國立中央大學104學年度碩士班考試入學試題

所別：化學工程與材料工程學系碩士班 甲組(一般生)　科目：化工熱力學及化學反應工程　共 2 頁 第 1 頁
本科考試可使用計算器，廠牌、功能不拘　*請在答案卷（卡）內作答

1. (10%)
Figure 1 shows the enthalpy-concentration diagram for aqueous sulfuric acid at 0.1 MPa.
   a. (5%) Estimate the final temperature of mixing one mole of sulfuric acid and four moles of water, each starting at 21.2 °C. (State the assumptions made)
   b. (5%) Based on the diagram, explain why sulfuric acid should be added to water for safety concerns.

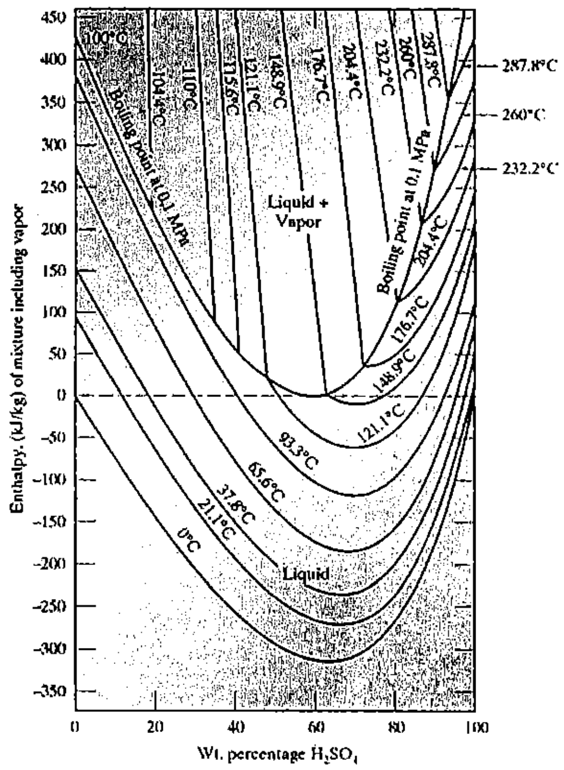

Figure 1

2. (15%)
Liquefaction is an important industrial process. Liquefied gases can be produced through a throttling process, i.e. isenthalpic Joule-Thomson expansion.
   a. (5%) Derive Joule-Thomson coefficient ($\mu = (\partial T/\partial P)_H$) for a gas that follows the equation of state $P\underline{V} = RT + BP$, where the virial coefficient B is a function of temperature only.
   b. (5%) What is the operating condition for Joule-Thomson expansion that can be used to liquefy gases?
   c. (5%) What happens to the liquefaction of an ideal gas using the same process?

3. (25%)
The activity coefficient model is a very useful tool in many thermodynamic calculations, such as vapor-liquid equilibrium (VLE). Please solve the following VLE problems using the activity coefficient model with the assumption of an ideal vapor phase.
   a. (10%) Determine the total pressure and vapor phase composition in equilibrium with an equimolar mixture of C and D at 80 °C using van Laar equations for binary mixtures:
   $\ln\gamma_1 = \dfrac{\alpha}{\left[1+\dfrac{\alpha x_1}{\beta x_2}\right]^2}$, $\ln\gamma_2 = \dfrac{\beta}{\left[1+\dfrac{\beta x_2}{\alpha x_1}\right]^2}$ and the following data: $P_C^{vap}(T=80°\mathrm{C}) = 1$ bar, $P_D^{vap}(T=80°\mathrm{C}) = 0.85$ bar, $\lim_{x_C\to 0}\gamma_C = \gamma_C^\infty = 2.7183$, and $\lim_{x_D\to 0}\gamma_D = \gamma_D^\infty = 1.6488$

   b. (15%) It is reported in the literature that the excess Gibbs function $\dfrac{\underline{G}^{ex}}{RT} = Ax_A x_B$ can be used to describe the binary system of A and B. The constant $A = 0.5$ at 35 °C is determined from experimental vapor-liquid equilibrium data. The vapor pressures of pure A and pure B are given by
   $$\ln P_A^{vap} = 12.33 - \frac{3850}{T} \quad \text{and} \quad \ln P_B^{vap} = 12.58 - \frac{3850}{T}$$
   where P^{vap} is in bar and T in K. Please determine whether this system forms an azeotrope at 35 °C, and if so, the azeotropic composition. Hint: $(\partial P/\partial x_A)_T = 0$ at azeotrope.

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4. (10%)

An experimental study was carried out in a continuous stirred tank reactor (CSTR) to determine the kinetics of the following liquid-phase reaction:

$A \rightarrow B + C$

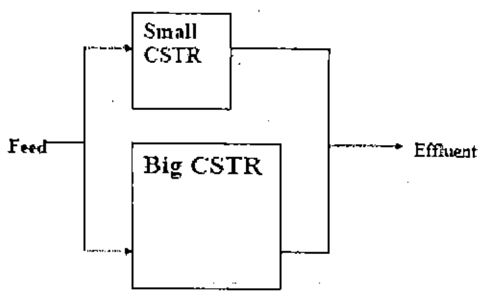
Altogether four test runs were carried out. The reactor volume was same for all test runs and equal to 5.0 liters. The volumetric flow rate was also the same for all test runs and equal to 1.5 liters/minute. Only the feed concentration was varied for each of the 4 test runs. The inlet and outlet concentrations of the reactant were determined using a spectrometric technique and are reported in the table below

	Run-1	**Run-2**	**Run-3**	**Run-4**
$C_{A,in}$ **(mol/L)**	1.0	2.5	5.0	10.0
$C_{A,out}$ **(mol/L)**	0.5	1.6	3.7	8.1

Apply the differential method to determine the rate law for the reaction. Report the reaction rate constant (k) with units and the reaction-order with respect to A.

5. (15%)

A reactant stream is split to feed, in parallel, two CSTRs, one of which is twice the volume of the other. The effluents from the two CSTRs are combined. The reaction of interest follows a first-order rate law. How should the feed stream be split in order to maximize the total reactant conversion in the combined effluent from the two CSTRs?



6. (25%)

There is a first-order irreversible liquid-phase reaction, R➔P, in a jacketed cylinder CSTR with height of 3 m and diameter of 1 m. Equimolar of R and inert I are fed to the reactor at 450 K, and the molar feed rate of R is 80 mol/min. The space time is 100 min. The reaction rate constant is $6.6*10^{-3}$ min^{-1} at 350 K and the activation energy is 4 kcal/mol. The heat of reaction is -7.5 kcal/mol. Heat capacities of R, P, and I are all 20 cal/mol-K.

a. (5%) What is the conversion if the reactor works at constant temperature 450 K?

b. (8%) If the reactor works adiabatically, please determine the temperature and the conversion in the CSTR.

c. (4%) Continued from (b), the temperature within the CSTR at steady state has to be 600 K for the safety concern. Therefore, how will you change the feed temperature and what will be the conversion?

d. (8%) If the coolant at 300 K is fed to the jacket and the heat-transfer coefficient of the jacket wall is 800 cal/m^2-min-K, please determine the temperature and the conversion in the CSTR.

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