Seat No. ☐

King Mongkut's University of Technology Thonburi
Final Examination—2/2556
ChE 343 Chemical Engineering Kinetics & Reactor Design
(International Program)

Date:16 May 2014 Time: 9:00-12:00

Notes:

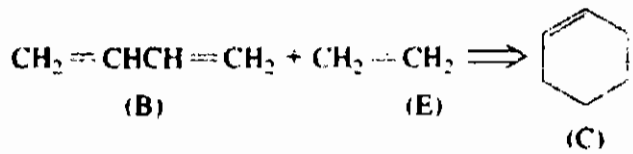
1. This exam paper includes 5 problems (100 points) in a total of 10 pages.
2. One textbook entitled "Essentials of Chemical Reaction Engineering written by Fogler" and hand-writing classnotes are allowed.
3. A calculator is allowed.
4. Do not take any exam materials/papers out of the exam room.

This exam paper has been evaluated and approved by the Department of Chemical Engineering's Committee.

(Assoc. Prof. Dr. Piyabutr Wanichpongpan)
Departmental Chair

Student Name_____ Student ID_____

1. (20%) Butadiene and ethylene can be reacted together to form cyclohexene as follows:



If equimolar butadiene and ethylene (C_B=C_E) at 450 °C and 1 atm are fed to a PFR operating abiabatically, what is the space time necessary to reach a fractional conversion of 0.1?

Data:

$k = 10^{7.5} \exp[-27{,}500/(R_g T)]$ L/mol/s

$\Delta H_r = -30000$ cal/mol

$C_{p_B} = 36.8$ cal/mol/K

$C_{p_E} = 20.2$ cal/mol/K

$C_{p_C} = 59.5$ cal/mol/K

2. (20%) The rate of product desorption can also influence the kinetics of a surface-catalyzed reaction. Consider the following simple catalytic cycle:

$$A + S \underset{}{\overset{K_1}{\rightleftharpoons}} A \cdot S$$

$$A \cdot S \overset{K_2}{\rightleftharpoons} B \cdot S$$

$$B \cdot S \xrightarrow{k_3} B + S$$

If desorption of B from the surface is rate-determining, then all elementary steps prior to desorption are assumed to be quasi-equilibrated.

Show that the final rate expression of this reaction is as follow:

$$r = \frac{kK_1K_2[\mathrm{A}]}{1 + (K_1 + K_1K_2)[\mathrm{A}]}\ ,$$

[A] = concentration of A

3. (20%) The double bond isomerization of 1-hexene to form 2-hexene was studied in a laboratory reactor containing rhodium particles supported on alumina at 150°C and atmospheric pressure.

$$H_2C{=}CH{-}CH_2{-}CH_2{-}CH_2{-}CH_3 \rightarrow H_3C{-}CH{=}CH{-}CH_2{-}CH_2{-}CH_3$$

The reaction was found to be first order in 1-hexene with a rate constant of 0.14 s^{-1}. The pore radius of the alumina is 10 nm, and D_{AB} is 0.050 cm^2s^{-1} and the porosity and tortuosity are assumed to be 0.5 and 4, respectively. Molecular weight of hexene (84 g mol^{-1}).

Find the largest pellet size that can be used in an industrial reactor to achieve 70 percent of the maximum rate.

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4. (20%) In a multiple reaction

$$A \rightarrow P \qquad r_P = 1.0C_A \text{ (kmol/m}^3\text{s)}$$
$$2A \rightarrow S \qquad r_S = 0.5C_A^2 \text{ (kmol/m}^3\text{ s)}$$

If the conversion of 98% is desired and the feed contains C_{A0}= 1, C_{P0}=0 (kmol/m^3).
Determine the concentration of P (C_P) and the space time in the following cases by keeping the instantaneous yield as high as possible:

4.1) CSTR
4.2) PFR

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5. (20%) The catalytic cracking of cumene over a silica-alumina catalyst at 950°C in a packed bed reactor :

$$\text{Cumene} \rightarrow \text{Propylene} + \text{Benzene}$$
$$C \rightarrow P + B$$

is shown to be a single-site mechanism postulated as follows:

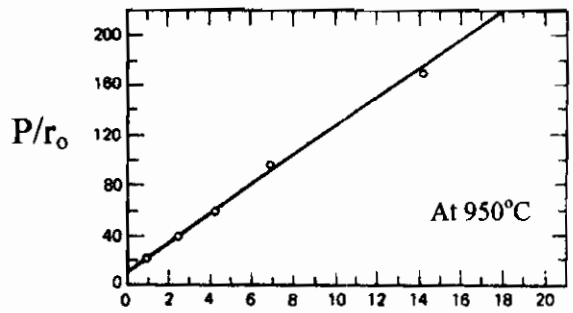
$$C + S \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} C\bullet S$$

$$C\bullet S \underset{k_{-2}}{\overset{k_2}{\rightleftharpoons}} B\bullet S + P$$

$$B\bullet S \underset{k_{-3}}{\overset{k_3}{\rightleftharpoons}} B + S$$

5.1) Assuming that the reactions are reversible and surface reaction is rate limiting step, **derive** the rate expression for this mechanism.

5.2) Is this mechanism consistent with the initial rate experimental data shown below ? Show the procedure.



P – Total pressure, atm

r_o = initial rate of reaction

5.3) If the catalyst particles are in the shape of sphere having diameter of 4 cm. The particle density of the catalyst (ρ_p) is 4000 kg/m^3, and the effective diffusivity of C in the catalyst particle is 10^{-2} m^2/s. If this reaction can be simplified as first order reaction with the rate constant of 2.0×10^{-4} m^3/kg-cat-s. The concentration of C in the feed to the reactor is 2.0 mol/m^3, and the volumetric flow rate is 1.0 m^3/s. The total pressure is 1 atm. What weight of catalyst is required to achieve a conversion of cumene of 0.9 when the internal transport resistances are taken into account ?