MURANG'A UNIVERSITY OF TECHNOLOGY

SCHOOL OF PURE, APPLIED AND HEALTH SCIENCES

DEPARTMENT OF PHYSICAL AND BIOLOGICAL SCIENCES

UNIVERSITY ORDINARY EXAMINATION

2021/2022 ACADEMIC YEAR

THIRD YEAR **FIRST** SEMESTER EXAMINATION FOR, BACHELOR OF SCIENCE IN ANALYTICAL CHEMISTRY AND INDUSTRIAL CHEMISTRY

ACH 303: CHEMICAL THERMODYNAMICS II AND PHASE EQUILIBRIUM

DURATION: 2 HOURS

Instructions to candidates:

1. Answer question One and Any Other Two questions.
2. Mobile phones are not allowed in the examination room.
3. You are not allowed to write on this examination question paper.

Useful Constants

1 atmosphere = 10132HM-2 = 760 mmHg

Molar gas volume at STP = 22.415 litres

Gas constant R = 0.08205 litre –atm k^{-1} mol^{1-} = 8.314Jk^{-1} mo^{l-}

1 litre = 1000 cm^3 = 1 dm^3

0ºC = 273 K

SECTION A: ANSWER ALL QUESTIONS IN THIS SECTION

QUESTION ONE (30 MARKS)

a) Given that dq_{rev}= CvdT + P ΔV show that (5 marks)

$$\Delta S = C_p \left(\frac{T_2}{T_1}\right) - ln\left(\frac{P_2}{P_1}\right)$$

b) Determine the entropy changes for the following equation.

$2C_{(graphite)} + 3H_{2\ (g)} \rightarrow C_2H_{6\ (g)}$

Given the entropy of C(graphite) = 5.69 JK^{-1} $mo1^{-1}$

$H_{2(g)}$ = 130.59 JK^{-1} $mo1^{-1}$ and $C_2H_{6\ (g)}$ 229.49 $Jmol^{-1}$ K^{-1} (2 marks)

c) 3dm^3 of hydrogen, initially at STP, are expanded isothermally and reversibly to a volume of 7dm^3. Calculate ΔG for the process. (4 marks)

d) Given dG = VdP – SdT derive Gibb's – Helmholtz equation. (5 marks)

e) Given that the free energies of formation of N_2O_4 and NO_2 at 25ºC are 98.5k J and 51.5kJ per mole, respectively, calculate K_p and K_c at one atmosphere and 25ºC for reaction

$N_2\ O_4(g) \rightleftharpoons 2NO_2\ (g)$ (6 marks)

f) Glycerine, $C_3H_8O_3$ is a non-vilatile non-electrolyte with a density of 1.26g/ml at 25ºC. Calculate the vapour pressure at 25 ºC of solution made by adding 50ml of glycerin to 500.0 ml of water with a density of 1.0g/ml. The vapour pressure of pure water at 25ºC is 23.8 torr. (C= 12, H = 1, 0 = 16) (4 marks)

g) Calculate the concentration of CO_2 in a soft drink is bottled with a partial pressure of CO_2 of 4.0 atmospheres, over the liquid at 25ºC, given the Henry's constant for CO_2 at this temperature as 3.1 x 10^{-2} mol/litre - atm (2 marks)

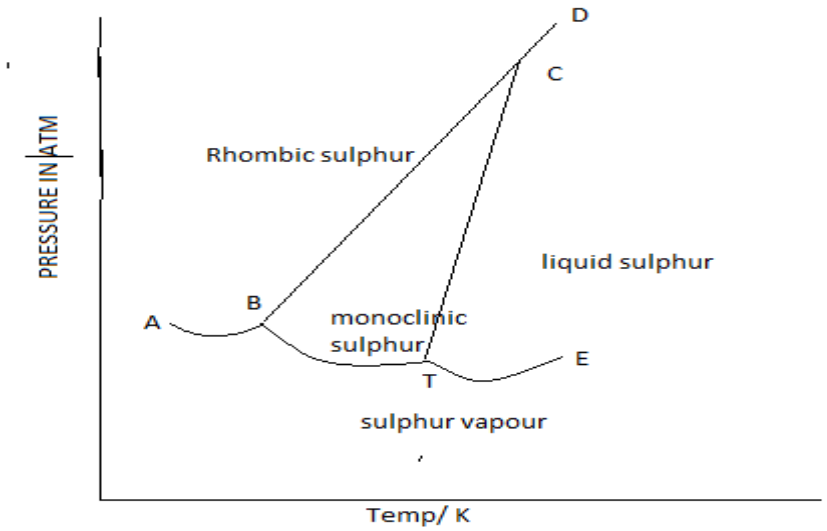
h) Define the following terms

i) Entropy (1 mark)

ii) Supersaturated solution (1 mark)

