INDIAN INSTITUTE OF TECHNOLOGY, KHARAGPUR
Mid-Spring Semester Examination 2022-23
Department of Chemistry
Subject No. **CY11003** Subject Name: **Chemistry**
Date: 12.04.2023 Session: AN, Duration: 2 Hrs. Full Marks: 30

Write answers to the parts of each question together at one place.
Symbols carry their usual meaning. This question paper contains 6 questions in 3 pages.
No question will be entertained during the examination.

Gas constant (R) = 8.314 J K^{-1} mol^{-1} = 0.082 L atm K^{-1} mol^{-1}

Question 1. [1 x 5 = 5]

Choose the correct answer from the given options.

(i) Identify the correct statement for 1 mole of an ideal gas

a. $\left(\frac{\partial U}{\partial T}\right)_P - \left(\frac{\partial H}{\partial T}\right)_V = R$

b. $\left(\frac{\partial U}{\partial T}\right)_V - \left(\frac{\partial H}{\partial T}\right)_P = R$

c. $\left(\frac{\partial U}{\partial T}\right)_V - \left(\frac{\partial H}{\partial T}\right)_P = -R$

d. $\left(\frac{\partial U}{\partial T}\right)_P - \left(\frac{\partial H}{\partial T}\right)_V = -R$

(ii) At a constant temperature and pressure, the maximum non-expansion work is given by the change in

a. G b. A c. U d. H

(iii) The entropy change (in J K^{-1}) when 224 g each of O_2, N_2 and H_2 gases are mixed at 1 atm and 273 K is

[Given: Mol. wt. of O_2, N_2, and H_2, are 32, 28, and 2, respectively. Consider the gases as ideal gas.]

a. 469.6 b. 339.6 c. 282.20 d. 100.44

(iv) In the phase diagram of water, the slope of the phase coexistence line between ice and water (at the normal melting point of ice) is _____ and the slope of the phase coexistence line between water and water vapor (at the normal boiling point of water) is _____.

a. Positive, Negative b. Negative, Positive
c. Positive, Positive d. Negative, Negative

(v) For the reaction $2A + B \leftrightarrows 2C$, $\Delta G^0 = 2$ kJ mol^{-1} at 500 K. The equilibrium constant of the reaction $A + \frac{B}{2} \leftrightarrows C$ at the same temperature is

a. 1.572 b. 0.786 c. 0.393 d. 3.144

Question 2.

(a) Prove the following relation:

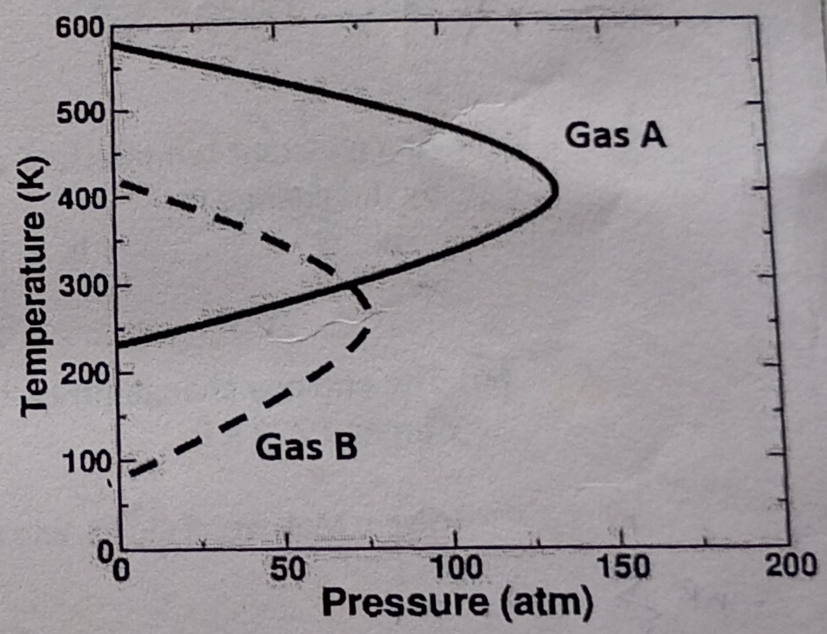
$$\left(\frac{\partial H}{\partial V}\right)_T = -V^2 \left(\frac{\partial P}{\partial T}\right)_V \left(\frac{\partial (T/V)}{\partial V}\right)_P$$ [2]

(b) 16 g of an ideal gas kept at 273 K and 10 bar pressure expands adiabatically and reversibly to 1 bar. Calculate the final temperature of the gas and the work done during the process. [Given: Mol. wt. of the gas = 32 and $\gamma = 1.4$]. [3]

Question 3.

