

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]

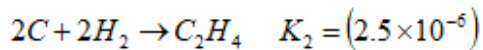
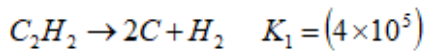
Marks: 100

Duration: 180 mins.

Answer 5 out of 8 questions.

- 1) Mercury has a density of $13.69 \times 10^3 \text{ kg/m}^3$ in the liquid state (10)
A) and $14.193 \times 10^3 \text{ kg/m}^3$ 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) 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 (10)
A)
- $$\text{N}_2 + 3 \text{H}_2 \rightarrow 2 \text{NH}_3$$
- 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)
- $$\text{CH}_4 + \text{H}_2\text{O} \rightarrow \text{CO} + 3 \text{H}_2 \quad (1)$$
- $$\text{CH}_4 + 2 \text{H}_2\text{O} \rightarrow \text{CO}_2 + 4 \text{H}_2 \quad (2)$$
- 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_j as functions of ϵ_1 and ϵ_2 .
- 3) Calculate standard heat of reaction and free energy change at 37°C for the following reaction, if the equilibrium constant is 5.3 fold higher than standard state equilibrium constant (10)
A)
- $$\text{ATP} + \text{H}_2\text{O} \rightleftharpoons \text{ADP} + \text{P}_i + \text{H}^+ \quad (\Delta G^\circ = - 30.5 \text{ kJ/mol})$$
- B) In a laboratory investigation, acetylene is catalytically hydrogenated to ethylene at 1120°C and 1 bar. If the feed is an equimolar mixture of acetylene and hydrogen, what is the (10)

composition of the product stream at equilibrium?



- 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 $b=3.707 \times 10^{-5} \text{ m}^3/\text{mol}$. (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 H_1^∞ and H_2^∞

- 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: $a = 1.0$; $b = -0.753 \times 10^{-3}$; $c = 0.15 \times 10^{-5}$.

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

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

	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 (20)
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.

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