CHM Eng 140 MIDTERM #1 PART I EXAMINATION

[redacted]

TOTAL POINTS

50 / 50

QUESTION 1

Question 1 22 pts

1.1 1A 8 / 8

✓ **+ 8 pts Correct**

+ 2 pts Component balance

+ 0 pts Incorrect

+ 5 pts Partially correct

+ 0 pts answer incorrect

+ 6 pts Answer incorrect

1.2 1B 7 / 7

✓ **+ 7 pts Correct**

+ 0 pts Missing

+ 4 pts Partially correct

+ 5 pts Answer incorrect

+ 2 pts material balance

+ 0 pts Incorrect

+ 2 pts conversion definition

1.3 1C 7 / 7

✓ **+ 7 pts Correct**

+ 0 pts Incorrect component balance

+ 0 pts Missing

+ 4 pts partially correct

+ 0 pts incorrect

+ 2 pts Material balance

+ 5 pts Answer Incorrect

QUESTION 2

Question 2 28 pts

2.1 2A 3 / 3

✓ **- 0 pts Correct**

- 1 pts rate law incorrect

- 1 pts rate law units incorrect

- 1 pts rate constant units incorrect

2.2 2B 7 / 7

✓ **- 0 pts Correct**

- 7 pts Incomplete or incorrect

- 1 pts No Vt in reaction term

- 1 pts sign error on reaction term

- 2 pts Ca in reaction term should be tank concentration

- 1 pts removed Q from the balance

- 1 pts Solved as an unsteady state problem

- 2 pts solved using an incorrect reaction order

- 1 pts Volumetric flow rate used instead of tank volume in reaction term

- 2 pts missing inlet and outlet balance terms

+ 1 pts some attempt to solve

- 1 pts missing term in balance

- 1 pts error in reaction term

2.3 2C 4 / 4

✓ **- 0 pts Correct**

- 2 pts Incorrect calculation of concentration of B

- 1 pts Math error in calculating concentration of B/no final answer for Cb

- 2 pts Concentration of B not calculated

- 4 pts incomplete

- 1 pts Ca incorrect but method to calculate Cb correct

+ 1 pts some attempt to solve

- 1 pts Incorrect calculation of Ca

- 0 pts Incorrect bc first order reaction used, no additional penalty

- 0.5 pts sig figs

- 0 pts only incorrect because of missing term, no additional penalty

2.4 2D 4 / 4

✓ **- 0 pts Correct**

- 4 pts incomplete or incorrect

- 0 pts Incorrect bc of previous error, no penalty

+ 1 pts general equation correct

- 2 pts Used fractional conversion equation for first order rate law

+ 1 pts attempt to solve

- 2 pts conversion based on Ca0/moles fed instead of moles reacted/moles fed

- 1 pts correct set up, no final answer

2.5 2E 8 / 8

✓ **- 0 pts Correct**

- 2 pts Incorrect overall conversion (Fa=0.725)

- 2 pts Not getting Ca,out(1) = 4.63 mol/L on first reactor and incorrect set up/equation

- 2 pts Not getting Ca,in(2) = 4.63 mol/L on second reactor and incorrect set up/equation

- 2 pts Not getting Ca,out(2) = 2.75 mol/L on second reactor and incorrect set up/equation

- 1.5 pts Attempt with correct equation for overall conversion

- 1 pts Attempt with correct equation for overall conversion with numbers

- 8 pts Incorrect

- 1.75 pts Attempt/incorrect balance equation for Ca,out(1) = 4.63 mol/L on first reactor

- 1.75 pts Attempt/incorrect balance equation for Ca,out(2) = 2.75 mol/L on second reactor

- 1.5 pts Attempt with correct balance equation for Ca,out(1) = 4.63 mol/L on first reactor

- 1.5 pts Attempt with correct balance equation for Ca,out(2) = 2.75 mol/L on second reactor

- 0.5 pts Correct balance equation but not getting Ca,out(1) = 4.63 mol/L on first reactor

- 0.5 pts correct balance equation but not getting Ca,out(2) = 2.75 mol/L on second reactor

