

ChE 344
Winter 2013
Mid Term Exam II
Tuesday, April 9, 2013

Open Course Textbook Only
Closed everything else (i.e., Notes, In-Class Problems and Home Problems)

Name _____

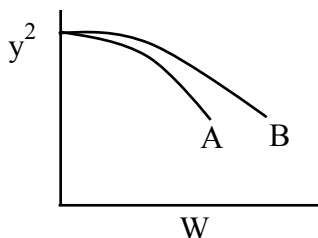
Honor Code (Please sign in the space provided below)

“I have neither given nor received unauthorized aid on this examination, nor have I concealed any violations of the Honor Code.”

(Signature)

- 1) ____ / 5 pts
- 2) ____ / 5 pts
- 3) ____ / 5 pts
- 4) ____ / 5 pts
- 5) ____ /10 pts
- 6) ____ /10 pts
- 7) ____ /10 pts
- 8) ____ /15 pts
- 9) ____ /15 pts
- 10) ____ /20 pts
- Total ____ /100 pts

- (5 pts) 1) (a) The following plot gives the square pressure drop parameter, y , as a function of catalyst weight, W for an adiabatic endothermic reaction and for an exothermic reaction. The flow is turbulent. The flow properties and catalyst properties are the same in both cases. Assume the absolute magnitude of the heats of reaction and heat capacities are identical as are the feed conditions. Which curve corresponds to the endothermic reaction? _____



Explain:

- (b) The Hercules explosion (P13-3_B) could have been prevented by continually increasing the ratio of water to ammonia chloride in the feed to shut the reactor down. Circle the correct answer

True

False

Insufficient information to tell

- (c) For an endothermic adiabatic reaction, the addition of inerts up to a certain amount will increase the conversion for a first order reaction when the reactant flow rates, F_{A0} , is held constant

True

False

Insufficient information to tell

- (d) For an endothermic adiabatic reaction, the addition of inerts after a certain amount has been added will decrease the conversion for a first order reaction when the reactant flow rates, F_{A0} , is held constant

True

False

Insufficient information to tell

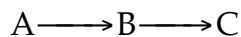
- (e) In PFR counter-current heat exchange, as one moves down the reactor away from the reactant entrance the ambient temperature will decrease once it falls below the reactor temperature

True

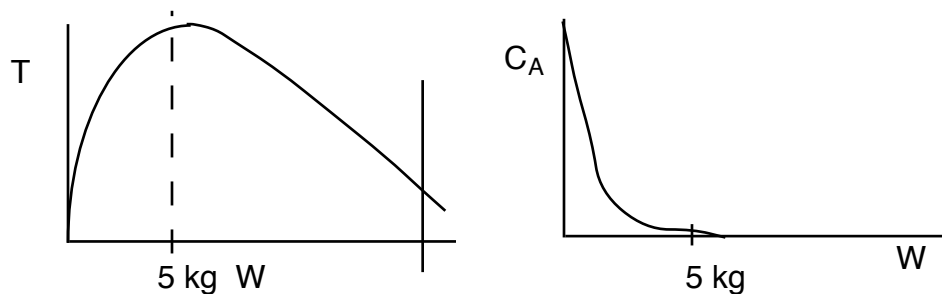
False

Insufficient information to tell

(5 pts) 2) The elementary series reaction



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 are endothermic.
- T F (d) The above profiles could represent an adiabatic system where only one of the reactions is exothermic
- T F (e) Assuming the activation energies are virtually the same for both reactions, the above profiles could represent an adiabatic system where increasing the feed temperature will increase the concentration of B in the exit stream.

(5 pts) 3) Monsanto Explosion: (Circle the correct answer)

(a) The addition of inerts will decrease the time between the time the heat exchanger came back on line and the time of explosion.

True

False

Insufficient information to tell

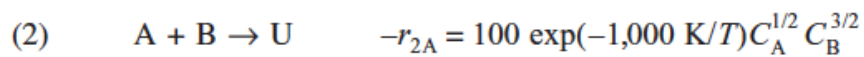
(b) If inerts had been added to the reactor it is possible that the explosion would not have occurred.

