ChE 344
Chemical Reaction Engineering
Winter 1999
Mid Term Exam

Open Book, Notes, Disk, and Web

Name________________________________

Honor Code____

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1) ____/ 5 pts

2) ____/ 6 pts

3) ____/ 6 pts

4) ____/ 4 pts

5) ____/ 5 pts

6) ____/ 5 pts

7) ____/15 pts

8) ____/10 pts

9) ____/ 9 pts

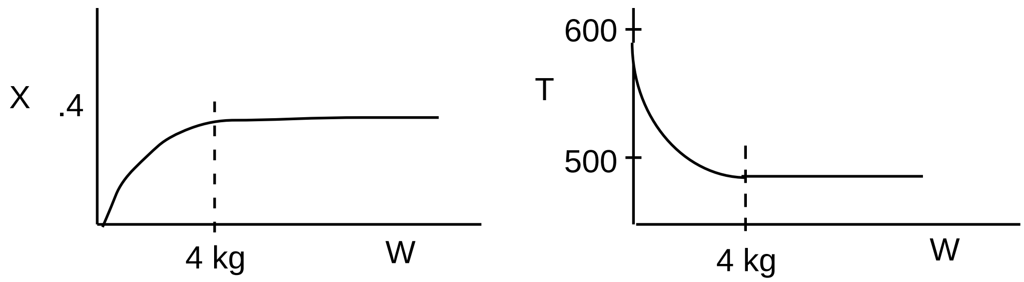
10) ____/10 pts

11) ____/ 25pts

Total ____/100pts

At the End of the Exam Turn Off Your Computer

(5 pts) 1) The isomerization of A to B was carried out in a packed bed reactor. The catalyst does not decay. The following profiles were obtained



Circle the correct true (T) or False (F) answer for this system

T F a) The above profiles could represent an adiabatic system where the addition of inerts to the feed stream will increase the conversion.

T F b) A small decrease in the flow rate will produce a small increase in the conversion.

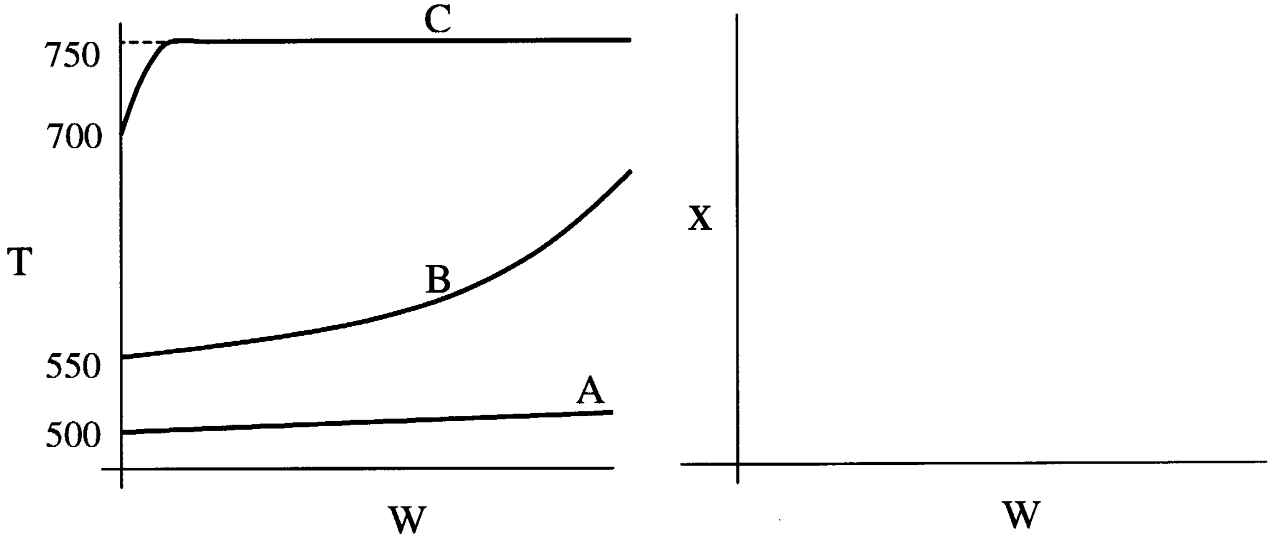
T F c) An increase in the feed temperature will <u>always</u> increase the conversion.

