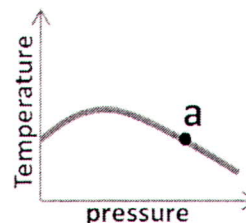


Symbols carry their usual meaning.

Gas Constant $R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1} = 0.08206 \text{ dm}^3 \text{ atm K}^{-1} \text{ mol}^{-1}$

1. Answer the following [1 mark X 6 = 6]

- i. State whether each of the following statements regarding chemical potential (μ) is true or false: (a) μ is a state function. (b) μ is an intensive property. (c) SI unit of μ is J/mol (d) The chemical potential of benzene in a solution of benzene and toluene at 300 K and 1 bar must be equal to G_m of pure benzene at 300 K and 1 bar.
- ii. An ideal-gas reaction mixture is in a constant-temperature bath. State whether each of the following will change (or not change) the value of K_p° . (a) Addition of a reactant. (b) Addition of an inert gas. (c) Change in pressure for a reaction with $\Delta n \neq 0$. (d) Change in temperature of the bath.
- iii. The reaction $2\text{O}_3 \rightarrow 3\text{O}_2$, in a closed system, initially contains 5.80 mol O_2 and 6.20 mol O_3 . At some later time, 5.20 mol of O_3 is present. What is the extent of the reaction at this time?
- iv. The adjacent figure shows a qualitative sketch of an isenthalpic curve for a Joule-Thompson expansion experiment for a real gas. (a) At point a, what happens to the temperature upon Joule-Thompson expansion of the real gas – decreases/increases/remains constant. (b) What is the value of μ_{JT} at point a: > 0 , $= 0$, or < 0 .
- v. For a real gas, state whether each of the following statements is true or false:
a) $\Delta U = C_V dT$ (b) $\Delta U_V = C_V dT$ (c) $\Delta H = C_P dT$ (d) $\Delta H_P = C_P dT$
- vi. The enthalpy of vaporization of ethanol is 43.5 kJ/mol at its normal boiling point of 352 K. Calculate (a) the entropy of vaporization of ethanol at this temperature and pressure, and (b) the entropy change of its surroundings at 352 K and 1 atm.



2. Answer the following [2 marks X 3 = 6]

- i. What is the value of the compression factor (Z) for a van der Waals gas with $a = 0$ and $V_m = 10b$? a and b are van der Waals constants and V_m is the molar volume of the van der Waals gas.
- ii. Consider a two-phase system in a constant-temperature bath consists of liquid water in equilibrium with water vapor. Suppose we reversibly increase the system's volume, holding T and P constant, causing some of the liquid to vaporize. State whether each of ΔH , ΔS , ΔS_{univ} , and ΔG is positive, zero, or negative.
- iii. For the reaction $2\text{H}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{H}_2\text{O}(\text{l})$, $\Delta H_{298}^\circ = -572 \text{ kJ mol}^{-1}$. If $\Delta_f S_{298}^\circ$ of $\text{H}_2\text{O}(\text{l})$ is $-163 \text{ J mol}^{-1} \text{ K}^{-1}$. Find $\Delta_f G_{298}^\circ$ of $\text{H}_2\text{O}(\text{l})$.

Questions 3 to 8 carry 3 marks each.

3. One mole of an ideal monoatomic gas at 1 bar and 300 K is expanded adiabatically against a constant pressure of 0.5 bar until the final pressure reaches a value of 0.5 bar. What are the values of q , w , ΔU , and ΔH ?
4. For a van der Waals gas, $\pi_T = a/V_m^2$. Calculate ΔU_m for the isothermal expansion of nitrogen gas from an initial volume of 1.00 dm^3 to 24.8 dm^3 at 298 K. ($a = 1.337 \text{ dm}^6 \text{ atm mol}^{-2}$)
5. Derive Maxwell relation starting from the Fundamental equation of thermodynamics for dH and use it to show that $(\partial V / \partial S)_p = \alpha T V / C_p$. C_p = the constant pressure heat capacity and α = expansion coefficient.
6. The constant pressure molar heat capacity of O_2 gas from 300 K to 1200 K is given by $C_p(T) / \text{J K}^{-1} \text{ mol}^{-1} = 25.72 + (12.98 \times 10^{-3} \text{ K}^{-1}) T - (38.62 \times 10^{-7} \text{ K}^{-2}) T^2$, where T is in Kelvin. Calculate the value of ΔS when 1 mol of O_2 gas is heated at constant pressure from 300 K to 1200 K.
7. The entropy of vaporization of water is $109.0 \text{ J K}^{-1} \text{ mol}^{-1}$ at 1 atm. The corresponding densities of liquid water and water vapor are 0.96 kg dm^{-3} and $6.0 \times 10^{-4} \text{ kg dm}^{-3}$, respectively. Calculate the pressure required for increasing the boiling temperature of water by 1.0°C . DO NOT neglect the volume of liquid water.
8. For the reaction $\text{N}_2\text{O}_4(g) \rightleftharpoons 2\text{NO}_2(g)$, measurements of the composition of equilibrium mixtures gave K_p° is 0.144 at 25.0°C and K_p° is 0.321 at 35.0°C . Find ΔS° and ΔG° at 25°C for this reaction. Assume ΔH° is constant in the temperature range between 25.0°C and 35.0°C .