True

False

Insufficient information to tell

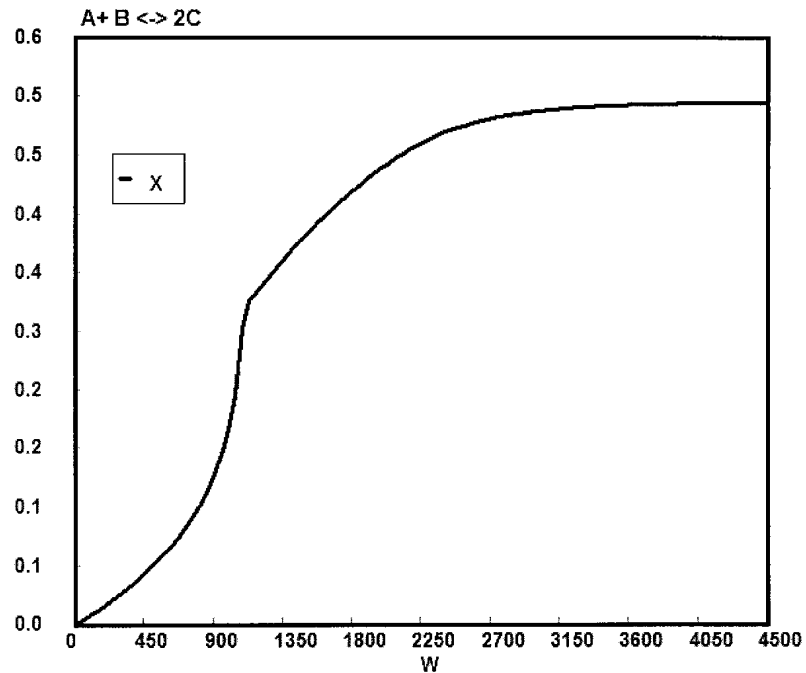
(5 pts) 4) (*Reactor selection and operating conditions*) For each of the following sets of reactions, describe your reactor system and conditions to maximize the selectivity to D. Make sketches where necessary to support your choices. The rates are in (mol/dm³·s), and concentrations are in (mol/dm³).



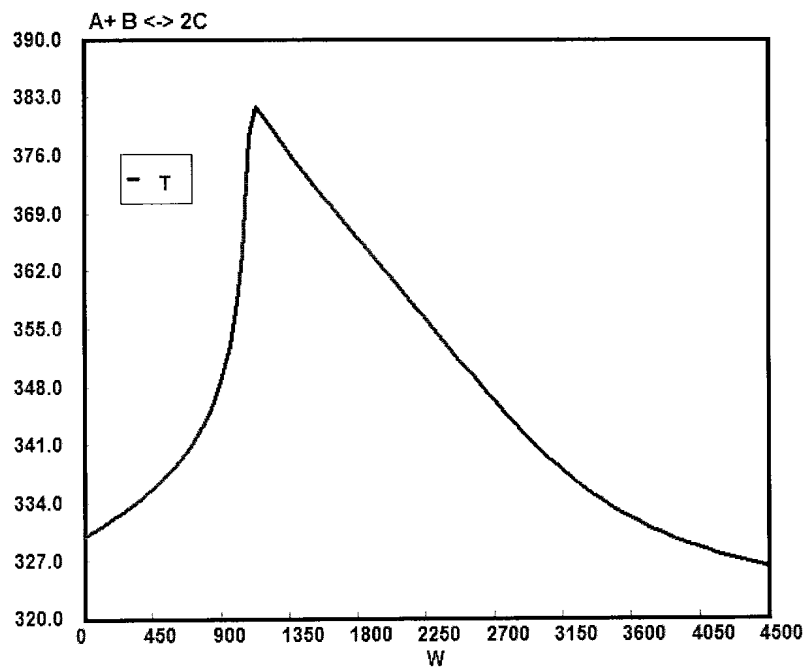
(10 pts) 5) The curves below show the conversion or temperature profiles for the Problem 12-3_B base case. Sketch the requested profiles for the parameters identified. Be sure to label which curve is the maximum and which is the minimum.