T F d) A decrease in feed temperature will <u>always</u> increase the conversion.

T F e) There could be a heat exchanger attached to the reactor with the heat flow given by

$$\frac{d\dot{Q}}{dW} = \left(\frac{400\ \text{kJ}}{\text{kg min K}}\right)(T - 400)$$

(6 pts) 2) The isomerization of A to B was carried out adiabatically in a packed bed reactor. The catalyst does not decay.

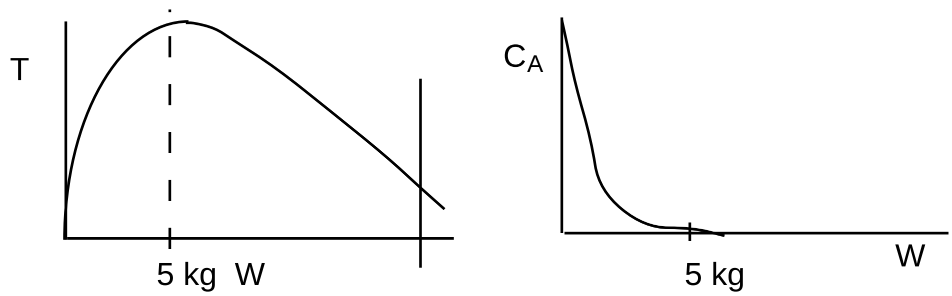


Sketch the corresponding temperature conversion profiles for A, B, and C.

(6 pts) 3) The series reaction

$$A \longrightarrow B \longrightarrow C$$

is carried out in a packed bed reactor. The following profiles were obtained.



Circle the correct true (T) or False (F) answer for this system

T F a) The above profiles could represent a system where the reactions are carried out adiabatically.

T F b) The above profiles could represent a system where there is a heat exchanger attached to the system.

T F c) The above profiles could represent an adiabatic system where both of the reactions could be endothermic.

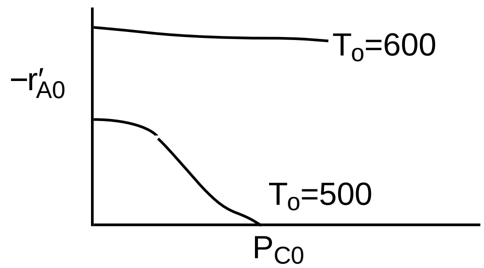
T F d) The above profiles could represent an adiabatic system where only one of the reactions is exothermic

T F e) The above profiles could represent a system where the addition of inerts could decrease the exit molar flow rate of the desired product, B.

T F f) The above profiles could represent an adiabatic system where increasing the feed temperature will increase the concentration of B in the exit stream.

(4 pts) 4) The irreversible gas phase reaction of A and B to form C and D was carried out in a packed bed reactor in which there is no catalyst decay.

The following figure shows the rate of reaction at the reactor entrance as a function the partial pressure of C for various entering temperatures, T_o



Circle the correct answer True (T), False (F), or Cannot Tell (CT) from the information given for the above system

T F CT a) The reaction is exothermic.

T F CT b) The reaction is endothermic.

T F CT c) Species C is adsorbed on the catalyst surface at 400°K.

T F CT d) Species C is adsorbed on the catalyst at 700°K.

(5 pts) 5) Circle the correct true (T) or False (F) answer

T F a) Multiple steady states can exist for an irreversible endothermic first order reactions.

T F b) Multiple steady states can only exist for reversible reactions.

T F c) Multiple steady states can only exist for adiabatic reactions.

T F d) Reactor staging is used for irreversible reactions.

T F e) The effects of pressure drop are more pronounced for adiabatic-exothermic reactions than for adiabatic endothermic reactions.

