

# 國立臺灣科技大學

115學年度碩士班招生

## 試題

系所組別：0600化學工程系碩士班

科    目：化工熱力學與動力學

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(總分為100分;所有試題務必於答案卷內頁依序作答)

1. (15%) Benzaldehyde ( $C_7H_6O$ ) is a liquid over a wide temperature range (melting point =  $-26.0^\circ C$ ; boiling point =  $179^\circ C$ ). The vapour pressure of liquid benzaldehyde is  $p_1 = 0.669$  kPa at  $T_1 = 50.0^\circ C$  and  $p_2 = 5.34$  kPa at  $T_2 = 90.0^\circ C$  ( $R = 8.31$  J  $K^{-1}$  mol $^{-1}$ ). Assume the vapor behaves as an ideal gas and the enthalpy of vaporization ( $\Delta H_{vap}$ ) is approximately constant over this temperature range. The slope of the liquid-vapour coexistence curve on a P-T phase diagram is given by the entropy of vaporization divided by the molar volume change upon vaporization ( $\frac{dP}{dT} = \frac{\Delta S_{vap}}{\Delta V_{vap}}$ ). The thermodynamic relation linking  $\Delta S_{vap}$  and  $\Delta H_{vap}$  is applicable only for a phase transition at phase equilibrium (i.e., on the coexistence line). Starting from the slope relation above and the assumptions provided, determine the  $\Delta H_{vap}$  in kJ mol $^{-1}$ .

2. (20%) At  $T=300$ K, the saturation vapor pressure of pure liquid A is  $P_A^* = 90.0$  kPa, and that of pure liquid B is  $P_B^* = 55.0$  kPa. The A-B system forms ideal solutions in both the liquid and vapor phases. A vapor phase in equilibrium with the liquid has a mole fraction of A equal to  $y_A = 0.400$ .

(10%) (1) Using Raoult's law and Dalton's law, calculate the total vapour pressure (P) in kPa at equilibrium.

(10%) (2) A rigid, closed container holds a total of  $n_{tot} = 1.00$  mol of the A-B mixture with an overall composition  $z_A = 0.330$  at 300 K. If the system reaches the same vapour-liquid equilibrium state as in part (a) (i.e., the same equilibrium (x), (y), and (P)), determine the vapour-phase fraction  $\beta = \frac{n_v}{n_{tot}}$ . (You may assume vapour-liquid equilibrium obeys Raoult's law and Dalton's law.)

3. (15%) A refrigeration unit is used to chill a brine stream from  $18.0^\circ C$  to  $-12.0^\circ C$  at a mass flow rate of  $12.0$  kg s $^{-1}$ . Heat rejected by the unit is discharged to the surroundings at  $35.0^\circ C$ . The specific heat capacity of the brine may be taken as constant at  $c_p = 3.8$  kJ kg $^{-1}$  K $^{-1}$ . If the thermodynamic efficiency of the refrigeration system is  $\eta = 0.30$  (defined as the ratio of the minimum reversible work required to change the state of the brine to the actual work input  $\eta = \frac{\dot{W}_{ideal}}{\dot{W}_{actual}}$ ), determine the required power input  $\dot{W}_{actual}$  in kW.



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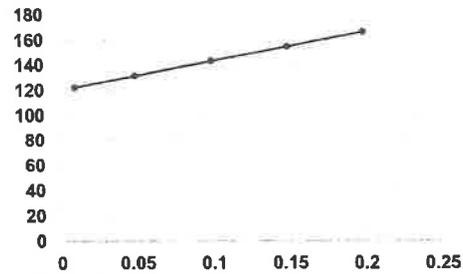
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4. (25%) Urea can be decomposed by urease into ammonia and carbon dioxide. [Urea + Urease  $\rightleftharpoons$  2NH<sub>3</sub> + CO<sub>2</sub> + Urease]. The initial concentration of urea is 0.3 mol/dm<sup>3</sup>. The reaction is to be carried out isothermally at the same temperature as that used to obtain the provided kinetic data. Assume that the reaction follows single-substrate enzyme kinetics with a steady-state enzyme-substrate complex. Using the provided kinetic data, calculate the time (in minutes) required to convert 80% of the initial urea to ammonia and carbon dioxide in a 0.9-dm<sup>3</sup> well-mixed batch reactor. For parameter estimation, plot  $S$  versus  $S/(-r_s)$  as shown in the figure.

$S$ (kmol/m <sup>3</sup> )	$-r_s$ (kmol/m <sup>3</sup> · s)
0.01	8.17661E-05
0.05	0.000380228
0.1	0.000699301
0.15	0.000970874
0.2	0.001204819



5. (25%) Consider the elementary, gas-phase, reversible reaction carried out isothermally:  $A \rightleftharpoons 4C$ , where  $k_1$  is the forward reaction rate constant. Pure A enters at a temperature of 500K and a pressure of 12 atm. At this temperature,  $K_C = 0.38$  (mol/dm<sup>3</sup>)<sup>3</sup>.

a) (5 %) Write the rate law in terms of  $K_C$  and  $k_1$ .

Calculate the equilibrium conversion for each of the following situations:

b) (10 %) The gas-phase reaction is carried out in a constant-volume batch reactor.

c) (10 %) The gas-phase reaction is carried out in a constant-pressure batch reactor.

