The University of Jordan
School of Engineering
Chemical Engineering Department

(0905421) Chemical Reaction Engineering I	**In-Class Assessment # 1 (Chapter 1)**
Partner (1) Name: عبدالله الشنتواني	**Partner (2) Name:** نائل غيث
Identity (1) #: 0147452	**Identity (2) #:** 2131049

Q1: Consider the reaction

$$A + 2B \rightarrow 3C$$

In which the rate of disappearance of A is 5 moles of A per dm^3 per second at the start of the reaction. At the start of the reaction:

(a) What is $-r_A$? r_A = 5 mol A/(dm^3.s)

(b) What is the rate of formation of B?

1 mol A ⟶ 2 mol B

r_B = −10 mol B/dm^3.s

(c) What is the rate of formation of C?

r_C = 15 mol C/dm^3.s

(d) What is the rate of disappearance of C?

r_C = −15 mol C/(dm^3.s)

(e) What is the rate of formation of A, r_A?

r_A = −5 mol A/(dm^3.s)

(f) What is $-r_B$?

rate of disappearance of B

Q2: For the reaction

$$A \rightarrow B$$

Calculate the time to reduce the number of moles by a factor of 10 ($N_A = \frac{N_{A0}}{10}$) in a batch reactor for the above reaction with $-r_A = kC_A$, when $k = 0.046\ min^{-1}$.

$$t = \int_{N_{A0}}^{N_A} \frac{dN_A}{+r_A V}$$

$$= \int_{N_{A0}}^{N_A} \frac{dN_A}{-kC_A V}$$

$$= \int_{N_{A0}}^{N_A} \frac{dN_A}{k \frac{N_A}{V} V}$$

$$= \frac{-1}{k} \int_{N_{A0}}^{N_A} \frac{dN_A}{N_A} \qquad N_{A0} = 10 N_A$$

$$= \frac{1}{k} \ln|N_A| \Big]_{N_{A0}}^{N_A}$$

$$= \frac{1}{k} \ln|N_A| - \ln|10N_A|$$

$$= \frac{1}{k} \ln\left(\frac{1}{10}\right)$$

$$= 50.056\ min$$

The reaction A→B is to be carried out isothermally in a continuous-flow reactor.

(a) Calculate the PFR volume to consume 99% of A ($C_A=0.01C_{A0}$) when the entering molar flow rate is 5 mol A/h, the volumetric flow rate is constant at 10 dm^3/h and the rate is $-r_A=(3dm^3/mol\bullet h)C_A^2$.

(b) Calculate the CSTR volume to consume 99% of A ($C_A=0.01C_{A0}$) when the entering molar flow rate is 5 mol A/h, the volumetric flow rate is constant at 10 dm^3/h and the rate is $-r_A=(3dm^3/mol\bullet h)C_A^2$.

(c) Compare the CSTR ad PFR volumes!

a) $V = \int_{F_{A0}}^{F_A} \frac{dF_A}{-r_A}$

$= \int_{F_{A0}}^{F_A} \frac{dF_A}{-3C_A^2}$

$= \frac{1}{-3(0.05)^2} \int_{5}^{0.05} dF_A$

$= 66000$

$C_A = 0.01 C_{A0}$

$C_{A0} = \frac{5 mol/h}{10 dm^3/h}$

$= 0.5 mol/dm^3$

$C_A = 5\times10^{-3}$

$F_{A0} = 0.05 mol/h$

B) $V = \frac{v_0 C_{A0} - v C_A}{-r_A}$

$= \frac{v_0 C_{A0} - v C_A}{-3 C_A^2}$

$= \frac{10(0.5 - 5\times10^{-7})}{-3(5\times10^{-7})^2}$

$C_{A0} = \frac{5 mol/h}{10 dm^3/h}$

$= 0.5 mol/dm^3$

$C_A = 5\times10^{-7} mol/dm^3$

Ⓐ $V = \int_{F_{A_0}}^{F_A} \frac{dF_A}{r_A}$

$= \int_{F_{A_0}}^{F_A} \frac{dF_A}{-3C_A^2}$

$F_A = C_A v$

$dF_A = v\,dC_A$

$= \int_{F_{A_0}}^{F_A} \frac{-dF_A}{3C_A^2}$

$C_{A_0} = 0.5\ mol/dm^3$

$C_A = 0.005\ mol/dm^3$

$= \int_{C_{A_0}}^{C_A} \frac{v\,dC_A}{3C_A^2}$

$= \frac{v}{3}\int_{C_{A_0}}^{C_A} \frac{dC_A}{C_A^2} \quad = \frac{10}{3}\int_{0.5}^{0.005} \frac{dC_A}{C_A^2}$

