# 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 = 8.314kj/kmol.k**

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

$ds = (Cp – R)\, d \ln T + R\, d \ln V$ (**8 Marks**)

b) One K mole of an ideal gas at $27^0C$ 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 $\Delta G^0 = -RTInKp$ (**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:

$Cv = \frac{dU}{dT}$ and $Cp = \frac{dH}{dT}$

Show that for a perfect gas, Cp – Cv = R

(Hint : $\Delta H = \Delta U + RT\,\Delta n$ where $\Delta n$ 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 $25^0$C (**6 Marks**)

Q3. a) From the following data, determine $\Delta H_f^0$ for diborane, $B_2H_{6(g)}$ at 298K.

$B_2H_{6(g)} + 3O_{2(g)} \rightarrow B_2O_{3(s)} + 3H_2O_{(g)}$ $\Delta H = -1941\,kJmol^{-1}$

$2B_{(s)} + \frac{3}{2}O_{2(g)} \rightarrow B_2O_{3(s)}$ $\Delta H = -2368\,kJmol^{-1}$

$H_{2(g)} + \frac{1}{2}O_{2(g)} \rightarrow H_2O_{(g)}$ $\Delta H = -241.8\,kJmol^{-1}$

(**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

$$W_{rev} = -nRTIn\frac{V_f}{V_i}$$

(**6 Marks**)

c) Using the path method or otherwise show that

$$\Delta H^0_{r,T} = \Delta H^0_{f,298,P} - \Delta H^0_{f,298,R} + \int_{298}^{T} \Delta CpdT$$

(**8 Marks**)

Q4. a) Explain how the signs of $\Delta H$ and $\Delta S$ 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

$$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$$

i) Calculate the equilibrium constants for the shift reaction at 25$^0$C and at 300$^0$C (Assume $\Delta H^0$ and $\Delta S^0$ to be independent of temperature) Data given

| Substance | $\Delta H^0_f(kJ/mol)$ | $S^0(J/k.mol)$ |
|---|---|---|
| $CO_{2(g)}$ | -393.5 | 213.6 |
| $CO_{(g)}$ | -110.5 | 197.6 |
| $H_2O_{(g)}$ | -241.8 | 188.7 |
| $H_{2(g)}$ | 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

$dU + p_{ext}dV - T_{surr}dS < 0$. 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***