

Title : variable volume System

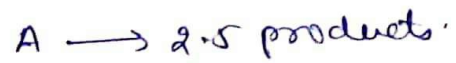
Date: 23-03-2020

Name of Faculty: Hemant Balsora

Lecture No : I (9.30-10.30 AM)

Source of information : Octave Levenspiel, “Chemical Reaction Engineering”,3rd Edition, John Wiley & Sons Pvt Ltd.

Ex. A gas-phase gaseous feed of pure A (200 mol/lit, 100 mol/min) decomposes to give variety of products in a PFR. The kinetics of the decomposition is given by



$$-r_A = 10 (\text{min}^{-1}) C_A$$

Find the conv. in 22 lit reactor

pure $\frac{Y_{A0}}{N_{T0}} = 1$, $\delta = \frac{2.5 - 1}{1} = 1.5$

$$\boxed{\epsilon_A = 1.5}$$

for PFR $V = C_{A0} V_0 \int_0^x \frac{dx}{10 C_A}$

$$V = \frac{2 \times 100}{10} \int_0^x \frac{dx}{\frac{C_{A0}(1-x)}{(1+\epsilon_A x)}}$$

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$$V = 10 \int_0^x \frac{dx}{(1-x)} (1+\epsilon_A x)$$

$$V = 10 \int_0^x \left[\frac{1}{1-x} + 1.5 \frac{x}{(1-x)} \right] dx$$

$$V = 10 \int_0^x \left[\frac{1}{1-x} + 1.5 \left[\frac{1-x-1}{(1-x)} \right] \right] dx$$

$$V = 10 \int_0^x \left[\frac{1}{1-x} - 1.5 \left[1 - \frac{1}{(1-x)} \right] \right] dx$$

$$V = 10 \int_0^x \left[\frac{1}{1-x} - 1.5 + \frac{1.5}{1-x} \right] dx$$

$$= 10 \int_0^x \left[\frac{2.5}{(1-x)} - 1.5 \right] dx$$

$$22 = 10 \left[-2.5 \ln(1-x) \Big|_0^x - 1.5x \Big|_0^x \right]$$

$$2.2 = -2.5 \ln(1-x) - 1.5x$$

$$\boxed{x = 73.3\%}$$

A. gaseous reactant A decomposes as per the following
 rxn. stoichiometry & kinetics $A \rightarrow 3R$
 $-r_A = 0.60 C_A \text{ mol/lit. min.}$, Determine the conversion of A in
 a 50% A + 50% A inert, feed with $V_0 = 180 \text{ l/min}$
 ($C_{A0} = 330 \text{ mmol/lit}$) to a 1000 l MFR.

Soln: $A \rightarrow 3R$. $\delta = \frac{3}{1} - \frac{1}{1} = 2$

$Y_{A0} = \frac{50}{50+50} = 0.50$, $\epsilon_A = \delta \times Y_{A0} = 2 \times 0.50 = 1$

CSTR, $V = \frac{F_{A0} x}{-r_A}$

$V = \frac{F_{A0} x}{0.60 C_A}$

$V = \frac{F_{A0} x}{0.60 C_{A0} (1-x) (1+\epsilon_A x)}$

$V = \frac{V_0 (C_{A0} \cdot x (1+x))}{C_{A0} \times 0.60 (1-x)}$

$V = \frac{330 \times 180^2}{0.60} \frac{x(1+x)}{(1-x)}$

$\frac{1000 \times 0.60}{180} = \frac{x(1+x)}{(1-x)}$

~~$x = 0.667$~~

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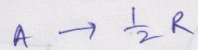
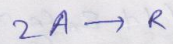
EX. 2

A gaseous feed of pure A with $C_{A0} = 1 \text{ mol/lit}$ enters a MFR of 2 lit volume and reacts to give R. The rxn kinetics and stoichiometry are given by $2A \rightarrow R$, $-r_A = 0.05 C_A^2 \text{ mol/lit}\cdot\text{s}$.

Find the feed rate (lit/min) that will give an outlet concentration $C_A = 0.5 \text{ mol/lit}$.

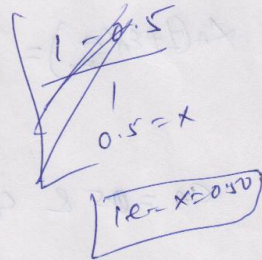
Soln

pure A 100% A $F_{A0} = 1$



$$S = \frac{1}{2} - 1 = -\frac{1}{2}$$

$$\text{then } \epsilon = -\frac{1}{2} \times 1 = -0.5$$



$$V = \frac{F_{A0} X}{-r_A} = \frac{C_{A0} V_0 X}{-r_A}$$

Given, $V = 2 \text{ lit}$, $C_{A0} = 1 \text{ mol/lit}$, $C_A = 0.5 \text{ mol/lit}$

$$V = \frac{C_{A0} V_0 X}{0.05 C_A^2}$$

Since we know

$$C_A = \frac{C_{A0} (1-x)}{(1+\epsilon x)}$$

$$\frac{C_A}{C_{A0}} = \frac{1-x}{(1+\epsilon x)}$$

$$\frac{C_A}{C_{A0}} + \epsilon \frac{C_A}{C_{A0}} X_A = 1 - X_A$$

$$\frac{C_A}{C_{A0}} = 1 - X_A (1 + \epsilon \frac{C_A}{C_{A0}})$$

$$X_A (1 + \epsilon \frac{C_A}{C_{A0}}) = \left(1 - \frac{C_A}{C_{A0}}\right) \Rightarrow X_A = \frac{1 - \frac{C_A}{C_{A0}}}{(1 + \epsilon \frac{C_A}{C_{A0}})}$$

$$C_A = 0.5 \text{ \& } C_{A0} = 1$$

$$X_A = \frac{1 - 0.5}{1 - 0.5 \times 0.5}$$

$$X_A = \frac{1 - 0.5}{1 - 0.25} = \frac{0.5}{0.75} = \frac{2}{3}$$

ie

$$2 = \frac{C_{A0} V_0 X}{0.05 C_{A0}^2 (1-x)^2} \Rightarrow X_A = 0.667$$

$$2 \times 0.05 \times (1 - 0.667)^2 = V_0 \times 0.667 (1 - 0.5 \times 0.667)$$

$$0.01108 = V_0 \times 0.667$$

$$V_0 = 0.03739 \text{ lit/sec}$$

$$\text{or } V_0 = 2.28 \text{ lit/min}$$

Phone number of faculty – (9879318632)

Assignment –

At 650 °C phosphine decomposes as per the following reaction : $4 \text{PH}_3(\text{g}) \rightarrow \text{P}_4(\text{g}) + 6 \text{H}_2(\text{g})$ with $-r_{\text{PH}_3} = 10 \text{h}^{-1} C_{\text{PH}_3}$. find the size of PFR operating at 650 °C and 11.4 atm needed to achieve 75% conversion of 10 mol/hr of Phosphine in a 2/3 Phosphine and 1/3 inert feed.

(Ans:17.04 lit)