Question Paper

Exam Date & Time: 18-Nov-2019 (02:00 PM - 05:00 PM)

MANIPAL ACADEMY OF HIGHER EDUCATION

INTERNATIONAL CENTRE FOR APPLIED SCIENCES
End semester theory examination NOVEMBER -2019
III SEMESTER B.Sc. (Applied Sciences) in Engg
CHEMICAL ENGG. THERMODYNAMICS-II [ICHM 232 - S2]

Marks: 100 **Duration: 180 mins.**

Answer 5 out of 8 questions.

1) A) The partial molar volume of methanol in a methanol - water solution at X_1 = 0.3881 is 39.176 cm^3/mol. The density of the mixture is 905.376 kg/m^3. Determine the partial molar volume of water? (8)

B) On addition of chloroform to acetone at 298 K, the volume of mixture varies with composition as follows: (12)

Mol fraction of $CHCl_3$, x_1	0	0.194	0.385	0.559	0.788	0.889	1
V x 10^3, m^3/mol	77	76.5	76.75	77.55	79.08	79.82	80.67

Determine the partial molar volume of both components at a mole fraction x_1=0.44.

2) A) 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: (12)

$CH_3COOH + C_2H_5OH \rightarrow CH_3COOC_2H_5 + H_2O$

The standard heat of formation and standard free energy of formation are - 3640 J and - 4650 J respectively. If initially there is 1 mol of each of acetic acid and ethanol, estimate the mole fraction of ethyl acetate in the reacting mixture at equilibrium.

B) Consider a vessel which initially contains only n_0 mol of water vapor. If decomposition occurs according to the reaction, (8)

$$H_2O \rightarrow H_2 + \frac{1}{2}O_2$$

find expressions which relate the number of moles and the mole fraction of each chemical species to the reaction coordinate ϵ.

3) A) The gas phase oxidation of SO_2 to SO_3 is carried out at a pressure of 1 bar and temperature of 855 K with 20% excess air in an (18)

adiabatic reactor. Determine the equilibrium composition.

$$SO_2 + \frac{1}{2}O_2 \rightarrow SO_3 \qquad \Delta H^o_{298} = -98890\ J \qquad \Delta G^o_{298} = -70866\ J$$

B) What is the significance of reaction coordinate? (2)

4) At 200K, the compressibility factor pf oxygen varies with pressure as given below (15)

A)

P, bar	1	4	7	10	40	70	100
Z	0.99701	0.98796	0.9788	0.96956	0.8734	0.7764	0.6871

Evaluate the fugacity of oxygen at this temperature and 100 bar.

B) The density of gaseous ammonia at 473 K and 50 bar is 24.3 kg/m^3. Estimate its fugacity. (5)

5) The molar volume of a binary liquid system of species 1 and 2 at fixed T and P is: (10)

A)

$$V(cm^3/mol) = 500\,x_1 + 1000\,x_2 + x_1x_2(50\,x_1 + 40x_2)$$

Determine expressions for $\overline{V_1}$ and $\overline{V_2}$ as functions of x_2.

B) The molar volume of a binary liquid system of species 1 and 2 at fixed T and P is: (10)

$$V(cm^3/mol) = 500\,x_1 + 1000\,x_2 + x_1x_2(50\,x_1 + 40\,x_2)$$

Determine numerical values for the pure-species enthalpies V_1 and V_2, and numerical values for the partial enthalpies at infinite dilution $\overline{V_1}^{\infty}$ and $\overline{V_2}^{\infty}$

6) Determine the fugacity and fugacity coefficient of steam at 623 K and 1000 kPa using enthalpy and entropy values from steam tables. Assume that steam behaves ideally at 101.3 kPa. (10)

A)

Data: At 1000 kPa and 623 K, H = 3159 kJ/kg; S = 7.3 kJ/kg K. At 101.3 kPa and 623 K, H = 3176 kJ/kg; S = 8.38 kJ/kg K.

B) Do the following equations satisfy Gibbs-Duhem equations? (10)

$$\ln\gamma_1 = Ax_2^2 + Bx_2^2(3x_1 - x_2)$$
$$\ln\gamma_2 = Ax_1^2 + Bx_1^2(x_1 - 3x_2)$$

7) A) n-Heptane and toluene form ideal solution. At 373 K, their vapour pressures are 106 and 74 kPa respectively. Determine the composition of the liquid and vapour in equilibrium at 373 K and 101.3 kPa. (5)

B) Benzene & Toluene form an ideal solution. The vapour pressure of both components are given by (15)

$$logP^s = A - \frac{B}{T + C}$$

	A	B	C
Benzene (1)	6.87987	1196.760	219.161
Toluene (2)	6.95087	1342.310	219.187

Draw P-x-y diagram at 95°C.

8) A) The following data were reported for vapour-liquid equilibrium for ethanol-water system at 298 K: (18)

x_1	0.122	0.163	0.226	0.32	0.337	0.437	0.44	0.579	0.83
y_1	0.474	0.531	0.562	0.582	0.589	0.62	0.619	0.685	0.849
P, kPa	5.57	6.02	6.38	6.76	6.8	7.02	7.04	7.3	7.78

The vapor pressures of ethanol and water are 7.86kPa and 3.17 kPa respectively. Calculate the van Laar constants.

$$\ln \gamma_1 = \frac{Ax_2^2}{\left[\left(\frac{A}{B}\right)x_1 + x_2\right]^2}$$

$$\ln \gamma_2 = \frac{Bx_1^2}{\left[\left(\frac{B}{A}\right)x_2 + x_1\right]^2}$$

$$A = \ln \gamma_1 \left(1 + \frac{x_2 \ln \gamma_2}{x_1 \ln \gamma_1}\right)^2$$

$$B = \ln \gamma_2 \left(1 + \frac{x_1 \ln \gamma_1}{x_2 \ln \gamma_2}\right)^2$$

B) Define activity coefficient. (2)

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