(3 Hours) **Total Marks: 80**

N.B.: 1. Question **No.1.**is**compulsory.**

2. Attempt any **three** questions out of the remaining **five** questions.

3. Assume **suitable** data wherever **required.**

4. **Figures** to the **right** indicates **full** marks.

1. a. Define fugacity coefficient and discuss its role to real and ideal gas mixtures. [5]

b. State Henry's law and show that the Raoult's law is a special case of the Henry's law. [5]

c. Discuss the Scatchard-Hildebrand theory [5]

d. Explain Lewis/Randall rule and its application [5]

2. a. The excess Gibbs free energy for the system chloroform (1) and ethanol (2) at 55ºC is well represented by $\frac{G^E}{RT} = (1.42x_1 + 0.59x_2)x_1x_2$. The vapour pressures of chloroform and ethanol at 55ºC are 82.37 and 37.31 kPa respectively. Calculate the total pressure and y_1 at 55ºC and at $x_1 = 0.25$. [12]

b. A stream of nitrogen flowing at the rate of 2 kg/s and a stream of hydrogen flowing at the rate of 0.5 kg/s mix adiabatically in a steady flow process. If the gases are assumed to be ideal, what is the rate of entropy increase as a result of the process? [8]

3. a. Develop a general equation to calculate $\ln \hat{\phi}_i$ values from compressibility-factor data. [8]

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 = m^3/mol [12]

4. a. The molar volume of binary liquid mixture is given by:

$$V = 9 \times 10^{-3}x_1 + 50 \times 10^{-3}x_2 + x_1x_2(6 \times 10^{-3}x_1 + 9 \times 10^{-3}x_2)$$

Obtain expression for $\overline{V}_1$ and $\overline{V}_2$ and show that they satisfy the Gibbs-Duhem equation. [12]

b. Distinguish between the bubble point and dew-point temperature. Why does the boiling point diagram at a higher pressure lie above that at a lower pressure? [8]

5. a. For real solution, express entropy change of mixing in terms of activity of the components in solution [5]

b. Explain quasi-chemical theory (UNIQUAC) of liquid mixtures to solutions containing molecules of different sizes. [7]

c. For a binary solution at constant temperature show that $\int_0^1 \ln \frac{\gamma_1}{\gamma_2} = 0$ [8]

6. Write short notes on any four: [20]
   a. Van Laar equation
   b. Flory-Huggins theory
   c. UNIFAC method
   d. Fugacity of pure liquid
   e. Maxwell relations.
