ChE 344
Chemical Reaction Engineering
Winter 1999
Exam I
Part 2 (20%)

Open Book, Notes, and Disk
Closed Web

Name_______________________________

I have neither given nor received aid on this examination nor have I spent more than one hour working on Part 2 of this exam.

Signed____________________________________________

Start Time____________________

Finish Time__________________
The gas phase reactions take place isothermally in a membrane reactor packed with catalyst. Pure A enters the reactor at 24.6 atm and 500K and a flow rate of A of 10 mol/min

\[ A \xrightarrow{k_{1C}} B + C \quad r'_{1C} = k_{1C} \left[ C_A - \frac{C_B C_C}{K_{1C}} \right] \]

\[ A \rightarrow D \quad r_{2D} = k_{2D} C_A \]

\[ 2C + D \rightarrow 2E \quad r'_{3E} = k_{3E} C_C^2 C_D \]

Only species B diffuses out of the reactor through the membrane. At what point in the reactor is the

(a) the concentration of B is a maximum at \( W = \) 9 kg

(b) the concentration of C is a maximum at \( W = \) 43

(c) Explain why the curves look the way they do.

(d) Vary \( k_{1C} \) (.1 to 1000) and write a paragraph describing what you observe. Explain whether or not what you observe is reasonable.

Additional Information

Overall mass transfer coefficient \( k_B = 1.0 \text{ dm}^3 / \text{kg cat\cdot min} \)

\( k_{1C} = 2 \text{ dm}^3 / \text{kg cat\cdot min} \)
\( K_{1C} = 0.2 \text{ mol/dm}^3 \)
\( k_{2D} = 0.4 \text{ dm}^3 / \text{kg cat\cdot min} \)
\( k_{3E} = 5 \text{ dm}^9 / \text{mol}^2 \cdot \text{kg cat\cdot min} \)
\( W_f = 100 \text{ kg} \)
Equations:  
\[ \frac{d(F_b)}{d(w)} = r_{1c} - k_b C_b \]  
\[ \frac{d(F_a)}{d(w)} = -r_{1c} - r_{2d} \]  
\[ \frac{d(F_c)}{d(w)} = r_{1c} - r_{3e} \]  
\[ \frac{d(F_d)}{d(w)} = r_{2d} - 0.5 r_{3e} \]  
\[ \frac{d(F_e)}{d(w)} = r_{3e} \]  
\[ k_b = 1 \]  
\[ k_{1c} = 2 \]  
\[ K_{1c} = 0.2 \]  
\[ k_{2d} = 0.4 \]  
\[ k_{3e} = 5 \]  
\[ F_t = F_a + F_b + F_c + F_d + F_e \]  
\[ C_{ao} = 0.6 \]  
\[ C_b = C_{ao} F_b / F_t \]  
\[ C_a = C_{ao} F_a / F_t \]  
\[ C_c = C_{ao} F_c / F_t \]  
\[ C_d = C_{ao} F_d / F_t \]  
\[ r_{2d} = k_{2d} C_a \]  
\[ r_{3e} = k_{3e} C_c^{**2} \]  
\[ r_{1c} = k_{1c} (C_a - C_b C_c / K_{1c}) \]  
\[ w_0 = 0, \quad w_f = 100 \]  

Initial values:  
\[ 0 \]  
\[ 10 \]  
\[ 0 \]  
\[ 0 \]  
\[ 0 \]  
\[ k_{1c} \]  
\[ K_{1c} \]  
\[ k_{2d} \]  
\[ k_{3e} \]  
\[ F_t \]  
\[ C_{ao} \]  
\[ C_b \]  
\[ C_a \]  
\[ C_c \]  
\[ C_d \]  
\[ r_{2d} \]  
\[ r_{3e} \]  
\[ r_{1c} \]  
\[ w_0 \]  
\[ w_f \]  

Diagram: Graph showing the relationship between Ca, Cb, and Cc over a range of w values.
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**Page 3**

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The gas phase reactions take place isothermally in a membrane reactor packed with catalyst. Pure A enters the reactor at 24.6 atm and 500K and a flow rate of A of 10 mol/min

\[ A \rightleftharpoons B + C \quad r'_{IC} = k_{1C} \left[ C_A - \frac{C_B C_C}{K_{1C}} \right] \]

\[ A \rightarrow D \quad r_{2D} = k_{2D} C_A \]

\[ 2C + D \rightarrow 2E \quad r'_{3E} = k_{3E} C_C^2 C_D \]

Only species B diffuses out of the reactor through the membrane. At what point in the reactor is the

(a) the concentration of B is a maximum at \( W = \) ____________

(b) the concentration of C is a maximum at \( W = \) ____________

(c) Explain why the curves look the way they do.