(2 pt) (a) Sketch the conversion for the maximum flow rate, i.e., 8 mol/min, and for the minimum flow rate, i.e., 1 mol/min

Flow Rate: Base case shown below for $F_{A0} = 5$



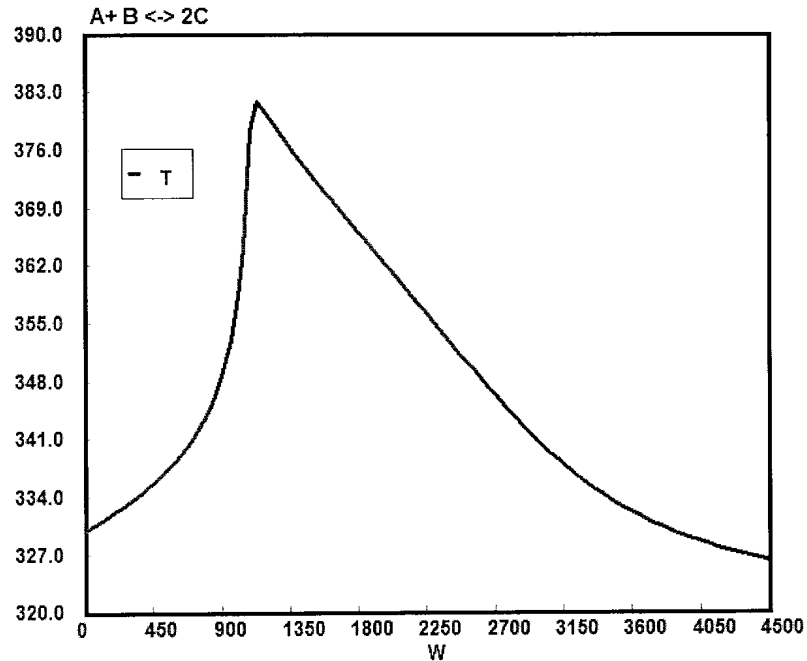
(2 pt) (b) Inert, Θ_I : Sketch the temperature profiles for $\Theta_I = 0.5$ and $\Theta_I = 4$. The base case shown below is for $\Theta_I = 1$



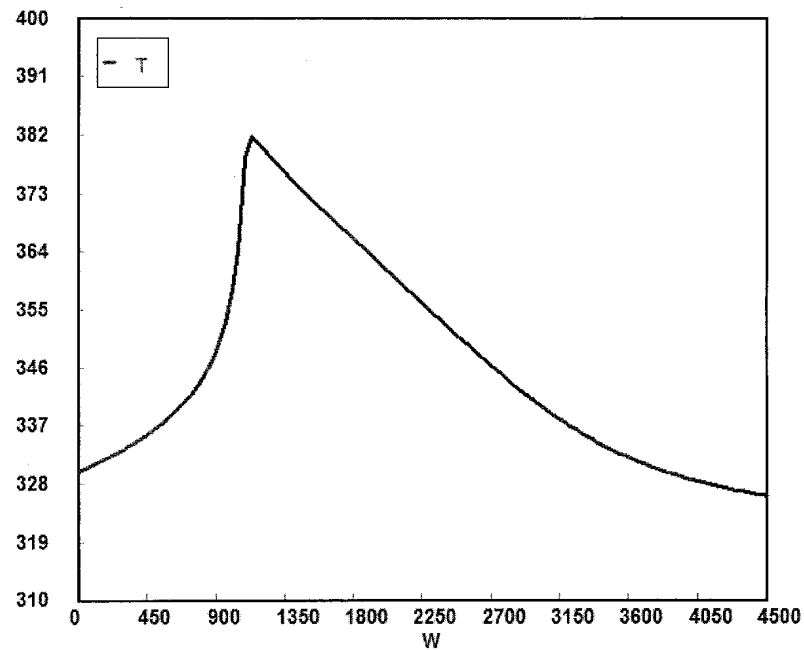
5) (continued)

(2 pt) (c) Sketch the temperature profiles for $\frac{U_a}{\rho_b} = 0.1 \text{ cal/kg} \cdot \text{s} \cdot \text{K}$ and for

$\frac{U_a}{\rho_b} = 0.8 \text{ cal/kg} \cdot \text{s} \cdot \text{K}$. The base case profile $\left(\frac{U_a}{\rho_b} = 0.5 \text{ cal/kg} \cdot \text{s} \cdot \text{K} \right)$ is shown below

