Chapter Five

Environmental systems: modeling and reactor design

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Homework

Problem 14, Page 235

14 Consider the irreversible conversion of a single reactant (A) to a single product (P) for the following reaction: A → P. Evaluate the following data to determine whether the reaction is zero-, first-, or second-order. Also, determine the magnitude of the rate constant *k* and list the appropriate units.

Time (minutes)	Concentration of A (g/L)
0	1.00
11	0.50
20	0.25
48	0.10
105	0.05

Problem 29, Page 236

29 Several reactor configurations are to be considered for reducing the influent substrate concentration from 100 mg/L to 15 mg/L at a design flow rate of 5 million gallons per day (MGD). Assume that substrate removal follows first-order kinetics and the first-order rate constant *k* is 8.0 d^{-1}. Determine the reactor volume required for the following configurations operating at steady-state:

a. One ideal plug flow reactor.
b. One ideal complete-mix reactor.
c. Three ideal complete-mix reactors in series.
d. Ten ideal complete-mix reactors in series.

Problem 30, Page 236

30 A complete-mix flow reactor is designed to treat an influent waste stream containing 130 mg/L of casein at a flow rate of 380 liters per minute (Lpm). Assume that casein removal follows first-order removal kinetics with a rate constant *k* of 0.5 h^{-1} and that the effluent should contain 13 mg/L of casein at steady state. Determine:

a. The detention time in hours.
b. The volume of the reactor in cubic meters.

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Time (minutes)	Concentration of A (g/L)
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11	0.50
20	0.25
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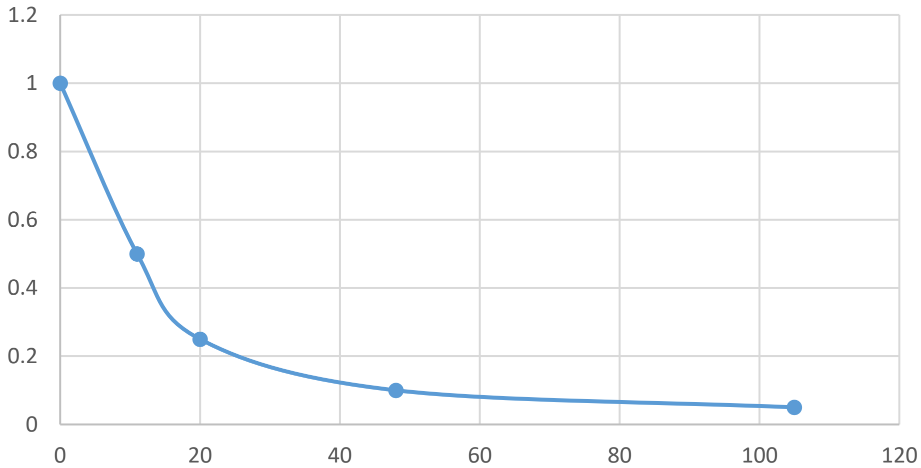
105	0.05

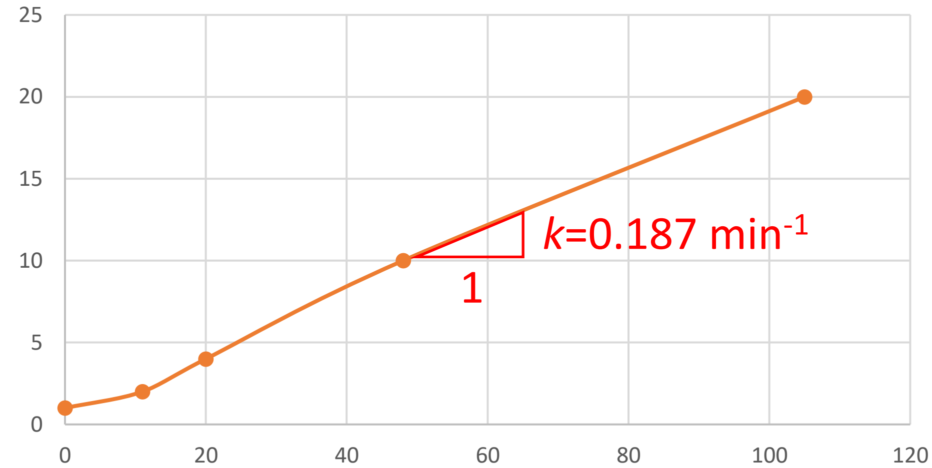
Time	C_A	$\ln C_A$	$1/C_A$
min	g/L	ln(g/L)	L/g
0	1	0	1
11	0.5	-0.693	2
20	0.25	-1.386	4
48	0.1	-2.303	10
105	0.05	-3.000	20

