BT209

Bioreaction Engineering

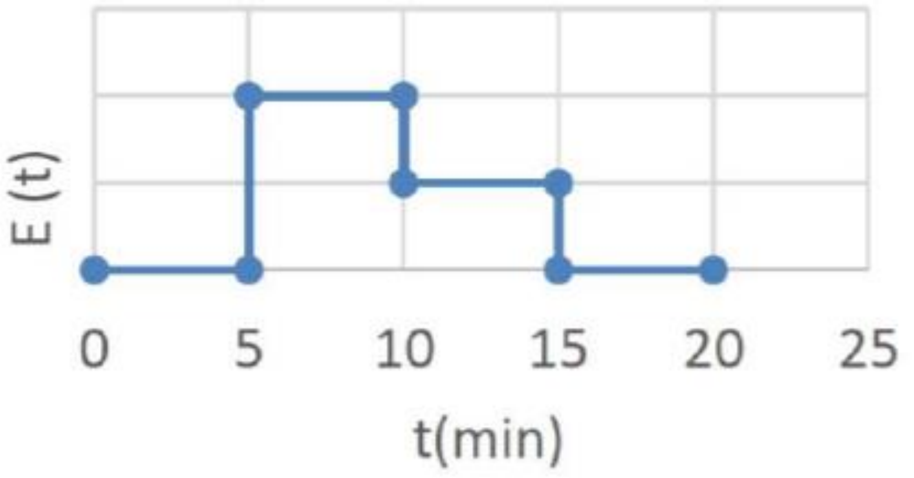
28/04/2023 (Extra class)

Tutorial: (RTD and non ideal reactor)

Problem 1

Segregation model

1) A reactor has a residence time distribution showing in the Fig. A second order reaction (A→P) is carried out in this reactor. The feed concentration of A is 1.5 mol/L. The rate constant of the reaction is 0.2 L/(mol.min). What would be the conversion of A in this reactor considering the segregated flow model?



Solution

Segregated model: $\bar{X} = \int_0^{\infty} X(t)_{\text{batch}}\, E(t)\,dt$

For 2^{nd} order rxn:

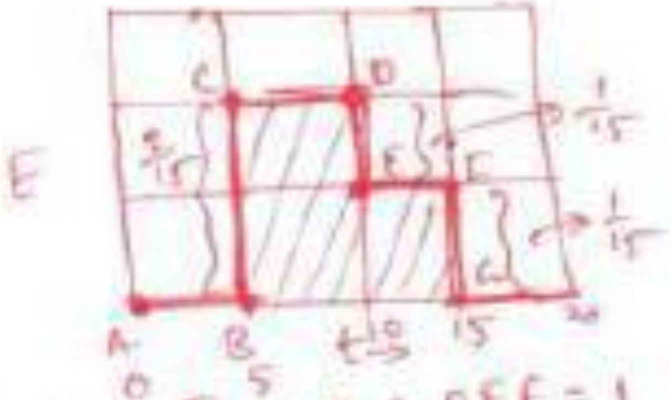
$$\frac{dC_A}{dt} = kC_A^2 \Rightarrow X = \frac{C_{A0}kt}{1+C_{A0}kt} = \frac{0.3t}{1+0.3t}$$

$$\bar{X} = \int_0^{\infty} \frac{0.3t}{1+0.3t} E(t)\,dt$$

$$= \int_0^{5} \frac{0.3t}{1+0.3t} \times 0 + \int_5^{10} \frac{0.3t}{1+0.3t} \times \frac{2}{15}$$

$$+ \int_{10}^{15} \frac{0.3t}{1+0.3t} \times \frac{1}{15} + \int_{15}^{\infty} \frac{0.3t}{1+0.3t} \times 0$$

$$= 0.72$$



$\int_0^{\infty} E\,dt = 1 \therefore$ Area BCDEF = 1

$\therefore BC \times (10-5) + \frac{1}{2} BC(15-10) = 1$

$BC = \frac{2}{15}$

$FG = \frac{1}{15}$

Problem 2

Tank in series (TIS) model

2) A sample of the tracer was injected as a pulse to a tubular reactor and the effluent concentration measured as a function of time, resulting in the following data:

t(min)	0	1	2	3	4	5	6	7	8	9	10	12	14
C(g/m³)	0	1	5	8	10	8	6	4	3	2.2	1.5	0.6	0

A first order reaction (A→P) is carried out in this tubular reactor (diameter=10 cm and length=6.36 m). The feed concentration of A is 10 mol/L. The rate constant of the reaction is 0.25 min^{-1}. What would be the conversion of A in this reactor considering the TIS model?

Solution

t	0	1	2	3	4	5	6	7	8	9	10	12	14
c	0	1	5	8	10	8	6	4	3	2.2	1.5	0.6	0
E	0	0.02	0.1	0.16	0.2	0.16	0.12	0.08	0.06	0.044	0.03	0.012	0
tE	0	0.02	0.2	0.48	0.8	0.8	0.72	0.56	0.48	0.4	0.3	0.14	0
t^2E	0	0.02	0.4	1.44	3.2	4	4.32	3.92	3.84	3.60	3.0	1.68	0

$$\therefore \int_0^\infty c(t)\,dt = 50\ g\cdot min, \quad \bar{t} = \int_0^\infty t E\,dt = 5.15\ min$$

$$\int_0^\infty t^2 E\,dt = \frac{1}{3}\left[1(0)+4(0.02)+2(0.4)+4(1.44)+2(2.2)+4(4.0)+2(4.32)+4(3.92)+2(3.84)+4(3.6)+1(3.0)\right]$$

$$+\frac{2}{3}\left[3.0+4(1.68)+0\right]$$

$$= 32.63\ min^2$$

$$\therefore \sigma^2 = \int_0^\infty (t-\bar{t})^2 E\,dt = \int_0^\infty t^2 E\,dt - \bar{t}^2$$

$$= 32.63 - (5.15)^2 = 6.10\ min^2$$

n=5.15x 5.15 /(6.10)=4.34 =5

T_i=T/4.34=5.15/4.34=1.187

For first order reaction, x=1-1/(1+k T_i)^n=1-1/(1+0.25 * 1.187)^4.34 = 1-1/3.089= 1-0.3237=0.686