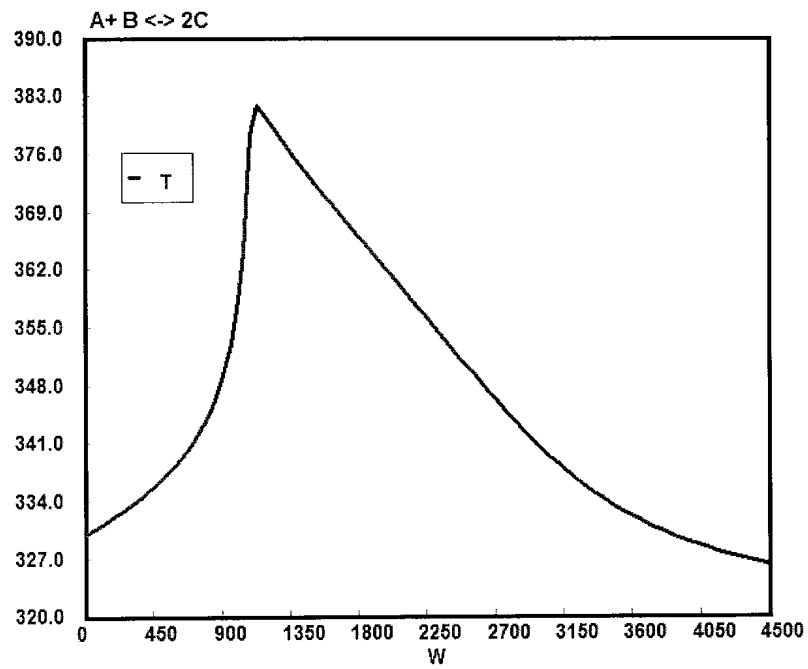


(2 pt) (d) Sketch the temperature profiles for an inlet temperature $T_0 = 310$ and for $T_0 = 350$ on the base case profile shown below for $T_0 = 330\text{K}$

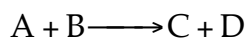


5) (continued)

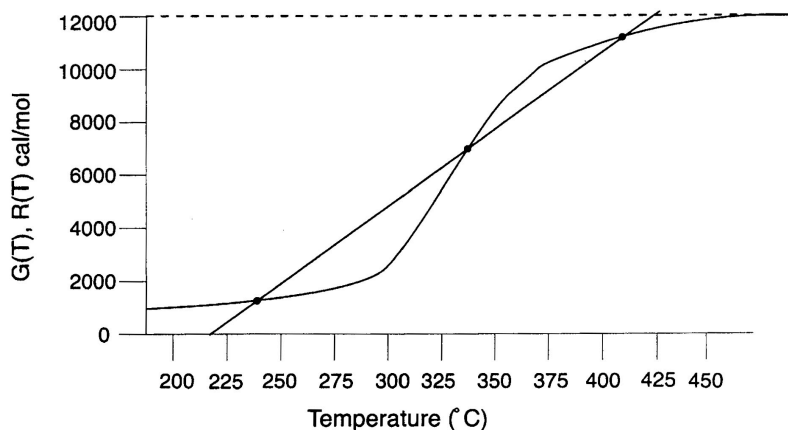
- (2 pt) (e) Sketch the temperature profiles for constant coolant temperatures of $T_a = 300\text{K}$ and for $T_a = 340\text{K}$ on the base case profile shown below for $T_a = 320\text{K}$



(10 pts) 6) The irreversible reaction



is carried out adiabatically 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?

$\Delta H_{Rx} = \underline{\hspace{2cm}}$ cal/mol

(b) What are the inlet temperatures for ignition and extinction?

Ignition = $\underline{\hspace{2cm}}$ °C

Extinction = $\underline{\hspace{2cm}}$ °C

(c) What are all the corresponding temperatures in the reactor corresponding to the inlet ignition and extinction temperature?

Ignition

$T = \underline{\hspace{1cm}}$ °C, $\underline{\hspace{1cm}}$ °C

Extinction

$T = \underline{\hspace{1cm}}$ °C, $\underline{\hspace{1cm}}$ °C

(d) What are the upper and lower conversions corresponding to at the ignition and extinction temperatures?

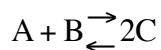
X (Ignition) = $\underline{\hspace{1cm}}$, $\underline{\hspace{1cm}}$

X (Extinction) = $\underline{\hspace{1cm}}$, $\underline{\hspace{1cm}}$

(e) In the above figure, what is the conversion at the unstable steady state?

X = $\underline{\hspace{2cm}}$

(10 pts) 7) The reaction



is carried out in a packed bed reactor. Match the following temperature and conversion profiles for the four different heat exchange cases adiabatic, constant T_a , co-current exchange and counter current exchange.

