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

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

$$A \xrightarrow{} D \qquad r'_{2D} = k_{2D} C_A$$

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

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. Explain whether or not what you observe is reasonable.

Additional Information

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

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

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

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

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

$W_f = 100\ kg$

Equations:	Initial values:
d(Fb)/d(w)=r1c-kb*Cb	0
d(Fa)/d(w)=-r1c-r2d	10
d(Fc)/d(w)=r1c-r3e	0
d(Fd)/d(w)=r2d-0.5*r3e	0
d(Fe)/d(w)=r3e	0

kb=1

k1c=2

K1c=0.2

k2d=0.4

k3e=5

Ft=Fa+Fb+Fc+Fd+Fe

Cao=0.6

Cb=Cao*Fb/Ft

Ca=Cao*Fa/Ft

Cc=Cao*Fc/Ft

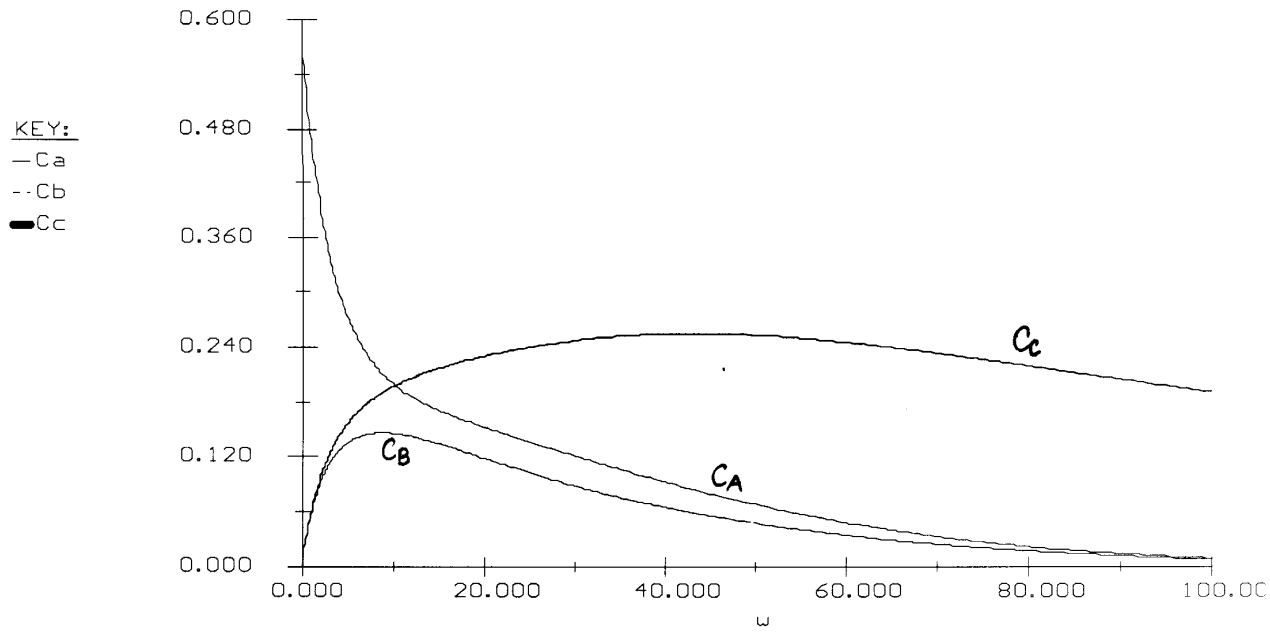
Cd=Cao*Fd/Ft

r2d=k2d*Ca

r3e=k3e*Cc**2*Cd

r1c=k1c*(Ca-Cb*Cc/K1c)

$w_0 = 0, \quad w_f = 100$



w	Ca	Cb	Cc
0	0.6	0	0
1	0.47542677	0.055665523	0.057312207
2	0.3957166	0.089633734	0.094926815
3	0.34130399	0.11132724	0.12127758
4	0.30234209	0.12549092	0.14067946
5	0.27342888	0.13473066	0.1555247
6	0.25141063	0.14057054	0.16721873
7	0.23424883	0.14399972	0.17667399
8	0.22058921	0.14567933	0.18449782
9	0.20952241	0.14605676 C_{Bmax}	0.19109747
10	0.20039388	0.14545751	0.19676552
11	0.19274558	0.14411239	0.2017048
12	0.18620294	0.142213	0.20608209
13	0.18051593	0.13989007	0.21000599
14	0.17547977	0.13725259	0.21356561
15	0.17093754	0.13438588	0.21682896

