Exam.Code:0908
Sub. Code: 6702

2062

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.*

x-x-x

1.a) Heat in the amount of 8 kJ is added to a closed system while its internal energy decreases by 12 kJ. Calculate the work done by the system.

b) For a cyclic process the change in internal energy (ΔU) is _____

c) The number of degrees of freedom for mixture of ice and water (liquid) is _____

d) For a system in equilibrium at a given temperature and pressure, the Gibbs free energy must be _____ (minimum/maximum)

e) A Carnot heat engine receives 250 kW of heat from a hot reservoir at 800 K and reject heat to a cold reservoir at 320 K. Calculate the power developed by the engine.

f) Define activity coefficient.

g) The equilibrium constant K, for a chemical reaction depends only on temperature. State whether the statement is true or false

h) State Raoult's law.

i) The value of Compressibility factor for an ideal gas is _____

j) The change in Gibbs free energy for vaporization of a pure substance is _____

(1×10)=10

SECTION-A

2a). 1 kg air is heated reversibly at constant pressure from an initial state of 300 K and 1 bar until its volume triples. Calculate heat, work, change in enthalpy, change in internal energy for the process. Assume air to be ideal gas and take $Cp = 29\,J/mol\,K$

b). One mole of ideal gas initially at 30°C and 1 bar pressure undergoes the following mechanically reversible changes. It is compressed isothermally to a point such that when it is heated at constant volume to 120 °C its final pressure is 12 bar. Calculate Q, W, ΔU and ΔH for the process. Take $C_p = \frac{7}{2}R$ (5,5)

3a). What is the principle of Claude process for air liquefaction? With the help of a diagram explain the process.

b). What is the function of analyzer and rectifier in vapor absorption refrigeration? (8,2)

4a). A reversible heat engine operates between hot reservoir at a temperature of 600 °C and cold reservoir at a temperature of 40 °C. The engine drives a reversible refrigerator which operates

Contd.....P/2

between reservoir temperatures of 40 and -20 °C. The heat transfer to the heat engine is 2000 kJ and the net work output of the combined engine refrigerator plant is 360 kJ. Calculate the heat transfer to the refrigerant and the net heat transfer to the reservoir at 40°C.

b). Ammonia is synthesized according to the reaction: $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$ The standard heat of reaction at 25 °C is -46,100 J/mol. The specific heats (J/mol K) are given below. Calculate the standard heat of reaction at 700 °C.

$C_p(NH_3) = 29.75 + 25.11 \times 10^{-3} T$

$C_p(N_2) = 27.27 + 4.93 \times 10^{-3} T$

$C_p(H_2) = 27.01 + 3.51 \times 10^{-3} T$ (5,5)

SECTION-B

5 Binary system acetonitrile (1) and nitromethane (2) conforms closely to Raoult's law. Vapor pressure for the pure species are given by the following Antoine equations:

$$lnP_1^{sat}\ (kPa) = 14.2724 - \frac{2945.47}{T\ (K) - 49.15}$$

$$lnP_2^{sat}\ (kPa) = 14.2043 - \frac{2972.64}{T\ (K) - 64.15}$$

Calculate (a) x_1 and y_1 at 75°C and 66 kPa (b) P and x_1 at 75°C and y_1=0.4 (c) P and y_1 at 75°C and x_1=0.4 (10)

6a). Define Chemical potential. What is its significance?

b). The enthalpy of a binary liquid system of species 1 and 2 at fixed T and P is represented by the equation $H = 400x_1 + 600x_2 + x_1x_2(40x_1 + 20x_2)$ where H is in J/mol. Determine

(1) the expressions for $\overline{H_1}$ and $\overline{H_2}$ as function of mole fraction x_1

(2) numerical values for the pure species enthalpies H1 and H2

(3) partial enthalpies at infinite dilution $\overline{H_1^{\infty}}$ and $\overline{H_2^{\infty}}$ (4,6)

7a) Write a note on Microbial heat generation.

b) Acetic acid is esterified in the liquid phase with ethanol at 100 °C and atmospheric pressure to produce ethyl acetate and water according to the reaction

$$CH_3COOH\ (l) + C_2H_5OH\ (l) \rightarrow CH_3COOC_2H_5(l) + H_2O\ (l)$$

If initially there is 1 mol each of acetic acid and ethanol, estimate the mole fraction of ethyl acetate in the reaction mixture at equilibrium.

Given $\Delta H^o_{298} = -3640\ J$ and $\Delta G^o_{298} = -4650\ J$ (4,6)

x-x-x