中原大學 100 學年度 碩士班 入學考試

3 月 19 日 15:30~17:00 化學工程學系

誠實是我們珍視的美德，
我們喜愛「拒絕作弊，堅守正直」的你！

科目：熱力學及動力學

■可使用計算機，惟僅限不具可程式及多重記憶者　　□不可使用計算機

1. (15%) One kilogram of steam contained in a horizontal frictionless piston and cylinder is reversibly and adiabatically compressed from 0.05 MPa and 150 ^oC to 1.2 MPa. Calculate
   (a) The final temperature of the steam in the cylinder?
   (b) The work required for the compression.

T / ^oC	P / MPa	V / (m^3/kg)	U / (kJ/kg)	H / (kJ/kg)	S / (kJ/kg K)
150	0.05	3.889	2585.6	2780.1	7.9401
500	1.20	0.2946	3122.8	3476.3	7.6759
600	1.20	0.3339	3295.6	3696.3	7.9435

2. (15%) Based on the van der Waals equation, $P = \frac{RT}{\underline{V} - b} - \frac{a}{\underline{V}^2}$, calculate

   (a) the parameters a and b of van der Waals equation for a fluid with T_c = 304.2 K and P_c = 73.76 bar. Note that $a = \frac{27R^2T_c^2}{64P_c}$, $b = \frac{RT_c}{8P_c}$.

   (b) the values of $\left(\frac{\partial P}{\partial T}\right)_{\underline{V}}$ and $\left(\frac{\partial P}{\partial \underline{V}}\right)_T$ for this fluid at 450 K and $\underline{V}$ = 0.25 × 10^{-3} m^3/mol.

   Note that R = 8.314 × 10^{-5} bar m^3 / (mol K)

3. (20%) Estimate the bubble point and dew point pressures and the equilibrium mole fractions of components of a fluid contains 26 moles of *n*-pentane, 32 moles of *n*-hexane, and 42 moles of *n*-heptane at 80 ^oC. The vapor pressure for these components can be expressed as

$$\ln P_5^{\text{vap}} = 10.442 - \frac{3223.3}{T}$$

$$\ln P_6^{\text{vap}} = 10.456 - \frac{3569.4}{T}$$

$$\ln P_7^{\text{vap}} = 11.431 - \frac{4233.8}{T}$$

where P is in bar and T in K. The subscripts 5, 6, 7 designate *n*-pentane, *n*-hexane, and *n*-heptane, respectively. The system can be assumed to obey the Raoult's law (i.e., $y_i P = x_i P_i^{\text{vap}}$).

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4. (20%) The concepts of Chemical Reaction Engineering
   (a) Please describe the classification of chemical reactions useful in reactor design. (5%)
   (b) Ideal reactors have three ideal flow or contacting patterns. Please show these ideal reactor types and give a brief discussion. (5%)
   (c) It is important to control the effect of temperature on product distribution to the optimum reactor system. Please discuss the optimum temperature progression for irreversible reactions, endothermic reversible reactions, and exothermic reversible reactions.(10%)

5. (15%) Chemical Reaction - Kinetics

Consider rate law for the following consecutive reaction:

$$A \xrightarrow{k_1} X \xrightarrow{k_2} Z \qquad \text{I.C.} \quad [A]=[A]_0;\ [X]=[Z]=0$$

Where k_1 and k_2 are the rate constant of the consecutive reaction. In the initial condition of the reaction, there is only A reactant with the concentration of $[A]_0$.

What is the expression for the concentration of [A], [X], [Z] as a function of time?

And please calculate the reaction time to get the maximum concentration of [X].

6. (15%) Reactor design for single reactions

In the presence of a specific enzyme E, which acts as a homogeneous catalyst, a harmful organic A present in industrial waste water degrades into harmless chemicals. At a given enzyme concentration C_E tests in a laboratory mixed flow reactor give the following results:

C_{A0}, mmol/m^3	2	5	6	6	11	14	16	24
C_A, mmol/m^3	0.5	3	1	2	6	10	8	4
τ, min	30	1	50	8	4	20	20	4

We wish to treat 0.1 m3/min of this waste water having C_{A0}=10 mmol/m^3 to 90% conversion with this enzyme at concentration C_E.

One possibility of the reactor design for this single reaction is to use a long tubular reactor (assume plug flow) with possible recycle of exit fluid. What design do you recommend? Please give the size of the reactor, tell if it should be used with recycle, and if so determine the recycle flow rate in cubic meters per minute (m^3/min). Sketch your recommendation design.