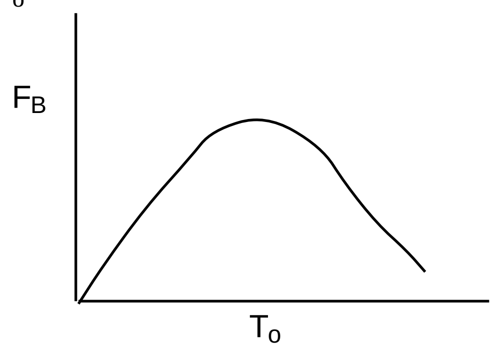
(5 pts) 6) The reactions

$$(1) \qquad A \rightleftarrows B + C$$

$$(2) \qquad A \rightarrow D + E$$

$$(3) \qquad A + C \rightarrow F + G$$

are carried out in a packed bed reactor where B is the desired product. The flowrate of species B exiting the reaction is shown below as a function of the entering temperature, T_o



Circle the correct true (T) or False (F) answer

T F a) The above figure could represent an adiabatic system where the reaction 1 is adiabatic exothermic and reversible.

T F b) The above figure could represent an adiabatic system where the reaction 1 is adiabatic, endothermic and reversible.

T F c) The above figure could represent an adiabatic system where all reactions are endothermic.

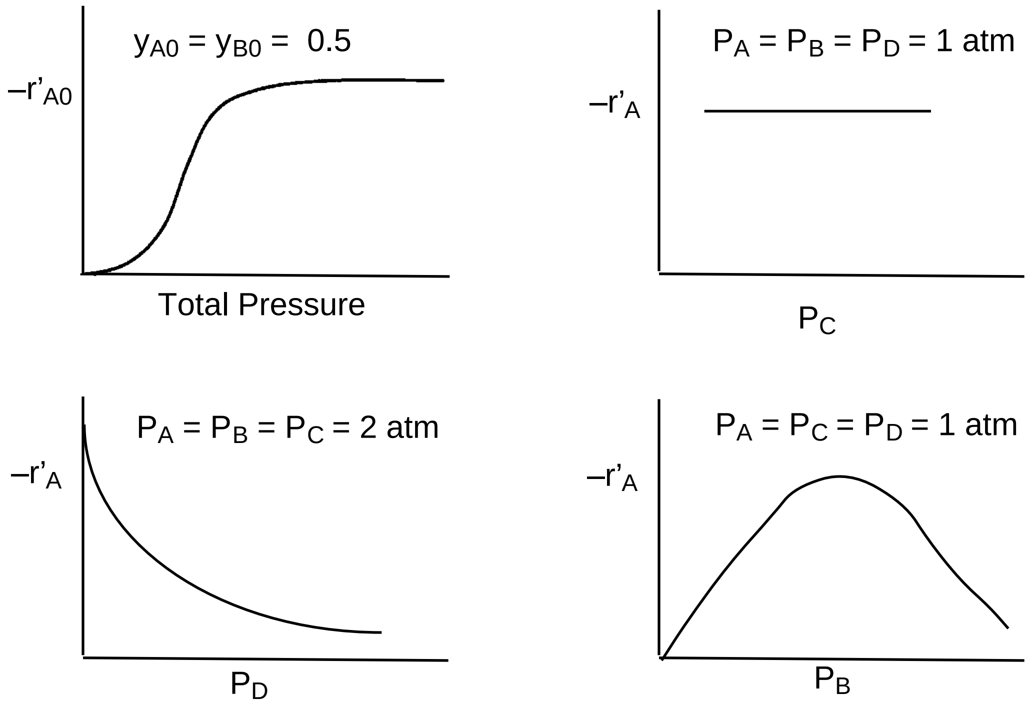
T F d) The above figure could represent a system where the reactions 1 and 3 are endothermic and reaction 2 is exothermic.

T F e) The above figure could represent a system where the reactions 1 and 2 are endothermic and reaction 3 is exothermic.