2.6 2F 2 / 2

✓ **- 0 pts Correct**

- 2 pts Icorrect

- 1 pts Partially correct

1) a) mol balance B around reactor:

out = G

$\dot{n}_{B,3} = 0.3\,\dot{n}_{A,2}$

mol balance B around sep 1

$\dot{n}_{B,3} = 0.05\,\dot{n}_4 + \dot{n}_{B,5}$

mol balance B around sep 2

$\dot{n}_{B,5} = 50$ mol/s

mol balance C around reactor:

$\dot{n}_{C,3} = 0.3\,\dot{n}_{A,2} = \dot{n}_{B,3}$

mol balance C around sep 1:

$\dot{n}_{C,5} = 0.95\,\dot{n}_4$

$\therefore \dot{n}_{B,3} = 0.95\,\dot{n}_4$

$0.05\,\dot{n}_4 + 50 = 0.95\,\dot{n}_4$

$\dot{n}_4 = \frac{50 \text{ mol/s}}{0.90} = 55.6$ mol/s

b) $\dot{n}_{B,3} = 0.05\,\dot{n}_4 + \dot{n}_{B,5} = 0.05\,\dot{n}_4 + 50$ mol/s $= 52.77$ mol/s

$\dot{n}_{B,3} = 0.3\,\dot{n}_{A,2}$; $\dot{n}_2 = \dot{n}_{A,2}$

$52.77 = 0.3\,\dot{n}_2$

$\dot{n}_2 = 176$ mol/s

c) $\dot{n}_1 + \dot{n}_7 = \dot{n}_2$

$\dot{n}_{A,3} = 0.7\,\dot{n}_2$

$\dot{n}_{A,5} = \dot{n}_{A,7} = \dot{n}_{A,3} = 0.7\,\dot{n}_2$

$\dot{n}_1 + 0.7\,\dot{n}_2 = \dot{n}_2$

$\dot{n}_1 = 0.3\,\dot{n}_2$

$= 52.8$ mol/s

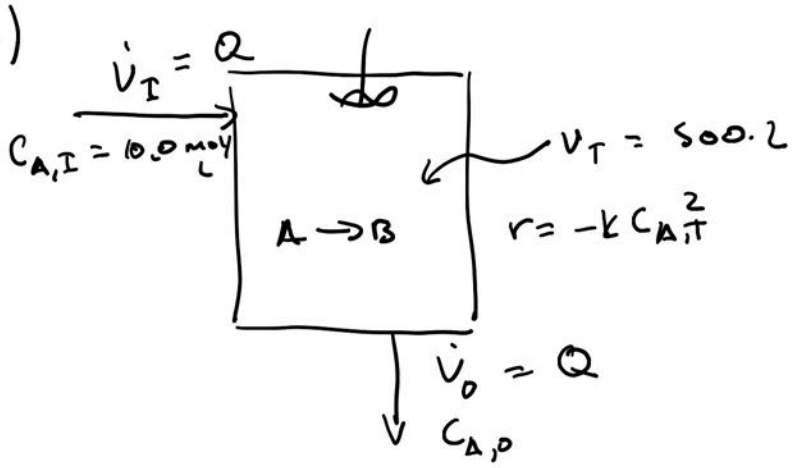
2) a) $r = -k C_A^2$

$r [=] \frac{mol}{L \cdot min}$ $\quad C_A [=] \frac{mol}{L}$

$\frac{mol}{L \cdot min} [=] [k] * \frac{mol^2}{L^2}$ $\quad k [=] \frac{L}{mol \cdot min}$

$k = 0.0100$

b)



Steady state → $\frac{dC_{A,T}}{dt} = 0$

$Q = 10.0$ L/min

$C_{A,T} = C_{A,o}$ (well mixed)

V_T is constant

Species A Balance:

Acc. = I − O + ~~G~~ (0) − C

$I = C_{A,I} \dot{V}_I = C_{A,I} Q$

$O = C_{A,O} \dot{V}_o = C_{A,O} Q$

$C = k C_{A,T}^2 V_T = k C_{A,O}^2 V_T$

$Acc. = \frac{d(C_{A,T} V_T)}{dt} = V_T \frac{dC_{A,O}}{dt}$

$V_T \frac{dC_{A,T}}{dt} = C_{A,I} Q - C_{A,O} Q - k C_{A,O}^2 V_T$

$0 = C_{A,I} Q - C_{A,O} Q - k C_{A,O}^2 V_T$; assumes $\frac{dC_{A,T}}{dt} = 0$ due to steady state