$= 660\ dm^3$

ⓑ $V = \frac{F_{A_0} - F_A}{-r_A} = \frac{5 - 0.05}{3(0.005)^2} = 66000\ dm^3$

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(0905421) Chemical Reaction Engineering I	In-Class Assessment # 2 (Chapter 2)
Partner (1) Name: عبدالله الشيخ احمد	Partner (2) Name: نادين غنيمات
Identity (1) #: 0147452	Identity (2) #: 2131049

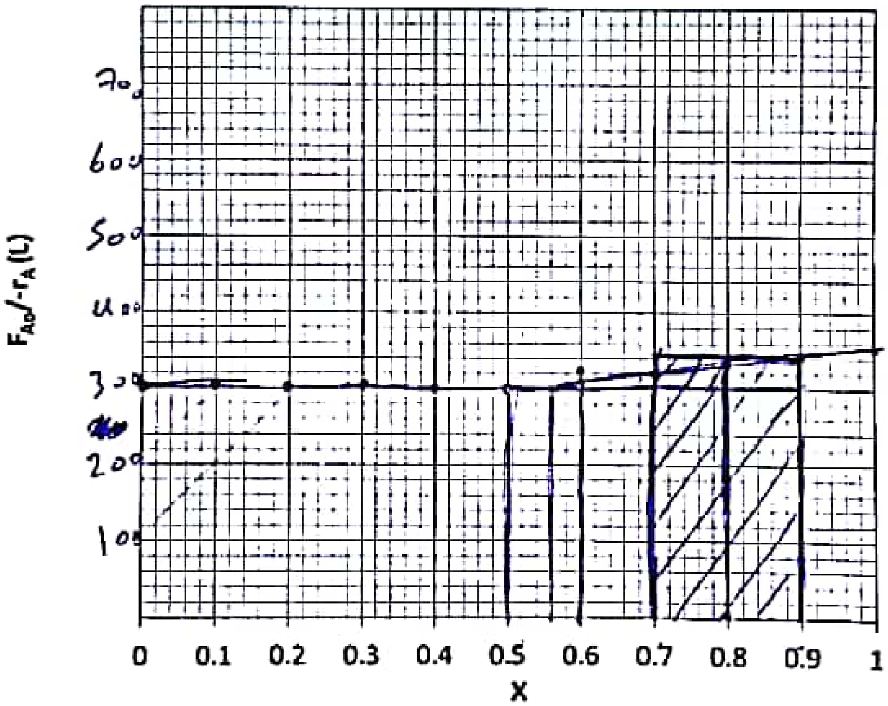
For the irreversible gas-phase reaction: $A \rightarrow 2B$ the following correlation was determined from laboratory data (the initial concentration of A is 2 mol/L):

$$For\ X \leq 0.5: \frac{1}{-r_A} = 30\ \frac{L.s}{mol}$$

$$For\ X > 0.5: \frac{1}{-r_A} = 30 + 10(X - 0.5)\ \frac{L.s}{mol}$$

The volumetric flow rate is 5 L/s.

$F_{A0} = \frac{2\ mol}{L} \cdot \frac{5\ L}{s} = 10\ mol/s$



a. Graph Levenspiel plot ($F_{A0}/-r_A$ vs. X)

$\frac{1}{2} \times 0.1 \times 10$

b. Over what range of conversions are the plug-flow reactor and CSTR volumes identical?

$0 \leq X \leq 0.5$

c. What conversion will be achieved in a CSTR that has a volume of 90 L?

$$V = \frac{F_{A_0} X}{-r_A} = \frac{V \cdot -r_A}{F_{A_0}} = X = \frac{90}{18 * 30} = 0.3$$

d. What plug-flow reactor volume is necessary to achieve 70% conversion?

