GD

DEPARTMENT OF CHEMISTRY
INDIAN INSTITUTE OF TECHNOLOGY, KHARAGPUR

Session: Autumn 2016-17 **Exam:** Midterm Exam **No. of Students:** 670

Subject No.: CY11001 **Subject Name:** Chemistry **Time:** 2hrs. **Full Marks:** 40

PLEASE READ THE INSTRUCTIONS GIVEN BELOW BEFORE ANSWERING THE PAPER

(This question paper contains 4 pages, including this page)

---

1. **This Question Paper has TWO parts (i.e., PART-A and PART-B). Make sure that each of you have received both, PART-A and PART-B of the Question Paper.**
2. **Answer ALL questions.**
3. **ALL QUESTIONS OF PART- A and PART-B SHOULD BE ANSWERED SERIALLY.**
4. **ANSWERS OF PART-A MUST BE WRITTEN TOGETHER.**
5. **LEAVE A PAGE BLANK IN THE ANSWER SCRIPT IN BETWEEN THE ANSWERS OF PART-A and THE ANSWERS OF PART-B.**
6. **ANSWER SCRIPTS SUBMITTED WITHOUT FOLLOWING THE INSTRUCTION No.3, No. 4 and No. 5 MAY NOT BE EVALUATED**

---

1. **All symbols used in the question paper have their usual meaning**
2. **Mention the sign convention used.**
3. **Clearly state whether you are using reduction or, oxidation potential in electrochemistry.**
4. **No credit will be given without workout being shown wherever necessary.**

[Supplied Data: $k = 1.38 \times 10^{-23}$ J K^{-1}; $R = 8.314$ J K^{-1} mol^{-1}; 1 bar $= 1 \times 10^5$ Pa; 1 Faraday $= 96{,}500$ C mol^{-1}; 1 atm $= 760$ Torr]

PART – A

Q1. Write the correct option (a/b/c/d) in the Answer Script ....(1 × 10 = 10)

(i) Chemical potential μ_i of a component i in a homogeneous mixture can be defined as:

(a) $\mu_i = \left(\frac{\partial G}{\partial n}\right)_{T,P,n_j}$; **(b)** $\mu_i = \left(\frac{\partial H}{\partial n}\right)_{T,P,n_j}$; **(c)** $\mu_i = \left(\frac{\partial A}{\partial n}\right)_{T,P,n_j}$; **(d)** $\mu_i = \left(\frac{\partial U}{\partial n}\right)_{T,P,n_j}$

(ii) What will be the activity for 'm' molal solution of an AB_2 electrolyte?

(a) $(\gamma_\pm\ m^3)$; **(b)** $(\gamma_\pm\ m)^3$; **(c)** $4(\gamma_\pm\ m)^3$; **(d)** $(\gamma_\pm\ m_\pm^3)$

(iii) Which of the following statements is always true for a liquid mixture of two components A and B in equilibrium with a mixture of their vapours?

(a) $\mu_A(l) = \mu_B(l)$ and $\mu_A(g) = \mu_B(g)$;
(b) $\mu_A(l) = \mu_A(g) = \mu_B(l) = \mu_B(g)$
(c) $\mu_A(l) = \mu_A(g)$ and $\mu_B(l) = \mu_B(g)$;
(d) $\mu_A(l) \neq \mu_A(g) \neq \mu_B(l) \neq \mu_B(g)$

(iv) Which of the following is a reversible process?

(a) Melting of ice at 0°C and 1 atm.;
(b) Melting of ice at 25°C and 1 atm.;
(c) Evaporation of water at 25°C and 1 atm.
(d) Freezing of water at –10°C and 1 atm.

(v) At inversion temperature of a gas, the value of Joule-Thomson coefficient (μ_{JT}) will be:

(a) $\mu_{JT} = 0$; **(b)** $\mu_{JT} > 0$; **(c)** $\mu_{JT} < 0$; **(d)** $\mu_{JT} \approx \infty$

(vi) What will happen to the chemical potential of O_2 when 1.0 mole of O_2 gas is added to a container that already contained 1.0 mole of O_2 gas?

(a) μ (O_2) will increase; **(b)** μ (O_2) will decrease; **(c)** μ (O_2) will remain unchanged

(vii) Which one is the correct condition for spontaneous reaction in an electrochemical cell

(a) $\Delta G_{T,P} < 0$, $E_{cell} > 0$;
(b) $\Delta G_{T,P} > 0$, $E_{cell} < 0$
(c) $\Delta G_{T,V} < 0$, $E_{cell} < 0$;
(d) $\Delta G_{T,P} = 0$, $E_{cell} = 0$

(viii) What fraction of the total quantity of heat (q_h) taken from the source that is at temperature T_h can be converted into work in a reversible cyclic process? (ΔT is the temperature difference between the source and the sink)

(a) $\Delta T \times T_h$; **(b)** $\Delta T / T_h$; **(c)** zero ; **(d)** $T_h / \Delta T$.

