ChE 344
Winter 2011
Mid Term Exam II
Wednesday, April 6, 2011

Open Book, Notes, and Web

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."

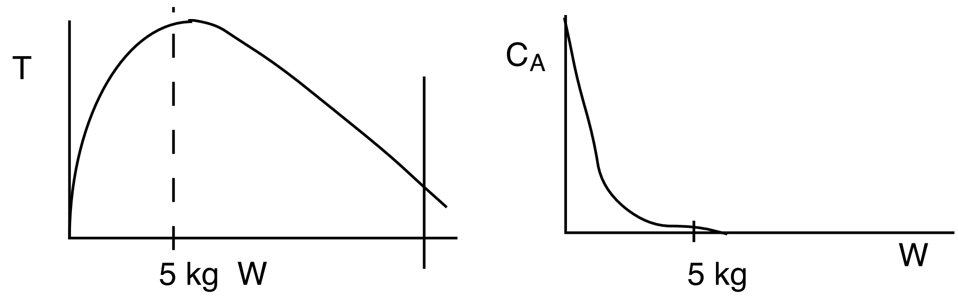
____
(Signature)

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

(5 pts) 1) 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.

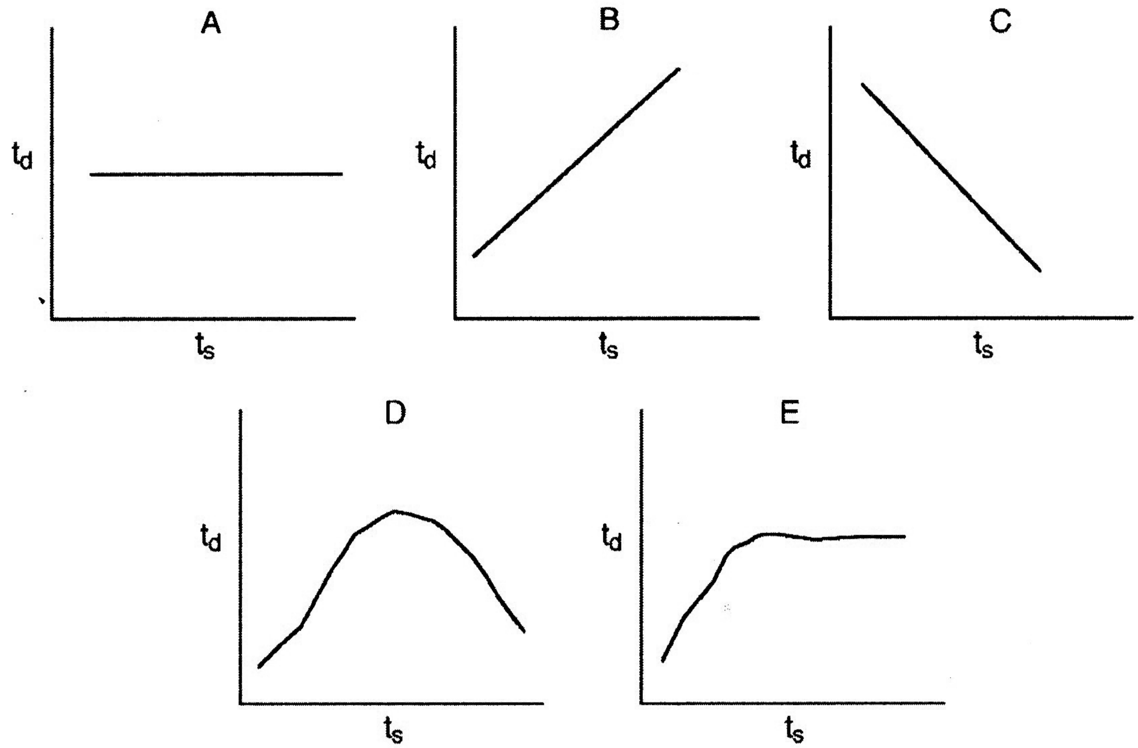
T F (b) The above profiles could represent a system where there is a heat exchanger attached to the system.

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) 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) 2) Let's revisit the explosion in Example 13-2. Suppose that the heating had not failed for 10 minutes down time, t_d, which occurred at 55 minutes after startup, t_s, but instead at a later time, t_s. Which of the following figures relates the down time, t_d, to the time after startup that the heat exchanger failed, t_s, for which the reactor would not explode?



