# ChE 344 Chemical Reaction Engineering Winter 1999 Exam I

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 hour working on Part 2 of this exam.	: more than one
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

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

the concentration of B is a maximum at

$$W = 9 \text{ kg}$$

the concentration of C is a maximum at

$$W = 43$$

- Explain why the curves look the way they do. (c)
- Vary k<sub>1C</sub> (.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  $k_B = 1.0 \text{ dm}^3/\text{kg cat} \cdot \text{min}$ 

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

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

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

$$k_{2D} = 0.4 \text{ dm}^3/\text{kg cat} \cdot \text{min}$$
 $k_{3E} = 5 \text{ dm}^9/\text{mol}^2 \cdot \text{kg cat} \cdot \text{min}$ 

$$W_f = 100 \text{ kg}$$

# Initial values: Equations: d(Fb)/d(w)=r1c-kb\*Cb0 d(Fa)/d(w) = -r1c - r2d10 d(Fc)/d(w)=r1c-r3e0 d(Fd)/d(w) = r2d-0.5\*r3e0 d(Fe)/d(w)=r3e0 kb=1 k1c=2K1c=0.2k2d=0.4k3e=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 rlc=klc\*(Ca-Cb\*Cc/Klc) $w_0 = 0$ , $w_{f} = 100$ 0.600 KEY: 0.480 — Ca --СЬ **-**C⊂ 0.360 $C_{c}$ 0.240 0.120 CB CA

