

Roll No.: \_\_\_\_\_

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B.Tech. Degree Examinations – June 2012

Fourth Semester  
Chemical Engineering

### CHE212 Chemical Engineering Thermodynamics

Time: Three hours

Maximum: 100 Marks

**Answer all questions**

**Part – A**

**(10 x 2 = 20 marks)**

1. Write an informatory note on extensive and intensive property with suitable examples?
2. Define the term adiabatic flame temperature? How can it be estimated?
3. What are the characteristics of an ideal solution?
4. Define chemical potential. What is its physical significance?
5. State Raoult's law. Show that it is a simplified form of the Lewis-Randall rule.
6. Define activity coefficient. How do you distinguish between the activity coefficient based on the Lewis-Randall rule and that based on the ideal dilute solution?
7. What do you mean by property changes of mixing? How are these related to the activities of the components in the mixture?
8. Distinguish between the bubble-point and dew-point temperatures.
9. What are the salient features of an ideal liquid solution? How does the total pressure over an ideal solution vary with composition?
10. How is the equilibrium constant  $K$  related to the standard free energy change? Does  $K$  vary with pressure?

**PART – B**

**(4 x 5 = 20 marks)**

11. A rigid insulated cylinder has two compartments separated by a thin membrane. While one compartment contains 1 kmol nitrogen at a certain temperature and pressure, the other contains 1 kmol of  $\text{CO}_2$  at the same temperature and pressure. The membrane is ruptured and the two gases are allowed to mix. Assume that the gases behave as ideal gases. Calculate the increase in entropy of the contents of the cylinder. Universal gas constant  $R=8314 \text{ J/kmol.K}$ .
12. At high temperature and pressure  $\text{N}_2$  obeys the equation of state  $P(V-b) = RT$ . Calculate the fugacity of  $\text{N}_2$  at  $1000^\circ\text{C}$  and  $1000 \text{ atm}$ , if  $b = 39.1 \text{ ml/mol}$ . Calculate the fugacity coefficient also.
13. The activity coefficients of benzene (A) – cyclohexane (B) mixtures at  $40^\circ\text{C}$  are given by  $RT \ln \gamma_A = bx_B^2$  and  $RT \ln \gamma_B = bx_A^2$ . At  $40^\circ\text{C}$ , A and B form an azeotrope containing 49.4 mol% A at a total pressure of 202.6 mm Hg. If the vapor pressure of pure A and B are 182.6 and 183.5 mm Hg respectively, calculate the total pressure of the vapor at  $40^\circ\text{C}$  in equilibrium with a liquid mixture containing 12.6 mol% A.

14. An equimolar mixture of benzene and toluene is contained in a piston/cylinder arrangement at a temperature  $T$ . What is the maximum pressure below with this mixture will exist as a vapor phase alone? At the given  $T$ , the vapor pressures of benzene and toluene are 1530 and 640 mm Hg, respectively. Assume that Raoult's law is valid.

### PART – C

(5 x12 = 60 marks)

15. An ideal gas ( $C_p = 5 \text{ kcal/kmol } ^\circ\text{C}$ ,  $C_v = 3 \text{ kcal/kmol } ^\circ\text{C}$ ) is changed from 1 atm and  $2.24 \text{ m}^3$  to 10 atm and  $2.24 \text{ m}^3$  by the following reversible process
- Isothermal compression
  - Adiabatic compression followed by cooling at constant volume
  - Heating at constant volume followed by cooling at constant pressure.

Calculate  $Q$ ,  $W$ ,  $\Delta U$  and  $\Delta H$  of the overall process in each case.

16. The azeotrope of the benzene-cyclohexane system has a composition of 53.2 mol% benzene with a boiling point of 350.6 K at 101.3 kPa. At this temperature, the vapor pressure of benzene (1) is 100.59 kPa and the vapor pressure of cyclohexane (2) is 99.27 kPa. Determine the activity coefficients for the solution containing 10 mol% benzene.

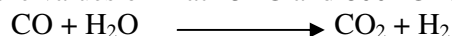
17. The excess Gibbs free energy for cyclohexanone (1)/phenol(2) is given by

$$G^E/RT = -2.1x_1x_2$$

where  $x_1$  and  $x_2$  are the mole fractions of components 1 and 2 in the liquid phase. The vapor pressures of components at 417 K are  $P_1^{\text{sat}} = 75.2 \text{ kPa}$  and  $P_2^{\text{sat}} = 31.66 \text{ kPa}$ .

- Derive expressions for activity coefficients of each component as a function of composition.
  - Verify whether the expressions derived in (a) satisfy the Gibbs-Duhem equation.
  - Determine the equilibrium pressure  $P$  and vapor composition for a liquid composition  $x_1 = 0.8$  and 417 K. Assume vapor phase to be ideal gas.
18. In a laboratory investigation, ethanol is esterified to produce ethyl acetate and water at  $100^\circ\text{C}$  and 1 atm pressure according to the following equation
- $$\text{CH}_3\text{COOH (l)} + \text{C}_2\text{H}_5\text{OH} = \text{CH}_3\text{COOC}_2\text{H}_5 \text{ (l)} + \text{H}_2\text{O (l)}$$
- What is the equilibrium constant for the reaction at  $100^\circ\text{C}$ ? What is the composition of the reaction mixture if initially one mol each of acetic acid and ethanol are present? The data given for the reaction are  $\Delta G_{298}^\circ = 1160 \text{ cal}$  and  $\Delta H_{298}^\circ = 1713 \text{ cal}$ .

19. Calculate the values of  $K$  at  $25^\circ\text{C}$  and  $800^\circ\text{C}$  for the water gas reaction



Using the following data

Substance	$\text{H}_2$	$\text{CO}$	$\text{H}_2\text{O}$	$\text{CO}_2$
$\Delta H_f^\circ \text{ (kJ)}$	0	-110.52	-241.83	-392.51
$\Delta G_f^\circ \text{ (kJ)}$	0	-137.27	-228.60	-394.40

where  $\Delta H_f^\circ \text{ (kJ)}$  and  $\Delta G_f^\circ \text{ (kJ)}$  refer to standard state enthalpy and free energy change respectively at  $25^\circ\text{C}$ .

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