B. Tech.

(SEM. VI) EXAMINATION, 2006-07

CHEMICAL ENGINEERING THERMODYNAMICS

Time : 3 Hours] [Total Marks : 100

Note : (1) Attempt all questions.
(2) All questions carry equal marks.
(3) Steam table is permitted.
(4) In case of numerical problems assume data wherever not provided.
(5) Be precise in your answer.

1. Attempt any two parts of the following : 10×2=20

(a) Fifty (50) kmol per hour of air is compressed from \( P_1 = 1.2 \) bar to \( P_2 = 6.0 \) bar in a steady flow compressor. Delivered mechanical power is 98.8 kW. Temperature and velocities are:

\[
T_1 = 300 \text{ K} \quad T_2 = 520 \text{ K} \\
U_1 = 10 \text{ms}^{-1} \quad U_2 = 3.5 \text{ ms}^{-1}
\]

Estimate the rate of heat transfer from the compressor. Assume for air \( C_p = \frac{7}{2}R \) and that enthalpy is independent of pressure.
(b) In a steady-state flow process 1 mol S$^{-1}$ of air at 600 K and 1 atm is continuously mixed with 2 mol S$^{-1}$ of air at 450 K and 1 atm. The product stream is at 400 K and 1 atm. Determining the rate of heat transfer and the rate of entropy generation for the process. Assume that air is an ideal gas with $C_p = 7/2\ R$. That the surroundings are at 300 K and that kinetic and potential energy charges are negligible.

(c) Derive relation for calculation of ideal work in a steady state flow process. What is lost work?

2. Attempt any two parts of the following: $10 \times 2 = 20$

(a) Calculate the fugacity of C ammonia at $t = 200^\circ C$ and $P = 100$ atm if we have:

<table>
<thead>
<tr>
<th>$P$, atm</th>
<th>$V_0$, cm$^3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>1866</td>
</tr>
<tr>
<td>60</td>
<td>570.8</td>
</tr>
<tr>
<td>100</td>
<td>310.9</td>
</tr>
<tr>
<td>150</td>
<td>176.7</td>
</tr>
</tbody>
</table>

(b) Derive following relations:

(i) $dH = C_p dT + \left[ V - T \left( \frac{\partial V}{\partial T} \right)_p \right] dP$

(ii) $\frac{G^R}{RT} = \int_0^P (z - 1) \frac{dP}{p}$

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(c) Reported values for the virial co-efficients of Isopropanol vapour at 200°C are:

\[ B = -388 \text{ cm}^3 \text{ mol}^{-1} \]
\[ C = -26,000 \text{ cm}^6 \text{ mol}^{-2} \]

Calculate \( V \) and \( Z \) for Isopropanol vapour at 200°C and 10 bar with the help of the virial equation truncated to three terms.

3. Attempt any four parts of the following: \( 5 \times 4 = 20 \)

(a) What is change in entropy when 0.7 m\(^3\) of CO\(_2\) and 0.3 m\(^3\) of N\(_2\) each at 1 bar and 25°C blend to form a gas mixture at the same condition? Assume ideal gases.

(b) Derive Cribbs Duhem equations.

(c) Derive fundamental property relation.

(d) Show that \( \mu_i^{ig} = G_i^{ig} + RT \ln y_i \)

(e) If \( \frac{G^E}{RT} = (-2.6 x_1 - 1.8 x_2) x_1 x_2 \)

Find expressions for \( \ln y_1 \) and \( \ln y_2 \).

(f) Show that multiple phases at the same T and P are in equilibrium when the chemical potential of each constituent species in the same in all phases.
4. Attempt any **four** parts of the following: \(5 \times 4 = 20\)
   
   (a) Define ideal solution. What is Lewis/Randall rule?
   
   (b) Derive Margules equation.
   
   (c) Define the critical point of a mixture. Show a portion of a PT diagram in the critical region.
   
   (d) Draw P-xy and T-xy diagram for azeotropic mixture.
   
   (e) Explain the characteristics of vapour / liquid / liquid equilibrium with help of a T-xy diagram.
   
   (f) Show T xy and P xy diagram for binary system of immiscible liquids.

5. Answer any **two** parts of the following: \(10 \times 2 = 20\)
   
   (a) Derive the following:
   
   \(\sum \gamma_i \mu_i = 0\)

   (ii) \(i \Delta G^0 = - \sum \Delta G_i^0\)

   (b) Develop relation for equilibrium constants for gas-phase reaction.

   (c) One kilo mol of Carbon at 25°C reacts with 2 kmol of oxygen at 25°C to form an equilibrium mixture of CO\(_2\), CO and O\(_2\) at 3000 K, 0.1 MPa pressure. Determine the equilibrium composition. Data: \(K = 0.1089\)