0.000

0.000

20.000

40.000

60,000

80.000

100.00

W	Ca	Cb	Cc
0	0.6	0	0
1	0.47542677	0.055665523	0.05731220
2	0.3957166	0.089633734	0.09492681
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
3	0.22058921	0.14567933	0.18449782
9	0.20952241	0.14605676 CB	0.19109747
10	0.20039388	0.14545751	0.19676552
11	0.19274558	0.14411239	0.2017048
L2	0.18620294	0.142213	0.20608209
L3	0.18051593	0.13989007	0.21000599
. 4	0.17547977	0.13725259	0.21356561
L5	0.17093754	0.13438588	0.21682896
Dago	3		
Paue	3		
Page	Ca	Cb	Cc
J		<u>Cb</u> 0.082939372	Cc 0.24923824
2	Ca		
2 3	Ca 0.11540527	0.082939372	0.24923824
3 2 3 3 3 4	Ca 0.11540527 0.11246995	0.082939372	0.24923824
32 33 34 35	Ca 0.11540527 0.11246995 0.10955929	0.082939372 0.080411562 0.077954689	0.24923824 0.25018771 0.25104033
32 33 34 35	Ca 0.11540527 0.11246995 0.10955929 0.10667407	0.082939372 0.080411562 0.077954689 0.075564162	0.24923824 0.25018771 0.25104033 0.25180175
3 2 3 3 3 4 3 5 3 6	Ca 0.11540527 0.11246995 0.10955929 0.10667407 0.10381858	0.082939372 0.080411562 0.077954689 0.075564162 0.073243848	0.24923824 0.25018771 0.25104033 0.25180175 0.25246582
32 33 34 35 36 37	Ca 0.11540527 0.11246995 0.10955929 0.10667407 0.10381858 0.10099316	0.082939372 0.080411562 0.077954689 0.075564162 0.073243848 0.070988078	0.24923824 0.25018771 0.25104033 0.25180175 0.25246582 0.25303952
v 32 33 34 35 36 37 38	Ca 0.11540527 0.11246995 0.10955929 0.10667407 0.10381858 0.10099316 0.098199861	0.082939372 0.080411562 0.077954689 0.075564162 0.073243848 0.070988078 0.068795593	0.24923824 0.25018771 0.25104033 0.25180175 0.25246582 0.25303952 0.25352379
32 33 34 35 36 37 38 39	Ca 0.11540527 0.11246995 0.10955929 0.10667407 0.10381858 0.10099316 0.098199861 0.095441974	0.082939372 0.080411562 0.077954689 0.075564162 0.073243848 0.070988078 0.068795593 0.066667214	0.24923824 0.25018771 0.25104033 0.25180175 0.25246582 0.25303952 0.25352379 0.2539166
v 32 33 34 35 36 37 38 39	Ca 0.11540527 0.11246995 0.10955929 0.10667407 0.10381858 0.10099316 0.098199861 0.095441974 0.092719153	0.082939372 0.080411562 0.077954689 0.075564162 0.073243848 0.070988078 0.068795593 0.066667214 0.064597554	0.24923824 0.25018771 0.25104033 0.25180175 0.25246582 0.25303952 0.25352379 0.2539166 0.25422487 0.25444382 0.25457928
32 33 34 35 36 37 38 39 40 41 42	Ca 0.11540527 0.11246995 0.10955929 0.10667407 0.10381858 0.10099316 0.098199861 0.095441974 0.092719153 0.09003593	0.082939372 0.080411562 0.077954689 0.075564162 0.073243848 0.070988078 0.068795593 0.066667214 0.064597554 0.062589436	0.24923824 0.25018771 0.25104033 0.25180175 0.25246582 0.25303952 0.25352379 0.2539166 0.25422487 0.25444382 0.25457928
w 32 33 34 35 36 37 38 39 40 41 42	Ca 0.11540527 0.11246995 0.10955929 0.10667407 0.10381858 0.10099316 0.098199861 0.095441974 0.092719153 0.09003593 0.087392152	0.082939372 0.080411562 0.077954689 0.075564162 0.073243848 0.070988078 0.068795593 0.066667214 0.064597554 0.062589436 0.060638394	0.24923824 0.25018771 0.25104033 0.25180175 0.25246582 0.25303952 0.25352379 0.2539166 0.25422487 0.25444382 0.25457928
32 33 34 35 36 37 38 39 40 41	Ca 0.11540527 0.11246995 0.10955929 0.10667407 0.10381858 0.10099316 0.098199861 0.095441974 0.092719153 0.09003593 0.087392152 0.084788515	0.082939372 0.080411562 0.077954689 0.075564162 0.073243848 0.070988078 0.068795593 0.066667214 0.064597554 0.062589436 0.060638394 0.058741887	0.24923824 0.25018771 0.25104033 0.25180175 0.25246582 0.25303952 0.25352379 0.2539166 0.25422487 0.25442382 0.25457928
w 32 33 34 35 36 37 38 39 40 41 42 43	Ca 0.11540527 0.11246995 0.10955929 0.10667407 0.10381858 0.10099316 0.098199861 0.095441974 0.092719153 0.092719153 0.09003593 0.087392152 0.084788515 0.082228183	0.082939372 0.080411562 0.077954689 0.075564162 0.073243848 0.070988078 0.068795593 0.066667214 0.064597554 0.062589436 0.060638394 0.058741887 0.056900712	0.24923824 0.25018771 0.25104033 0.25180175 0.25246582 0.25303952 0.25352379 0.2539166 0.25422487 0.25444382 0.25457928 0.25463452 0.25460796

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

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

the concentration of B is a maximum at

$$W =$$

the concentration of C is a maximum at

$$W =$$

- (c) Explain why the curves look the way they do.
- Vary k<sub>1C</sub> (.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  $k_B = 0.2 \text{ dm}^3/\text{kg cat} \cdot \text{min}$ 

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

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

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

$$k_{2D} = 0.4 \text{ dm}^3/\text{kg cat} \cdot \text{min}$$
 $k_{3E} = 5 \text{ dm}^9/\text{mol}^2 \cdot \text{kg cat} \cdot \text{min}$ 

$$W_f = 100 \text{ kg}$$

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

the concentration of B is a maximum at

the concentration of C is a maximum at

- Explain why the curves look the way they do. (c)
- (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  $k_B = 5.0 \text{ dm}^3/\text{kg cat} \cdot \text{min}$ 