Figure 1

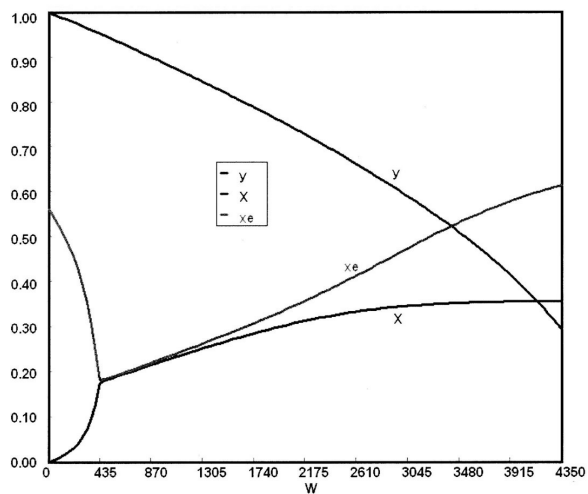


Figure 2

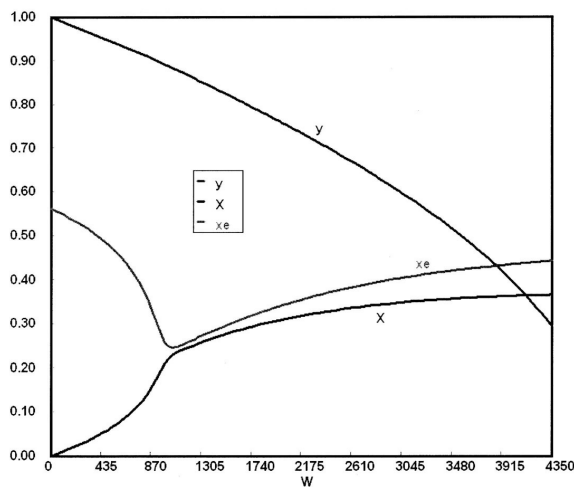


Figure 3

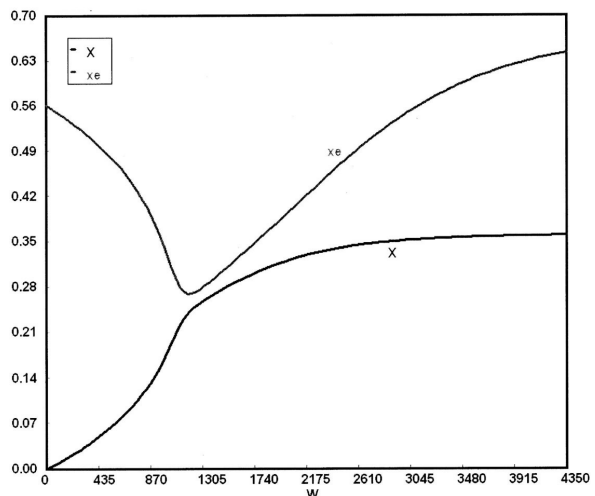
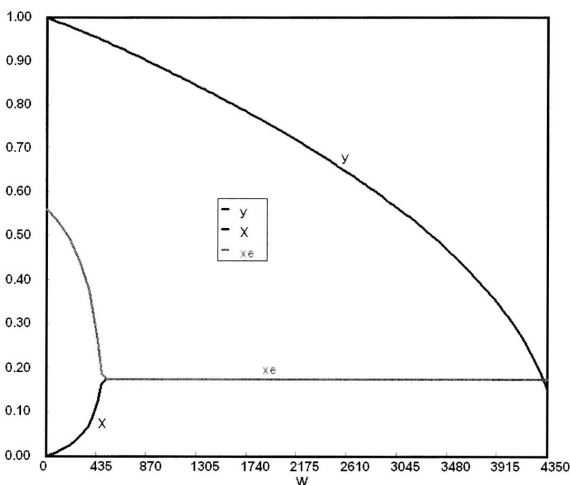


Figure 4



7) (continued)

