MANICALAND STATE UNIVERSITY OF APPLIED SCIENCES

FACULTY OF ENGINEERING, SCIENCE AND TECHNOLOGY

DEPARTMENT: CHEMICAL AND PROCESSING ENGINEERING

MODULE: CHEMICAL ENGINEERING THERMODYNAMICS II

CODE: CHEP212

SESSIONAL EXAMINATIONS
APRIL 2023

DURATION: 3 HOURS

EXAMINER: MR D NYADENGA

INSTRUCTIONS

1. *Answer **any four** questions.*
2. *Start a new question on a fresh page.*
3. *Total marks 100.*

Additional material(s): *Steam Tables, Conversions Table,*
Antoine Equation Constants Table,
Periodic Table

QUESTION 1

a) Define *partial molar property of species **i** in solution*. Also state the formula that represent the partial molar property of species ***i*** in solution. [2]

b) A stream of methane gas flowing at the rate of 16 kg/s and a stream of ethane gas flowing at the rate of 15 kg/s are mixed in a steady flow process. The temperature of the whole system is constant at 25 °C. Assuming the gases to be ideal, calculate the rate of change in total Gibbs free energy. [6]

c) Show that $\gamma_i = {}^{\hat{\Phi}_i}/_{\Phi_i}$ [4]

d) The excess enthalpy (heat of mixing) of a liquid mixture of species 1 and 2 at fixed *T* and *P* is given by:

$$H^E = x_1 x_2 (40x_1 + 20x_2)$$

i. Determine the expressions for $\overline{H}_1{}^E$ and $\overline{H}_2{}^E$ as functions of x_1. [9]

ii. Show that the expressions obtained in part a) satisfy the Gibbs/Duhem equation. [4]

QUESTION 2

a) Starting from $\overline{H}_i{}^{id} = H_i$, show that $H^E = \Delta H$ where H^E is the excess solution enthalpy and ΔH is the enthalpy change or heat of mixing. [4]

b) $LiCl{\cdot}3H_2O(s)$ and $H_2O(l)$ are mixed isothermally at 25 °C to form a solution containing 8 mol of H_2O for each mole of $LiCl$. Calculate the heat effect per mole of solution. Data for standard enthalpy changes of formation at 298 K is:

Chemical component	Enthalpy change of formation
$LiCl{\cdot}3H_2O(s)$	- 1 311 300 J/mol of $LiCl$
$H_2O(l)$	- 285 830 J/mol of H_2O
$LiCl$ in 8 mol H_2O	- 440 529 J/mol of $LiCl$

[9]

c) A 150 lb_m batch of 30 wt % *NaOH* solution in water at 70 °F and atmospheric pressure is heated in an insulated tank by injection of live steam drawn through a valve from a line containing wet steam (x = 0.4) at 1.3 bar. The process is stopped when the *NaOH* solution reaches a concentration of 25 wt %. Determine the temperature of this final solution in °F. The *H-x* graph for $NaOH/H_2O$ system is attached at the end of the question paper. [12]

QUESTION 3

a) State *two* major assumptions that reduce VLE calculations to Raoult's law. [2]

b) Why does a mixture of ammonia and n-octane **not** obey Raoult's law? [3]

c) Sketch the P vs x,y phase diagram at constant T of a binary solution that obeys Raoult's law, where species 1 is the more volatile component, labelling all the regions, curves and limiting points. [7]

d) Show that when y_i is unknown Raoult's law can be expressed as:

$P = \sum_i x_i P_i^{sat}$ [3]

e) A system of n-heptane (1)/cyclohexane (2) is at T = 70 °C and x_1 = 0.65. Assuming that Raoult's law applies, determine the pressure of the system and y_1. The saturation pressures are calculated using the Antoine Equation. [10]

QUESTION 4

a) With the aid of a diagram, describe a reverse osmosis operation. [6]

b) A concentrated binary solution containing mostly species 2 (but $x_2 \neq 1$) is in equilibrium with a vapour phase containing both species 1 and 2. The pressure of this two-phase system is 2.5 bar; the temperature is 25 °C. Determine good estimates of x_1 and y_1 given that H_1 = 550 bar and P_2^{sat} = 0.03166 bar. [8]

c) A binary system of species 1 and 2 consists of vapour and liquid phases in equilibrium at temperature T, for which:

- $\ln \gamma_1 = 1.8{x_2}^2$ $\ln \gamma_2 = 1.8{x_1}^2$
- $P_1^{sat} = 1.24$ bar $P_2^{sat} = 0.89$ bar

Assuming that the modified Raoult's law applies,

i. Show that an azeotrope exists for the system. [5]

ii. Determine the azeotropic composition at T. [6]

QUESTION 5

The following reaction of ideal gases reaches equilibrium at 625 K and 1 bar:

$$C_3H_{8(g)} \longrightarrow C_2H_{4(g)} + CH_{4(g)} \qquad \Delta H = +ve$$

K at 625 K is 1.5236. Initially there are 3 moles of C_3H_8 and 1 mole of CH_4.

a) Calculate the equilibrium composition of the system. [10]

b) If the pressure is reduced to 0.6 bar and temperature is maintained at 625 K, determine the new equilibrium composition. [10]

c) Explain the effect on the equilibrium composition of decreasing the temperature of the system to 400 K whilst maintaining pressure at 1 bar. [4]

d) If N_2 (g) is added to the system whilst $T = 625$ K and $P = 1$ bar, how is K affected? [1]

Note: $\prod_i (y_i)^{\nu_i} = K \left(\frac{P}{P^o}\right)^{-\nu}$

END OF EXAMINATION

H-x graph for *NaOH/H₂O*