



MACHAKOS UNIVERSITY

University Examinations for 2021/2022 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, $R = 8.314 \text{ JK}^{-1}\text{mol}^{-1} = 0.08206 \text{ L atm K}^{-1}\text{mol}^{-1}$
- $0^\circ\text{C} = 273 \text{ K}$
- $1 \text{ atm} = 760 \text{ mmHg} = 101325 \text{ Nm}^{-2}$
- $C_v = \frac{3}{2}R$ for a monatomic gas

SECTION A - COMPULSORY.

QUESTION ONE (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) Use the following data to draw a phase diagram for a substance A and B system:
- I) Melting point of B is 655 °C
 - II) Melting point of A is 500 °C
 - III) One Eutectic point at 180 °C with 25% A and another at 350 °C with 85 % of A.
 - IV) A solid compound BA_2 is formed which melts at 580 °C. (6 marks)
- d) i) Define an isothermal change (2 marks)
- ii) 0.2 moles of an ideal gas were expanded isothermally at 273 K from 8 dm³ to 10 dm³. Determine the energy (q) absorbed from the surroundings. (3 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 $3.6 \times 10^4 \text{ Nm}^{-2}$ and $1.12 \times 10^4 \text{ Nm}^{-2}$, 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 ₂ H _{6(g)}	231.0	-1567

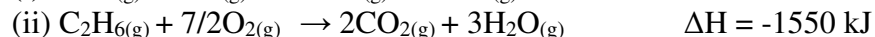
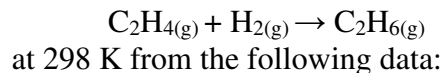
Determine whether the following reaction is thermodynamically possible.



SECTION B: ANSWER ANY TWO QUESTIONS

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

ii) Calculate the enthalpy of the reaction;



- b) When one mole of liquid benzene was completely burnt in oxygen to form liquid water and CO_2 gas, $\Delta H = -3250 \text{ kJ}$ 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.

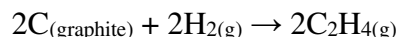
i) Sketch a well labeled phase diagram of water (8 marks)

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

QUESTION THREE (20 MARKS)

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

ii) Calculate the entropy change for the reaction:



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



(5 marks)

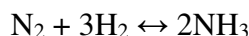
- b) The boiling point of water at a pressure of 50 atmospheres is 265 °C and at 1 atmosphere is 100 °C. Assuming the temperature of the sink is 40 °C, compare the theoretical efficiencies of a steam engine operating between the boiling point of water and that of the sink at: a) 1 atmosphere b) 50 atmospheres. (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 FOUR (20 MARKS)

- a) i) Derive the Gibb's - Helmholtz equation. (5 marks)
ii) For the reversible reaction

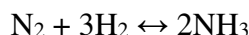


At 773 K, the value of K_P , with partial pressures in atmospheres, is 1.44×10^{-5} at low pressures where the gases behave ideally. Determine the corresponding value of K_C with concentrations in mole litre⁻¹. (5 marks)

- b) Using a Heat vs. 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)

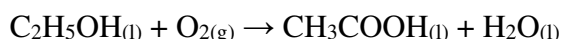
QUESTION FIVE (20 MARKS)

- a) i) Derive the Van't Hoff Equation (4 marks)
ii) The equilibrium constant K_P for the reaction:



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:



from the following data.

- i. $\text{H}_{2(g)} + \frac{1}{2} \text{O}_{2(g)} \rightarrow \text{H}_2\text{O}_{(l)} \quad \Delta G = -238\text{kJ}$
ii. $2\text{C}_{(\text{graphite})} + 3\text{H}_2\text{O}_{(g)} + \frac{1}{2} \text{O}_{2(g)} \rightarrow \text{C}_2\text{H}_5\text{OH}_{(l)} \quad \Delta G = -176\text{kJ}$
iii. $2\text{C}_{(\text{graphite})} + 2\text{H}_2\text{O}_{(g)} + \text{O}_{2(g)} \rightarrow \text{CH}_3\text{COOH}_{(l)} \quad \Delta G = -394\text{kJ}$

(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)