c) $V_T = 500.$ $C_{A,I} = 10.0$ $Q = 10.0$ $k = 0.0100$

$$0 = 10.0(10.0) - 10.0C_{A,0} - 0.0100\,C_{A,0}^2(500.)$$

$$0 = 100. - 10.0\,C_{A,0} - 5.00\,C_{A,0}^2$$

$$C_{A,0} = \frac{10.0 \pm \sqrt{100. - 4(-5.00)(100.)}}{-10.0}$$

$$= 3.58 \text{ or } -5.58$$

$$\boxed{C_{A,0} = 3.58 \text{ mol/L}}$$

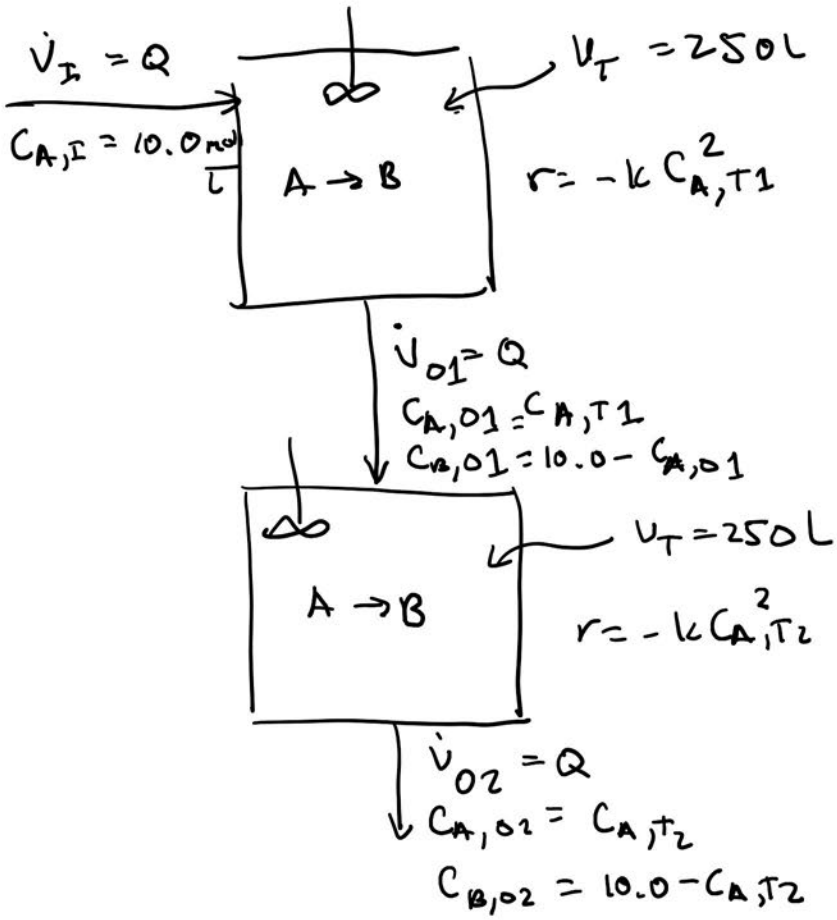
$$C_{A,0} + C_{B,0} = C_{A,I} = 10.0$$

$$\boxed{C_{B,0} = 6.42 \text{ mol/L}}$$

d) $$f_A = \frac{C_{A,I} - C_{A,0}}{C_{A,I}} = \frac{10.0 - 3.58}{10.0} = \boxed{0.642}$$

e) (con. next page)

e)



Tank 1: recycling eqn. from B, but $V_T = 250$.

$C_{A,I} = 10.0 \frac{mol}{L}$

$Q = 10.0 L/min$

$k = 0.0100$

$$0 = C_{A,I} Q - C_{A,O1} Q - k C_{A,O1}^2 V_T$$

$$0 = 100 - 10 C_{A,O1} - 2.5 C_{A,O1}^2$$

$$C_{A,O1} = \frac{10 \pm \sqrt{100 - 4(-2.5)(100)}}{2(-2.5)} = 4.63 \frac{mol}{L} \text{ or } -8.63$$

Tank 2: $C_{A,I} = 4.63 \text{ mol/L}$

$$0 = 4.63(10) - 10 C_{A,O2} - 2.5 C_{A,O2}^2$$

$$C_{A,O2} = \frac{10 \pm \sqrt{100 - 4(-2.5)(46.33)}}{2(-2.5)} = 2.75 \text{ mol/L}$$

$$f_A = \frac{C_{A,I} - C_{A,O2}}{C_{A,I}} = \frac{10.0 - 2.75}{10.0} = \boxed{0.725}$$

f) The effective residence time was increased by placing 2 CSTR's in series. This increased residence time increased the conversion.