Homework

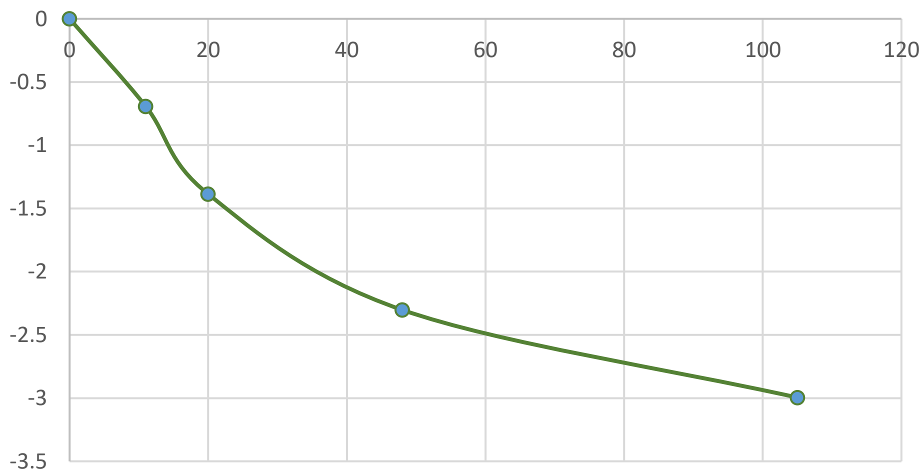
C_A-t



$1/C_A$-t



$\ln C_A$-t



This reaction is second-order, with the rate constant k is 0.187 min^{-1}.

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(a) One ideal plug flow reactor

Plug-flow reactor

Attention

- Substrate removal reaction follows first-order
- At steady-state

$$\tau = \frac{1}{k}\ln\left(\frac{C_0}{C_t}\right) = \frac{1}{8}\ln\left(\frac{100}{15}\right) = 0.237\ \mathrm{d}$$

$$\tau = Q \cdot \tau = 19000 \times 0.237 = 4506\ \mathrm{m}^3$$

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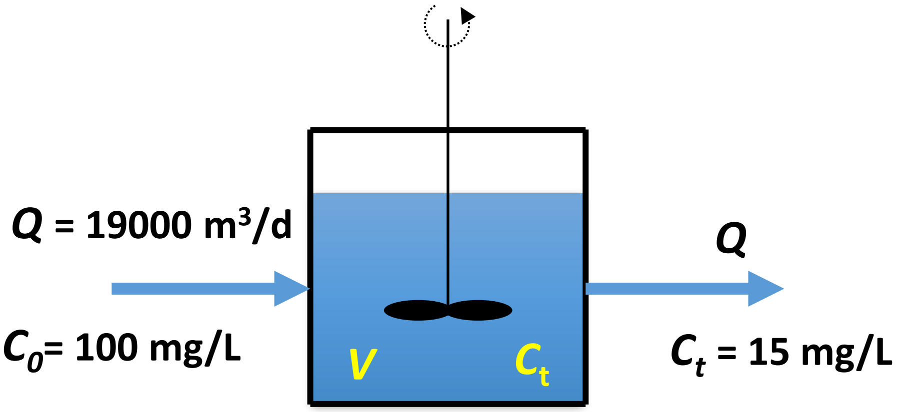
(b) One ideal complete-mix reactor



Mass balance in this reactor

$$[accumulation] = [inputs] - [outputs] + [reaction]$$

At steady-state $V\left(\frac{dC}{dt}\right)_{accmu} = QC_0 - QC_t + rV = Q(C_0 - C_t) - VkC_t = 0$

$$V = \frac{Q(C_0 - C_t)}{kC_t} = \frac{19000(0.1 - 0.015)}{8 \times 0.015} = 13458 \text{ m}^3$$

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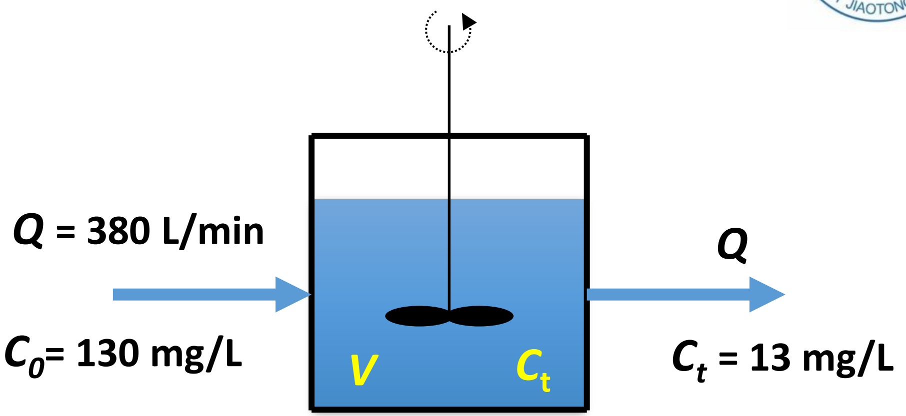

Mass balance in this reactor

$$[accumulation] = [inputs] - [outputs] + [reaction]$$

At steady-state $$V\left(\frac{dC}{dt}\right)_{accmu} = QC_0 - QC_t + rV = Q(C_0 - C_t) - VkC_t = 0$$

$$\frac{V}{Q} = \tau = \frac{(C_0 - C_t)}{kC_t} = \frac{0.13 - 0.013}{0.5 \times 0.013} = 18\ \mathrm{h}$$

$$V = Q \cdot \tau = 380\,\frac{\mathrm{L}}{\mathrm{min}} \times 18\ \mathrm{h} \times 60\,\frac{\mathrm{min}}{\mathrm{h}} = 410.4 \times 10^3\ \mathrm{L} = 410.4\ \mathrm{m}^3$$

The end