Exam. Code: 0908
Sub. Code: 33363

2056

B.E. (Biotechnology) Fourth Semester
BIO-412: Thermodynamics

Time allowed: 3 Hours **Max. Marks: 50**

NOTE: ***Attempt five questions in all, including Question No. I which is compulsory and selecting two questions from each Section. Assume missing data, if any.***

x-x-x

Q.1.a) One mole of an ideal gas is expanded isothermally and reversibly at 27°C from a volume of 2.28 m^3 to 4.56 m^3. Calculate Q, W and ΔE. (2)

b) Explain dry compression and wet compression in a vapor compression refrigeration system. (2)

c) Define fugacity and explain its physical meaning. (2)

d) The molar composition of a binary solution is 65% benzene and 35% toluene. The vapor pressure of pure benzene is 13.33 kPa while that of toluene is 6.67 kPa. Calculate the vapor pressure of solution using Raoult's Law. (2)

e) A system initially containing 3 mol H_2S and 5 mol O_2 and undergoes the reaction:

$$2H_2S(g) + 3O_2(g) \rightarrow 2H_2O(g) + 2SO_2(g)$$

Develop expressions for the mole fractions of reacting species as functions of ε. (2)

SECTION-A

Q.2. An ideal gas initially at 300 K and 1 bar undergoes a three-step mechanically reversible cycle in a closed system. In step 12, pressure increases isothermally to 5 bar; in step 23, pressure increases at constant volume; and in step 31, the gas returns adiabatically to its initial state. Calculate Q, W, ΔU, and ΔH for each step and the whole process. Take $C_p = \frac{7}{2}R$ and $C_V = \frac{5}{2}R$. (10)

Q.3. Two reversible heat engines, A and B, operate in series such that the heat rejected by engine A is supplied to engine B. Engine A receives 200 kJ of heat from a hot reservoir at 400°C. Engine B rejects heat to a cold reservoir at 5°C. The work output of engine A is twice the work output of engine B. Determine (a) the intermediate temperature between engines A and B (b) the efficiency of each engine (c) the amount of heat rejected to the cold reservoir. (10)

Q.4a). Estimate the pressure of CO_2 at 500 K using van der Waals equation of state. The van der Waals constants for CO_2 are a = 0.364 Nm^4/mol^2 and b = 4.267×10^{-5} m^3/mol and the molar volume of CO_2 is 0.39×10^{-3} m^3/mol. (5)

b). What is the Joule-Thompson effect? Explain the principle and its industrial application. (5)

SECTION-B

Q.5. The vapor pressure of Methanol (1) and Ethanol (2) can be evaluated by the following Antoine equations

$lnP_1^s(kPa) = 16.58 - \frac{3638.27}{T(K)-34.29}$ $\quad\quad$ $lnP_2^s(kPa) = 16.90 - \frac{3795.17}{T(K)-42.85}$

Assuming methanol and ethanol form an ideal solution, calculate

(a) x_1 and y_1 at 340 K and 80 kPa $\quad\quad$ (b) P and y_1 at 340 K and x_1=0.6

(c) P and x_1 at 340 K and y_1= 0.5 (10)

Q.6a). For the water gas shift reaction, the standard enthalpy change and standard Gibbs free change are -40.16 kJ/mol and -28.52 kJ/mol at 298K. Calculate the equilibrium constant at 800 K. Assume ΔH^0 is constant in this temperature range. (4)

b). Ammonia synthesis reaction $N_2(g) + 3H_2(g) \rightarrow 2NH_3$ is carried out at a temperature of 675 K and 20 bar pressure. The feed contains 1 mol N_2, 3 mol H_2 and 2 mol argon. The equilibrium constant for the reaction is 2×10^{-4}. Determine how the conversion of nitrogen is affected by the presence of argon. (6)

Q.7. For the cracking reaction given below the standard heat of reaction and Gibbs standard free energy change at 298 K is 82.7 kJ/mol and 42.3 kJ/mol respectively.

$$C_3H_8(g) \rightarrow C_2H_4(g) + CH_4(g)$$

Estimate the standard free energy change and equilibrium constant at 500 K. The specific heat data as a function of temperature is given below.

$C_{p_{C_3H_8}}$(J/mol K) = $14.15 + 7.56\times10^{-2}$ T – 17.63×10^{-6} T^2

$C_{p_{C_2H_4}}$(J/mol K) = $3.95 + 15.50\times10^{-2}$ T – 69.0×10^{-6} T^2

$C_{p_{CH_4}}$(J/mol K) = $19.89 + 5.024\times10^{-2}$ T – 12.69×10^{-6} T^2 (10)

x-x-x