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

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

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

$$k_{2D} = 0.4 \text{ dm}^3/\text{kg cat} \cdot \text{min}$$
 $k_{3E} = 5 \text{ dm}^9/\text{mol}^2 \cdot \text{kg cat} \cdot \text{min}$ 

$$W_f = 100 \text{ kg}$$

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 B+C 
$$r_{1C} = k_{1C} C_A - \frac{C_B C_C}{K_{1C}}$$

$$A \qquad D \qquad \qquad r_{2D} = k_{2D} C_A$$
 
$$2C + D \qquad 2E \qquad \qquad r_{3E} = k_{3E} C_C^2 C_D$$

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 =
- <u>W = \_\_\_\_</u> the concentration of C is a maximum at
- Explain why the curves look the way they do. (c)
- Vary k<sub>1C</sub> (.1 to 1000) and write a paragraph describing what you. Explain (d) whether or not what you observe is reasonable.

## **Additional Information**

Overall mass transfer coefficient k<sub>B</sub> = 1.0 dm<sup>3</sup>/kg cat•min

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

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

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

$$k_{2D} = 0.4 \text{ dm}^3/\text{kg cat} \cdot \text{min}$$
  
 $k_{3E} = 5 \text{ dm}^9/\text{mol}^2 \cdot \text{kg cat} \cdot \text{min}$ 

$$W_f = 100 \text{ kg}$$

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

$$A \qquad B+C \qquad \qquad r_{1C} = k_{1C} C_A - \frac{C_B C_C}{K_{1C}}$$
 
$$A \qquad D \qquad \qquad r_{2D} = k_{2D} C_A$$

$$2C + D 2E r_{3E} = k_{3E} C_C^2 C_D$$

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  $k_{\rm 1C}$  (.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<sub>R</sub> = 1.0 dm<sup>3</sup>/kg cat • min

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

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

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

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

$$W_f = 100 \text{ kg}$$

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

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

the concentration of B is a maximum at

 $\mathbf{W} =$ 

the concentration of C is a maximum at

W =

- Explain why the curves look the way they do.
- Vary k<sub>1C</sub> (.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  $k_B = 1.0 \text{ dm}^3/\text{kg cat} \cdot \text{min}$ 

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

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

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

$$K_{1C} = 0.2 \text{ mol/dm}^3$$
 $k_{2D} = 0.4 \text{ dm}^3/\text{kg cat} \cdot \text{min}$ 
 $k_{3E} = 20 \text{ dm}^9/\text{mol}^2 \cdot \text{kg cat} \cdot \text{min}$ 

$$W_f = 100 \text{ kg}$$

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

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

<u>W</u> =

(b) the concentration of C is a maximum at

<u>W</u> =

- (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  $k_B = 1.0 \text{ dm}^3/\text{kg cat} \cdot \text{min}$ 

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

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

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

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

$$W_f = 100 \text{ kg}$$

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

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

<u>W</u> =

**(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  $k_B = 15 \text{ dm}^3/\text{kg cat} \cdot \text{min}$ 

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

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

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

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

$$W_f = 100 \text{ kg}$$

#### Η

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

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

the concentration of B is a maximum at

$$W =$$

the concentration of C is a maximum at

Explain why the curves look the way they do.

(d) Vary  $k_{\rm 1C}$  (.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  $k_B = 1.0 \text{ dm}^3/\text{kg cat} \cdot \text{min}$ 

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

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

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

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

$$W_f = 100 \text{ kg}$$

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

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
- <u>W = </u>
- **(b)** the concentration of C is a maximum at
- <u>W</u> =
- (c) Explain why the curves look the way they do.
- (d) Vary  $k_{\rm 1C}$  (.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  $k_B = 1.0 \ dm^3/kg \ cat \bullet min$   $k_{1C} = 2 \ dm^3/kg \ cat \bullet min$   $K_{1C} = 0.2 \ mol/dm^3$   $k_{2D} = 2 \ dm^3/kg \ cat \bullet min$   $k_{3E} = 5 \ dm^9/mol^2 \bullet kg \ cat \bullet min$   $W_f = 100 \ kg$