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B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2008.

Fourth Semester

Bio-Technology

BT 1253 — CHEMICAL THERMODYNAMICS AND BIO-THERMODYNAMICS

(Regulation 2004)

Time : Three hours

Maximum : 100 marks

Assume any missing data suitably.

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. State the law of corresponding states and explain its significance.
2. What is a control — volume?
3. What is an inversion point?
4. What is the difference between refrigerator and heat pump?
5. Can the entropy of a systems ever decrease? Why or why not?
6. Define fugacity and fugacity coefficient of a real gas.
7. What is the difference between bubble point pressure and dew point pressure?
8. What is the basic equation for vapour - liquid equilibrium calculations?
9. What is standard Gibbs free energy change of a chemical reaction and how is it related to the equilibrium constant?
10. What is C.O.P of a refrigeration system?

11. (a) (i) A cylinder of volume 0.1 m^3 is filled with ethylene to a pressure of 8.25 MPa at 25°C . Determine the mass of ethylene in the cylinder using the ideal gas law. (10)
- (ii) Determine Joule-Thomson coefficient for Vander Waal's gas. (6)

Or

- (b) (i) A rigid and insulated tank of 2 m^3 capacity is divided into two equal compartments by a partition. One compartment contains an ideal gas at 600°K and 1 MPa while the second compartment contains the same gas at 300°K and 0.1 MPa . Determine the final temperature and pressure of the gas in the tank if the partition gets punctured. Assume $\gamma = 1.4$ for the gas. (5 + 5 = 10)
- (ii) Prove the following

$$\left(\frac{\partial C_V}{\partial V}\right)_T = T \left(\frac{\partial^2 P}{\partial T^2}\right)_V$$

$$\left(\frac{\partial C_P}{\partial P}\right)_T = -T \left(\frac{\partial^2 V}{\partial T^2}\right)_P \quad (3 + 3 = 6)$$

12. (a) (i) The Van Laar constants A and B for the system ethanol(1) and benzene(2) at 50°C are 1.7910 and 1.8262, respectively. Calculate the activity coefficients of the components in a solution containing 60 mol% ethanol. (10)
- (ii) Write down the Redlich-Kister equation and explain the significance of terms in the equation. (6)

Or

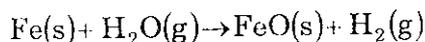
- (b) (i) Two substances A and B are known to form ideal solutions. An equimolar vapor mixture of A and B initially at 100°C and 100 kPa is isothermally compressed till condensation starts. Determine the pressure at which condensation begins and the composition of the liquid that forms. The saturation pressures of A and B at 100°C are $P_A^s = 120 \text{ kPa}$ and $P_B^s = 150 \text{ kPa}$. (10)
- (ii) In the binary mixture the activity coefficient (γ_1) of component 1 is given by $R \ln \gamma_1 = Ax_2^2 + Bx_2^3$

This equation is valid in the entire range of composition $x_2 = 0$ to $x_2 = 1$. Derive an expression to determine the activity coefficient of component 2 in the above solution. (6)

13. (a) (i) Starting from criterion of equilibrium between liquid and vapour phases, derive the basic equation for VLE. (8)
- (ii) The saturation pressures of water at 80°C and 100°C are 47.36 kPa and 101.33 kPa, respectively. Estimate the approximate enthalpy of vaporization of water. (8)

Or

- (b) (i) How do you predict the low pressure VLE data for a binary system using excess Gibb's energy model? (8)
- (ii) At 65°C, a liquid solution containing 80 mol% A and 20 mol% B is in equilibrium at 760 mm Hg with a vapour containing 84.3 mol% A and 15.7% B. Estimate the pressure and vapour composition equilibrium with a liquid containing 50% A and 50% B at 65°C. At this temperature the vapour pressures are $P_A^{\circ} = 800$ mm of Hg, $P_B^{\circ} = 600$ mm of Hg. (8)
14. (a) (i) What is the effect of temperature on equilibrium constant of a reaction? Explain in detail. (8)
- (ii) Water is usually used for extinguishing fires. In industrial installations, iron is extensively used as a construction material. It is possible for the following reaction to take place at high temperature which occurs in the case of fire:



The presence of hydrogen in a fire is extremely dangerous. Assuming that equilibrium is achieved, determine the fraction of H_2O which decomposes at 1000°C. The equilibrium constant for the reaction at 1000°C is 1.6. (8)

Or

- (b) (i) How does the dilution of a reaction mixture with inert gas affect the degree of conversion in a gas phase reaction? (6)
- (ii) Calculate the decomposition pressure, that is the equilibrium pressure of gaseous species that results from the decomposition, of calcium carbonate at 1200° K. The isobaric molar heat capacities of $\text{CaCO}_3\text{(s)}$ and CaO(s) are given by

$$C_p(\text{CaCO}_3) = 82.34 + 49.75 \times 10^{-3} T - 12.87 \times 10^5/T^2$$

$$C_p(\text{CaO}) = 41.84 + 20.25 \times 10^{-3} T - 4.51 \times 10^5/T^2$$

Where C_p is in J/mol K and T in K.

Data:

$$\Delta H_{298}^{\circ} = 177.73 \text{ kJ}$$

$$\Delta G_{298}^{\circ} = 130.126 \text{ kJ} \quad (10)$$

15. (a) (i) A refrigeration system require 1.5 kW of power for a refrigeration rate of 4 kJs^{-1} .
- (1) What is the coefficient of performance?
 - (2) How much heat is rejected in condenser?
 - (3) If heat rejection is at 40°C , what is the lowest temperature the system can positively maintain. (8)
- (ii) A heat exchanger is used to heat 100 kg/mm of water from 25°C to 70°C . For this purpose, saturated steam at 100°C enters the heat exchanger and leaves as saturated liquid at 100°C . Calculate the entropy change of water, steam and the universe in one minute. (8)

Or

- (b) (i) Explain the working of vapour absorption refrigeration cycle. (6)
- (ii) Air, an ideal gas with $\gamma = 1.4$, enters an adiabatic compressor at 25°C and 0.1 MPa and leaves at 1 MPa and 330°C . Calculate the isentropic efficiency of the compressor. (10)