SECTION B – ANSWER ANY TWO QUESTIONS IN THIS SECTION
QUESTION TWO (20 MARKS)

2.a). Below is a phase diagram for sulphur.



i) Identify the phases present in point T.

ii) What does curve AB and BC represent.

(5 marks)

b) You are provided with the following entropies and enthalpies of composition at 25ºC.

Substance	Sin JK^{-1}	Δ H in kJ
$C_{(graphite)}$	5.69	-396
$H_{2(g)}$	131.0	-287
C_6H_6	186.19	-3264.58

State whether the following reaction is thermodynamically state.

$C_{(graphite)} + 3H_{2(g)} \rightarrow C_6H_{6(l)}$ (5 marks)

c) Calculate the entropy change when 3 moles of a perfect gas is allowed to expand at 300K from a volume of $4dm^3$ to 11 dm^3. (3 marks)

d) The boiling point of glycerol is 290ºC at a pressure of 1 atmosphere, while at 5 atmospheres it is 410 ºC. Assuming a temperature sink of 60ºC, compare the theoretical efficiencies of a steam engine operating between boiling point of glycerol and that of sink at
(i) 1 atm

(ii) 5 atm

(4 marks)

e) Given $\Delta G = -RT \ln K_p$ derive the Vaint Hoff's equation. (3 marks)

QUESTION THREE (20 MARKS) Type equation here.

3. a). Given $C_2H_2 + 2H_2 \rightarrow C_2H_6$, $\Delta H^o_{298} = -480kJ$ and the molar entropy values also at 298 K are ;

$S_{C_2H_2} = 202\ Jk^{-1}$

$S_{H_2} = 131\ Jk^{-1}$

$S_{C_2H_6} = 230\ Jk^{-1}$

From this data determine the equilibrium constant at 298 K for this synthesis. (5 marks)
b) State four methods that can be used to purify impure metals. (4 marks)

c) State the third law of thermodynamics. (1 mark)

d) For the reversible reaction
$N_2 + 3H_2 \rightleftharpoons 2NH3$, at 773K the value of K_P with partial pressures in atmosphere, is 1.44×10^{-5} at low pressures where gases behave ideally. Determine the corresponding value of K_c with concentrations in mole litre $^{-1}$. (3 marks)

e) Determine the equilibrium for the reaction $N_2 + 3H_2 \rightleftharpoons 2NH_3$ at 673K, given K_p at 773K is 1.44×10^{-4} and the mean enthalpy of formation, ΔH_v, for one mole of ammonia at this temperature range is -52.608kJ. (4 marks)

f) The enthalpy of fusion of monoclinic sulphur is 1.26kJ/mol.
Determine the enthalpy change when 3 moles of monoclinic sulphur melt at 392k.

QUESTION FOUR (20 MARKS)

4. a). The molar heat capacity at constant pressure of ozone gas is expressed by $C_p = 28.87 + 4.3 \times 10^{-2} T - 2.04 \times 10^{-6} T^2\ Jk^{-1}\ mo1^{-}$. Calculate the increase in entropy when 1 mole of ozone gas is heated from 35º to 135 ℃. (4 marks)
b) A mixture is made by mixing 3 moles of benzene (C_6H_6) and 5 moles of toluene (C_7H_8) at 25℃, the vapour pressure of pure benzene is 80 torr and pure toluene is 25 torr at 25 ℃. Calculate the mole fraction of toluene and the total vapour pressure of the mixture. (4 marks)
c) Briefly show how changes in (i) pressure and ii) temperature, affect entropy. (4 marks)
d) The following expression is of the total entropy of the system and the surrounding;
$T\partial s \geq \partial q$. Explain. (2 marks)

e) State two factors that affect solubility and show how each of them affect solubility. (4 marks)
f) State the "Roults' law". (1 mark)
g) State the second law of thermodynamics. (1 mark)