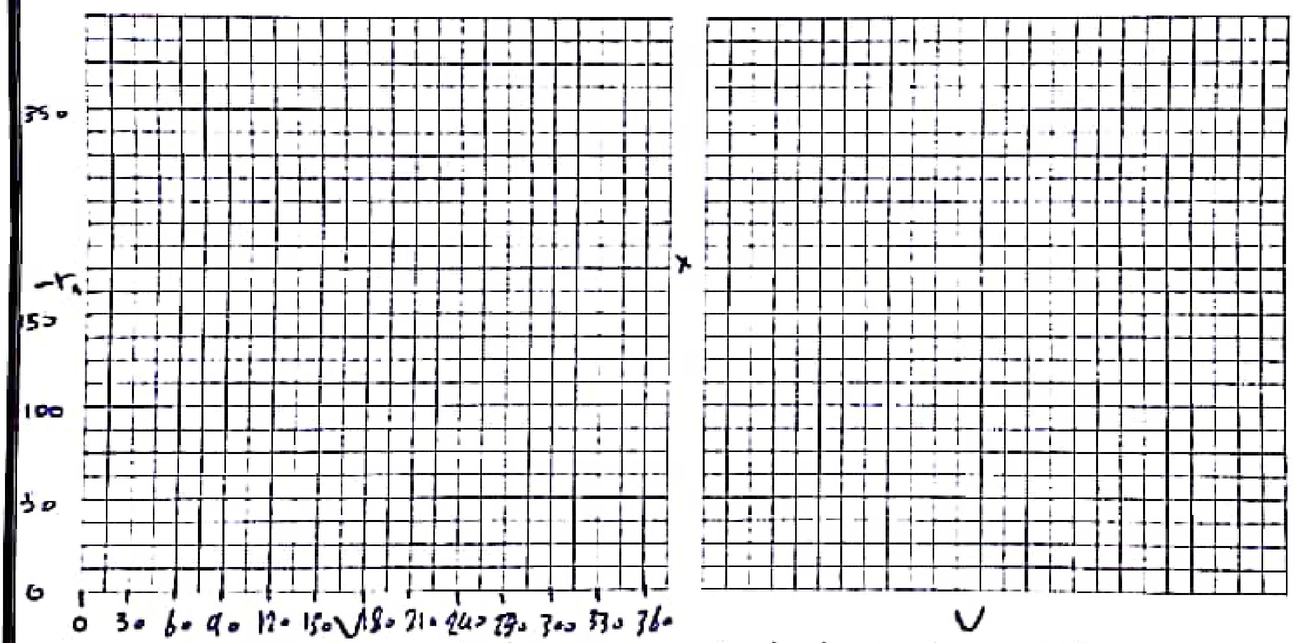
$$V = F_{A_0} \int_0^{0.7} \frac{dx}{-r_A} = \int_0^{0.7} \frac{F_{A_0}}{-r_A} dx = \frac{0.75}{3}\left[300 + 4 * 300 + 320\right]$$

$$= 212.33 L$$

e. What CSTR reactor volume is required if effluent from the plug-flow reactor in part (d) is fed to a CSTR to raise the conversion to 90%?

$$A = 0.2 \times 340$$
$$= 68 L$$

f. Plot the rate of reaction and conversion as a function of PFR volume.



g. If the reaction is carried out in a constant-pressure batch reactor in which pure A is fed to the reactor, what length of time is necessary to achieve 40 % conversion?

X	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.
$-r_A$	$\frac{1}{30}$		$\frac{1}{30}$		$\frac{1}{30}$		$\frac{1}{31}$		$\frac{1}{33}$		$\frac{1}{[illegible]}$
V	0		60		126		180.5		244.5		312.5

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(0905421) Chemical Reaction Engineering I	In-Class Assessment # 10 (Chapter 5)
Partner (1) Name: ____________	Partner (2) Name: ____________
Identity (1) #: ____________	Identity (2) #: ____________

The reaction A → B is carried out in a constant volume batch reactor. Determine the reaction order and specific reaction rate from the following data.

