



INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR

Mid Autumn Semester Examination

Department of Chemistry

Sub. No. CY11001 Subject Name: Chemistry

Date 15.09.2015 FN, Duration: 2 Hrs. Full Marks: 30

No. of Students 645, UG 1st Yr.

Write answers to the parts of each question together at one place.

Symbols carry their usual meaning.

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

1. Answer the following [1 X 3 = 3]

- (a) Which of the following cyclic integrals must have value equal to zero for a closed system with P - V work only?

$$\oint (-PdV), \oint (PdV + VdP), \oint (dq_P), \oint (dq_{rev})$$

- (b) Write whether ΔS and ΔS_{total} are positive, zero, or negative for - (i) Adiabatic expansion of a real gas into vacuum. (ii) Reversible cooling of an ideal gas at constant V .
- (c) For each of the following pairs of systems, write which one has the greater S , (A or B).
(i) A) 1 mol of a perfect gas at 0 °C and 1 atm or B) 1 mol of the same perfect gas at 0 °C and 5 atm. (ii) A) 5 g of Fe at 20 °C and 1 atm or B) 10 g of Fe at 20 °C and 1 atm.

2. True or False? [0.5 X 6 = 3]

- (a) For an isolated system, equilibrium has been reached when S is maximum.
(b) The Gibbs energy of 12 g of ice at 0 °C and 1 atm is equal to the Gibbs energy of 12 g of liquid water at 0 °C and 1 atm.
(c) At very high pressure, the chemical potential of a real gas is higher than that of an ideal gas.
(d) C_v is independent of T for every ideal gas.
(e) C_p is a state function.
(f) For a constant-volume process in a closed system, $\Delta H = \Delta U$.

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

- (a) Derive an expression for the isothermal reversible work for expansion of a van der Waals gas.
(b) Find ΔG when 0.2 mol of He(g) is mixed at constant T and P with 0.3 mol of O₂(g) at 300 K. Assume the gases are ideal.
(c) Argon has normal melting and normal boiling points of 83.8 K and 87.3 K respectively. Its triple point is 83.8 K and 0.7 atm. Its critical T and P are 151 K and 48 atm. Draw a qualitative sketch of the phase diagram and state whether Argon is a solid, liquid, or gas at (i) 1.2 atm, 86 K and (ii) 0.9 atm, 90 K.

Questions 4 to 9 carry 3 marks each.

4. Calculate the boiling temperature of water at 2 atm pressure. Assume that the enthalpy of vaporization of water (40.7 kJ/mol) remains constant. Consider water vapour as an ideal gas.
 5. For the equilibrium, $\text{N}_2\text{O}_4 (\text{g}) \rightleftharpoons 2\text{NO}_2 (\text{g})$, the degree of dissociation (α) is 0.201 at 298.15 K and 1 bar total pressure. Calculate the equilibrium constant K_p° . Assume the ideal behaviour of the gases. What is the value of K_p° at 298.15 K and 10 bar total pressure?
 6. Calculate the pressure exerted by N_2 at 300 K for molar volumes of (a) 250 L mol^{-1} and (b) 0.100 L mol^{-1} using the (a) ideal gas and (b) the van der Waals equations of state. The values of parameters a and b for N_2 are $1.370 \text{ bar dm}^6 \text{ mol}^{-2}$ and $0.387 \text{ dm}^3 \text{ mol}^{-1}$, respectively. (c) Is the attractive or repulsive interaction greater for N_2 at 300 K and $V_m = 0.100 \text{ L mol}^{-1}$?
 7. Given that $\mu_{JT} = 0.25 \text{ K atm}^{-1}$ for nitrogen, calculate the value of its isothermal Joule–Thomson coefficient. Calculate the energy that must be supplied as heat to maintain constant temperature when 15.0 mol N_2 flows through a throttle in an isothermal Joule–Thomson experiment and the pressure drop is 75 atm. $C_{p,m} = 29.125 \text{ JK}^{-1} \text{ mol}^{-1}$.
 8. Calculate the change in the entropies of the system and the surroundings when a sample of nitrogen gas of mass 14 g at 298 K and 1.00 bar doubles its volume in (i) an isothermal reversible expansion, (ii) an irreversible expansion against zero pressure with no change in temperature, and (iii) an adiabatic reversible expansion. Assume nitrogen as an ideal gas.
 9. 0.10 mol of an ideal gas at initial temperature of 300 K with initial volume of 2.00 L was expanded adiabatically into vacuum to a final volume of 6.00 L. Calculate ΔG , ΔA .
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