MACHAKOS UNIVERSITY

University Examinations for 2022/2023 Academic Year

SCHOOL OF PURE AND APPLIED SCIENCES

DEPARTMENT OF PHYSICAL SCIENCES

SECOND YEAR FIRST SEMESTER EXAMINATION FOR BACHELOR OF SCIENCE (ANALYTICAL CHEMISTRY)

SCH 204: CHEMICAL THERMODYNAMICS AND PHASE EQUILIBRIA

DATE: **TIME:**

INSTRUCTIONS:

- The paper consists of **two** sections.
- Section **A** is **compulsory** (30 marks).
- Answer any **two** questions from section **B** (each 20 marks).

Required data

- Gas Constant, R = 8.314 $JK^{-1}mol^{-1}$ = 0.08206 L atm K^{-1} mol^{-1}
- 0 ºC = 273 K
- 1 atm = 760 mmHg = 101325 Nm^{-2}
- $C_v = \frac{3}{2}R$ for a monatomic gas

Section A – Compulsory
QUESTION ONE (COMPULSORY) (30 MARKS)

a) Distinguish between;

i) System and Surrounding (2 marks)

ii) Triple point and Eutectic point (2 marks)

iii) A phase and a component (2 marks)

b) i) Define adiabatic change (2 marks)

ii) 6 moles of an ideal monatomic gas at 400 K are compressed adiabatically to one quarter of the original volume. Calculate the temperature of the gas after compression. (3 marks)

c) i) Define an isothermal change (2 marks)

ii) 0.2 moles of an ideal gas were expanded isothermally at 273 K from 8 dm^3 to 10 dm^3. Determine the energy (q) absorbed from the surroundings. (3 marks)

d) Use the following data to draw a phase diagram for a substance A and B system:

I) Melting point of B is 655 ºC

II) Melting point of A is 500 ºC

III) One Eutectic point at 180 ºC with 25% A and another at 350 ºC with 85 % of A.

IV) A solid compound BA_2 is formed which melts at 580 ºC.

(6 marks)

e) i) State the Raoult's Law (1 mark)

ii) Calculate the vapour pressure of a solution containing 11.7 g benzene (MW = 78) and 4.6 g methylbenzene (MW = 92) at 50 °C, if the vapour pressure of the pure components at this temperature are 3.6×10^4 Nm^{-2} and 1.12×10^4 Nm^{-2}, respectively. (3 marks)

f) i) Define entropy of a system (1 mark)

ii) Provided the following entropies and enthalpies of combustion at 25 °C;

Substance	S (JK^{-1})	ΔH(kJ)
$C_{(graphite)}$	5.9	-396
$H_{2(g)}$	131.0	-287
$C_2H_{6(g)}$	231.0	-1567

Determine whether the following reaction is thermodynamically possible.

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

SECTION B: ANSWER ANY TWO QUESTIONS

a) i) Derive the Gibb's - Helmholtz equation. (5 marks)

ii) For the reversible reaction

$$N_2 + 3H_2 \leftrightarrow 2NH_3$$

At 773 K, the value of K_P, with partial pressures in atmospheres, is 1.44×10^{-5} at low pressures where the gases behave ideally. Determine the corresponding value of K_C with concentrations in mole litre^{-1}. (5 marks)

b) Using a Heat versus Temperature diagram, explain how one mole of ice changes when heat is added to it. (8 marks)

c) Briefly explain why Pb-Sn alloys are used as solders (2 marks)

QUESTION THREE (20 MARKS)

a) i) State Hess's law of constant heat summation. (2 marks)

ii) Calculate the enthalpy of the reaction;

$C_2H_{4(g)} + H_{2(g)} \rightarrow C_2H_{6(g)}$
at 298 K from the following data:

(i) $C_2H_{4(g)} + 3O_{2(g)} \rightarrow 2CO_{2(g)} + 2H_2O_{(g)}$ $\Delta H = -1395$ kJ
(ii) $C_2H_{6(g)} + 7/2O_{2(g)} \rightarrow 2CO_{2(g)} + 3H_2O_{(g)}$ $\Delta H = -1550$ kJ
(iii) $H_{2(g)} + 1/2O_{2(g)} \rightarrow H_2O(g)$ $\Delta H = -243$ kJ (4 marks)

b) When one mole of liquid benzene was completely burnt in oxygen to form liquid water and CO_2 gas, $\Delta H = -3250$ kJ at 298 K. Calculate the enthalpy of reaction at constant volume at the same temperature. (4 marks)

c) Water exhibits three phases i.e., ice, liquid water and vapour.

i) Sketch a well labeled phase diagram of water (8 marks)

ii) Show that the triple point of water is invariant (2 marks)

QUESTION FOUR (20 MARKS)

a) i) Define the third law of thermodynamics (2 marks)

ii) Calculate the entropy change for the reaction:

$2C_{(graphite)} + 2H_{2(g)} \rightarrow 2C_2H_{4(g)}$

Given the following standard entropies at 25 °C in units J $K^{-1}mole^{-1}$;

$C_{(graphite)}$	5.7
$H_{2(g)}$	131.2
$C_2H_{4(g)}$	221.0

(5 marks)

b) The boiling point of water at a pressure of 50 atmospheres is 265 °C and at 1 atmosphere is 100 °C. Assuming the temperature of the sink is 40 °C, compare the theoretical efficiencies of a steam engine operating between the boiling point of water and that of the sink at: a) 1 atmosphere b) 50 atmospheres. (5 marks)

c) i) Sketch a Cu-Ni binary phase diagram clearly showing all the phases (4 marks)

ii) Explain how the Lever Rule can be used to determine the amount of each phase of the Cu-Ni alloy mixture (4 marks)

QUESTION FIVE (20 MARKS)

a) i) Derive the Van't Hoff Equation (4 marks)

ii) The equilibrium constant K_P for the reaction:

$$N_2 + 3H_2 \leftrightarrow 2NH_3$$

is 1.64×10^{-4} at 673K and 1.44×10^{-5} at 773 K. Determine the mean enthalpy of formation, ΔH_V, for one mole of ammonia from its elements in this temperature range. (3 marks)

b) Calculate the Gibb's Free Energy change (ΔG), at 25 °C for the reaction:

$$C_2H_5OH_{(l)} + O_{2(g)} \rightarrow CH_3COOH_{(l)} + H_2O_{(l)}$$

from the following data.

i. $H_{2(g)} + ½\ O_{2(g)} \rightarrow H_2O_{(l)}$ $\Delta G = -238kJ$

ii. $2C_{(graphite)} + 3H_2O_{(g)} + 1/2\ O_{2(g)} \rightarrow C_2H_5OH_{(l)}$ $\Delta G = -176kJ$

iii. $2C_{(graphite)} + 2H_2O_{(g)} + O_{2(g)} \rightarrow CH_3COOH_{(l)}$ $\Delta G = -394kJ$

(3 marks)

c) Sketch clearly a well labeled phase diagram for sulphur system (5 marks)
From the diagram;

i) Identify all the triple points and the melting point of each allotrope (2 marks)

ii) Discuss the application of the phase rule in the Sulphur system (3 marks)