(15 pts) 7) The catalytic reaction

$$A + B \longrightarrow C + D$$

was carried out in a differential reactor with the following results



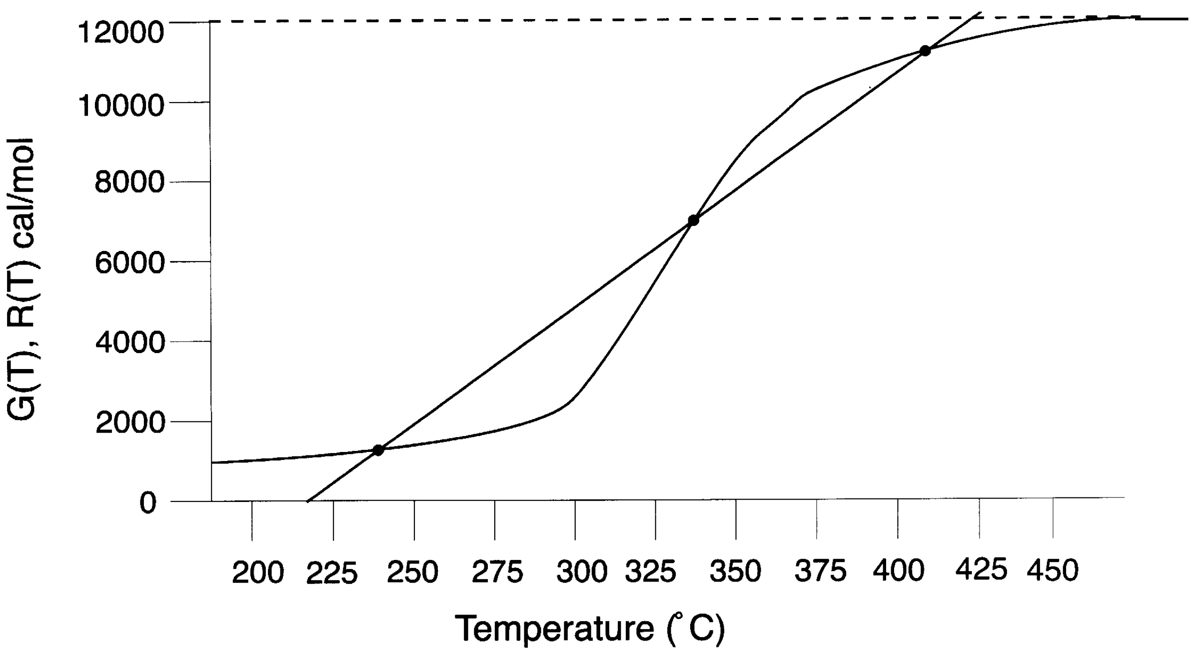
a) What is the rate law consistent with the experimental data?

b) What is the mechanism and rate limiting step consistent with the rate law? (Can be done by inspection).

(10 pts)8) The irreversible reaction

$$A + B \longrightarrow C + D$$

is carried out in a CSTR. The "heat generated" [G(T)] and the "heat removed" [R(T)] curves are shown below



a) What is the ΔH_{Rx} of the reaction?

ΔH_{Rx} = cal / mol

b) What are the ignition and extinction temperatures?

Ignition = °C

Extinction = °C

c) What are the conversions just before the ignition and extinction temperatures?

