CHEMICAL AND BIOCHEMICAL ENGINEERING THERMODYNAMICS (BIO 2251)

Type: DES

Q1. Construct ideal gas thermometer and show the minimum possible temperature it can reach with proper scientific explanation (2)

Q2. A rigid, nonconducting tank with a volume of 4 m^3 is divided into two unequal parts by a thin membrane. One side of the membrane, representing 1/3 of the tank, contains Nitrogen gas at *6* bar and 373.15 K and the other side, representing 2/3 of the tank, is evacuated (vacuumed). The membrane ruptures and the gas fills the tank.

(a) What is the final temperature of the gas? How much work is done? Is the process Reversible?

(b) Describe a reversible process by which the gas can be returned to its initial state. How much work is done?

Assume nitrogen is an ideal gas for which $C_P = (7/2)\,R$ and $C_V = (5/2)\,R$. (3)

Q3. An ideal gas, Cp = (5/2) R and Cv = (3/2) R, is changed from P = 1 bar and $V_1 = 12$ m^3 to $P_2 = 12$ bar and $V_2 = 1$ m^3 by the following mechanically reversible processes:

(a) Isothermal compression.

(b) Adiabatic compression followed by cooling at constant pressure.

(c) Adiabatic compression followed by cooling at constant volume.

(d) Heating at constant volume followed by cooling at constant pressure.

(e) Cooling at constant pressure followed by heating at constant volume.

Calculate Q, W, **ΔU,** and ΔH for each of these processes, and sketch the paths of all Processes on a single P **V** diagram. (5)

Q4. Why Gibb's free energy calculation is very important in Biological thermodynamics and how it is derived? (2)

Q5. MIT students went to see Shimla during December holidays, the Temperature was very cold outside (4^O C), but they were in a hotel which maintains the temperature of 24^O C all the time. They bought 10 liter container of drinking water from a local grocery shop, which was kept overnight outside without heater. Students brought the container inside and they realized it is cold to drink and they kept it in hotel room to reach it to room temperature. Calculate the entropy change of water in the container, the entropy changes of the surroundings and the entropy change of the universe. Neglect the heat capacity of container and take heat capacity of water as 4.18 J/g.K. (4)

Q6. A 50 kg steel casting (C_P = 0.5 KJ/Kg. K) at a temperature of 400°C is quenched in 200 kg of oil (C_P = 2.5 KJ/Kg.K) at 25°C. If there are no heat losses, what is the change in entropy of (a) the casting (b) the oil and (c) both considered together? (4)

Q7. Elucidate the difference between partial molar property and Chemical potential. Explain when both of them will become same. (2)

Q8. During the extraction of compounds from natural source, a new molecule was identified. Near its triple point it is found that the vapor pressure over the liquid (P_l^{sat}) and over the solid (P_S^{sat}) are given by

$\ln P_l^{sat} = -3{,}010/T + 13.2$ and $\ln P_S^{sat} = -3{,}820/T + 16.1$ the data given: Temperature in K and vapor pressure in bar

- Calculate the triple point temperature T_{tp} and pressure P_{tp} of the new molecule
- Is the new molecule a solid, liquid or a gas at (1 bar, 298 K)
- What is ΔH_{subl} ? (approximate) (4)

Q9. A Company was started in Manipal to produce carbonated drink called Biopop. Assuming that carbonated drink contains only CO_2 and water, determine the compositions of the vapor and liquid phases in sealed can of Biopop and the pressure exerted on the can at room temperature (25°C) and at the refrigerated temperature (4°C). The Henry's constant for CO_2 in water at 25°C is 1250 bar and at 4°C is 920 bar. One of the main criteria for carbonated drink is the pH; it should be 2.5. To get the pH 2.5, the mole fraction of CO_2 in liquid phase should be around 0.02. vapor pressure of water at 25^0 C and 4^0 C are 0.03166 and 0.00813 bar respectively. (4)

Q10. A vessel divided into two parts by a partition, contains 4 mol of nitrogen gas at 75^0C and 40 bar on one side and 2.5 mol of argon gas at 130^0C and 20 bar on the other. If the partition is removed and the gases mix adiabatically and completely, what is the change in entropy? Assume nitrogen to be an ideal gas with $C_V = (5/2)R$ and argon to be an ideal gas with $C_V = (3/2)R$. Molecular weight of Nitrogen = 28 and atomic weight of argon = 40. (3)

Q11. Consider the reaction for the production of methanol from CO and H_2

$$CO\ (g) + 2H_2\ (g) = CH_3OH\ (g)$$

The value of K at 500 K is 6.23×10^{-3}.

a. A gas stream containing equimolar amounts of CO and H_2 is passed over a catalyst at 1 bar. What is the extent of reaction at equilibrium?

b. To obtain a more complete reaction the pressure is raised to 100 bar and 2 mol of hydrogen is used per mole of CO. What is the equilibrium extent of reaction?

c. If the reactant gases contain a mole of nitrogen in addition to 1 mol of CO and 2 mol of hydrogen, what is the equilibrium extent of reaction at 100 bar? (5)

Q12. A system initially containing 2 mol C_2H_4 and 3 mol O_2 and 1 mol of CO_2 undergoes the reactions:

$C_2H_4(g) + \frac{1}{2} O_2(g) \rightarrow ((CH_2)_2)O\ (g)$

$C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O\ (g)$

Develop expressions for the mole fractions of each species in the reaction mixture as the functions of the reaction coordinates of the two reactions. (2)

Q13. How living cells uses two tricks and modifies energetically unfavorable reaction to a favorable reaction in any biochemical pathways? Explain. (3)

Q14. Assuming as ideal solution, derive expression for osmotic pressure in semipermeable membrane. (4)

Q15. It is desired to measure the osmotic pressure *to* determine the molecular weight of the unknown protein. 1.93 g of the protein is dissolved to make 520 cm^3 of aqueous solution at 25°C, the height of the dilute solution rises 0.71 cm above the pure solvent. Determine the osmotic pressure and the molecular weight. Assume density of solution similar to water as 1000 kg/m^3 at 25° C. (3)