B.Tech.(Chemical Engineering) Fifth Semester (C.B.S.)

Chemical Engineering Thermodynamics

P. Pages : 2 **NRT/KS/19/3785**

Time : Three Hours * 0 0 5 9 * Max. Marks : 80

Notes : 1. All questions carry marks as indicated.
2. Solve **any five** questions.
3. Due credit will be given to neatness and adequate dimensions.
4. Assume suitable data whenever necessary.
5. Diagrams and chemical equations should be given whenever necessary.
6. Illustrate your answers whenever necessary with the help of neat sketches.
7. Use of non programmable calculator is permitted.

1. a) Determine the equation of state parameters for Van der Waal equation of state. Also discuss the equation of state parameters for cubic equation of state. **10**

b) Calculate the reversible work done in compressing $0.0283 m^3$ of mercury at a constant temperature of 273.15 K from 1 atm to 3000 atm. The isothermal compressibility of mercury at 273.15K is **6**

$$K = 3.9 \times 10^{-6} - 0.1 \times 10^{-9} P$$

where P is in atm and K is in atm^{-1}.

2. a) Discuss multistage compression in comparison with single stage compression. Derive the equation for work required for both the cases. **8**

b) Carbon dioxide at 1 bar and 300K is to be compressed to a pressure of 10 bar in a single stage compressor at a rate of $100 m^3/h$. Assuming that CO_2 behaves is an ideal gas, calculate the temperature of the gas after compression and the work required Take $r = 1.3$. **8**

3. a) A heat pump is used for heating the inside of a building in the winter and for air conditioning in the summer. The average winter temperatures are 278K outside and 293K inside. The average summer temperatures are 303K outside and 299K inside. A 5K approach is allowed in all cases. Determine the work required in both cases as a function of heat input assuming ideal cycle. **8**

b) Write note on absorption - Refrigeration cycle. Derive the equations involved in it. **8**

4. a) Derive the equations for partial properties in binary solutions. Discuss the graphical interpretations. **8**

b) A 298.15K and atmospheric pressures the volume change of mixing of binary liquid mixtures of species 1 and 2 is given by the equation $\Delta V = x_1 x_2 (45x_1 + 25x_2)$. **8**

where ΔV is in cm^3/mol. At these conditions $V_1 = 110$ and $V_2 = 90 cm^3/mol$.

Determine the partial molar volumes $\overline{V}_1$ and $\overline{V}_2$ in the mixture containing 40 mol% of species 1 at the given conditions.

5. a) For the system methanol (1) / methyl acetate (2), the following equation provide a reasonable correlation for the activity coefficients. **12**

$$\ln r_1 = A x_2^2$$

$$\ln r_2 = A x_1^2$$

where $A = 2.771 - 0.00523T$

In addition, the following Antonies equation provide vapour pressures.

$$\ln P_1^{sat} = 16.59158 - \frac{3643.31}{T - 33.424}$$

$$\ln P_2^{sat} = 14.25326 - \frac{2665.54}{T - 53.424}$$

where T is in Kelvins and the vapor pressure are in kPa. Assuming the validity of modified Raults law, Calculate

i) P and (y_i) for $T = 318.15K$ and $x_i = 0.70$

ii) P and (x_i) for $T = 318.15K$ and $y_i = 0.15$

iii) T and (y_i) for $P = 101.33kPa$ and $x_1 = 0.2$

iv) T and (x_i) for $P = 101.33kPa$ and $y_1 = 0.65$

v) The azeotropic pressure and azeotropic composition, for $T = 318.15K$.

b) Write a note on equilibrium and stability in phase equilibria. **4**

6. a) The following reaction reaches equilibrium at 500°C and 2 bar : **8**

$$4HCl_{(g)} + O_{2(g)} \rightarrow 2H_2O_{(g)} + 2Cl_{2(g)}$$

If system initially contains 5 mol HCl for each mole of oxygen, what is the composition of the system at equilibrium? Assume ideal gases.

	ΔH^o_{248}	ΔG^o_{298}
HCl	–92307	–95299
H_2O	–241818	–228572

b) Discuss the effect of temperature on equilibrium constant and derive the equation for equilibrium constant for following cases **8**

i) ΔH^o = constant

ii) ΔH^o dependent on temperature.

7. a) Explain PVT behavior of pure substances and define volume expansivity and isothermal compressibility. **8**

b) Derive Maxwell's relations. Also explain the significance of Maxwell's equations. **8**

8. a) Explain Gibb's theorem and derive **8**

$$S^{ig} = \sum_i y_i S_i^{ig} - R \sum_i y_i \ln y_i$$

b) At 300 K and 1 bar, the volumetric data for a liquid mixture of benzene and cyclohexane are represented by **8**

$$V = 1.09 \times 10^{-6} - 16.8 \times 10^{-6} x - 2.64 \times 10^{-6} x^2$$

where x is the mole fraction of benzene and v has units of m^3 / mol. Determine the expressions for volume change of mixing for the standard state based on Lewis – Randall Rule.

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