Figure A

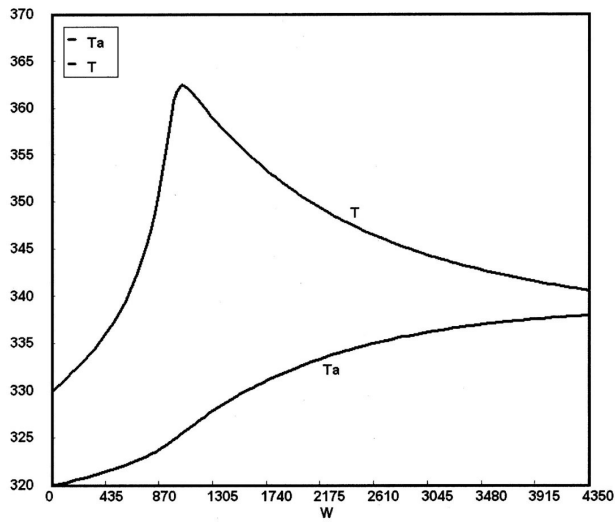


Figure B

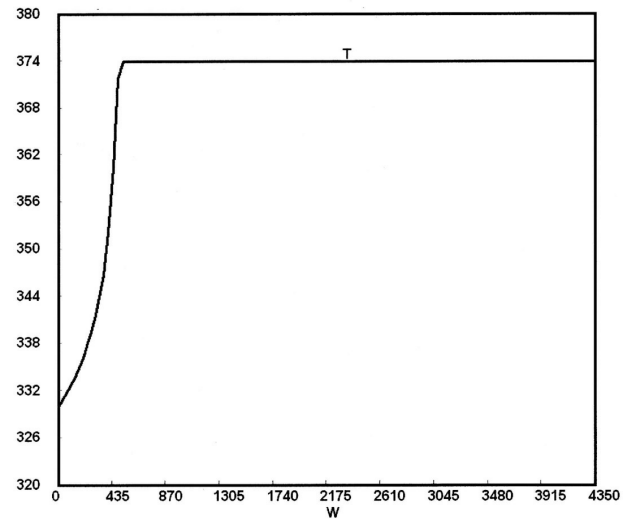


Figure C

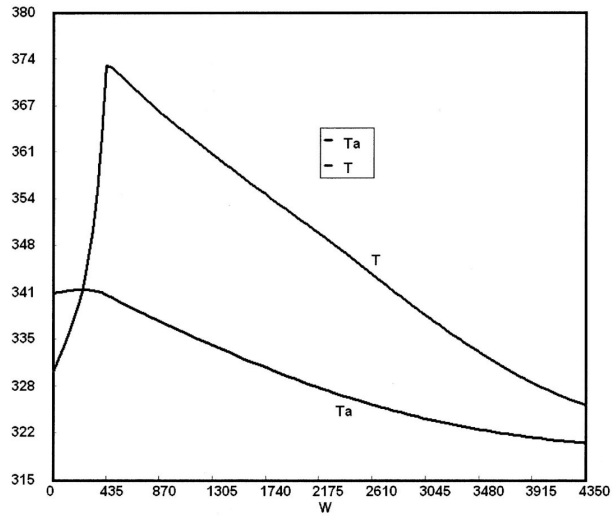
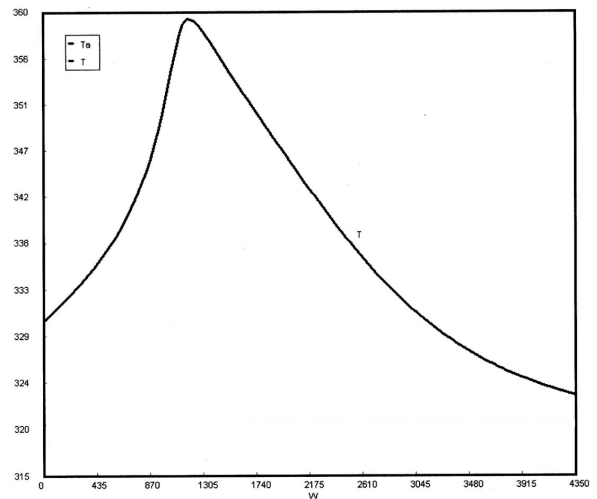
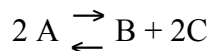


