

III B.Tech. I Semester Regular Examinations, November -2005
CHEMICAL ENGINEERING THERMODYNAMICS-II
 (Chemical Engineering)

Time: 3 hours

Max Marks: 80

Answer any FIVE Questions
 All Questions carry equal marks

★★★★★

1. If the heat capacity of a substance is correctly represented by an equation of the form, $C_P = A + BT + CT^2$
 Show that the error resulting when $\langle C_p \rangle_H$ is assumed equal to C_P evaluated at the arithmetic mean of the initial and final temperature is $C(T_2 - T_1)^2 / 12$. [16]
2. (a) Explain the Standard Heat of Combustion with suitable example.
 (b) Calculate the standard heat at 25°C for the following reaction,
 $4HCl_{(g)} + O_2(g) \rightarrow 2H_2O(g) + 2Cl_{(g)}$
 Standard heat of formation of $HCl_{(g)} = -92,307$ J
 Standard heat of formation of $H_2O_{(g)} = -241,818$ J
 (c) Given that the latent heat of vaporization of water at 100°C is 2,257 J / gm.
 Estimate the latent heat at 300°C. The critical temperature is 647.1 °K Do not use steam table. [6+5+5]
3. (a) State the equilibrium criteria usually applied by chemical engineers in the solution of phase-equilibrium problems.
 (b) Explain the term partial residual Gibbs Energy. With its help define fugacity coefficient of a species in solution and show that fugacity of a species 'i' in an ideal-gas mixture is equal to its partial pressure. [8+8]
4. (a) Write Gibbs/Duhem equation and explain its importance in VLE studies.
 (b) For a binary system of 1-propanol
 i. and Water
 ii. calculate the activity coefficients for components using Wilson's activity coefficient correlations. Given $V_1 = 75.14 \text{ cm}^3/\text{mol}$, $V_2 = 18.07 \text{ cm}^3/\text{mol}$, $a_{12} = 775.48$ and $a_{21} = 1351.90 \text{ Cal/mol}$. [8+8]
5. The excess Gibbs energy for a binary system is given by :
 $G^E / RT = 0.68 X_1 X_2$
 The pure component vapor pressures are given by :
 $\ln P_1^{sat} / kPa = 14.39155 - \frac{2795.817}{t/^\circ C + 230.002}$
 $\ln P_2^{sat} / kPa = 16.59381 - \frac{3644.297}{t/^\circ C + 239.765}$
 Obtain the t-x,y diagram for this system at 70 kPa. [16]
6. Estimate V, ϕ, H^R, S^R for Ethylene Oxide(1)-Ethylene(2) with mole fractions $y_1 = 0.68$ and $y_2 = 0.32$ at $t = 25^\circ \text{C}$ and $P = 420 \text{ kPa}$. [16]

Component	t_c , $^{\circ}K$	P_c , bar	ω
Ethylene Oxide	469.0	71.9	0.200
Ethylene	282.4	50.4	0.085

7. Show three types of constant pressure liquid-liquid solubility diagram with proper labeling. What do you mean by upper and lower consolute temperature. [16]
8. Consider the reaction $C_4H_4(g) \rightarrow C_4H_6(g) + H_2(g)$. the standard free energy change is given by:
 $\Delta G_T^0 = 24,760 - 5.01T \ln T + 3.09T$
where ΔG_T^0 is in J / mol butene and T is in K.
- (a) Over what range of temperature is the reaction promising from a thermodynamic viewpoint?
- (b) For reaction of pure butene at 800 K, calculate the equilibrium conversion for operation at 1 and 5 atm total pressure, assuming ideal gases.
- (c) Repeat part (b) at 1 atm for a feed of 50 mol % butene and 50 mol % inert gas and compare the results. [6+5+5]

III B.Tech. I Semester Regular Examinations, November -2005
CHEMICAL ENGINEERING THERMODYNAMICS-II
 (Chemical Engineering)