w	Ca	Cb	Cc
32	0.11540527	0.082939372	0.24923824
33	0.11246995	0.080411562	0.25018771
34	0.10955929	0.077954689	0.25104033
35	0.10667407	0.075564162	0.25180175
36	0.10381858	0.073243848	0.25246582
37	0.10099316	0.070988078	0.25303952
38	0.098199861	0.068795593	0.25352379
39	0.095441974	0.066667214	0.2539166
40	0.092719153	0.064597554	0.25422487
41	0.09003593	0.062589436	0.25444382
42	0.087392152	0.060638394	0.25457928
43	0.084788515	0.058741887	0.25463452 C_{Cmax}
44	0.082228183	0.056900712	0.25460796
45	0.079711463	0.055112089	0.25450344
46	0.07724071	0.053375881	0.25432101
47	0.074815671	0.051689129	0.25406506

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

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

$$A \xrightarrow{} D \qquad r'_{2D} = k_{2D} C_A$$

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

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. Explain whether or not what you observe is reasonable.

Additional Information

Overall mass transfer coefficient $k_B = 0.2\ dm^3/kg\ cat \cdot min$

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

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

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

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

$W_f = 100\ kg$

B

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

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

$$A \xrightarrow{} D \qquad r'_{2D} = k_{2D} C_A$$

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

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. Explain whether or not what you observe is reasonable.

Additional Information

Overall mass transfer coefficient $k_B = 5.0\ dm^3/kg\ cat \cdot min$

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

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

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

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

$W_f = 100\ kg$

C

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

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

$$A \xrightarrow{} D \qquad r'_{2D} = k_{2D} C_A$$

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

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. Explain whether or not what you observe is reasonable.

Additional Information

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

$k_{1C} = 0.2 \text{ dm}^3/\text{kg cat} \cdot \text{min}$

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

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

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

$W_f = 100 \text{ kg}$

D

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

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

$$A \xrightarrow{} D \qquad r'_{2D} = k_{2D} C_A$$

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

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. Explain whether or not what you observe is reasonable.

Additional Information

Overall mass transfer coefficient $k_B = 1.0\ dm^3/kg\ cat \bullet min$

$k_{1C} = 10\ dm^3/kg\ cat \bullet min$

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

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

$k_{3E} = 5\ dm^9/mol^2 \bullet kg\ cat \bullet min$

$W_f = 100\ kg$

E

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

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

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

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

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. Explain whether or not what you observe is reasonable.

Additional Information

Overall mass transfer coefficient $k_B = 1.0\ dm^3/kg\ cat \bullet min$

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

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

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

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

$W_f = 100\ kg$

F

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

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

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

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

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. Explain whether or not what you observe is reasonable.

Additional Information

Overall mass transfer coefficient $k_B = 1.0\ dm^3/kg\ cat \bullet min$

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

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

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

$k_{3E} = 10\ dm^9/mol^2 \bullet kg\ cat \bullet min$

$W_f = 100\ kg$

G

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

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

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

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

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. Explain whether or not what you observe is reasonable.

Additional Information

Overall mass transfer coefficient $k_B = 15\ dm^3/kg\ cat \bullet min$

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

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

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

$k_{3E} = 5\ dm^9/mol^2 \bullet kg\ cat \bullet min$

$W_f = 100\ kg$

H

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

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

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

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

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. Explain whether or not what you observe is reasonable.

Additional Information

Overall mass transfer coefficient $k_B = 1.0\ dm^3/kg\ cat \bullet min$

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

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

$k_{2D} = 0.8\ dm^3/kg\ cat \bullet min$

$k_{3E} = 5\ dm^9/mol^2 \bullet kg\ cat \bullet min$

$W_f = 100\ kg$

I

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

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

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

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

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. Explain whether or not what you observe is reasonable.

Additional Information

Overall mass transfer coefficient $k_B = 1.0\ dm^3/kg\ cat \bullet min$

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

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

$k_{2D} = 2\ dm^3/kg\ cat \bullet min$

$k_{3E} = 5\ dm^9/mol^2 \bullet kg\ cat \bullet min$

$W_f = 100\ kg$