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 (2 mol/lit, 100 mol/min) decomposes to give variety of products in a PFR. The kinetics of the decomposition is given by

$$A \longrightarrow 2.5 \text{ products}$$

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

Find the conv. in 22 lit Reactor

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

$$\boxed{\varepsilon_A = 1.5}$$

for PFR $V = C_{A0} v_0 \int_0^x \frac{dx}{10\, C_A}$

$$V = \frac{\not{2} \times 100}{10} \int_0^x \frac{dx}{\frac{\not{C_{A0}}(1-x)}{(1+\varepsilon_A x)}}$$

$$V = \frac{\not{2} \times 100}{10} \int_0^x \frac{dx}{\frac{\not{C_{A0}}(1-x)}{(1+\varepsilon_A x)}}$$

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

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

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

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

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

(3)

$$= 10 \int_0^x \frac{2.5}{(1-x)} - 1.5$$

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

$$2.2 = -2.5 \ln[1-x] - 1.5x$$

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

A gaseous reactant A decomposes as per the following rxn. stoichiometry & kinetics $A \rightarrow 3R$
$-r_A = 0.60\, C_A$ mol/lit.min. , Determine the conversion of A is a 50% A + 50% A inert, feed with $v_0 = 180$ l/min ($C_{A0} = 330$ mmol/lit) to a 1000 l MFR.

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

$y_{A0} = \frac{50}{50+50} = 0.50$, $\quad \varepsilon_A = \delta \times y_{A0} = 2 \times 0.50 = 1$

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

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

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

$V = \frac{v_0 C_{A0} \cdot x\,(1+x)}{C_{A0} \times 0.60\,(1-x)}$

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

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

~~x = 0.917~~

$x = 0.667$

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

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

**Soln** pure A 100% A & $y_{A0} = 1$

$$2A \rightarrow R$$

$$A \rightarrow \frac{1}{2}R$$

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

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

$$V = \frac{F_{A0}X}{-r_A} = \frac{C_{A0} \times v_0 \times x}{-r_A}$$

given that $V = 2$ lit, $C_{A0} = 1$ mol/lit, & $C_A = 0.5$ mol/lit

$$V = \frac{C_{A0} \times v_0 \times x}{0.05\,C_A^2}$$

since we know

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

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

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

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

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

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

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

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

$$\boxed{X_A = 0.667}$$

$$2 = \frac{C_{A0} \times v_0 \times x}{0.05 \times C_{A0}^2 \frac{(1-x)^2}{(1-0.5x)^2}}$$

$$2 \times 0.05 \times (1-0.667)^2 = v_0 \times 0.667\,(1 - 0.5 \times 0.667)^2$$

$$0.01108 = v_0 \times 0.667\,($$

$$v_0 = 0.03739 \text{ lit/sec}$$

or $\boxed{v_0 = 2.25 \text{ lit/min}}$ Ans

**Phone number of faculty – (9879318632)**

**Assignment** –

At 650 $^{o}C$ phosphine decomposes as per the following reaction : $4\ PH_3(g) \rightarrow P_4(g) + 6\ H_2(g)$ with $-r_{PH3} = 10 h^{-1} C_{PH3}$ . find the size of PFR operating at 650 0C 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)