Time: 3 hours

Max Marks: 80

Answer any FIVE Questions
 All Questions carry equal marks

★★★★★

1. If the heat capacity of a substance is correctly represented by an equation of the form, $C_P = A + BT + CT^2$
 Show that the error resulting when $\langle C_p \rangle_H$ is assumed equal to C_P evaluated at the arithmetic mean of the initial and final temperature is $C(T_2 - T_1)^2 / 12$. [16]
2. (a) What is adiabatic flame temperature? Explain.
 (b) Carbon monoxide reacts with water vapour to form CO_2 and hydrogen
 $CO(g) + H_2(g) \rightarrow CO_2(g) + H_2(g)$
 $\Delta H_{298}^0 = -41.190 \text{ kJ}$
 The reactants are at 298K and is stoichiometric proportions. Seventy five percent of CO is converted in the reaction The product leaves the reaction chamber at 800K. The mean heat capacity (J/mol.K) are 30.35 for CO, 45.64 for CO_2 , 36.00 for water vapour, and 29.30 for H_2 . Determine the quantity of heat to be added or removed is the reaction chamber per 1000 kg of hydrogen produced. [6+10]
3. Derive the relation for the calculation of Gibbs free energy of ideal gas mixture. [16]
4. (a) Distinguish between Empirical activity correlation coefficients and molecular thermodynamics based activity coefficients correlations.
 (b) Given $V_1 = 40.73 \text{ cm}^3/\text{mol}$, $V_2 = 18.07 \text{ cm}^3/\text{mol}$, $a_{12} = 107.38$ and $a_{21} = 469.55 \text{ Cal/mol}$ for a binary system Methanol
 i. – Water
 ii. calculate γ_1, γ_2 by Wilson's activity correlation coefficients. [8+8]
5. (a) Characterize ideal solutions.
 (b) Two substances A and B are known to form ideal solution. An equimolar vapor mixture of A and B initially at 100 C and 100 Kpa is isothermally compressed till the mixture condenses. Determine the pressures at which condensation begins and terminates and also the compositions of the vapor and liquid phases. The saturation pressures of A and B at 100 C are 120 Kpa and 150 Kpa, respectively. [6+10]
6. Estimate z , H^R and S^R at 70⁰ C and 200 Kpa for an equimolar vapour mixture of propane and pentane using virial expansions.
 $B_{11} = -276$; $B_{22} = -809$; $B_{12} = -466 \text{ CM}^3/\text{mol}$. [16]

7. Why does Immiscibility occur in liquid solution. How would you estimate the composition of the vapor phase in equation with two immiscible liquid phase?[16]
8. Consider the reaction $C_4H_4(g) \rightarrow C_4H_6(g) + H_2(g)$. the standard free energy change is given by:
 $\Delta G_T^0 = 24,760 - 5.01T \ln T + 3.09T$
where ΔG_T^0 is in J / mol butene and T is in K.
- (a) Over what range of temperature is the reaction promising from a thermodynamic viewpoint?
- (b) For reaction of pure butene at 800 K, calculate the equilibrium conversion for operation at 1 and 5 atm total pressure, assuming ideal gases.
- (c) Repeat part (b) at 1 atm for a feed of 50 mol % butene and 50 mol % inert gas and compare the results. [6+5+5]

III B.Tech. I Semester Regular Examinations, November -2005
CHEMICAL ENGINEERING THERMODYNAMICS-II
 (Chemical Engineering)

Time: 3 hours

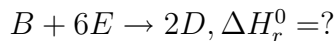
Max Marks: 80

Answer any FIVE Questions
 All Questions carry equal marks

★ ★ ★ ★ ★

1. Pyrites are roasted in SO_2 plant to produce SO_2 . The gases leaving are at 500°C , have molar composition of $SO_2 = 7.055\%$, $O_2 = 10.55\%$, $SO_3 = 0.785\%$, $N_2 = 81.64\%$. Calculate the heat content of gas mixture (1 kmol) over 25°C .
 $C_{p,SO_2} = 6.147 + 13.844 \times 10^{-3}T - 91.03 \times 10^{-7}T^2$
 $C_{p,O_2} = 6.732 + 1.505 \times 10^{-3}T - 1.7913 \times 10^{-7}T^2$
 $C_{p,SO_3} = 6.077 + 23.53 \times 10^{-3}T - 96.7 \times 10^{-7}T^2$
 $C_{p,N_2} = 6.529 + 1.488 \times 10^{-3}T - 2.27 \times 10^{-7}T^2$. [16]

2. (a) Calculate the heat of reaction of the following reaction:



$$\text{Given: } 2A + B \rightarrow 2C, \Delta H_{r1}^0 = -1000 \text{ (kJ/mol)}$$

$$\text{And } A + D \rightarrow C + 3E, \Delta H_{r2}^0 = -2000 \text{ (kJ/mol)}$$

- (b) Explain: Hess's law, standard enthalpy of reaction, mole of reaction, standard state used in heat effects calculations. [8+8]

3. Show that chemical potential of a component in all phases is same at thermodynamics equilibrium. [16]

4. If in a binary liquid mixture at a given T and P: $\ln \gamma_1 = x_2^2 (0.273 - 0.096 x_1)$ and $\ln \gamma_2 = x_1^2 (0.273 + 0.096 x_1)$

- (a) Determine the implied expression for $\frac{G^E}{RT}$.