CHM Eng 140 MIDTERM #1 PART II EXAMINATION

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TOTAL POINTS

50 / 50

QUESTION 1

Question 1 15 pts

1.1 1A 10 / 10

✓ **- 0 pts Correct**

- 1 pts incorrect species A balance

- 1 pts incorrect accumulation term

- 1 pts didn't use well mixed assumption

- 1 pts incorrect in stream

- 1 pts incorrect out stream

- 1 pts incorrect initial condition

- 1 pts missing integration constant if used an indefinite integral

- 1 pts didn't apply IC

- 2 pts incorrect final answer

1.2 5 / 5

✓ **- 0 pts Correct**

- 2 pts incorrect theta equation

- 3 pts incorrect final concentration

- 1 pts consistent with incorrect part A

QUESTION 2

Question 2 35 pts

2.1 2A 3 / 3

✓ **- 0 pts Correct**

- 3 pts Incorrect

- 1 pts Dimensions rather than units

- 2 pts Units are mixed (e.g., min*s in denominator)

2.2 2B 15 / 15

✓ **- 0 pts Correct**

- 2 pts Mass balance not shown or incorrect

- 2 pts Inlet term incorrect

- 2 pts Accumulation term incorrect

- 2 pts Outlet term incorrect

- 3 pts Show work for integration, initial condition

- 3 pts Q=3t not used in differential equation or in evaluation of integral

- 3 pts rhoA in accum. and/or outlet term should not be included (check units)

- 4 pts Incorrect integration

- 3 pts incorrect integration, but defined IC

- 4 pts Integration constant evaluation with IC incorrect

- 2 pts Final answer incorrect

- 15 pts Incorrect

2.3 2C 10 / 10

✓ **- 0 pts Correct**

- 2 pts No written species balance (what are in and out terms? On which unit is balance performed?)

- 3 pts Incorrect balance (e.g., accumulation term kept)

- 2 pts Inlet terms incorrect (or not clearly defined)

- 2 pts Outlet term incorrect (or not clearly defined)

- 2 pts rho_a included in stream 3 or stream 5 term (or both), or not included in stream 4.

- 2 pts For no work

- 2 pts Answer incorrect, or not expressed purely in terms of the variables desired

- 10 pts Not correct

2.4 2D 3 / 3

✓ **- 0 pts Correct**

- 0 pts OK, followed correct procedure

- 3 pts Incorrect

- 2 pts Incomplete answer, but right track

- 1 pts Calc error

2.5 2E 4 / 4

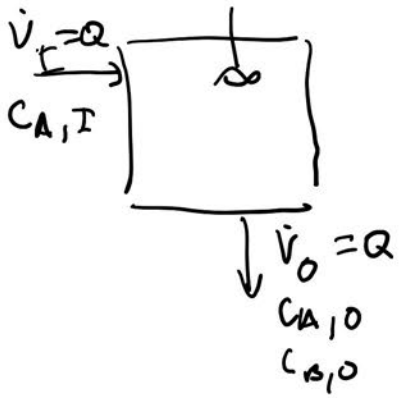
✓ **- 0 pts** **Correct**

- 2 pts t=0 min does not equal p_a

- 2 pts for incorrect answer at Q1/3, need exact answers for full part e credit!

- 1 pts calc/minor error

1)



$\rho_A = \rho_B$

V_T constant

$C_{A,T} = C_{A,O}$ (well mixed)

species balance of A

$$ACC = I - O + G - C$$

$$ACC = \frac{d(C_{A,T}\, V_T)}{dt} = V_T \frac{d C_{A,T}}{dt} = V_T \frac{d C_{A,O}}{dt}$$

$$I = C_{A,I}\, \dot{V}_I = C_{A,I}\, Q$$

$$O = C_{A,O}\, \dot{V}_O = C_{A,O}\, Q$$

$$V_T \frac{d C_{A,O}}{dt} = C_{A,I}\, Q - C_{A,O}\, Q = Q(C_{A,I} - C_{A,O})$$

$$\int_0^{C_{A,O}(t)} \frac{d C_{A,O}}{C_{A,I} - C_{A,O}} = \int_0^t \frac{Q}{V_T}\, dt$$

