NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF INDUSTRIAL TECHNOLOGY
BACHELOR OF ENGINEERING (HONS) DEGREE
Part Two Supplementary Examination 2014

TCE 2204 Chemical Engineering Thermodynamics 1B

Duration of Examination 3 Hours

Instructions to Candidates

1. Answer **Question One** and any other **Three** questions.
2. Show all your steps clearly in your calculation.
3. Start the answers for each question on a new page.

---

1. a) Describe the three distinct equilibrium situations which exist for the case of an ideal liquid solution in equilibrium with a solid phase that consists of immiscible species. [6]

   b) Discuss the assumptions upon which the Raoult's law is based on. [4]

   c) For H_2O at a temperature of 300°C and for pressures up to 10 000kPa (100bar) plot values of f_i and Φ_i calculated from data from steam tables vs P. [10]

   d) Sketch the PT diagram for a pure substance and show the sublimation curve. [5]

2. a) The excess enthalpy (heat of mixing) for a liquid mixture of species 1 and 2 at fixed T and P is represented by the equation:

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

   where H^E is in J/mol. Determine expressions for H^E_1 and H^E_2 as functions of x_1. [10]

   b) With the aid of a diagram, explain in detail the meaning of the two equations below. [10]

$$\overline{M}_1 = M + x_2 \frac{dM}{dx_1} \qquad \overline{M}_2 = M - x_1 \frac{dM}{dx_1}$$

c) Some expressions for G^E/RT are incapable of representing LLE. An example is the Wilson equation: $G^E/RT = -x_1\ln(x_1+x_2\Lambda_{12}) - x_2\ln(x_2+x_1\Lambda_{21})$

Show that the stability criteria are satisfied for all values of Λ_{12}, Λ_{21} and x_1. [5]

3. a) Explain the concept of non-random molecular orientation. [5]

   b) Describe the conditions under which the fugacity coefficient is equal to 1. [4]

   c) 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 25 °C blend to form a gas mixture at the same condition? Assume ideal gases. [10]

   d) State and explain the three aspects that describe the nature of excess properties. [6]

4. a) Explain why are Hx diagrams are more convenient to use than heats of solution diagrams. [7]

   b) With the aid of a diagram illustrate the steps involved in pressure, temperature flash calculations. [10]

   c) Is the relationship between equilibrium constant and temperature linear? If not, what is the relationship? If the reaction is exothermic, how does the K change with temperature? [8]

5. a) State the exact expression for the equilibrium constant of a liquid phase reaction and explain its practical significance. [5]

   b) Discuss the conditions for which the Lewis/Randall rule and Henry's law apply.

   [6]

   c) Explain how the actual concentration of a species is related to the extent of reaction. [5]

   d) The enthalpy of a binary liquid system of species 1 and 2 at fixed T and P is represented by the equation

$$H = 400x_1 + 600x_2 + x_1x_2(40x_1 + 20x_2)$$

   where H is in J/mol. Determine expressions for $\bar{H}_1$ and $\bar{H}_2$ as functions of x_1, numerical values for the pure- species enthalpies H_1 and H_2, and numerical values for the partial enthalpies at infinite dilution $\bar{H}_1^{\infty}$ and $\bar{H}_2^{\infty}$. [9]

END OF EXAM