(d) Vary \( k_{IC} \) (.1 to 1000) and write a paragraph describing what you observe. Explain whether or not what you observe is reasonable.

Additional Information

Overall mass transfer coefficient \( k_B = 0.2 \text{ dm}^3 / \text{kg cat} \cdot \text{min} \)

\[ k_{1C} = 2 \text{ dm}^3 / \text{kg cat} \cdot \text{min} \]

\[ K_{1C} = 0.2 \text{ mol/dm}^3 \]

\[ k_{2D} = 0.4 \text{ dm}^3 / \text{kg cat} \cdot \text{min} \]

\[ k_{3E} = 5 \text{ dm}^9 / \text{mol}^2 \cdot \text{kg cat} \cdot \text{min} \]

\( W_f = 100 \text{ kg} \)
Only species B diffuses out of the reactor through the membrane. At what point in the reactor is the

(a) the concentration of B is a maximum at \( W = \) _____________

(b) the concentration of C is a maximum at \( W = \) _____________

(c) Explain why the curves look the way they do.

(d) Vary \( k_{1C} \) (.1 to 1000) and write a paragraph describing what you observe. Explain whether or not what you observe is reasonable.

**Additional Information**

Overall mass transfer coefficient \( k_B = 5.0 \text{ dm}^3/\text{kg cat} \cdot \text{min} \)

\( k_{1C} = 2 \text{ dm}^3/\text{kg cat} \cdot \text{min} \)

\( K_{1C} = 0.2 \text{ mol/dm}^3 \)

\( k_{2D} = 0.4 \text{ dm}^3/\text{kg cat} \cdot \text{min} \)

\( k_{3E} = 5 \text{ dm}^9/\text{mol}^2 \cdot \text{kg cat} \cdot \text{min} \)

\( W_f = 100 \text{ kg} \)

The gas phase reactions take place isothermally in a membrane reactor packed with catalyst. Pure A enters the reactor at 24.6 atm and 500K and a flow rate of A of 10 mol/min

\[ A \underset{\Delta}{\longrightarrow} B + C \]  

\[ r'_{1C} = k_{1C} \left[ \frac{C_A - \frac{C_B C_C}{K_{1C}}}{C_A - \frac{C_B C_C}{K_{1C}}} \right] \]
A \rightarrow D \quad \quad \quad r'_{2D} = k_{2D} C_A

2C + D \rightarrow 2E \quad \quad \quad r'_{3E} = k_{3E} C_C^2 C_D

Only species B diffuses out of the reactor through the membrane. At what point in the reactor is the

(a) the concentration of B is a maximum at \( W = \)_____________________

(b) the concentration of C is a maximum at \( W = \)_____________________

(c) Explain why the curves look the way they do.

(d) Vary \( k_{1C} \) (.1 to 1000) and write a paragraph describing what you observe. Explain whether or not what you observe is reasonable.

Additional Information

Overall mass transfer coefficient \( k_B = 1.0 \ \text{dm}^3/\text{kg \ cat} \cdot \text{min} \)
\( k_{1C} = 0.2 \ \text{dm}^3/\text{kg \ cat} \cdot \text{min} \)
\( K_{1C} = 0.2 \ \text{mol/dm}^3 \)
\( k_{2D} = 0.4 \ \text{dm}^3/\text{kg \ cat} \cdot \text{min} \)
\( k_{3E} = 5 \ \text{dm}^9/\text{mol}^2 \cdot \text{kg \ cat} \cdot \text{min} \)
\( W_f = 100 \ \text{kg} \)

The gas phase reactions take place isothermally in a membrane reactor packed with catalyst. Pure A enters the reactor at 24.6 atm and 500K and a flow rate of A of 10 mol/min

\[
A \leftrightarrow B + C \quad r'_{1C} = k_{1C} \left[ C_A - \frac{C_B C_C}{K_{1C}} \right]
\]

\[
A \rightarrow D \quad r'_{2D} = k_{2D} C_A
\]
2C + D → 2E \quad r'_{3E} = k_{3E} \ C_C^2 C_D

Only species B diffuses out of the reactor through the membrane. At what point in the reactor is the

(a) the concentration of B is a maximum at \( W = \) 

(b) the concentration of C is a maximum at \( W = \) 

(c) Explain why the curves look the way they do.

