J 1211

B.E./B.Tech. DEGREE EXAMINATION, MAY/JUNE 2006.

Third Semester

Industrial Bio-Technology

IB 235 — CHEMICAL THERMODYNAMICS AND BIO THERMODYNAMICS

Time : Three hours

Maximum : 100 marks

Answer ALL questions.

PART A — ($10 \times 2 = 20$ marks)

1. A system consisting of some fluid is stirred in a tank. The rate of work dond on the system by the stirrer is 2.25 hp. The heat generated due to stirring is dissipated to the surroundings. If the heat transferred to the surroundings is 340 kJ/h, determine the change in internal energy.

2. State the Second Law of Thermodynamics.

3. A heat engine operates between a heat source at 700 K and a heat sink at 300 K. What is the maximum efficiency of the engine?

4. Give the mathematical relation between work and heat.

5. Define the term fugacity.

6. Write the phase rule.

7. State Raoult's law.

8. Define the term 'Equilibrium constant'.

9. Show the relation between rate constant and temperature of biochemical reaction.

10. Assuming that air is a mixture of 21% oxygen and 79% nitrogen by volume, calculate entropy of 1 kmol air relative to pure oxygen and nitrogen, all at the same temperature and pressure.

PART B — (5 × 16 = 80 marks)

11. Heat is transferred to 10 kg of air which is initially at 100 kPa and 300 K until its temperature reaches 600 K. Determine the change in internal energy, the change in enthalpy, the heat supplied, and the work done in the following progress :

(i) Constant volume process

(ii) Constant pressure process.

Assume that air is an ideal gas for which the P-V-T relationship is PV = nRT, where n is the number of moles of the gas and R is the ideal gas constant. R = 8.314 kJ/kmol K. Take C_P = '29.099 kJ/kmol K, C_V = 20,785 kJ/kmol K and molecular weight of air = 29.

12. (a) (i) It is required to freeze 1 kg water at 273 K by means of a refrigeration machine which operates in the surroundings at 300 K. The latent heat of fusion of ice at 273 K is 334.11 kJ/kg. Determine :

(1) The minimum amount of work required

(2) The heat given up to the surroundings.

(ii) A steel casting at a temperature 725 K and weighing 35 kg is quenched in 150 kg oil at 275 K. If there are no heat losses, determine the change in entropy. The specific heat (CP) of steel is 0.88 kJ/kg K and that of oil is 2.5 kJ/kg K.

Or

(b) (i) A 30 per cent by mole methanol – water is to be prepared. How many cubic meters of pure methanol (molar volume, 40.727×10^{-6} m³/mol) and pure water (molar volume, 18.068×10^{-6} m³/mol) are to be mixed to prepare to m³ of the desired solution? The partial molar volumes of methanol and water in a 30 per cent solution are 38.632×10^{-6} m³/mol and 17.765×10^{-6} m³/mol, respectively.

(ii) The volume of aqueous solution of NaCl at 298 K was measured for a series of molalities (moles of solute per kg of solvent) and it was found that the volume various with molality according to the following expression.

$$V = 1.003 \times 10^{-3} + 0.1662 10^{-4} m + 0.177 10^{-5} m^{1.5} + 0.12 \times 10^{-6} m^2$$

Where m is the molality and V is in m^3. Calculate the partial molar volumes of the components at $M = 0.1$ mol/kg.

14.

13. (a) (i) The fugacity of component 1 in binary liquid mixture of components 1 and 2 at 298 K and 20 bar is given by $\bar{f}_1 = 50x_1 - 80x_1^2 + 40x_1^3$ where $\bar{f}_1$ is in bar and x_1 is the mole fraction of component 1. Determine :

(1) The fugacity of pure component 1

(2) The fugacity coefficient ϕ_1

(3) The Henry's law constant K_1

(4) The activity coefficient Y_1.

(ii) Will it be possible to prepare 0.1 m^3 of alcohol – water solution by mixing 0.03 m^3 alcohol with 0.07 m^3 pure water? If not possible, what volume should have been mixed in order to prepare a mixture of the same strength and of the required volume? Density of ethanol and water are 789 and 997 kg/m^3 respectively. The partial molar volumes of ethanol and water at the desired compositions are : Ethanol = 53.6 10^{-6} m^3/mol; water = 18×10^{-6} m^3/mol.

Or

(b) Construct the $P-x-y$ diagram for the cyclohexane (i) -benzene (ii) system at 313 K given that at 313 K the vapour pressures are $P_1^S = 24.62\,kPa$ and $P_2^S = 24.41\,kPa$. The liquid–phase activity coefficients are given by In $Y_1 = 0.458x_2^2$, In $Y_2 = 0.458x_1^2$.

14. (a) The azeotrope of the ethanol – benzene system as a composition of 44.8% (mol) ethanol with a boiling point of 341.4 K at 101.3 kPa. At this temperature the vapour pressure of benzene is 68.9 kPa and the vapour Pressure of ethanol is 67.4 kPa. What are the activity coefficients in a solution containing 10% alcohol?

Or

(b) From vapour – liquid equilibrium measurements for ethanol – benzene system at 318 K and 40.25 kPa it is found the vapour in the equilibrium with the liquid containing 38.4% (mol) benzene contained 56.6% (mol) benzene. The system forms and azeotrope at 318 K. At this temperature, the vapour pressures of ethanol and benzene are 22.9 and 29.6 kPa respectively. Determine the composition and total pressure of azeotrope. Assume that Van Laar equation is applicable for the system.

15. (a) n-Butane is isomerised to i-butane by the action of catalyst at moderate temperatures it is found that the equilibrium is attained at the following compositions.

Temperature, K	Mol %, n-butane
317	31.00
391	43.00

Assuming that activities are equal to the mol fractions, Calculate the standard free energy of the reaction at 317 K and 391 K and average value of heat of reaction over the temperature range.

Or

(b) A mixture of 1 mol CO and 1 mol water vapour is undergoing the water – gas shift reaction at a temperature of 1100 K and pressure of 1 bar.

$$CO(g) + H_2O(g) \rightarrow CO_2(g) + H_2(g)$$

The equilibrium constant for the reaction is $K = 1$. Assume that the gas mixture behaves as ideal gas. Calculate

(i) The fractional dissociation of steam

(ii) The fractional dissociation of steam if the reactant stream is diluted with 2 mol nitrogen.