Exam.Code:0908
Sub. Code: 6302

2014

B.E. (Biotechnology) Fourth Semester

BIO-412: Thermodynamics

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

NOTE: Attempt <u>five</u> questions in all, including Question No. I which is compulsory and selecting two questions from each Section.

x-x-x

Q.1.a) In an adiabatic process, a gas releases 900 J of heat while doing 600 J of work. Determine the change in internal energy for this process.

b) Define the Joule Thomson effect.

c) If a substance has a high specific heat capacity, how does it affect its response to temperature changes when compared to a substance with a low specific heat capacity?

d) The molar composition of a solution is 60% benzene and 40% toluene. The vapor pressure of pure benzene is 100 mmHg while that of toluene is 50 mmHg. Calculate the vapor pressure of the solution using Raoult's Law.

e) A gas sample occupies a volume of 2.5 L at a temperature of 300 K and a pressure of 3.0 atm. Calculate the number of moles of gas in the sample using the ideal gas law.

f) In an adiabatic expansion, if a gas does work on its surroundings, what happens to its internal energy?

g) The fugacity coefficient value tends to approach unity as the pressure approaches _________

h) Which refrigerant property is responsible for the phase change from vapor to liquid in the condenser?

i) 400 J of heat is supplied to a heat engine, it performs 250 J of work. Determine its thermal efficiency.

j) Explain the significance of the critical point in the context of Vapor-Liquid Equilibrium.

(1×10)=10

SECTION-A

Q.2a). An enclosed container holds 1.5 kmol of gaseous nitrogen at a constant temperature of 400 K. Using the van der Waals equation of state, calculate the pressure within the container. The van der Waals constants for Nitrogen are given: $a = 1.39\ Nm^4/mol^2$ and $b = 3.97 \times 10^{-5}\ m^3/mol$

b). A factory mixes 2.5 kg/s of cold water at 18°C with 1.8 kg/s of hot water at 80°C to create a combined stream. During this process, 40 kJ/s of heat is lost to the surroundings. Given the specific heat of water as 4.18 kJ/kg K, determine the temperature of the resulting warm water stream. (5,5)

Q.3a). An ideal gas initially at 300 K and 1 bar pressure 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 the process. Take $Cp = \frac{7}{2}R$ and $Cv = \frac{5}{2}R$

b). Calculate the standard heat of the reaction at 25°C for the following reaction:
$4HCl(g) + O_2(g) \rightarrow 2H_2O(g) + 2Cl_2(g)$. The standard heats of formation at 298.15 K are $HCl(g)$: − 92,307 J/mol and $H_2O(g)$: −241,818 J/mol. (7+3)

P.T.O.

Q.4a). With the help of a diagram explain the Linde Hampson process for air liquefaction.

b). An industrial unit integrates a heat engine and a heat pump to facilitate water heating. The heat engine operates with an efficiency of 30%, while the heat pump has a coefficient of performance (COP) of 5. Determine the ratio of the heat transferred to the circulating water for heating purposes to the heat transferred to the heat engine. (5+5)

SECTION-B

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

$lnP_1^s(kPa) = 14.2724 - \frac{2945.47}{T(°C)-224}$ $\qquad$ $lnP_2^s(kPa) = 14.2043 - \frac{2972.64}{T(°C)-209}$

Calculate (a) P and y_1 at 75°C and x_1=0.6 (b) x_1 and y_1 at 75°C and P = 62 kPa (c) P and x_1 at 75°C and y_1= 0.4 (10)

Q.6a). Briefly explain the factors that influence heat generation in microbial cultures during metabolic processes.

b). The equilibrium constant for the reaction 2A+B $\rightleftharpoons$ 3C, at 300 K is 2.5×10^{-2}. The reaction is known to be endothermic with an enthalpy change of +50 kJ/mol. Calculate the new equilibrium constant if the temperature is increased to 400 K. (5+5)

Q.7. The following reaction reaches equilibrium at 500°C and 2 bar pressure:

$$4HCl(g) + O_2(g) \rightarrow 2H_2O\ (g) + 2Cl_2\ (g)$$

If the system initially contains 5 mol HCl for each mole of oxygen, what is the composition of the system at equilibrium? Assume ideal gases. Given $\Delta H_{rxn_{298}} = -114408\ J/mol$, $\Delta G_{rxn_{298}} = -75948\ J/mol.$ (T in °K)

HCl : $C_p/R = 3.156 + 0.623 \times 10^{-3}T + 0.151 \times 10^5 T^{-2}$

O_2 : $C_p/R = 3.639 + 0.506 \times 10^{-3}T - 0.227 \times 10^5 T^{-2}$

H_2O : $C_p/R = 3.470 + 1.450 \times 10^{-3}T + 0.121 \times 10^5 T^{-2}$

Cl_2 : $C_p/R = 4.442 + 0.089 \times 10^{-3}T - 0.334 \times 10^5 T^{-2}$ (10)

x-x-x