

2014

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

Time allowed: 3 Hours

Max. Marks: 50

NOTE: Attempt five questions in all, including Question No. 1 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: $a = 1.39 \text{ Nm}^4/\text{mol}^2$ and $b = 3.97 \times 10^{-5} \text{ m}^3/\text{mol}$
- 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 $C_p = \frac{7}{2}R$ and $C_v = \frac{5}{2}R$
- b). Calculate the standard heat of the reaction at 25°C for the following reaction:
 $4\text{HCl(g)} + \text{O}_2(\text{g}) \rightarrow 2\text{H}_2\text{O(g)} + 2\text{Cl}_2(\text{g})$. The standard heats of formation at 298.15 K are
 $\text{HCl(g)} : -92,307 \text{ J/mol}$ and $\text{H}_2\text{O(g)} : -241,818 \text{ J/mol}$. (7+3)

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(2)

- 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

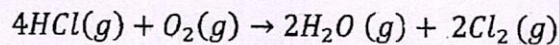
- Q.5. Binary system of acetonitrile (1) and nitromethane (2) conforms closely to Raoult's law. Vapor pressures for the pure species are given by the following Antoine equations

$$\ln P_1^s (\text{kPa}) = 14.2724 - \frac{2945.47}{T(^{\circ}\text{C}) - 224} \quad \ln P_2^s (\text{kPa}) = 14.2043 - \frac{2972.64}{T(^{\circ}\text{C}) - 209}$$

Calculate (a) P and y_1 at 75°C and $x_1=0.6$ (b) x_1 and y_1 at 75°C and $P = 62 \text{ kPa}$ (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 $+50 \text{ kJ/mol}$. 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:



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 $\Delta H_{rxn,298} = -114408 \text{ J/mol}$, $\Delta G_{rxn,298} = -75948 \text{ J/mol}$. (T in $^{\circ}\text{K}$)

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

$$\text{O}_2 : C_p/R = 3.639 + 0.506 \times 10^{-3}T - 0.227 \times 10^5 T^{-2}$$

$$\text{H}_2\text{O} : C_p/R = 3.470 + 1.450 \times 10^{-3}T + 0.121 \times 10^5 T^{-2}$$

$$\text{Cl}_2 : C_p/R = 4.442 + 0.089 \times 10^{-3}T - 0.334 \times 10^5 T^{-2} \quad (10)$$

x-x-x