Explain____

(5 pts) 3) The elementary gas phase reaction

$$A \rightleftarrows B + C$$

is carried out in a PFR. The following temperature profile was obtained

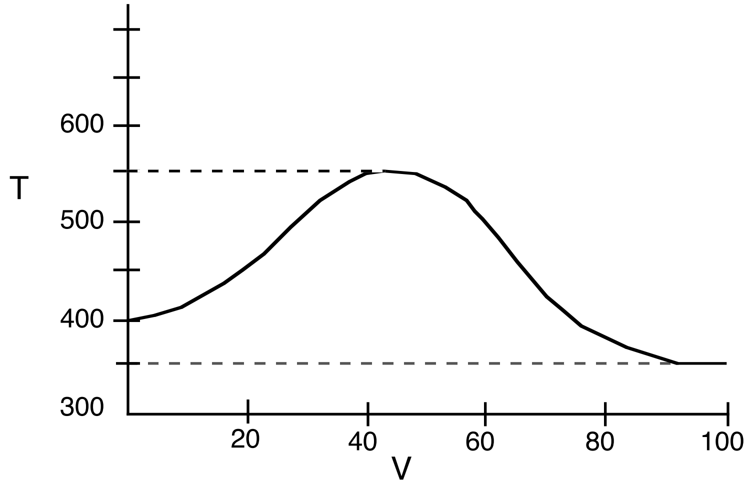
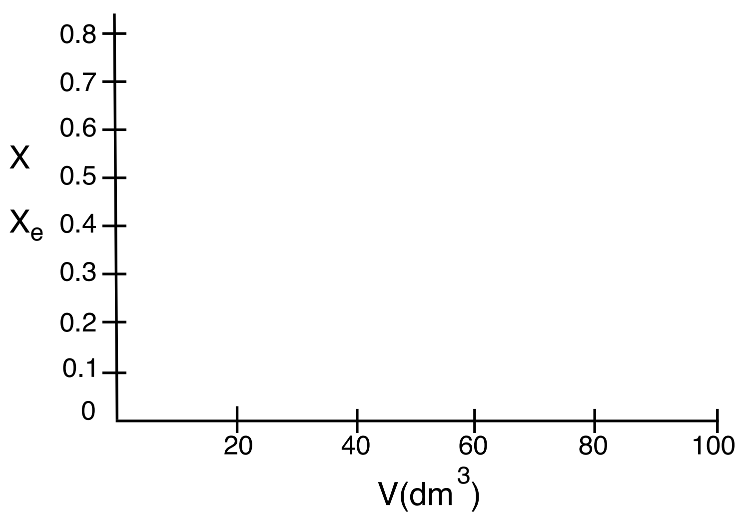


Figure EP5-1

(a) This figure corresponds to which heat exchange case?
1) Adiabatic
2) Isothermal
3) Constant ambient temperature co-current heat exchange
4) Variable T_a co-current
5) Variable T_a counter current

(b) On the figure above, sketch the temperature profile if the flow rate were reduced by a factor of 3.

(c) Sketch X and X_e corresponding to Figure EP5-1 with $X_e = 0.6$ where T = 400 K



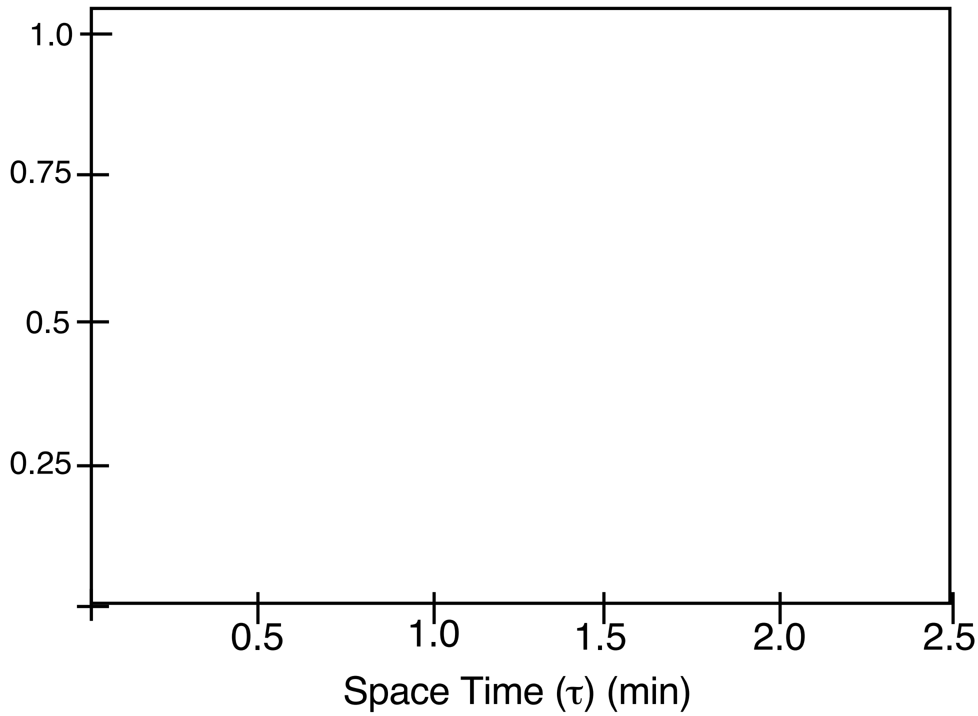
(d) On this same figure, sketch X and X_e when the flow rate is decreased by a factor of 3.

