NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF INDUSTRIAL TECHNOLOGY

DEPARTMENT OF CHEMICAL ENGINEERING

CHEMICAL ENGINEERING THERMODYNAMICS 1B

TCE 2204

Supplementary Examination Paper

August 2024

This examination paper consists of 4 pages

Time Allowed: 3 hours

Total Marks: 100

Special Requirements: Chemical Engineering Thermodynamics Tables

INSTRUCTIONS

1. Answer ANY FOUR (4) questions.
2. Each question carries 25 marks.
3. Use of calculators is permissible.

MARK ALLOCATION

QUESTION	MARKS
1.	**25**
2.	**25**
3.	**25**
4.	**25**
TOTAL ATTAINABLE MARKS	**100**

Answer ALL 4 questions

QUESTION 1

a. What is an azeotrope? [2]

b. Differentiate between minimum and maximum boiling azeotropes. [6]

c. State the Lewis/Randal rule. [2]

d. A binary system of species 1 and 2 consists of vapour and liquid phases in equilibrium at temperature T. The overall mole fraction of species 1 in the system is $z_1 = 0.65$. At temperature T, Assuming the validity the equation, $y_1P = x_1\gamma_1P_1^{sat}$

$\ln \gamma_1 = 0.67x_2^2$ $\quad\quad$ $\ln \gamma_2 = 0.67x_1^2$

$P_1^{sat} = 32.27\ \text{kPa}$ $\quad\quad$ $P_2^{sat} = 73.14\ \text{kPa}$

(i) Over what range of pressures can this system exist as two phases at given T and z_1? [6]

(ii) For a liquid-phase mole fraction $x_1 = 0.75$, what is the pressure P and what molar fraction V of the system is vapor? [4]

(iii) Show whether or not the system exhibits an azeotrope. [5]

QUESTION 2

a. Draw the PT diagram of a pure substance. [5]

b. What is compressibility factor. [2]

c. How many thermodynamic degrees of freedom are there for a pure substance existing as

i. saturated liquid [2]

ii. saturated vapour [2]

d. Acetic acid is esterified in the liquid phase with ethanol at 100°C and atmospheric pressure to produce ethyl acetate and water according to the reaction:

$CH_3COOH\ (l) + C_2H_5OH\ (l) \longrightarrow CH_3COOC_2H_5(l) + H_2O(l)$

If initially there is one mole each of acetic acid and ethanol, estimate the mole fraction of ethyl acetate in the reacting mixture at equilibrium. [14]

QUESTION 3

a. The system n-pentane (1), n-hexane (2), n-heptane (3) forms an ideal solution. If a feed stream of overall composition $x_1 = 0.3$, $x_2 = 0.3$ and $x_3 = 0.4$ is continuously fed to a flash vaporizer

maintained at 90°C and 200 kPa. Determine the compositions of the liquid and vapour streams leaving the flash unit and the fraction of the feed vaporized in the unit. [20]

$$x_i = \frac{z_i}{\left(\frac{L}{F}\right)+\left(1-\frac{L}{F}\right)K_i}$$

b. For a system in which the following reaction occurs,

$$CH_4 + H_2O \longrightarrow CO + 3\,H_2$$

Assume there are present initially 2 mol CH_4, 1 mol H_2O, 1 mol CO and 4 mol H_2. Determine expressions for the mol fractions y_1 as functions of ε. [5]

$$y_i = \frac{n_i}{n} = \frac{n_{i0}+v_i\varepsilon}{n_0+v\varepsilon}$$

QUESTION 4

a. Estimate the fugacity of one of the following liquids at its normal boiling point temperature and 200 bar: (a) n-Pentane; (b) Isobutylene; (c) 1-Butene [9]

$$\phi = exp\left[\frac{P_r}{T_r}(B^0 + \omega B^1)\right]$$

$$B^0 = 0.083 - \frac{0.422}{T_r^{1.6}} \qquad B^1 = 0.139 - \frac{0.172}{T_r^{4.2}}$$

b. If $LiC1.2H_2O(s)$ and $H_2O(1)$ are mixed isothermally at 298.15 K (25°C) to form a solution containing 10 mol of water for each mole of LiC1, what is the heat effect per mole of the solution? [5]

c. For SO_2 at 600 K and 300 bar, determine good estimates of the fugacity and G^R /RT. (The Lee/Keesler correlation is appropriate for this system) [6]

d. What is the change in entropy when 0.7 m^3 of CO_2 and 0.3 m^3 of N_2, each at 1 bar and 298.15 K blend to form a gas mixture at the same conditions? Assume ideal gases. [5]

(END OF QUESTION PAPER)