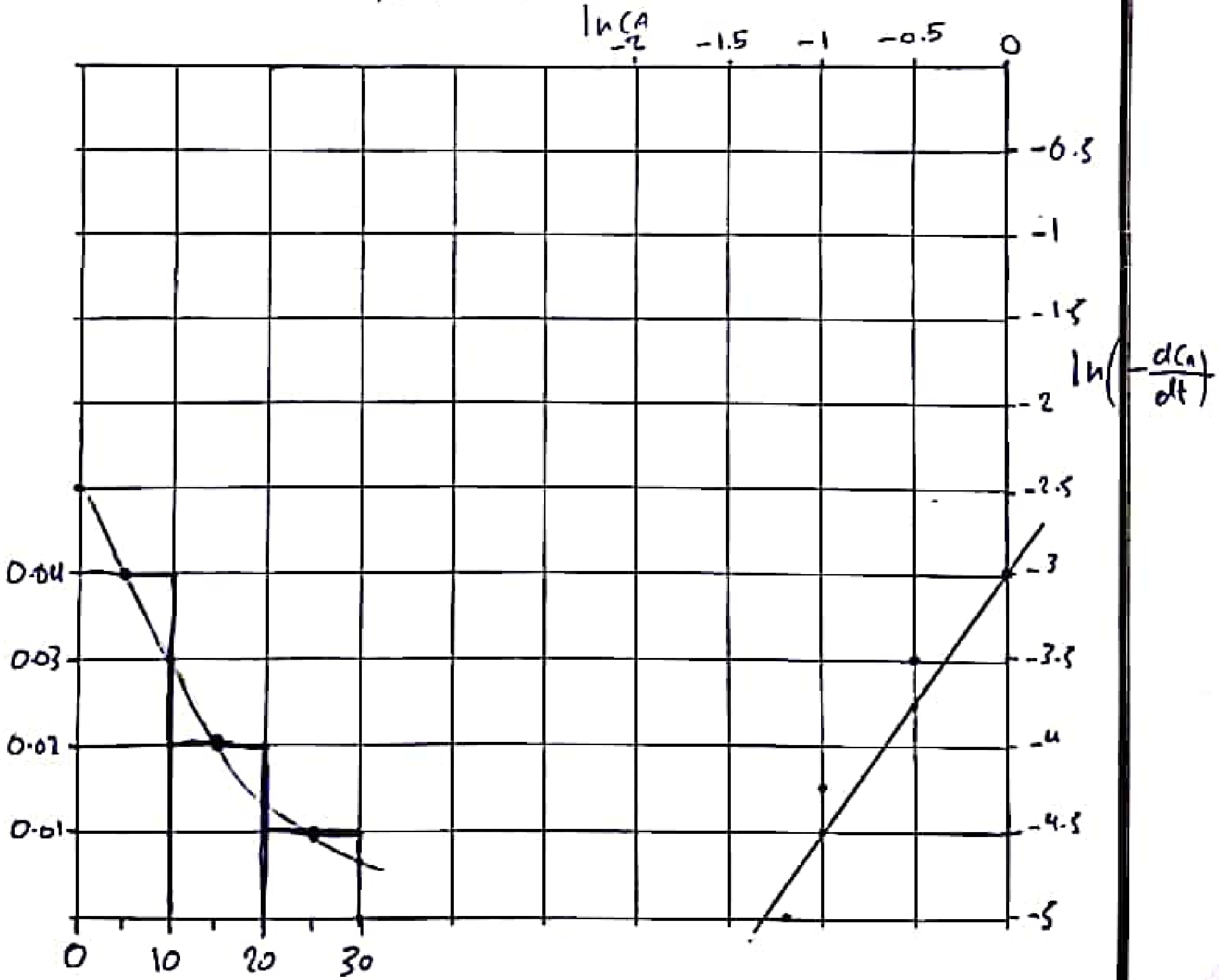
t (min)	0	10	20	30
C_A(mol/dm³)	1	0.6	0.4	0.3