(10 pts) 4) Consider the reaction

$$A \xrightarrow{k_1} D \xrightarrow{k_2} U$$

Pure A is fed to a 1.0 dm^3 CSTR where it reacts to form a desired product (D), which can then react further to produce an undesired product (U); both reactions are elementary and irreversible and everything is liquid phase. The entering concentration of A is 1 mole/dm^3 at a molar flow rate of 1 mol/min.

(a) Sketch graphs of the conversion of A, X, the instantaneous selectivity of D to U, $S_{D/U}$, and the instantaneous yield of D, Y_D, as a function of space time (make sure to label them on the plot). You may want to write a sentence or two of reasoning for partial credit purposes.



If at τ = 1.0 minutes the instantaneous selectivity, $S_{D/U}$, is (1/2) and the conversion of A is (0.5) what are the specific reactions rates k_1 and k_2?

(b) k_1 = __________

(c) k_2 = __________

Explain____

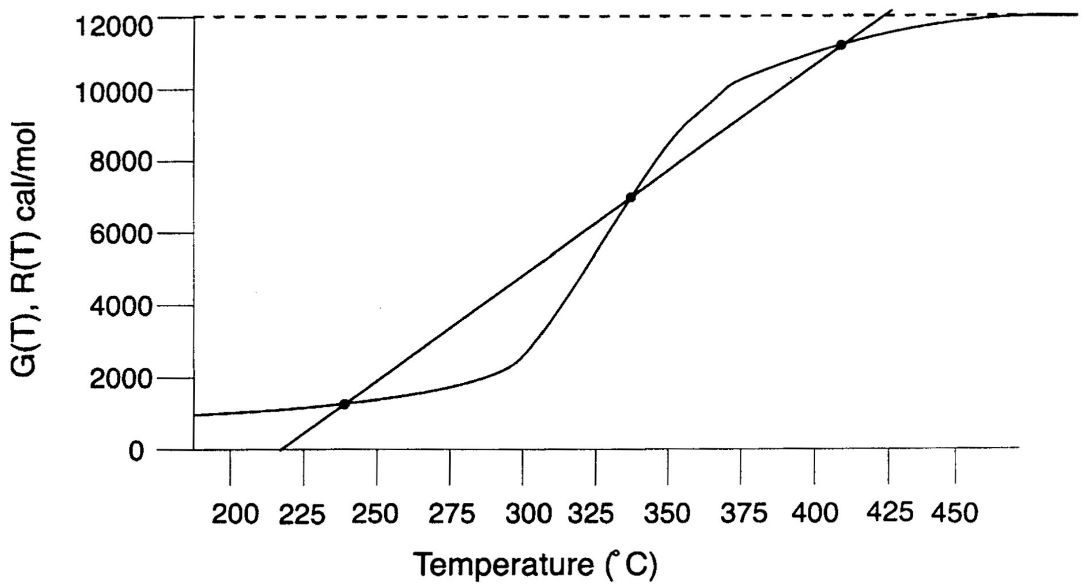
____

____

(15 pts) 5) The irreversible reaction

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

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?

