Question Paper

Exam Date & Time: 16-Nov-2018 (02:00 PM - 05:00 PM)

MANIPAL ACADEMY OF HIGHER EDUCATION

INTERNATIONAL CENTRE FOR APPLIED SCIENCES
END SEMESTER EXAMINATION
CHEMICAL ENGINEERING THERMODYNAMICS - II

CHEMICAL ENGG. THERMODYNAMICS-II [ICHM 232 - S2]

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

Answer 5 out of 8 questions.

1) (10)

A) Mercury has a density of 13.69 x 103 kg/m^3 in the liquid state and 14.193 x 10^3 kg/m^3 in the solid state, both measured at the melting point of 234.33 K at 1 bar. If the heat of fusion of mercury is 9.7876 kJ/kg, what is the melting point of mercury at 10 bar?

B) For the vaporization of water, derive the Clausius - Clapeyron equation (10)

2) (10)

A) The standard heat of formation and standard free energy of formation of ammonia at 298 K are - 46,100 J/mol and - 16,500 J/mol respectively. Calculate the equilibrium constant for the reaction

$$N_2 + 3\ H_2 \text{ --> } 2\ NH_3$$

At 500 K assuming that the standard heat of reaction is constant in the temperature range 298 K to 500 K.

B) Consider a system in which the following reactions occur (10)

$$CH_4 + H_2O \text{ --> } CO + 3\ H_2 \qquad (1)$$

$$CH_4 + 2\ H_2O \text{ --> } CO_2 + 4\ H_2 \qquad (2)$$

where the numbers (1) and (2) indicate the value of j, the reaction index. If 2 mol CH_4 and 3 mol H_2O are present initially, determine expressions for the y_i as functions of ϵ_1 and ϵ_2.

3) (10)

A) Calculate standard heat of reaction and free energy change at 37Â°C for the following reaction, if the equilibrium constant is 5.3 fold higher than standard state equilibrium constant

$ATP + H2O \Leftrightarrow ADP + P_i + H^+ \qquad (\Delta G^\circ = -30.5\ kJ/mol)$

B) In a laboratory investigation, acetylene is catalytically hydrogenated to ethylene at 1120Â°C and 1 bar. If the feed is an equilmolar mixture of acetylene and hydrogen, what is the (10)

composition of the product stream at equilibrium?

$$C_2H_2 \rightarrow 2C + H_2 \quad K_1 = (4 \times 10^5)$$

$$2C + 2H_2 \rightarrow C_2H_4 \quad K_2 = (2.5 \times 10^{-6})$$

4) For a closed system involving phase transition of a pure substance, prove that chemical potential of the substance in each phase is equal. (10)

A)

B) Derive an expression for the fugacity coefficient of a gas obeying the equation of state P(V-b)=RT and estimate the fugacity of ammonia at 10 bar and 298 K, given that b=3.707 x 10^{-5} m^3/mol. (10)

5) The enthalpy of a binary liquid system of species 1 and 2 at fixed T and P is: (20)

$$H = 400x_1 + 600x_2 + x_1x_2(40x_1 + 20x_2)$$

Determine expressions for $\overline{H_1}$ and $\overline{H_2}$ as functions of x_1,

numerical values for the pure-species enthalpies H_1 and H_2, and numerical values for the partial enthalpies at infinite dilution $\overline{H_1^\infty}$ and $\overline{H_2^\infty}$

6) Prove that if Henry's law is obeyed by component 1 in binary solution over certain concentration range, Lewis-Randall rule will be obeyed by component 2 over same concentration range. (10)

A)

B) The partial pressures of acetone (A) and chloroform (B) were measured at 298 K and are reported below: (10)

x_A	0	0.2	0.4	0.6	0.8	1.0
$\overline{p_A}$, bar	0	0.049	0.134	0.243	0.355	0.457
$\overline{p_B}$, bar	0.386	0.288	0.187	0.108	0.046	0

Calculate the activity and activity coefficient of chloroform in acetone at 298 K
(i) Based on the standard state as per Lewis-Randall rule.
(ii) Based on Henry's law

7) Derive an expression for the fugacity coefficient of a gas obeying the following equation of state. (10)

A)

$$Z = a + bP + cP^2$$

Where a, b and c are empirical constants and P is in bar
Determine the fugacity of oxygen at 293 K and 100 bar.
Data: a = 1.0; b = - 0.753 x 10^{-3}; c = 0.15 x 10^{-5}.

B) Benzene & Toluene form an ideal solution. The vapour pressure of both components are given by (10)

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

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

Draw T-x-y (Boiling point) and x-y (Equilibrium) diagram at 760 Torr.

8) Water (1)-hydrazine (2) system forms an azeotrope containing 58.5% (mol) hydrazine at 393 K and 101.3 kPa. Calculate the equilibrium vapour composition for a solution containing 20% (mol) hydrazine. The relative volatility of water with reference to hydrazine is 1.6 and may be assumed to remain constant in the temperature range involved. The vapour pressure of hydrazine at 393 K is 124.76 kPa. (20)

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