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T 3099

B.E./B.Tech. DEGREE EXAMINATION, APRIL/MAY 2008.

Fourth Semester

Bio - Technology

BT 1253 — CHEMICAL THERMODYNAMICS AND BIO-THERMODYNAMICS

(Regulation 2004)

Time : Three hours

Maximum : 100 marks

Any missing data can be suitably assumed.

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. What is physical significance of virial coefficients?
2. What is compressibility factor?
3. What is partial molar property?
4. Define fugacity and fugacity coefficient for a real gas.
5. What is the difference between bubble and dew point?
6. What are the characteristics of an ideal solution?
7. Is the Gibbs free energy change of a chemical reaction related to the work done by the system? Give an example.
8. What is the effect of pressure on the rate of conversion at equilibrium for a gas phase reaction?
9. What do you understand by the principle of increase in entropy?
10. Differentiate between available and unavailable energy.

PART B — (5 × 16 = 80 marks)

11. a) (i) Show $dH = C_p dt + \left(V - \frac{(C_p - C_v)k}{\beta} \right) dp$. (8)

- (ii) 1.5 kg of air at 8 bar occupies a volume of 2m³. It is heated at constant pressure until the volume is doubled. Calculate the work done, change in internal energy and heat added. (8)

Or

- (b) (i) Prove the following relation where μ is Joule - Thomson coefficient

$$\left(\frac{\partial C_p}{\partial P} \right)_T = -\mu \left(\frac{\partial C_p}{\partial T} \right)_P - C_p \left(\frac{\partial \mu}{\partial T} \right)_P \quad (8)$$

- (ii) The vapour pressures of ethyl benzene at 347.2° k and 460° k are 0.133 bar and 3.325 bar respectively. Estimate the enthalpy of vapourization of ethyl benzene. (8)

12. (a) (i) Explain the tangent - intercept method for determination of partial molar properties. (8)

- (ii) The volume of a solution formed from MgSO₄ and 1.0 kg of water fits the expression.

$$V = 1.00121 \times 10^{-3} + 34.69 \times 10^{-6} (m - 0.070)^2$$

Where m is the molarity of the solution? Calculate the partial molar volume of the salt and solvent when m = 0.05 mol/kg. (8)

Or

- (b) (i) The activity coefficient of n-propyl alcohol in a mixture of water (1) and alcohol (2) at 298°k referred to the pure liquid standard state is given below :

x_B	0	0.01	0.02	0.05	0.10	0.2
γ_B	12.5	12.3	11.6	9.92	6.05	3.12

Find γ_A in the solution containing 10% (mole) n-propyl alcohol. (8)

- (ii) Calculate the heat effects when 1.0 k mole of water is added to a solution containing 1 k. mole of sulphuric acid and 3 k. mole of water. The process is isothermal and occurs at 298°k

Data :

Heat of mixing for $\text{H}_2\text{SO}_4 (3\text{H}_2\text{O}) = -49000 \text{ kJ/k. mole H}_2\text{SO}_4$

Heat of mixing for $\text{H}_2\text{SO}_4 (4\text{H}_2\text{O}) = -54100 \text{ kJ/k. mole H}_2\text{SO}_4$ (8)

13. (a) (i) Two substances A and B are known to form ideal liquid solutions. A vapour mixture containing 50 mole % A and 50 mole % B is at 311°k and 101.3 Kpa. This mixture is compressed isothermally until condensation occurs. At what pressure condensation occurs and what is the composition of the liquid that forms? The vapour pressures of A and B are 142 Kpa and 122 Kpa respectively. (8)
- (ii) Show that Van-Laar equation is consistent with Duhem's equation. (8)

Or

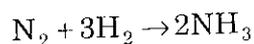
- (b) (i) Calculate the bubble point of a 5% liquid solution of methane at 37.8°C. The other component is propane. The value of K is given below.

K at 37.8°C

Component :	21.1 kg/cm ²	24.6 kg/cm ²	28.1 kg/cm ²
Methane :	8.1	6.5	5.8
Propane :	0.74	0.63	0.61

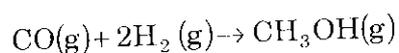
- (ii) The activity coefficient for component 1 in a binary solution can be represented by $\ln \gamma_1 = 4x_2^2 + 6x_2^3 + 8x_2^4$. Determine an expression for $\ln \gamma_2$. (8)

14. (a) (i) Calculate the equilibrium constant at 298°k of the reaction.



Given that free energy of formation of ammonia at 298°k is -16500 J/mol. (8)

- (ii) A gaseous mixture containing 30% Co, 50% H₂ and rest inert gas is sent to a reaction chamber for methanol synthesis. The following reaction occurs at 635° k and 310 bar.



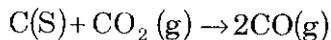
Assuming that gas mixture behaves like an ideal solution, calculate percent conversion of CO given that

$$K_f = 5 \times 10^{-5} \text{ and } K_\phi = 0.35. \quad (8)$$

Or

- (b) (i) 1 mol of carbon at 298°k reacts with 2 mol oxygen to form an equilibrium mixture of CO₂, CO and O₂ at 3000°k and 1 bar. If the equilibrium constant is $K = 0.328$, determine the equilibrium compositions. (8)

- (ii) Carbon-di-oxide is reduced by graphite according to the equation



Calculate the effect of pressure on the degree of conversion of pure CO₂ at 1000°k assuming total pressure of 1, 2 and 3 bar. Gas mixture may be treated as ideal gas and an equilibrium constant value of $K = 1.778$ may be assumed. (8)

15. (a) (i) In a tubular counter - flow heat exchanger 0.3 kg/s of water is heated from 40 to 80°C. Hot gases enter at 200°C and leave at 100°C. C_p for gases = 1. kJ/kg°k . The atmospheric temperature is 35°C. Find the loss of available energy due to this heat transfer. Calculate the entropy generated due to irreversible heat transfer.(8)
- (ii) Explain the working of Rankine power cycle. (8)

Or

- (b) (i) 900 kJ of energy was transferred from a work reservoir to heat reservoir at 97°C. Determine
- (1) The amount of entropy generation
 - (2) The amount of lost work
 - (3) The available energy
- The surrounding is at 27°C (8)
- (ii) In order to maintain a space at a constant temperature of -12°C, heat has to be continuously removed from the space at the rate of 1050 kJ/min. If the ambient temperature is 15°C Calculate
- (1) COP
 - (2) The minimum work required
 - (3) The refrigeration load in tonnes. (8)