ΔH_{Rx} = ____________________ cal/mol

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

Ignition = ____________________ °C

Extinction = ____________________ °C

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

Ignition

T = ________°C, ________°C

Extinction

T = ________°C, ________°C

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

X (Ignition) = ____________, ______

X (Extinction) = ____________, ______

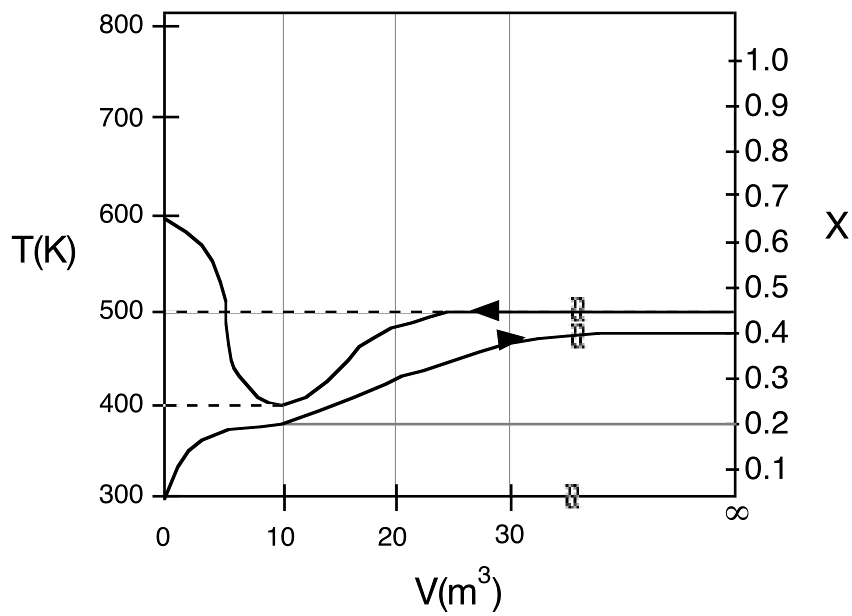
(e) For the figure above what is the conversion at the unstable steady state?

X = ________________

(20 pts) 6) The temperature and conversion in a virtually infinitely long 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 cal/(sec • m^3 • K) with T_a being constant. The gas-phase, reversible reaction is

$$2\,A \rightleftarrows B + C$$

and pure A is fed to the reactor at a concentration C_{A0} = 1.0 mol/m^3 and a molar flow rate of 10 mol/s. The absolute value of the heat of reaction is 5,000 cal/mol of A at 500K, and the heat capacities of A, B, and C are each 10 cal/mol/K.



(5 pt) (a) Sketch X_e versus V on the above figure.

(5 pt) (b) Using what is the equilibrium constant at 500 K?

K_e (500) = ____________

(10 pt) (c) What is the rate of disappearance of A, $-r_A$, at 10 m^3?

$-r_A$ = ____________

Note: You may want to bring your answers to parts (a) – (c) to the Final Exam as you may see a continuation of this problem, i.e., parts (d) – (f) on the Final Exam.

(20 pts) 7) The following elementary reactions are to be carried out in a PFR with a heat exchange with constant T_a

$$2A + B \rightarrow C \qquad \Delta H_{Rx1B} = -10 \frac{kJ}{mol\ B}$$

$$A \rightarrow D \qquad \Delta H_{Rx2A} = +10 \frac{kJ}{mol\ A}$$

$$B + 2C \rightarrow E \qquad \Delta H_{Rx3C} = -20 \frac{kJ}{mol\ C}$$

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 dm^3/s

<u>Additional information</u>

$$Ua = 100 \ J/dm^3/s/K$$

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

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

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

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

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

$$C_{P_C} = 30\ J/mol/K$$

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

$$C_{P_E} = 80\ J/mol/K$$

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

T_a = ______________

(20 pts) 8) **Study Problem (Modified)**

P12-6$_B$ The endothermic liquid-phase elementary reaction

$$A + B \rightarrow 2C$$

proceeds, substantially, to completion in a single steam-jacketed, continuous-stirred reactor (Table P12-6$_B$). From the following data, calculate the steady-state reactor temperature:

Reactor volume: 16 ft^3
Steam jacket heat transfer area: 10 ft^2
Jacket steam: 150 psig (365.9°F saturation temperature)
Overall heat-transfer coefficient of jacket, *U*: 150 Btu/h•ft^2•°F
Agitator shaft horsepower: 63,525 Btu/h
Heat of reaction, ΔH°_{Rx} = 20,000 Btu/lb-mol of A (independent of temperature)

TABLE P12-6$_B$ FEED CONDITIONS AND PROPERTIES

	Component		
	A	*B*	*C*
Feed (lb-mol/hr)	10.0	10.0	0
Feed temperature (°F)	80	80	—
Specific heat (Btu/lb-mol · °F	51.0	44.0	47.5
Molecular weight	128	94	111
Density (lb$_m$/ft^3	63.0	67.2	65.0

(Courtesy of the California Board of Registration for Professional & Land Surveyors.)