$-\Delta C_A/\Delta t$ 0.04 0.02 0.01

$-dC_A/dt$ = 0.05 0.03 0.013 0.007

$\ln\left(\frac{-dC_A}{dt}\right) = \ln k_A + \alpha \ln C_A$

$\ln\left(\frac{dC_A}{dt}\right)$	-3	-3.5	-4.3	-5
$\ln(C_A)$	0	-0.5	-1	-1.2



$\alpha = \frac{\Delta y}{\Delta x} = \frac{-4.5+3.75}{-1+0.5} = 1.5$

$\ln k_A = -3$

$k_A = 0.05$

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(0905421) Chemical Reaction Engineering I	In-Class Assessment # 12 (Chapter 6)
Partner (1) Name: براء الانشحو اري	Partner (2) Name:
Identity (1) #:	Identity (2) #:

P6-12 The following liquid-phase reactions were carried out in a CSTR at 325 K.

$3A \longrightarrow B + C$	$-r_{1A} = k_{1A}C_A$	$k_{1A} = 7.0\ \text{min}^{-1}$
$2C + A \longrightarrow 3D$	$r_{2D} = k_{2D}C_C^2C_A$	$k_{2D} = 3.0\ \text{L}^2/\text{mol}^2.\text{min}$
$4D + 3C \longrightarrow 3E$	$r_{3E} = k_{3E}C_DC_C$	$k_{3E} = 2.0\ \text{L/mol.min}$

The concentrations measured *inside* the reactor were $C_A = 0.10$, $C_B = 0.93$, $C_C = 0.51$, and $C_D = 0.049$ all in mol/L.

(a) What are r_{1A}, r_{2A}, and r_{3A}?

$\frac{-r_{2A}}{1} = \frac{r_{2D}}{3}$

$-r_{2A} = \frac{1}{3} r_{2D}$

$r_{3A} = 0$

$r_A = -k_{1A}C_A - \frac{k_{2D}C_C^2C_A}{3}$

(b) What are r_{1B}, r_{2B}, and r_{3B}?

$\frac{+r_{1B}}{1} = \frac{1}{3} \cdot -r_{1A}$

$r_{2B} = 0$

$r_{3B} = 0$

$r_B = \frac{+k_{1A}C_A}{3}$

(c) What are r_{1C}, r_{2C}, and r_{3C}?

$r_C = \frac{+k_{1A}C_A}{3} - \frac{2}{3}k_{2D}C_C^2C_A - k_{3E}C_DC_C$

$r_{1C} = +\frac{1}{3} r_{1A}$

$\frac{-r_C}{2} = \frac{r_{2D}}{3} = -r_C = \frac{2}{3} r_{2D}$

$r_{3C} = r_{3E}$

(d) What are r_{1D}, r_{2D}, and r_{3D}?

$r_D = k_{2D}C_C^2C_A - \frac{4}{3}k_{3E}C_DC_C$

$r_{1D} = 0$

$r_{2D} = k_{2D}C_C^2C_A$

$r_{3D} = \frac{4}{3} r_{3E}$

(e) What are r_{1E}, r_{2E}, and r_{3E}?

$r_{1E} = 0$

$r_{2E} = 0$

$r_{3E} = k_{3E} C_D C_C$

$r_E = k_{3E} C_D C_C$

(f) What are the net rates of formation of A, B, C, D, and E?

(g) The entering volumetric flow rate is 100 L/min and, the entering concentration of A is 3 M. What is the CSTR reactor volume?

Parts (h), (i), (j) are HOMEWORK! (Solve them using POLYMATH or MATLAB)

$v_0 = 100 L/min$

$C_{A0} = 3 mol/L$

$$V = \frac{F_{A0} - F_A}{-r_A} = \frac{(C_{A0} - C_A)v}{-r_A}$$

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(0905421) Chemical Reaction Engineering I	First Semester – 2016/2017
In-Class Assessment # 14 (Chapter 8)	
Partner (1) Name: ____________	Partner (2) Name: ____________
Identity (1) #: ____________	Identity (2) #: ____________

P8-6 (Continued)

The elementary irreversible organic liquid-phase reaction $A + B \rightarrow C$ is carried out adiabatically in a flow reactor. An equal molar feed in A and B enters at 27°C, and the volumetric flow rate is 2 dm^3/s and $C_{A0} = 0.1$ kmo/m^3.