Figure D

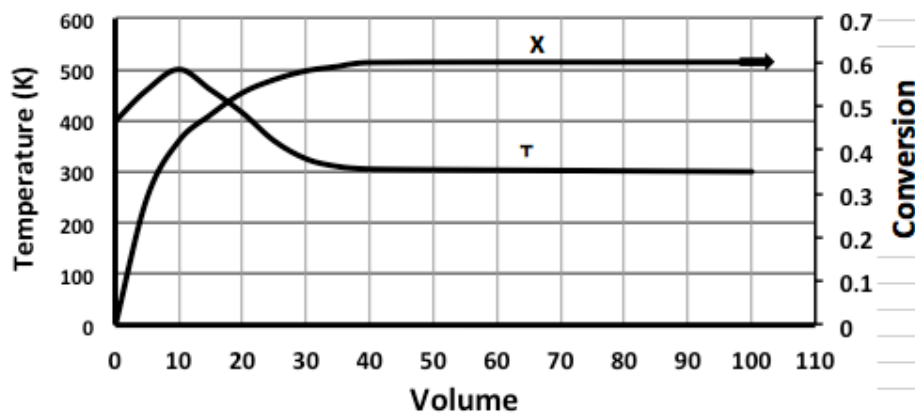


- (a) Figure 1 matches Figure ____
- (b) Figure 2 matches Figure ____
- (c) Figure 3 matches Figure ____
- (d) Figure 4 matches Figure ____

- (15 pts) 8) The temperature and conversion in a very long (i.e., virtually infinite) PFR are shown below as a function of the reactor volume. The reactor is surrounded by a jacket for heat transfer. The value of Ua is $100 \text{ cal}/(\text{sec} \cdot \text{m}^3 \cdot \text{K})$ with T_a being constant. The elementary gas-phase, reversible reaction is



and pure A is fed to the reactor at $0.05 \text{ mol}/\text{dm}^3$. The absolute value of the heat of reaction is $20,000 \text{ cal}/\text{mol}$ of A at 500K , and the heat capacities of A, B, and C are 10, 10, and 5 $\text{cal}/\text{mol}/\text{K}$, respectively.



- (7 pt) (a) What is the rate of disappearance of A at $V = 10 \text{ m}^3$?

$$-r_A = \underline{\hspace{2cm}} \text{ mol}/\text{m}^3 \cdot \text{s}$$

- (7 pt) (b) What is the total amount of heat removed (in cal/mol) from the entire reactor per mol of A fed in cal/mol ?

$$Q = \underline{\hspace{2cm}} \text{ cal}/\text{mol A}$$

- (1 pt) (c) What is the equilibrium conversion at 300 K

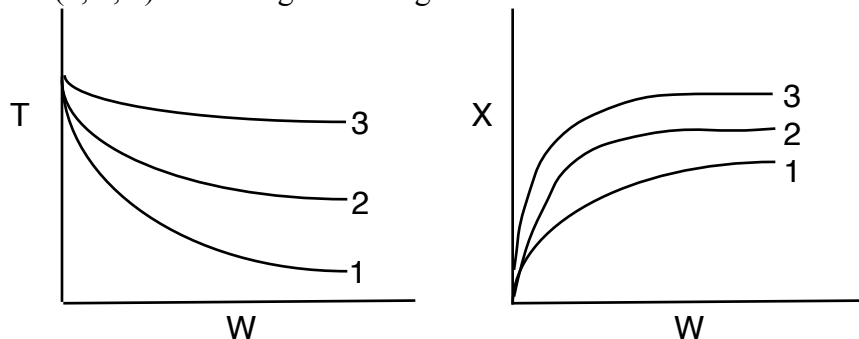
$$X_e = \underline{\hspace{2cm}}$$

(15 pts) 9) Circle the correct answer

(3 pt) (a) The reaction $A \rightarrow D$ is carried out adiabatically. The heat capacities of A and D are approximately equal at 20 J/mol-K. When a conversion of 50% is achieved in a PFR, the outlet temperature is 50 K higher than the inlet. What the heat of reaction?

- A) $\Delta H_{Rx} = 0.5 \text{ kJ/mol}$
- B) $\Delta H_{Rx} = -0.5 \text{ kJ/mol}$
- C) $\Delta H_{Rx} = 2 \text{ kJ/mol}$
- D) $\Delta H_{Rx} = -2 \text{ kJ/mol}$

(4 pt) (b) The conversion and temperature are shown below as a function of catalyst weight for three sets (1, 2, 3) of cooling or heating rates



Circle the correct answer.

A) One of the curves could correspond to an exothermic irreversible reaction with too high of a cooling rate.

True

False

Insufficient information to tell

B) One of the curves could correspond to an endothermic reversible reaction with too high of a heating rate.