(ix) Which one of the following fundamental equations is/ are applicable for any open system?

(a) $dG = VdP - SdT$;
(b) $dG = VdP - SdT + \Sigma\mu_i dn_i$;
(c) $dG = PdV + TdS + \Sigma\mu_i dn_i$;
(d) $dG = PdV - SdT + \Sigma\mu_i dn_i$

(x) $\Delta S > 0$ is a condition for spontaneity for which of the following systems:

(a) Closed system; **(b)** Open system; **(c)** Isolated system; **(d)** All systems

PART – B

ANSWERS OF Part B should begin on new Page in the Answer Script

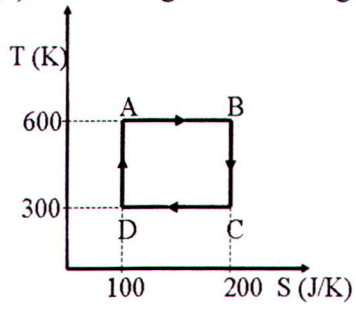
Q2. (a) Show that: $$U = G - P\left(\frac{\partial G}{\partial P}\right)_T - T\left(\frac{\partial G}{\partial T}\right)_P$$

(b) Prove the following relation: $$\left(\frac{\partial H}{\partial V}\right)_T = -V^2\left(\frac{\partial P}{\partial T}\right)_V\left(\frac{\partial (T/V)}{\partial V}\right)_P$$

(c) Two moles of an ideal gas at **45** °C are compressed adiabatically and reversibly from **75.0** litres to **20.0** litres. Calculate **q**, **w**, **ΔU**, and **ΔH** for the process. [Given: $\mathbf{C_V = 2.5\ R}$ for the gas].

....[2 + 3 + 5 =10]

Q3. (a) From the given T-S diagram (ABCD) of a reversible Carnot engine shown below, find the



(i) Net work delivered by the engine in each cycle
(ii) Heat taken from the source in each cycle
(iii) ΔS_{sink} in each cycle

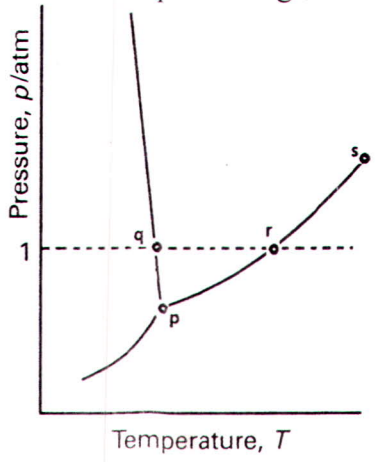
....[1 + 1 + 2 = 4]

(b) Calculate the following for a liquid whose vapour pressure (in ***Torr***) between 15 °C and 35 °C fits the expression: $\log(p_l) = 8.750 - \frac{1625}{T}$.

(i) The enthalpy of vaporization (in **kJ mol^{-1}**) of the liquid; **(ii)** The normal boiling point (**in K**)

....[2+ 2 = 4]

(c) Label the points (p, q, r, s) shown in the phase diagram of a one component system



....[$\frac{1}{2} \times 4 = 2$]

P.T.O

Q4. (a) For the following reaction at **25 °C** and **1 atm**, the Gibbs energy change is **+ 2.90 kJ mol^{-1}**.

C (*s*, **graphite**) → **C** (*s*, **diamond**)

Densities of graphite and diamond at **25 °C** are **2.25** and **3.51 g cm^{-3}** respectively.

(i) Will increase in pressure favour the conversion of graphite to diamond? Justify your answer.

(ii) If your answer in part (i) is yes, then calculate the maximum pressure necessary to make this reaction spontaneous at **25 °C**. ....[2 + 2 = 4]

(b) For the galvanic cell: **Pt | H_2 (*g*, P_{H2}) | HCl (*aq*, a_{H+}) | O_2 (*g*, P_{O2}) | Pt**

(i) Write the half-cell as well as complete cell reactions.

(ii) If the standard state Gibbs energy of formation ($\Delta_f G^o$) of **$H_2O(l)$** is **− 237.13 kJ mol^{-1}**. Calculate the EMF of the cell in the standard state.

(iii) Calculate the equilibrium constant of the overall cell reaction at **298** K. ....[2 + 2 + 2= 6]

****

S Bandyopadhyay Dey Mukherjee

Signature of the Paper Setters