(d) **Calculate the conversion that can be achieved in one 500-dm^3 CSTR and in two 250-dm^3 CSTRs in series.**

Additional Information

$H_A^o(273\ K) = -20\ kcal/mol$
$H_B^o(273\ K) = -15 kcal/mol$
$H_C^o(273\ K) = -41\ kcal/mol$
$C_{P_A} = C_{P_B} = 15\ cal/(mol.K)$
$C_{P_C} = 30\ cal/(mol.K)$
$k = 0.01\ L/(mol.s)\ at\ 300\ K$
$E = 10{,}000\ cal/mol$

$T = 300 + 200X$

$V = \frac{F_{A0} X}{-r_A}$

$-r_A = k C_A C_B$

$C_A = C_{A0}(1-x)$

$C_B = C_{B0}(1-x)$

$-r_A = k C_{A0}^2 (1-x)^2$

$V = \frac{v_0 C_{A0} x}{k C_{A0}^2 (1-x)^2}$

$V = \frac{v_0}{k C_{A0}} \frac{x}{(1-x)^2}$

$\frac{x}{(1-x)^2} = \frac{0.01\ L}{mol\ s} \left| \frac{0.1 \times 10^3\ mol}{m^3} \right| \frac{s}{2\ dm^3} \left| 500\ dm^3 \right| \frac{1\ m^3}{10^3\ dm^3}$

$\frac{x}{(1-x)^2} = \frac{1}{4}$

$(1-x)^2 = 4x$

$1 - 2x + x^2 = 4x$

$x^2 - 6x + 1 = 0$

$x = 0.17$

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(0905421) Chemical Reaction Engineering I **First Semester – 2016/2017**

In-Class Assessment # 13 (Chapter 8)

Partner (1) Name: ____________ **Partner (2) Name:** ____________

Identity (1) #: ____________ **Identity (2) #:** ____________

P8-5 CSTR with Heat Effect

The endothermic liquid-phase elementary reaction $A + B \rightarrow 2C$ proceeds, substantially, to completion in a single steam-jacketed, continuous-stirred reactor. From the following data, calculate the steady-state reactor temperature:

Reactor volume: 125 gal   Steam jacket area: 10 ft^2 Agitator shaft horsepower: 25 hp
Jacket steam: 150 psig (365.9 °F saturation temperature)
Overall heat-transfer coefficient of jacket, U: 150 Btu/ h.ft^2. °F
Heat of reaction, ΔH^o_{Rx} = +20,000 Btu/lb mol of A (independent of temperature)

Component	A	B	C
Feed (lbmol/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 (lb/lbmol)	128	94	222
Density (lb/ft^3)	63.0	67.2	65.0