(d) Vary \( k_{1C} \) (.1 to 1000) and write a paragraph describing what you observe. Explain whether or not what you observe is reasonable.

**Additional Information**

Overall mass transfer coefficient \( k_B = 1.0 \ \text{dm}^3/\text{kg cat}\cdot\text{min} \)

\( k_{1C} = 10 \ \text{dm}^3/\text{kg cat}\cdot\text{min} \)

\( K_{1C} = 0.2 \ \text{mol/dm}^3 \)

\( k_{2D} = 0.4 \ \text{dm}^3/\text{kg cat}\cdot\text{min} \)

\( k_{3E} = 5 \ \text{dm}^9/\text{mol}^2\cdot\text{kg cat}\cdot\text{min} \)

\( W_f = 100 \ \text{kg} \)

The gas phase reactions take place isothermally in a membrane reactor packed with catalyst. Pure A enters the reactor at 24.6 atm and 500K and a flow rate of A of 10 mol/min

\[
\begin{align*}
A & \overset{\text{B + C}}{\longrightarrow} \quad r'_{1C} = k_{1C} \left[ C_A - \frac{C_B C_C}{K_{1C}} \right] \\
A & \longrightarrow D \quad r'_{2D} = k_{2D} C_A \\
2C + D & \longrightarrow 2E \quad r'_{3E} = k_{3E} C_C^2 C_D
\end{align*}
\]
Only species B diffuses out of the reactor through the membrane. At what point in the reactor is the

(a) the concentration of B is a maximum at $W =$ ______________

(b) the concentration of C is a maximum at $W =$ ______________

(c) Explain why the curves look the way they do.

(d) Vary $k_{1C}$ (.1 to 1000) and write a paragraph describing what you observe. Explain whether or not what you observe is reasonable.

Additional Information

Overall mass transfer coefficient $k_B = 1.0 \text{ dm}^3 / \text{kg cat} \cdot \text{min}$

$k_{1C} = 2 \text{ dm}^3 / \text{kg cat} \cdot \text{min}$

$K_{1C} = 0.2 \text{ mol/dm}^3$

$k_{2D} = 0.4 \text{ dm}^3 / \text{kg cat} \cdot \text{min}$

$k_{3E} = 20 \text{ dm}^9 / \text{mol}^2 \cdot \text{kg cat} \cdot \text{min}$

$W_f = 100 \text{ kg}$

The gas phase reactions take place isothermally in a membrane reactor packed with catalyst. Pure A enters the reactor at 24.6 atm and 500K and a flow rate of A of 10 mol/min

\[
\begin{align*}
A & \rightleftharpoons B + C \\
A & \rightarrow D \\
2C + D & \rightarrow 2E
\end{align*}
\]

\[
\begin{align*}
r'_{1C} &= k_{1C} \left[ C_A - \frac{C_B C_C}{K_{1C}} \right] \\
r'_{2D} &= k_{2D} C_A \\
r'_{3E} &= k_{3E} C_C^2 C_D
\end{align*}
\]

Only species B diffuses out of the reactor through the membrane. At what point in the reactor is the
(a) the concentration of B is a maximum at \( W = \) __________

(b) the concentration of C is a maximum at \( W = \) __________

(c) Explain why the curves look the way they do.

(d) Vary \( k_1 \) (.1 to 1000) and write a paragraph describing what you observe. Explain whether or not what you observe is reasonable.

**Additional Information**

Overall mass transfer coefficient \( k_B = 1.0 \text{ dm}^3/\text{kg cat}\text{•min} \)

\( k_1 \) = 2 dm\(^3\)/kg cat\text{•min}

\( K_1 = 0.2 \text{ mol/dm}^3 \)

\( k_2 = 0.4 \text{ dm}^3/\text{kg cat}\text{•min} \)

\( k_3 = 10 \text{ dm}^9/\text{mol}^2\text{•kg cat}\text{•min} \)

\( W_f = 100 \text{ kg} \)

---

The gas phase reactions take place isothermally in a membrane reactor packed with catalyst. Pure A enters the reactor at 24.6 atm and 500K and a flow rate of A of 10 mol/min

\[ \begin{align*}
A &\longrightarrow B + C \\
A &\longrightarrow D \\
2C + D &\longrightarrow 2E
\end{align*} \]

\[ \begin{align*}
r_1' &= k_1 [ C_A - \frac{C_B C_C}{K_1} ] \\
r_2 &= k_2 D_A \\
r_3' &= k_3 C_C^2 C_D
\end{align*} \]

Only species B diffuses out of the reactor through the membrane. At what point in the reactor is the

(a) the concentration of B is a maximum at \( W = \) __________

(b) the concentration of C is a maximum at \( W = \) __________
(c) Explain why the curves look the way they do.

