BT209

Bioreaction Engineering

23/01/2023

Problem 1

For the decomposition A → R, C_{A0} = 1 mol/liter, in a batch reactor conversion is 75% after 1 hour, and is just complete after 2 hours. Find a rate equation to represent this kinetics.

Solution: Problem 1

For the decomposition A → R, C_{A0} = 1 mol/liter, in a batch reactor conversion is 75% after 1 hour, and is just complete after 2 hours. Find a rate equation to represent this kinetics.

Solution: Assume n^{th} order.

$$\frac{(n-1)kt_2}{(n-1)kt_1} = \frac{C_{A0}\left[\left(\frac{C_{A2}}{C_{A0}}\right)^{1-n} - 1\right]}{C_{A0}\left[\left(\frac{C_{A1}}{C_{A0}}\right)^{1-n} - 1\right]}$$

$$C_A^{1-n} - C_{A0}^{1-n} = (n-1)kt$$

n=1/2

k=1

$-r_A = (1 \ \text{mol/lit}^{1/2} \cdot \text{hr}) \ C_A^{1/2}$, mol/ Lit. hr

Q2. A 10-minute experimental run shows that 75% of liquid reactant is converted to product by a ½ order rate. What would be the fraction converted in a half-hour run? [0.5]

Q3. For the stoichiometry $A + B \rightarrow P$ find the reaction orders with respect to A and B [0.5]

C_A	2	2	3
C_B	125	64	64
$-r_A$	50	32	48

Q4. The maximum allowable temperature for a reactor is 800 K. At present, our operating set point is 780 K, the 20 K margin of safety to account for fluctuating speeds, sluggish controls etc. Now, with a more sophisticated control system, we would be able to raise our set point to 792 K, with the same margin of safety that we now have. By how much can the reaction rate, hence production rate, be raised by this change, if the reaction taking place in the reactor has an activation energy of 175 kJ/mol? [1]

Problem 2

A 10-minute experimental run shows that 75% of liquid reactant is converted to product by a ½ order rate.

What would be the fraction converted in a half-hour run?

Solution: Problem 2

A 10-minute experimental run shows that 75% of liquid reactant is converted to product by a ½ order rate.

What would be the fraction converted in a half-hour run?

solution.

At 20min X_A=1, so at 30 min X_A=1.

Problem 3

For the stoichiometry $A + B \rightarrow P$ find the reaction orders with respect to A and B

C_A	2	2	3
C_B	125	64	64
$-r_A$	50	32	48

Solution: Problem 3

For the stoichiometry $A + B \rightarrow P$ find the reaction orders with respect to A and B

C_A	2	2	3
C_B	125	64	64
$-r_A$	50	32	48

Solution: $50 = k.2^a.125^b$

$32 = k.2^a.64^b$

$48 = k.3^a.64^b$

$b = \log(50/32)/\log(125/64) = 0.6667$

$a = \log(32/48)/\log(2/3) = 1$

Problem 4

The maximum allowable temperature for a reactor is 800 K. At present, our operating set point is 780 K, the 20 K margin of safety to account for fluctuating speeds, sluggish controls etc. Now, with a more sophisticated control system, we would be able to raise our set point to 792 K, with the same margin of safety that we now have. By how much can the reaction rate, hence production rate, be raised by this change, if the reaction taking place in the reactor has an activation energy of 175 kJ/mol?

Original operating temperature $(T_1) = 780\,K$

New operating temperature $(T_2) = 792\,K$.

Activation energy of the reaction $= 175\,kJ/mol$

$= 175 \times 10^3\,J/mol$

$R = 8.314\,J/mol\,K$

From Arrhenius equation, we have,

$$k_1 = A e^{-E_a/RT_1} \longrightarrow (1)$$

$$k_2 = A e^{-E_a/RT_2} \longrightarrow (2)$$

Combining these two equations, we have,

$$\ln(k_1/K_2) = \frac{E_a}{R}\left[\frac{1}{T_2} - \frac{1}{T_1}\right] \rightarrow (3)$$

Putting all the known values in equation 3, we get,

$$\ln \frac{K_1}{K_2} = -0.40887$$

$$\Rightarrow \frac{k_1}{k_2} = 0.6644$$

$$\Rightarrow \frac{k_2}{K_1} = 1.505 \simeq 1.51.$$

Since rate is proportional to rate constant. so production rate can be raised 1.51 times