- (b) Generate the expressions for $\ln \gamma_1$ and $\ln \gamma_2$ from the expression of $\frac{G^E}{RT}$. [10+6]

5. The excess Gibbs energy for a binary system is given by :

$$G^E / RT = 0.468 X_1 X_2$$

The pure component vapor pressures are given by :

$$\ln P_1^{sat} / \text{kPa} = 14.39155 - \frac{2795.817}{t/^\circ\text{C} + 230.002}$$

$$\ln P_2^{sat} / \text{kPa} = 16.59381 - \frac{3644.297}{t/^\circ\text{C} + 239.765}$$

Obtain the P-x,y diagram for this system at 45°C . [16]

6. Calculate the fraction of liquid, liquid composition and vapor composition in a two phase system consisting of acetone acetonitrile - nitromethane at 80°C and 110 Kpa. The overall composition of the

mixture is $Z=0.45$, $Z=0.35$ and $Z=0.2$. The vapor pressures of the components (1), (2) and are 195.8 Kpa, 97.84 Kpa and 50.32 Kpa respectively. [16]

7. (a) Discuss the equilibrium adsorption of gases on solids with suitable examples. Mention limitations involved in the above.
- (b) Write short notes of the following
- i. Pure gas adsorption.
 - ii. Heat of adsorption. [8+8]
8. N_2O_4 at a low temperature is mixed with Air and heated to 25°C and 1 bar pressure. The mole fraction of N_2O_4 in the N_2O_4 – Air mixture before dissociation begins is 0.19. What is the extent of decomposition and what are the mole fractions of N_2O_4 and NO_2 present at equilibrium? The reaction equilibrium constant $K=0.154$. [16]

III B.Tech. I Semester Regular Examinations, November -2005
CHEMICAL ENGINEERING THERMODYNAMICS-II
(Chemical Engineering)

Time: 3 hours

Max Marks: 80

Answer any FIVE Questions
 All Questions carry equal marks

1. If the heat capacity of a substance is correctly represented by an equation of the form, $C_P = A + BT + CT^2$
 Show that the error resulting when $\langle C_p \rangle_H$ is assumed equal to C_P evaluated at the arithmetic mean of the initial and final temperature is $C(T_2 - T_1)^2 / 12$. [16]
2. Calculate the theoretical flame temperature for CO gas burnt at constant pressure with 150% excess air, when the reactants enter at 127° specific heats are in J/mol./K. These values are for CO_2 , O_2 , CO and N_2 are 53.59, 34.83, 29.23 and 33.03 respectively. [16]
3. (a) Define and explain partial property along with necessary equting.
 (b) The partial molar volume of ethanol in a 60% ethanol-water solution is $5.5 \times 10^{-6} m^3$. The density of the mixture is 849.4 kg/ m^3 . Calculate the partial molar volume of water in the mixture. [8+8]
4. (a) Given the $\gamma_1 = 2.7385$, $\gamma_2 = 1.2344$ of a binary liquid mixture at a given T and P and $x_1 = 0.3$ (mol/mol). Calculate the Van laar constants.
 (b) Ethanol (1) – Benzene (2) system forms an azeotrope with 44.8 mol% ethanol with a boiling point of 68.24 °C at 760 Torr. The saturation pressures of ethanol and benzene at 68.24 °C 506 Torr and 517 Torr, respectively. Estimate the van Laar constants for the system and evaluate the activity coefficients for a solution containing 10 mol% ethanol. Assume vapour phase is an ideal gas mixture. [8+8]
5. For a binary system of components 1 and 2, the excess Gibbs energy is represented by: $G^E/RT = 0.95 x_1x_2$
 Using modified Raoult's law,
 (a) Make a BUBL P calculation for $t = 343.15$ °K and $x_1 = 0.10$
 (b) Make a DEW P calculation for $t = 343.15$ °K and $y_1 = 0.10$
 (c) What is the azeotropic composition and pressure at $t = 343.15$ °K. [16]
6. Calculate the fraction of liquid, liquid composition and vapor composition in a two phase system consisting of acetone acetonitrile - nitromethane at 80°C and 110 Kpa. The overall composition of the mixture is $Z=0.45$, $Z=0.35$ and $Z=0.2$. The vapor pressures of the components (1), (2) and are 195.8 Kpa, 97.84 Kpa and 50.32 Kpa respectively. [16]
7. (a) Discuss estimation of solid solubility at high pressure.

- (b) Write short notes on solid vapour equilibrium. [8+8]
8. (a) Derive Van'tHoff equation from the fundamentals and discuss its applications.
- (b) It is desired to produce industrial methanol from the synthesis gas according to the reaction
 $CO(g) + 2H_2(g) \rightarrow CH_3OH(g)$ Calculate the equilibrium conversion at 1.5 bar and 3000°C if the stoichiometric quantities are used in the above reaction. ($K_{3000^\circ C} = 1.9 \times 10^{-2}$). [8+8]