(a) Represent a Carnot cycle in (i) a *P-V* diagram and (ii) in an *H-T* diagram. Label all steps of the Carnot cycle in both the diagrams. **[1.5 + 1.5]**

(b) The results from the Joule-Thomson (JT) expansion experiments involving two gases A and B are shown in the adjacent figure. Based on this figure, mention if gas A and gas B will show heating or cooling effect when subjected to JT throttling experiment at the four given experimental conditions. Give your answer in the following tabular format.



	T (in K)	*P* (in atm)	Gas A	Gas B
(i)	300	50		
(ii)	200	50		
(iii)	400	100		
(iv)	550	100		

Question 4.

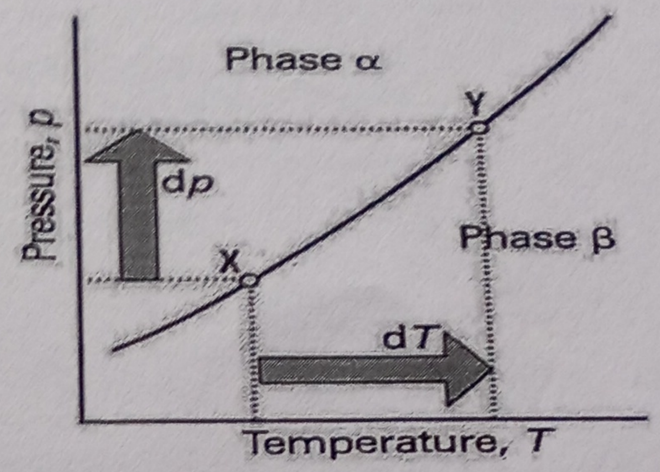
(a) Using the appropriate Maxwell relation, show that $\left(\frac{\partial S}{\partial V}\right)_T = 3.66 \times 10^{-3}$ atm K^{-1} for one mole of ideal gas at STP. [2]

(b) An ideal gas initially occupies a volume of 20.5 L at 300 K and 1 atm. The sample is compressed isothermally to a final volume that results in a reduction of its entropy by 10 J K^{-1}. What is the final volume of the gas? [3]

Question 5.

Consider the temperature (T)-pressure (p) phase diagram of a pure substance shown in the figure on right. As the system moves from X to Y along the solid line XY, the infinitesimal change in chemical potential of the i-th phase $(i = \alpha, \beta)$ is given by

$$d\mu_i = J_i dT + K_i dp.$$



(a) Starting from the definition of μ_i, find J_i and K_i. **[2]**

(b) Evaluate $\frac{dp}{dT}$ in terms of changes in entropy (ΔS_{trans}) and volume (ΔV_{trans}) for the transition $\beta \rightarrow \alpha$. **[3]**

Question 6.

(a) Show that the vapour pressure of a pure liquid varies with the temperature according to the following equation: $P = A \exp\left(-\frac{\Delta H_v^0}{RT}\right)$, where A is a constant, P is the pressure of the vapour at equilibrium, ΔH_v^0 is the molar heat of vaporisation (independent of temperature). **[2]**

(b)

(i) For the reaction $PCl_5\,(g) \leftrightarrows PCl_3\,(g) + Cl_2\,(g)$, Calculate the equilibrium constant using the following data at 25^0 C.

Substance	ΔH^0 (kJ mol^{-1})	ΔS^0 (J. K^{-1}. mol^{-1})
$PCl_5\,(g)$	-287	312
$PCl_3\,(g)$	-375	365
$Cl_2\,(g)$	0	223

(ii) Using the above result, calculate the equilibrium constant of

$$2\,PCl_5\,(g) \leftrightarrows 2\,PCl_3\,(g) + 2\,Cl_2\,(g)$$ **[2+1]**

End of Question Paper