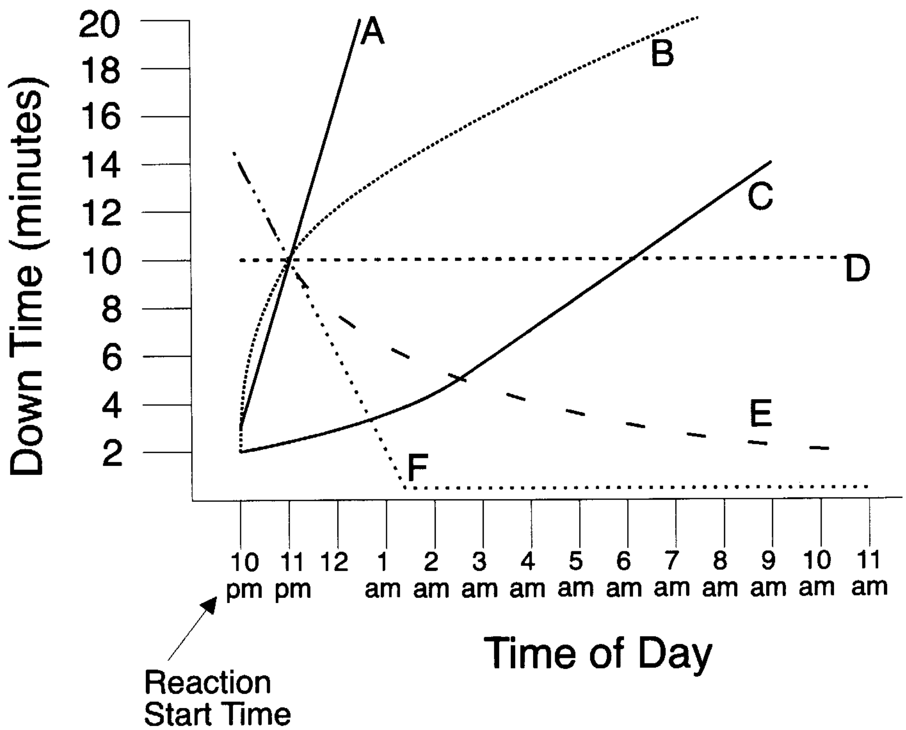
X (Ignition) =

X (Extinction) =

(9 pts) 9) Reconsider the example 9-2

a) Which of the following curves best describes the correlation between the shortest length of time the heat exchange stopped functioning (i.e. $\dot{Q} = 0$) (down time) and the time in the evening at which the malfunction occurred that will cause an explosion.

Ans________________________



b) If 10% more water had been added to the mixture in the reactor the explosion would not have occurred that evening.

True False

(10 pts)10) The vapor-phase cracking of gas-oil in Example 10-7 is carried out isothermally over a different catalyst, for which the rate law is

$$-r'_A = a(t)k'P_A^2 \quad \text{with} \quad k' = 1.0 \times 10^{-5} \frac{\text{kmol}}{\text{kgcat. s atm}^2} \quad \text{at } 400°\text{C and with } E_A = 5000 \frac{\text{cal}}{\text{mol}}$$

The decay law is

$$-\frac{da}{dt} = k_d a^2 P_B$$

with $k_d = 0.002\ \text{s}^{-1}\ \text{atm}^{-1}$ at 400°C and with $E_D = 35000$ cal/mol

Assuming that you can vary the entering temperature between 200°C and 700°C, what entering temperature would you recommend? (±25°C)

T_o = ________________ °C

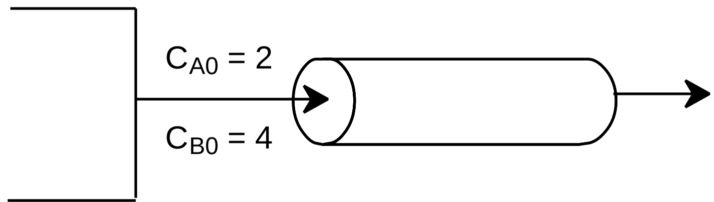
You can make any assumptions that were made in the example problem.

(25 pts) 11) The elementary liquid phase reactions

$$(1) \qquad A + 2B \longrightarrow 2C$$

$$(2) \qquad A + C \longrightarrow 2D$$

are carried out adiabatically in a 10 dm^3 PFR. After streams A and B mix, species A enters the reactor at a concentration of C_{A0} = 2 mol/dm^3 and species B at a concentration of 4 mol/dm^3. The entering volumetric flow rate is 10 dm^3/s.



Assuming you could vary the entering temperature between 300K and 600 K, what entering temperture would you recommend to maximize the concentration of species C exiting the reactor? (±25°K).

T_o = ________________ °C

Assume all species have the same density.

<u>Additional Information</u>

$C_{P_A} = C_{P_B} = 20$ cal/mol/K

$C_{P_C} = 60$ cal/mol/K

$C_{P_D} = 80$ cal/mol/K

$\Delta H_{Rx1A} = 20{,}000$ cal/mol A

$\Delta H_{Rx2A} = -10{,}000$ cal/mol A

$k_{1A} = 0.001 \dfrac{dm^6}{mol^2\ s}$ at 300K with E = 5000 cal/mol

$k_{2A} = 0.001 \dfrac{dm^3}{mol\ s}$ at 300K with E = 7500 cal/mol

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<u>Note:</u>

Before beginning write your POLYMATH program below in POLYMATH NOTATION

1.____
2.____
Continue