(d) Vary $k_{1C}$ (.1 to 1000) and write a paragraph describing what you observe. Explain whether or not what you observe is reasonable.

**Additional Information**

Overall mass transfer coefficient $k_B = 15 \text{ dm}^3/\text{kg cat}\cdot\text{min}$

- $k_{1C} = 2 \text{ dm}^3/\text{kg cat}\cdot\text{min}$
- $K_{1C} = 0.2 \text{ mol/dm}^3$
- $k_{2D} = 0.4 \text{ dm}^3/\text{kg cat}\cdot\text{min}$
- $k_{3E} = 5 \text{ dm}^9/\text{mol}^2\cdot\text{kg cat}\cdot\text{min}$
- $W_f = 100 \text{ kg}$

---

The gas phase reactions take place isothermally in a membrane reactor packed with catalyst. Pure A enters the reactor at 24.6 atm and 500K and a flow rate of A of 10 mol/min

$$
A \xrightarrow{r_{1C}} B + C \quad r'_{1C} = k_{1C} \left[ C_A - \frac{C_B C_C}{K_{1C}} \right]
$$

$$
A \rightarrow D \quad r'_{2D} = k_{2D} C_A
$$

$$
2C + D \rightarrow 2E \quad r'_{3E} = k_{3E} C_C^2 C_D
$$

Only species B diffuses out of the reactor through the membrane. At what point in the reactor is the

(a) the concentration of B is a maximum at \( W = \) ________________

(b) the concentration of C is a maximum at \( W = \) ________________

(c) Explain why the curves look the way they do.
(d) Vary \( k_{1C} \) (.1 to 1000) and write a paragraph describing what you observe. Explain whether or not what you observe is reasonable.

**Additional Information**

Overall mass transfer coefficient \( k_B = 1.0 \, \text{dm}^3/\text{kg} \cdot \text{cat} \cdot \text{min} \)

\[ k_{1C} = 2 \, \text{dm}^3/\text{kg} \cdot \text{cat} \cdot \text{min} \]

\[ K_{1C} = 0.2 \, \text{mol/dm}^3 \]

\[ k_{2D} = 0.8 \, \text{dm}^3/\text{kg} \cdot \text{cat} \cdot \text{min} \]

\[ k_{3E} = 5 \, \text{dm}^9/\text{mol}^2 \cdot \text{kg} \cdot \text{cat} \cdot \text{min} \]

\[ W_f = 100 \, \text{kg} \]

The gas phase reactions take place isothermally in a membrane reactor packed with catalyst. Pure A enters the reactor at 24.6 atm and 500K and a flow rate of A of 10 mol/min

\[ \text{A} \rightleftharpoons \text{B} + \text{C} \quad \quad \dot{r}_{1C} = k_{1C} \left[ C_A - \frac{C_BC_C}{K_{1C}} \right] \]

\[ \text{A} \rightarrow \text{D} \quad \quad \dot{r}_{2D} = k_{2D} C_A \]

\[ 2\text{C} + \text{D} \rightarrow 2\text{E} \quad \quad \dot{r}_{3E} = k_{3E} \, C_C^2 C_D \]

Only species B diffuses out of the reactor through the membrane. At what point in the reactor is the

(a) the concentration of B is a maximum at \( W = \) 

(b) the concentration of C is a maximum at \( W = \) 

(c) Explain why the curves look the way they do.

(d) Vary \( k_{1C} \) (.1 to 1000) and write a paragraph describing what you observe. Explain whether or not what you observe is reasonable.
Additional Information

Overall mass transfer coefficient $k_B = 1.0 \text{ dm}^3 / \text{kg cat}\cdot\text{min}$

$k_{1C} = 2 \text{ dm}^3 / \text{kg cat}\cdot\text{min}$
$K_{1C} = 0.2 \text{ mol/dm}^3$
$k_{2D} = 2 \text{ dm}^3 / \text{kg cat}\cdot\text{min}$
$k_{3E} = 5 \text{ dm}^9 / \text{mol}^2 \cdot \text{kg cat}\cdot\text{min}$
$W_f = 100 \text{ kg}$