NATIONAL OPEN UNIVERSITY OF NIGERIA PLOT 91, CADASTRAL ZONE, NNAMDI AZIKIWE EXPRESSWAY, JABI – ABUJA
FACULTY OF SCIENCES
DEPARTMENT OF CHEMISTRY
2025_2 EXAMINATIONS

COURSE CODE: CHM 301
COURSE TITLE: PHYSICAL CHEMISTRY III
COURSE UNIT: 2
INSTRUCTION: Answer question one (1) and any other two questions
Time: Two (2) hours

QUESTION 1

1. (a) 3 moles sample of Helium is expanded isothermally at 30°C from 20 dm^3 to 32 dm^3. Deduce the value of q, w, ΔU, and ΔH when the gas expands isothermally and (i) reversibly (4 marks) (ii) against a constant external pressure equal to the final pressure of the gas. (7 marks)

1. (b) Define decrease in Gibbs free energy (-dG) (2 marks)

1. (c) The property *G (Gibbs free energy)* or Δ*G* (the change in Gibbs free energy is very important because most experiment in the laboratory are carried out under this condition. From the Gibbs Free energy expression; $G = U + pV - TS$, show that $-dG = -dw_{net}$ (6 marks)

1. (d) Define the following (i) Internal energy of a system(U) (2 marks) (ii) total energy of a system (2 marks)

(e) Given the reaction; $N_{2(g)} + 3H_{2(g)} \rightarrow 2\ NH_{3(g)}$, find the standard Gibbs free energy of reaction at (i) 600 K, (4 marks) (ii) 1200 K from their values at 298 K with enthalpy of reaction equals -46.11 $kJmol^{-1}$and Gibbs free energy for the formation of ammonia being -16.45 $kJmol^{-1}$. (3 marks)

QUESTION 2

2. (a) State the zeroth law of thermodynamics. (2 marks)

2. (b) Describe briefly the following terms: (i) Isothermal process (2 marks) (ii) adiabatic process (2 marks) (iii) reversible process (2 marks)

2. (c) An ideal gas initially at 305 K and 2.00×10^5 Pa pressure occupies 0.45 m^3 space. What is the minimum amount of work required to compress the gas isothermally and reversibly so that the final pressure is 4.00×10^6Pa? (7 marks)

2. (d) Identify the extensive and intensive properties from these list of properties below:
temperature, density, volume, heat capacity, energy, conductivity (3 marks)

2. (e) What is the physical significance of decrease in Gibbs free energy? (2 marks)

QUESTION 3

3.(a) The temperature-volume relationship in a reversible adiabatic process could help to determine the final temperature of a system undergoing adiabatic expansion or compression. Using the equation below: $dU = dw$,
derive an expression for temperature-volume relationship in a reversible adiabatic process. (12 marks)

3.(b) Explain why the change in entropy of a system is not always a suitable criterion for spontaneous change? (2 marks)

3.(c) With reference to entropy, explain why Gibbs free energy can be used for determining spontaneity. (2 marks)

3. (d) Explain the relevance of Nernst Heat Theorem to Gibbs free energy change ΔG, enthalpy change ΔH, and entropy of substance at absolute temperature. (4 marks)

QUESTION 4

4. (a) A certain heat engine operates between 1000 K and 500 K. (i) What is the maximum efficiency of the engine? (3 marks) (ii) Calculate the maximum work that can be done for each 1.0 kJ of heat supplied by the hot source (3 marks) (iii) How much heat is discharged into the cold sink in a reversible process for each 1.0 kJ supplied by the hot source? (4 marks)

4. (b) The fugacity coefficient of a certain gas at 300 K and 1.8 MPa is 0.55. Calculate the difference of its molar Gibbs energy from that of a perfect gas in the same state. (6 marks)

4. (c) Calculate the change in chemical potential of a perfect gas when its pressure is increased isothermally from 78.0 kPa to 210 kPa at 40°C. (4 marks)

QUESTION 5

5. (a) The fugacity coefficient of a certain gas at 400 K and 2.1 MPa is 0.78. Calculate the difference of its molar Gibbs energy from that of a perfect gas in the same state. (6 marks)

5. (b) Calculate the change in chemical potential of a perfect gas when its pressure is increased isothermally from 40 kPa to 215 kPa at 60°C. (4 marks)

5. (c) Express equilibrium constant K_p for the reaction,

$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$

where initially 3 mol of NO and 1 mol of O_2 were mixed together. Derive an expression for the equilibrium constant, K_p, in terms of the extent of the reaction, ξ and the total pressure, P_t (6 marks).

5. (d) The relationship between the vapour pressure and temperature of a substance in the solid, liquid and vapour (gaseous) phases can be represented by a phase diagram. Sketch the phase diagram of a CO_2 system. (4 marks)