$$-\ln(C_{A,I} - C_{A,O}) \Big|_0^{C_{A,O}(t)} = \frac{Q}{V_T}\, t \Big|_0^t$$

$$-\ln \frac{C_{A,I} - C_{A,O}(t)}{C_{A,I}} = \frac{Q}{V_T}\, t$$

$$1 - \frac{C_{A,0}(t)}{C_{A,I}} = e^{-\frac{Q}{V_T}t}$$

$$C_{A,0}(t) = C_{A,I}\left(1 - e^{-\frac{Q}{V_T}t}\right) \qquad C_{A,I} = \rho_A$$

$$\boxed{C_{A,0}(t) = \rho_A\left(1 - e^{-\frac{Q}{V_T}t}\right)}$$

b) $\theta = \frac{V_T}{Q}$ $\qquad C_{A,0}(t) = \rho_A\left(1 - e^{-\frac{t}{\theta}}\right)$

$$\boxed{C_{A,0}\left(\frac{\theta}{2}\right) = \rho_A\left(1 - e^{-1/2}\right)}$$

2. a) $[3] * \min[=] \frac{L}{\min}$

$3\ [=] \frac{L}{\min^2}$

b) Mass balance A around cstr

Acc. $= I - O + G$ (G → 0)

$$\text{Acc.} = \frac{d\left(C_{A,3}\, V_T\right)}{dt} = V_T \frac{dC_{A,3}}{dt}$$

$$I = C_{A,2}\dot{V}_2 = \rho_A Q_2 = 3\rho_A t \qquad Q_2 = Q_3 = 3t$$

$$O = C_{A,3}\dot{V}_3 = C_{A,3} Q_3 = 3C_{A,3}t$$

$$V_T \frac{dC_{A,3}}{dt} = 3\rho_A t - 3C_{A,3}t = 3t\left(\rho_A - C_{A,3}\right)$$

$$\int_0^{C_{A,3}(t)} \frac{dC_{A,3}}{\rho_A - C_{A,3}} = \int_0^t \frac{3t}{V_T}\, dt$$

$$-\ln\left(\rho_A - C_{A,3}\right)\Big|_0^{C_{A,3}(t)} = \frac{3}{V_T} t \Big|_0^t$$

$$-\ln\left(\frac{\rho_A - C_{A,3}(t)}{\rho_A}\right) = \frac{3}{2V_T} t^2$$

$$1 - \frac{C_{A,3}(t)}{\rho_A} = e^{-\frac{3}{2V_T} t^2}$$

$$C_{A,3}(t) = \rho_A \left(1 - e^{-\frac{3}{2V_T} t^2}\right)$$

c) Mass balance of A around mixer

$$Q_5 C_{A,5} = Q_4 C_{A,4} + Q_3 C_{A,3}$$

$$Q_1 C_{A,5} = \rho_A (Q_1 - 3t) + 3t\, C_{A,3}$$

$C_{A,4} = \rho_A$

$Q_5 = Q_1$

$Q_4 = Q_1 - 3t$

$Q_3 = 3t$

$$C_{A,5} = \frac{\rho_A (Q_1 - 3t) + 3 C_{A,3} t}{Q_1}$$

d) $$C_{A,5} = \frac{\rho_A (Q_1 - 3t) + 3\rho_A + \left(1 - e^{-\frac{3}{2V_T} t^2}\right)}{Q_1}$$

e) $C_{A,5}(0) = \dfrac{\rho_A(Q_1) + 3\rho_A(0)(\text{---})}{Q_1}$

$$C_{A,5}(0) = \rho_A$$

$$C_{A,5}\left(\frac{Q_1}{3}\right) = \frac{\rho_A(Q_1 - Q_1) + 3\rho_A\frac{Q_1}{3}\left(1 - e^{-\frac{\frac{3}{2v_+}\left(\frac{Q_1}{3}\right)^2}{}}\right)}{Q_1}$$

$$C_{A,5}\left(\frac{Q_1}{3}\right) = \rho_A\left(1 - e^{-\frac{Q_1^2}{6v_+}}\right)$$