

BIRLA INSTITUTE OF TECHNOLOGY, MESRA, RANCHI
(END SEMESTER EXAMINATION)

CLASS: B.TECH.
BRANCH: CHEMICAL/CHEMICAL (P&P)

SEMESTER : III
SESSION : MO/19

SUBJECT: CL201 THERMODYNAMICS

TIME: 3.00Hrs.

FULL MARKS: 50

INSTRUCTIONS:

1. The question paper contains 5 questions each of 10 marks and total 50 marks.
 2. Attempt all questions.
 3. The missing data, if any, may be assumed suitably.
 4. Before attempting the question paper, be sure that you have got the correct question paper.
 5. Tables/Data hand book/Graph paper etc. to be supplied to the candidates in the examination hall.
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Q.1(a) An ideal gas is adiabatically and irreversibly compressed from 3 bar and 300 K to 6 bar in a closed system. The work required for the irreversible compression is 1.5 times the work that is required for reversible compression from the same initial temperature and pressure to the same final pressure. Find the temperature (In K) of the gas at the final state in the irreversible compression case. Given: $C_v = 30 \text{ J/mol/K}$; $R = 8.314 \text{ J/mol/K}$; $\gamma = 1.277$. [5]

Q.1(b) An ideal gas is initially at a pressure of 0.1 MPa and a total volume of 2 m^3 . It is first compressed to 1 MPa by a reversible adiabatic process and then cooled at constant pressure to a final volume of 0.2 m^3 . Find the total work done (In KJ) on the gas for the entire process. Given: $C_p = 2.5R$; $R = 8.314 \text{ J/mol/K}$. [5]

Q.2(a) One mole of a pure species exists in liquid-vapor equilibrium in a rigid container of volume $V = 1\text{L}$, a temperature of 300 K, and a pressure of 1 bar. The enthalpy of vaporization and the second virial coefficient in the pressure expansion are: [5]

$$\Delta h_{vap} = 16628 \text{ [J/mol]} \text{ and } B' = -10^{-7} \text{ [m}^3\text{/J]}$$

Assume the enthalpy of vaporization does not change with temperature. You may neglect the molar volume of the liquid relative to that of the gas. This container is heated until the pressure reaches 21 bar and is allowed to reach equilibrium. Both vapor and liquid phases are still present. Find the final temperature of this system.

Q.2(b) A rigid vessel of 0.06 m^3 volume contains an ideal gas, $C_v = (5/2) R$, at 500 K and 1 bar. (a) If heat in the amount of 15,000 J is transferred to the gas, determine its entropy change. (b) If the vessel is fitted with a stirrer that is rotated by a shaft so that work in the amount of 15,000 J is done on the gas, what is the entropy change of the gas if the process is adiabatic? [5]

Q.3(a) A heat engine operating in outer space may be assumed equivalent to a Carnot engine operating between reservoirs at temperature T_H and T_C . The only way heat can be discarded from the engine is by radiation, the rate of which is given by: [3]

$$\dot{Q}_C = kAT_C^4$$

Where k is a constant and A is the area of the radiator. Prove that, for fixed power output and for fixed temperature T_H , the radiator area A is minimum when the temperature ratio T_C/T_H is 0.75.

Q.3(b) One mole of *n*-butane in a piston-cylinder assembly undergoes an irreversible isothermal expansion against a constant external pressure until the forces balance. The initial pressure is 10 bar, and the initial molar volume is $3 \times 10^{-3} \text{ m}^3/\text{mol}$, and the final volume is $0.05 \text{ m}^3/\text{mol}$. Take the temperature of the surroundings to be 298 K. Work done by the system in the expansion process is 3107 J. Use the van der Waals equation of state and answer the following questions: (a) What is the change in internal energy during this process? (b) How much heat is transferred in this process? Given, $a = 1.39 \text{ J.m}^3/\text{mol}^2$; $b = 1.17 \times 10^{-4} \text{ m}^3/\text{mol}$. [7]

Q.4(a) A single P - x_1 - y_1 data point is available for a binary system at 25°C . [5]
Data: At 25°C , $P_1(\text{sat}) = 183.4 \text{ kPa}$; $P_2(\text{sat}) = 96.7 \text{ kPa}$.
For $x_1 = 0.253$, $y_1 = 0.456$, $P = 139.1 \text{ kPa}$.
Estimate from the data, the total pressure and vapor-phase composition at 25°C for an equimolar liquid mixture. Assume vapor-phase as ideal gas and liquid phase activity co-efficients are given by:

$$\ln \gamma_1 = x_2^2 (A_{12} + 2(A_{21} - A_{12})x_1)$$

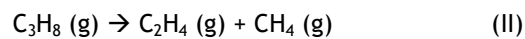
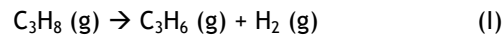
$$\ln \gamma_2 = x_1^2 (A_{21} + 2(A_{12} - A_{21})x_2)$$

- Q.4(b) At 298.15 K and atmospheric pressure the volume change of mixing of binary liquid mixtures of species 1 and 2 is given by the equation [5]

$$\Delta V = x_1 x_2 (45x_1 + 25x_2)$$

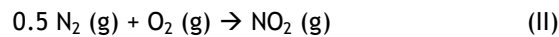
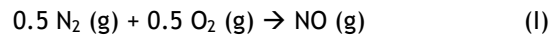
Where ΔV is in cm^3/mol . At these conditions, $V_1 = 110 \text{ cm}^3/\text{mol}$ and $V_2 = 90 \text{ cm}^3/\text{mol}$. Determine the partial molar volumes of species 1 and 2 in a mixture containing 40 mole % of species 1 at the given conditions.

- Q.5(a) Cracking propane is a route to light olefin production. Suppose that two cracking reactions occur in a steady-flow reactor: [7]



Initially only one mole of propane is present. The equilibrium constants at 750 K are found to be: $K_I = 0.016$ and $K_{II} = 21.328$. Calculate the product composition if both reactions go to equilibrium at 1.2 bar and 750 K.

- Q.5(b) Consider the reactions, [3]



If these reactions come to equilibrium after combustion in an internal-combustion engine at 2000 K and 200 bar, estimate the mole fractions of NO and NO_2 present if mole fractions of nitrogen and oxygen in the combustion products are 0.70 and 0.05. The equilibrium constants at 2000 K are found to be: $K_I = 0.02004$ and $K_{II} = 6.9373 \times 10^{-5}$.

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