



MACHAKOS UNIVERSITY

University Examinations 2019/2020 Academic year

SCHOOL OF PURE AND APPLIED SCIENCES

DEPARTMENT OF PHYSICAL SCIENCES

SECOND YEAR FIRST SEMESTER EXAMINATION FOR
BACHELOR OF SCIENCE IN ANALYTICAL CHEMISTRY

SCH 101: INTRODUCTION TO PHYSICAL CHEMISTRY

DATE: 9/12/2019

TIME: 8.30-10.30 AM

INSTRUCTIONS TO CANDIDATES

1. This paper contains **two sections, A and B**
2. Question number one (**Section A**) is **compulsory**
3. Choose **any other two** questions from section **B**.

Useful constants

$R=8.314\text{J/mol K}$ or $R=0.08206\text{L.atm/mol K}$

$C_p=\frac{5}{2}R$ $C_v=\frac{3}{2}R$ (monoatomic ideal gases)

$C_p=\frac{7}{2}R$ $C_v=\frac{5}{2}R$ (Diatomic ideal gases)

STP ($T=273.15\text{K}$, $1\text{atm}=101325\text{Nm}^{-2}$, $V=22.415\text{dm}^3$)

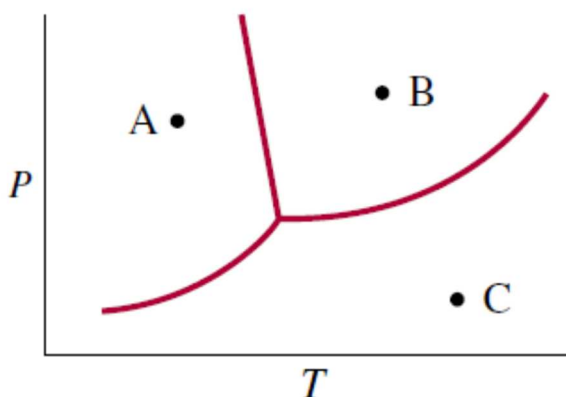
$\Delta U=nC_vdT$

$\Delta H=nC_pdT$

SECTION A (COMPULSORY)

QUESTION ONE (30 MARKS)

- a) State and give a mathematical expression for the first law of thermodynamics (3 marks)
- b) Using $C_v = \frac{dE}{dT}$ and $C_p = \frac{\delta q_p}{dT}$ show that for a perfect ideal gas $C_p = C_v + R$ (3 marks)
- c) The vapor pressure of ethyl ether is 405 mmHg at 18°C. Calculate its vapor pressure at 32°C, given its $\Delta H = 26 \text{ kJ/mol}$ (3 marks)
- d) The figure below shows a phase diagram of water. Predict what would happen as a result of the following changes:



- i) Starting at A, the temperature is raised at constant pressure (1 mark)
- ii) Starting at C, the temperature is lowered at constant pressure (1 mark)
- iii) Starting at B, the pressure is lowered at a constant temperature (1 mark)
- c) Using the generalized expression for clausius inequality, derive an alternative criterion for spontaneity at constant temperature and volume (3 marks)
- d) Differentiate between heat and work (2 marks)
- e) Classify the following as isolated, closed or open system (3 marks)
- i) Nitrogen and hydrogen reacting in a sealed tube to form ammonia
- ii) A glass vial containing Sulphuric acid is broken inside water in a beaker
- iii) Thermos flask
- f) A certain gas expands from 500 mL to 1500 mL very slowly at 25°C. If there is one mole of the gas in the chamber, calculate the work involved when the gas behaves ideally (3 marks)
- g) Critical temperature of methane and carbon dioxide are -81.9°C and 31.1°C respectively. Determine which of these gases has stronger intermolecular forces and why? (3 marks)

- h) Differentiate between enthalpy and entropy (2 marks)
- i) Explain how adding a solute affects the freezing point of a solvent (2 marks)

SECTION B (Answer any TWO questions)

QUESTION TWO (20 MARKS)

- a) If the normal boiling point of a substance is 335 k and its enthalpy of vaporization is 92.1 kJ/mol. Using Clausius Clapeyron equation $\ln \frac{P_1}{P_2} = -\frac{\Delta H_{vap}}{R} \left(\frac{1}{T_2} - \frac{1}{T_1} \right)$ calculate;
- Its boiling point when pressure is increased to 5 atm (5 marks)
 - What is the vapor pressure of the substance at 300 k? (5 marks)
- b) i) Define standard enthalpy of formation (2 marks)
- ii) Given the following standard enthalpies of formation, calculate the $\Delta H^\circ_{\text{Combustion}}$ of benzene and change in the internal energy of the system at 298 k (8 marks)

Compound	ΔH°_f (kJ/mol)
CO ₂ (g)	-393.51
C ₆ H ₆ (l)	+48.7
H ₂ O(l)	-285.83

QUESTION THREE (20 MARKS)

- a) A 4 L sample of hydrogen gas at 15 atm and 25°C is allowed to expand to a final pressure of 1 atm. Calculate q, w, ΔU and ΔH if the gas expands adiabatically and irreversibly
- given $\frac{T_2}{T_1} = \frac{\frac{C_v + P_2}{R}}{\frac{C_v + P_1}{R}}$ (10 marks)
- b) Show that change in internal energy (ΔU) is the same whether a system undergoes isochoric or isobaric process as long as the ΔT is the same. (5 marks)
- c) Using Gibbs phase rule, state and identify the number of intensive variables that must be defined when;
- Pure ice water is melted (2 marks)
 - When pure water boils (2 marks)
 - At the triple point (1 mark)

QUESTION FOUR (20 MARKS)

- a) Define the following terms
- i) Specific heat capacity (2 marks)
 - ii) Molar heat capacity. (2 marks)
- b) Describe the boundary conditions in;
- i) Open system (2 marks)
 - ii) Closed system (2 marks)
 - iii) Isolated system (2 marks)
- c) The standard molar enthalpy of formation of ammonia is -56.25kJ/mol . Using the heat capacity data given below, calculate the standard molar heat of formation of ammonia at 1000K (10 marks)
- $C_{p\text{N}_{2(g)}} \text{ J/mol. } k=26.98+(5.912\times 10^{-3}) T$
- $C_{p\text{NH}_{3(g)}} \text{ J/mol. } k=25.89+(32.58\times 10^{-3}) T$
- $C_{p\text{H}_{2(g)}} \text{ J/mol. } k=29.07-(0.837\times 10^{-3}) T$

QUESTION FIVE (20 MARKS)

- a) Sample of 1 mole of silver at 150°C is placed in contact with 1 mole of silver at 0°C forming an isolated system at constant pressure. Assuming the specific heat capacity of silver is 25.85J/mol K , Calculate
- i. The final temperature of both the silver samples (4 marks)
 - ii. Calculate ΔS for the hot silver (2 marks)
 - iii. Calculate ΔS for the cold silver (2 marks)
 - iv. The total ΔS of the system (1 mark)
 - v. Is the process spontaneous (1 mark)
- b) Two Carnot engines operate with a temperature difference of 250K between their hot and cold reservoirs. If engine A's hot reservoir is maintained at 1000K , while that of engine B is maintained at 1250K , which is the more efficient engine? (5 marks)
- c) Differentiate between state and non-state functions and give two examples in each case (5 marks)