MACHAKOS UNIVERSITY

University Examinations 2017/2018

SCHOOL OF PURE AND APPLIED SCIENCES
DEPARTMENT OF PHYSICAL SCIENCES

SECOND YEAR FIRST SEMESTER EXAMINATION FOR
BACHELOR OF SCIENCE (MATHEMATICS)
BACHELOR OF EDUCATION (SCIENCE)

SCH 201: CHEMICAL THERMODYNAMICS

DATE:5/12/2017 **TIME: 8.30-10.30 AM**

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) (30 MARKS)

1. a) Distinguish between an adiabatic and isothermal changes (2 marks)

b) Classify the following as either extensive or intensive property;

i) pressure ii) Density iii) Internal Energy iv) Heat Capacity (2 marks)

c) i) Using the definitions $C_v = \frac{dE}{dT}$ and $C_p = \frac{dH}{dT}$, show that for a perfect gas $C_p - C_v = R$ (4 marks)

ii) One mole of an ideal monatomic gas at 300 K is compressed reversibly and adiabatically to one half of the original volume. Determine the final temperature, ΔE and the work, w, for the expansion. (4 marks)

d) Given the following standard entropies for the reaction; $2C_{(s)} + 3H_{2(g)} \rightarrow C_2H_{6(g)}$

Substance	S^o (J $K^{-1}mole^{-1}$)
$C_{(s)}$	5.68
$H_{2(g)}$	130.5
$C_2H_{6(g)}$	229.5

i) Calculate the entropy change for the reaction (4 marks)

ii) From the value of the entropy of the reaction, comment on the spontaneity of the reaction (1 mark)

e) i) State the Hess's law of constant heat summation. (1 mark)

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. $C_2H_{4(g)} + 3O_{2(g)} \rightarrow 2CO_{2(g)} + 2H_2O_{(g)}$ ΔH = -1395 kJ

II. $C_2H_{6(g)} + 7/2O_{2(g)} \rightarrow 2CO_{2(g)} + 3H_2O_{(g)}$ ΔH = -1550 kJ

III. $H_{2(g)} + 1/2O_{2(g)} \rightarrow H_2O(g)$ ΔH = -243 kJ (5 marks)

iii) From the value of the enthalpy of the reaction, comment on the spontaneity of the reaction (1 mark)

f) Given the following data at 25 °C for the reaction;

$2CO_{2(g)} \rightarrow 2CO_{(g)} + O_{2(g)}$

I. $2H_2O_{(g)} \rightarrow 2H_{2(g)} + O_{2(g)}$ ΔG = -456.79 kJ

II. $CO_{2(g)} + H_{2(g)} \rightarrow H_2O_{(g)} + CO_{(g)}$ ΔG = -28.51 kJ

i) Calculate the Gibb's Free Energy change (ΔG) for the reaction (5 marks)

ii) From the value of the Gibb's Free Energy change of the reaction, comment on the spontaneity of the reaction (1 mark)

SECTION B: ANSWER ANY TWO QUESTIONS

2. a) Define the following terms;
   i) Enthalpy of a reaction
   ii) Molar heat capacity
   iii) State function
   iv) Energy
   v) System (5 marks)

   b) For the system A → B taking place at constant pressure show that:

   $\Delta H_{T2} = \Delta H_{T1} + \int \Delta C_P dT$ explaining all the terms used (5 marks)

   c) Given the following information:

   $CO_{(g)} + 1/2O_{2(g)} \rightarrow CO_{2(g)}$, $\Delta H^0_{298} = -283.3$ kJ and

Substance	C_p ($JK^{-1}mole^{-1}$)
$CO_{(g)}$	$26.6 + 0.76 \times 10^{-2}$ T
$CO_{2(g)}$	$26.4 + 4.66 \times 10^{-2}$ T
$O_{2(g)}$	$25.6 + 1.32 \times 10^{-2}$ T

   Determine
   i) ΔE for the formation of $CO_{2(g)}$ at 298 K (5 marks)
   ii) ΔH for the formation of $CO_{2(g)}$ at 398 K (5 marks)

3. a) i) Show that the variation of vapour pressure of a substance with temperature is given by

   $\frac{dP}{dT} = \frac{\Delta H_v}{T(V_B - V_A)}$. Explain what each of the terms represents. (5 marks)

   ii) Determine the enthalpy of vaporization of water given its boiling point to be 373 K, the rate of change of pressure with temperature is 2.717 cmHg/K, density of water is 0.962 g/mL, density of water vapour is 5.973×10^{-4} g/mL, density of mercury is 13.59 g /mL, and acceleration due to gravity is 981 cm/s^2. (5 marks)

   b) i) Define an exothermic process (1 mark)

   ii) The standard enthalpy of combustion of liquid ethanol is - 1365.61 kJ at 25 °C. Calculate its enthalpy of formation from the elements in their standard states at this temperature given that $\Delta H_{CO2} = -393.14$ kJ and $\Delta H_{H2O} = -285.56$ kJ. (4 marks)

   c) From second law of thermodynamics, show that $\Delta G = \Delta H + T\left(\frac{d(\Delta G)}{dT}\right)_P$ (5 marks)

4. a) i) Define a spontaneous reaction (1 mark)

ii) Explain three criteria that can be used to determine the spontaneity of a reaction (6 marks)

b) Show that for an ideal gas at constant pressure $\frac{d}{dT}\ln K_p = \frac{\Delta H^0}{RT^2}$ (4 marks)

c) Calculate the change in free energy when 11.21 dm^3 of a perfect gas at 0 °C and 760 mmHg pressure expands isothermally until its pressure is 190 mmHg. (4 marks)

d) 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)

5. a) i) Differentiate between a closed system and an open system (2 marks)

ii) State the first law of thermodynamics defining any quantities used (2 marks)

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

c) i) Explain the physical concept of entropy, its variation with temperature and hence the third law of thermodynamic (6 marks)

ii) The concept of entropy is used to derive an expression for the maximum efficiency of an engine. Such an engine must function in cycles. Briefly explain the Carnot Cycle (4 marks)

iii) Using the concept of the Carnot Cycle, derive the formula used to calculate the efficiency of an engine (2 marks)