$V = \frac{F_{A0} X}{-r_A}$ $-r_A = k C_A C_B$

$C_A = C_{A0}(1-X)$

$C_B = C_{A0}(\Theta_B - X)$

$V = 125 \text{ gal} \rightarrow = 16.7 \text{ ft}^3$

$\frac{lb}{lbmol}$ $\frac{lb}{ft^3}$ $\frac{lb}{ft^3} \cdot \frac{lbmol}{lb}$

$v_0 = v_{A0} + v_{B0}$
$= 34.3 \text{ ft}^3/h$

$C_{A0} = \frac{10}{34.3} = 0.29 \text{ lbmol/ft}^3$

$Q - W - F_{A0}X$

P8-13$_A$ The reaction

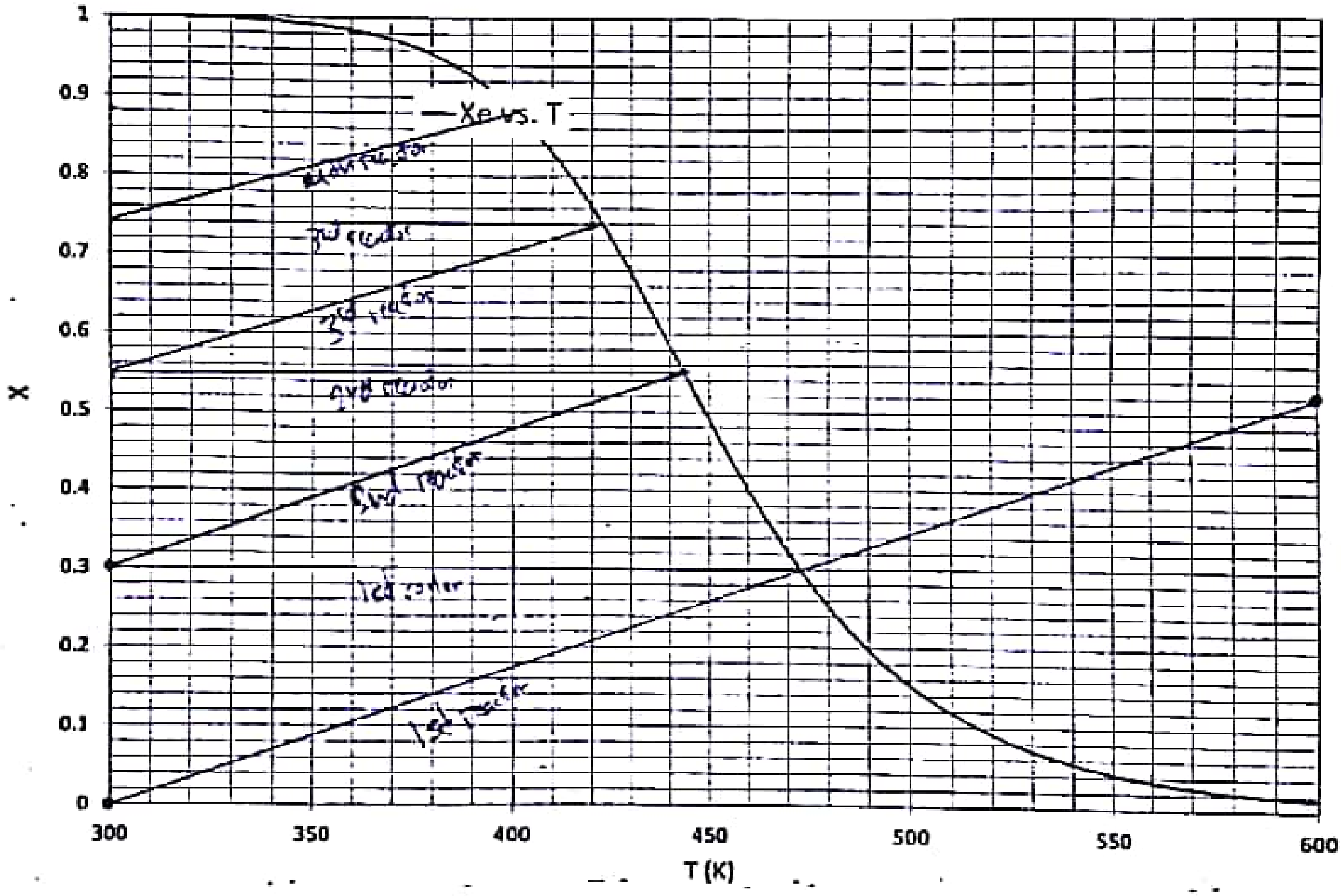
$$A + B \rightleftharpoons C + D$$

is carried out adiabatically in a series of staged packed-bed reactors with interstage cooling. The lowest temperature to which the reactant stream may be cooled is 27°C. The feed is equimolar in A and B and the catalyst weight in each reactor is sufficient to achieve 99.9% of the equilibrium conversion. The feed enters at 27°C and the reaction is carried out adiabatically. If four reactors and three coolers are available, what conversion may be achieved?

Additional information:

$\Delta H^\circ_{Rx} = -30{,}000$ cal/mol A $\quad C_{P_A} = C_{P_B} = C_{P_C} = C_{P_D} = 25$ cal/g mol · K

$K_e(50°C) = 500{,}000 \quad F_{A0} = 10$ mol A/min



$T = 300 + \frac{30000 \cdot X}{100}$ $\quad \Sigma\Theta_i C_{pi}$

$T = 300 + 300X$ $\quad$ $X = 0.88$

$T = 300 + 600(X - X_0)$