	—
Na(s)	0	0	51	ZnS(s)			
Na ⁺ (aq)	-240.	-262	59	(zinc blende)	-206	-201	58
NaBr(s)	-360.	-347	84	ZnSO ₄ (s)	-983	-874	120.
Na ₂ CO ₃ (s)	-1131	-1048	136				

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