BT209

Bioreaction Engineering

15/02/2023

Problem 1

We are planning to operate a batch reactor to convert A into R. This is a liquid reaction, the stoichiometry is A→R, and the rate of reaction is given in Table. How long must we react each batch for the concentration to drop from C_{A0} = 1.3 mollliter to C_{Af} = 0.3 mollliter?

C_A, mol/liter	$-r_A$, mol/liter · min
0.1	0.1
0.2	0.3
0.3	0.5
0.4	0.6
0.5	0.5
0.6	0.25
0.7	0.10
0.8	0.06
1.0	0.05
1.3	0.045
2.0	0.042

Simpson 1/3

$$\int_{x_0}^{x_2} f(x)\,dx = \int_{x_0}^{x_0+2h} f(x)\,dx$$

$$\approx \frac{1}{3} h (f_0 + 4 f_1 + f_2).$$

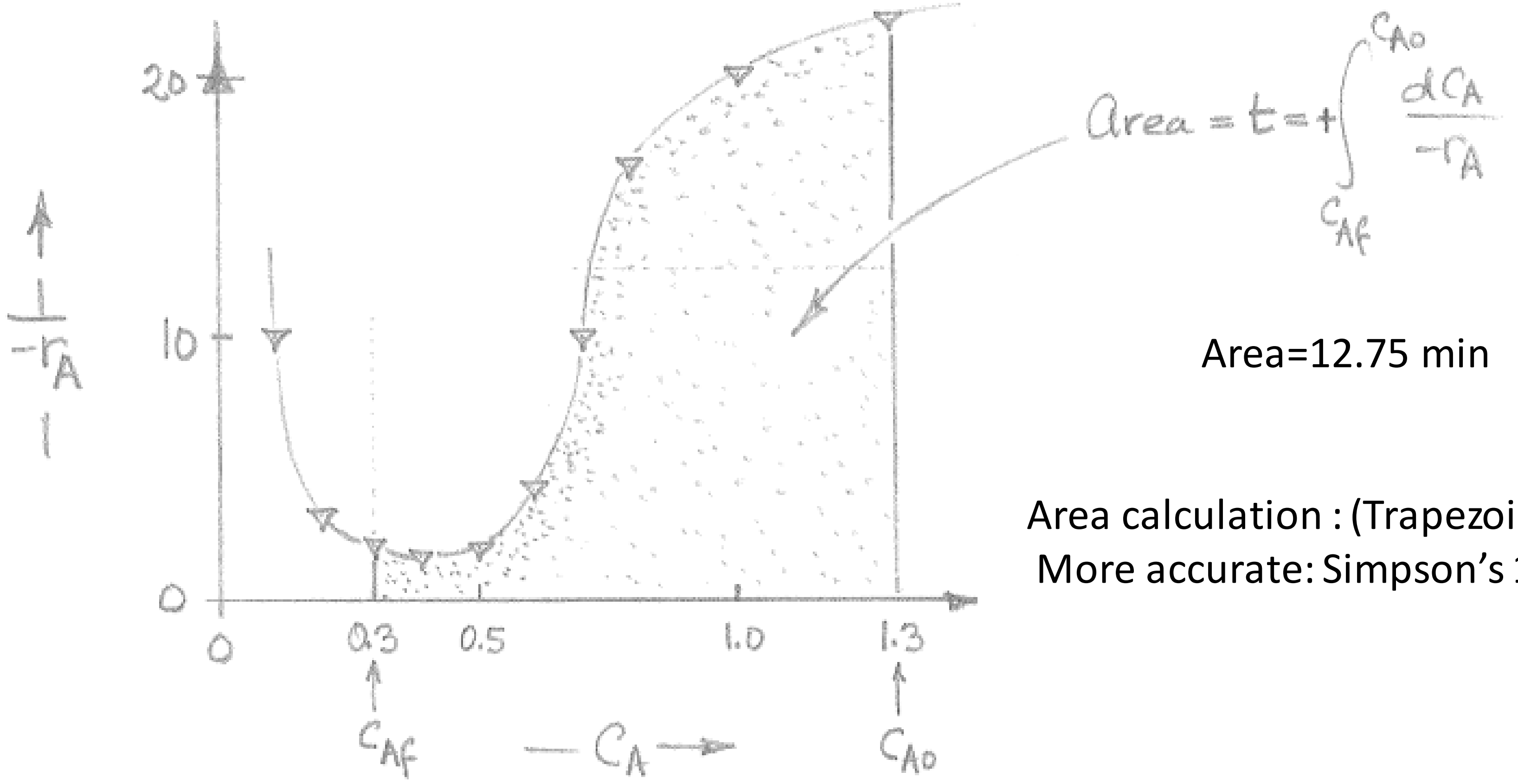
Composite Simpson 1/3

$$\int_a^b f(x)\,dx \approx \frac{\Delta x}{3}(f(x_0) + 4f(x_1) + 2f(x_2) + 4f(x_3) + \cdots + 4f(x_{n-1}) + f(x_n))$$

