T.E. - VI - Sem. Biotechnology 01/12/15

2/15 Thermodynamics & Biochemical Engineering TE/VI/CBGS/BT/TBE

Q.P. Code : 5671

(3 Hours) 22 [Total Marks : 80

Note:

1. Question No. 1 is compulsory.
2. Attempt any three questions out of remaining five questions.
3. Assume suitable data wherever necessary.
4. Figures to right indicate full marks.

Q.1 Write short notes on: (Any four) 20

a. General statements of second law of thermodynamics
b. Show that $C_p - C_v = R$ for an ideal gas.
c. Derive fundamental property relations.
d. Explain how fugacity of a pure gas is calculated using compressibility factor.
e. The coefficient of compressibility & β of mercury at 273 K and 1 bar are 3.9×10^{-6} bar^{-1} and 1.8×10^{-4} K^{-1} respectively. Calculate C_v of mercury given that $C_p = 0.14$ kJ/KgK.
Density (ρ) = 13.596×10^3 Kg/m^3

Q.2 a. Explain the following: 10

(i) Phase rule
(ii) Intensive & extensive properties
(iii) Open, closed & isolated system
(iv) Path & state function
(v) Homogenous & heterogeneous system

b. Find the second and third virial coefficient of Van der Waal's equation when expressed in form $Z = PV/RT = 1 + B/V + C/V^2 + D/V^3$ 10

Q.3 a. Water at 368 K is pumped from a storage tank at the rate of $25 m^3/hr$. The motor for the pump supplies work at a rate of 2 hp. The water passes through a heat exchanger where it gives up heat at the rate of 42000 kJ/min and is delivered to a second storage tank at an elevation of 20 m above the first tank. What is the temperature of water delivered to the second storage tank? Assume that enthalpy of water is zero at 273 K and specific heat of water is constant at 42 kJ/KgK. 10

b. The fugacity of component 1 in a binary liquid mixture at 298 K & 20 bar is: 5

$$\overline{f}_1 = 50x_1 - 80x_1^2 + 40x_1^3$$

where $\overline{f}_1$ is in bar and x_1 is mole fraction of component 1. Determine:

(i) fugacity of pure component 1
(ii) fugacity coefficient of pure component 1
(iii) Henry's law constant
(iv) Activity coefficient.

c. A gas mixture containing 3 mol CO_2, 5 mol H_2 and 1 mol water is undergoing the following reactions: 5

(i) $CO_2 + 3H_2 \rightarrow CH_3OH + H_2O$
(ii) $CO_2 + H_2 \rightarrow CO + H_2O$

Develop expressions for the mole fractions of the species in terms of the extent of reactions.

[P.T.O]

MD-Con. 9300-15.

Q.4 a. Derive expression for phase equilibrium in a single component system. 8

b. Write a note on thermodynamic diagrams. 12

Q.5 a. The azeotrope of ethanol-benzene system has a composition of 44.8% (mol) ethanol with a boiling point of 341.4 K at 101.3 kPa. At this temperature, the vapour pressure of benzene is 68.9 kPa and the vapour pressure of ethanol is 67.4 kPa. What are the activity coefficients in a solution containing 10% alcohol? 10

b. What is the criterion for chemical reaction equilibrium? Derive relationship between equilibrium constant & standard free energy change. 10

Q.6 a. Derive expression for Lewis-Randall rule. Under which conditions is it valid? 10

b. Derive Gibbs-Helmholtz equation. 5

c. Using Redlich-Kwong equation calculate the pressure of 0.5 Kg gaseous ammonia contained in a vessel of $0.03m^3$ at constant temperature of 338 K. The critical temperature and pressure is 405.5 K & 112.8 bar respectively. 5