True

False

Insufficient information to tell

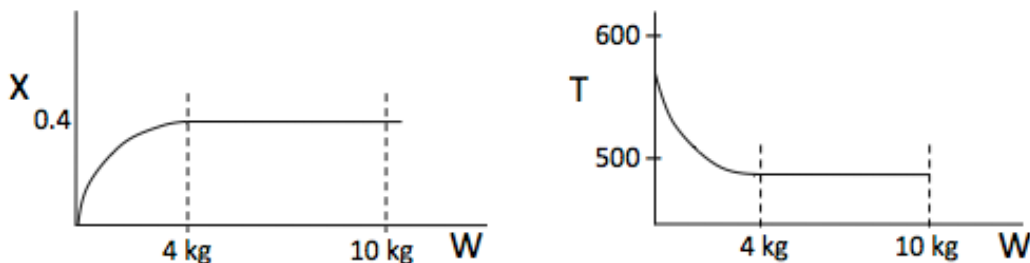
C) The reaction could be second order exothermic and carried out adiabatically.

True

False

Insufficient information to tell

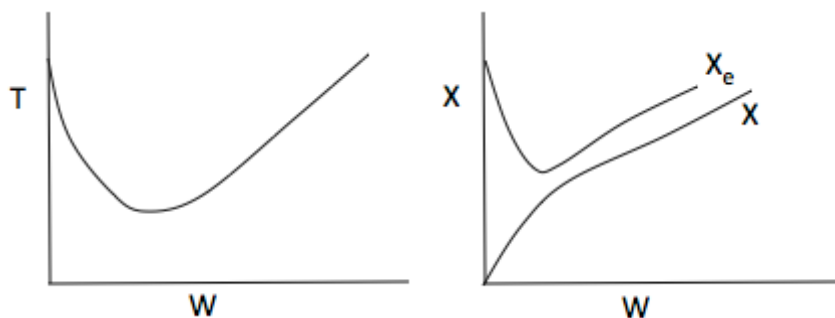
(4 pt) (c) The elementary isomerization of A to B was carried out in a packed bed reactor. The following profiles were obtained



If the total entering volumetric remains constant the addition of inerts to the feed stream will most likely

- A) Increase conversion.
- B) Decrease conversion.
- C) Have no effect.
- D) Insufficient information to tell

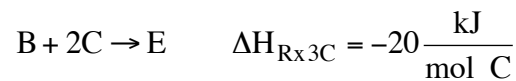
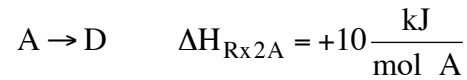
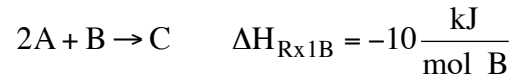
9) (continued)
(4 pt) (d)



Which of the following statements are true?

- A) The above reaction could be adiabatic.
- B) The above reaction could be exothermic with constant cooling temperature.
- C) The above reaction could be endothermic with constant heating temperature.
- D) The above reaction could be second order.

(20 pts) 10) The following elementary reactions are to be carried out in a PFR with a heat exchange with constant T_a



The reactants all enter at 400 K. Only A and B enter the reactor. The entering concentration of A and B are 3 molar and 1 molar at a volumetric flow rate of $10 \text{ dm}^3/\text{s}$

Additional information

$$U_a = 100 \text{ J/dm}^3/\text{s/K}$$

$$C_{P_A} = 10 \text{ J/mol/K}$$

$$k_{1A}(400 \text{ K}) = 1 \left(\frac{\text{dm}^3}{\text{mol}} \right)^2 / \text{s}$$

$$C_{P_B} = 20 \text{ J/mol/K}$$

$$k_{2A}(400 \text{ K}) = 0.5 \text{ s}^{-1}$$

$$C_{P_C} = 40 \text{ J/mol/K}$$

$$k_{3B}(400 \text{ K}) = 2 \left(\frac{\text{dm}^3}{\text{mol}} \right)^2 / \text{s}$$

$$C_{P_D} = 20 \text{ J/mol/K}$$

$$C_{P_E} = 100 \text{ J/mol/K}$$

(15 pt) (a) What coolant temperature is necessary such that at the reactor entrance, i.e., $V = 0$, that $\frac{dT}{dV} = 0$?

$$T_a = \underline{\hspace{2cm}} \text{ K}$$

(5 pt) (b) Repeat part (a) when an inert stream with a molar flow rate of 20 mol/s with $C_{P_I} = 100 \text{ J/mol/s}$ is added to the feed stream.

$$T_a = \underline{\hspace{2cm}} \text{ K}$$

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