Simpson 3/8

$$\int_a^b f(x)\,dx \approx \frac{\mathbf{3h}}{\mathbf{8}}[\mathbf{y_0} + \mathbf{3y_1} + \mathbf{3y_2} + \mathbf{y_3}]$$

$$t = C_{A0}\int_0^{X_A}\frac{dX_A}{-r_A} = -\int_{C_{A0}}^{C_A}\frac{dC_A}{-r_A} \qquad \text{for } \varepsilon_A = 0$$



Area=12.75 min

Area calculation : (Trapezoidal rule)

More accurate: Simpson's 1/3 rule

Problem 2

Enzyme E catalyses the fermentation of substrate A (the reactant) to product R. Find the size of mixed flow reactor needed for 95% conversion of reactant in a feed stream (25 liter/min) of reactant (2 mol/liter) and enzyme. The kinetics of the fermentation at this enzyme concentration are given by

$$A \xrightarrow{\text{enzyme}} R, \qquad -r_A = \frac{0.1\, C_A}{1 + 0.5\, C_A} \quad \frac{\text{mol}}{\text{liter} \cdot \text{min}}$$

Solution: Problem 2

$C_{A0} = 2 \text{ mol/lit}$

$v = 25 \text{ lit/min}$

$X_A = 0.95$

$V = ?$

$$-r_A = \frac{0.1\,C_A}{1+0.5\,C_A}$$

mol/lit·min

First of all $C_A = C_{A0}(1-X_A) = 2(1-0.95) = 0.1$

Then for mixed flow

$$V = \frac{v(C_{A0}-C_A)}{-r_A} = \frac{25(2-0.1)}{\frac{(0.1)(0.1)}{1+0.5(0.1)}} = 4987.5 \text{ lit} \cong 5\,m^3$$

Problem 3

A gaseous feed of pure A (1 mol/liter) enters a mixed flow reactor (2 liters) and reacts as follows:

$$2A \rightarrow R, \qquad -r_A = 0.05\, C_A^2 \;\frac{\text{mol}}{\text{liter} \cdot \text{sec}}$$

Find what feed rate (liter/min) will give an outlet concentration $C_A = 0.5$ mol/liter.

Solution: Problem 3

$2A \rightarrow R$ with $-r_A = 0.05\,C_A^2$, mol/lit·s

Evaluate terms $\varepsilon_A = \dfrac{1-2}{2} = -0.5$

$$X_A = \frac{C_{A0} - C_A}{C_{A0} + \varepsilon_A C_A} = \frac{1-0.5}{1+(-0.5)(0.5)} = \frac{2}{3}$$

So for mixed flow

$$v = \frac{V(-r_A)}{C_{A0} X_A} = \frac{(2)(0.05 \times 0.5^2)}{1(2/3)} = 0.0375 \text{ lit/s} = 2.25 \text{ lit/min}$$

Problem 4

Pure gaseous A at about 3 atm and 30°C (120 mmol/liter) is fed into a 1-liter mixed flow reactor at various flow rates. There it decomposes, and the exit concentration of A is measured for each flow rate. From the following data find a rate equation to represent the kinetics of the decomposition of A. Assume that reactant A alone affects the rate.

v_0, liter/min	0.06	0.48	1.5	8.1
C_A, mmol/liter	30	60	80	105

$A \rightarrow 3R$

Solution: Problem 4

$C_{A0} = 120$ mmol/lit
3 atm
30°C
Various v_0

Various C_A

$A \rightarrow 3R$

Find a rate equation

For each run

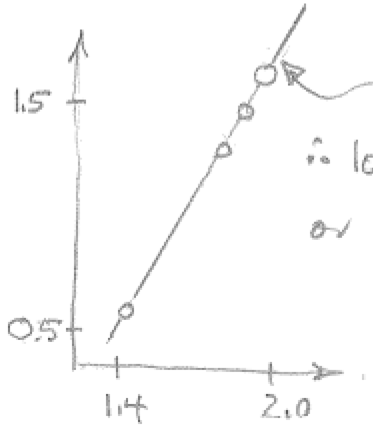
$$-r_A = \frac{C_{A0} X_A v_0}{V} = \frac{C_{A0}(C_{A0}-C_A)v_0}{(C_{A0}+\varepsilon_A C_A)V} = \frac{120(120-C_A)v_0}{(120+2C_A)}$$

$\varepsilon_A = \frac{3-1}{1} = 2$

Now tabulate

v_0	C_A	$-r_A$	$\log(-r_A)$	$\log C_A$
0.06	30	3.6	0.5563	1.477
0.48	60	14.4	1.1584	1.778
1.5	80	25.7	1.41	1.903
8.1	105	44.2	1.6452	2.07

given data



Slope $n=2$

$\therefore \log(-r_A) = \log k + 2\log C_A$

or $0.5563 = \log k + 2(1.477)$

$\therefore k = 0.004$

$\therefore -r_A = 0.004\, C_A^2$, mmol/lit·min