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 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 J /kmol.K .

12. At high temperature and pressure N_2 obeys the equation of state P(V-b) = RT. Calculate the fugacity of N_2 at 1000 °C and 1000 atm, if b = 39.1 ml/mol. Calculate the fugacity coefficient also.

13. The activity coefficients of benzene (A) – cyclohexane (B) mixtures at 40 °C are given by $RT \ln \gamma_A = bx^2_B$ and $RT \ln \gamma_B = bx^2_A$. At 40 °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 °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 kcal/kmol °C, C_V =3 kcal/kmol °C) is changed from 1 atm and 2.24 m^3 to 10 atm and 2.24 m^3 by the following reversible process
    a. Isothermal compression
    b. Adiabatic compression followed by cooling at constant volume
    c. Heating at constant volume followed by cooling at constant pressure.

    Calculate Q, W, ΔU and ΔH 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^{sat} =75.2 kPa and P_2^{sat} = 31.66 kPa.

    a) Derive expressions for activity coefficients of each component as a function of composition.
    b) Verify whether the expressions derived in (a) satisfy the Gibbs-Duhem
    c) equation.
    d) 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 °C and 1 atm pressure according to the following equation

    CH_3COOH (l) + C_2H_5OH = $CH_3COOC_2H_5$ (l) + H_2O (l)

    What is the equilibrium constant for the reaction at 100 °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 ΔG°_{298} = 1160 cal and ΔH°_{298} = 1713 cal.

19. Calculate the values of K at 25 °C and 800 °C for the water gas reaction

    $$CO + H_2O \longrightarrow CO_2 + H_2$$

    Using the following data

Substance	H_2	CO	H_2O	CO_2
ΔH_f° (kJ)	0	-110.52	-241.83	-392.51
ΔG_f° (kJ)	0	-137.27	-228.60	-394.40

where ΔH°_f (kJ) and ΔG°_f (kJ) refer to standard state enthalpy and free energy change respectively at 25 °C.

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