



THE CATHOLIC UNIVERSITY OF EASTERN AFRICA

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MAIN EXAMINATION

JANUARY – APRIL 2020 TRIMESTER

FACULTY OF SCIENCE

DEPARTMENT OF NATURAL SCIENCE (CHEMISTRY)

REGULAR PROGRAMME

CHEM 201: PHYSICAL CHEMISTRY II

Date: APRIL 2020

Duration: 2 Hours

INSTRUCTIONS: Answer Question ONE and ANY OTHER TWO Questions

Useful Information :

$$R = 8.314 \text{ kJ/kmol.k}$$

Q1. a) Given that $du = dQ + dw$ and $dQ = TdS$ show that

$$ds = (C_p - R) d \ln T + R d \ln V \quad \text{(8 Marks)}$$

b) One K mole of an ideal gas at 27°C is allowed to expand isothermally and reversibly from 1013.25 Kpa to 101.325 Kpa against a pressure that is reduced gradually.

Calculate:

- i) The work done (4 Marks)
- ii) The change in internal energy (2 Marks)
- iii) The heat change (3 Marks)
- iv) The enthalpy change (2 Marks)
- v) The entropy change (3 Marks)
- vi) The Gibb's free energy change (3 Marks)

- c) Show that for a general reaction

$$mN + nN \rightleftharpoons pP + qQ$$

At equilibrium $\Delta G^0 = -RT \ln K_p$ (5 Marks)

- Q2. a) Distinguish between an adiabatic and an isothermal change. (4 Marks)

- b) State the second law of thermodynamics (2 Marks)

- c) Using the definitions:

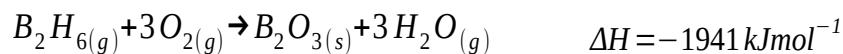
$$C_v = \frac{dU}{dT} \quad \text{and} \quad C_p = \frac{dH}{dT}$$

Show that for a perfect gas, $C_p - C_v = R$

(Hint : $\Delta H = \Delta U + RT \Delta n$ where Δn is the change in the amount of gas molecules in the reaction) (5 Marks)

- d) Calculate the work done when 50g of iron reacts with hydrochloric acid to produce hydrogen gas in
 i) A closed vessel of fixed volume (3 Marks)
 ii) An open beaker at 25°C (6 Marks)

- Q3. a) From the following data, determine ΔH_f^0 for diborane, $B_2H_6(g)$ at 298K.



(6 Marks)

- b) Show that the work done in a reversible isothermal expansion of an ideal gas from a volume V_i to final volume V_f is given by

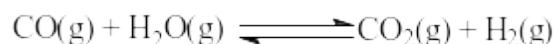
$$W_{rev} = -nRT \ln \frac{V_f}{V_i} \quad (6 \text{ Marks})$$

- c) Using the path method or otherwise show that

$$\Delta H_{r,T}^0 = \Delta H_{f,298,P}^0 - \Delta H_{f,298,R}^0 + \int_{298}^T \Delta C_p dT \quad (8 \text{ Marks})$$

- Q4. a) Explain how the signs of ΔH and ΔS may be used to predict the direction of a given reaction at different temperatures. **(6 Marks)**

- b) The water gas shift reaction can be represented as



- i) Calculate the equilibrium constants for the shift reaction at 25°C and at 300°C (Assume ΔH^0 and ΔS^0 to be independent of temperature)
Data given

Substance	ΔH_f^0 (kJ/mol)	S^0 (J/k.mol)	
$\text{CO}_{2(g)}$	-393.5	213.6	
$\text{CO}_{(g)}$	-110.5	197.6	
$\text{H}_2\text{O}_{(g)}$	-241.8	188.7	
$\text{H}_{2(g)}$	0	131.0	(12 Marks)

- ii) Comment on the effect of temperature for the shift reaction. **(2 Marks)**

Q5. a) Define the following terms as used in thermodynamics.

- i) Open system (2 Marks)
- ii) State variables (2 Marks)
- iii) State of a system (2 Marks)
- iv) State function (2 Marks)
- v) Intensive properties (2 Marks)
- vi) Reversible process (2 Marks)

b) The general criterion for a spontaneous change is

$dU + p_{\text{ext}}dV - T_{\text{surr}}dS < 0$. Describe the criterion for spontaneity under the following specific cases

- (i) Constant S and V (2 Marks)
- (ii) Constant S and p_{ext} (2 Marks)
- (iii) Constant T and P (4 Marks)

END