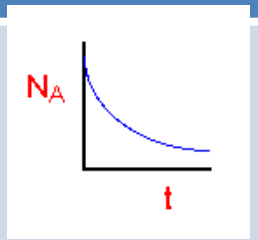
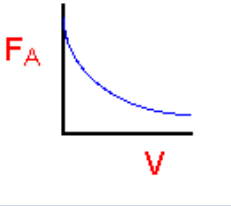
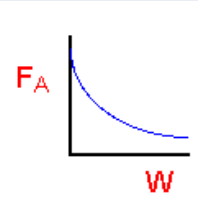
# 1. Mole Balances II

- **The Rate of Reaction, $-r_A$**
- **The General Mole Balance Equation**
- **Continuous Flow Reactors**
  - **CSTR (Continuous-Stirred Tank Reactor)**
  - **PFR (Tubular Reactor)**
  - **Packed-Bed Reactor**
- **Industrial Reactors**

# 4. Mole Balance on Different Reactor Types (p.25)

| Reactor | Design Equations | Graph |
|---|---|---|
| **Batch** | $\frac{dN_A}{dt} = r_A V \qquad t = \int_{N_{A0}}^{N_A} \frac{dN_A}{r_A V}$ |   |
| **CSTR** | $V = \frac{F_{A0} - F_A}{-r_A}$ | |
| **PFR** | $\frac{dF_A}{dV} = r_A \qquad V = \int_{F_{A0}}^{F_A} \frac{dF_A}{r_A}$ |   |
| **PBR** | $\frac{dF_A}{dW} = r'_A \qquad W = \int_{F_{A0}}^{F_A} \frac{dF_A}{r'_A}$ |   |

# Batch Reactor

- **General Mole Balance on System Volume V**

$$\text{In} - \text{Out} + \text{Gen.} = \text{Accum.}$$

$$F_{A0} - F_A + \int^V r_A dV = \frac{dN_A}{dt}$$

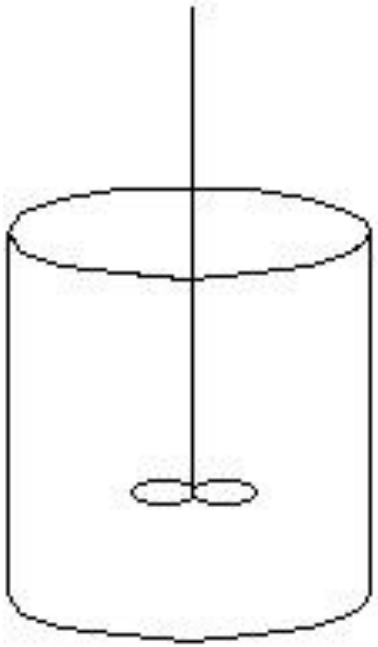
**- Batch - No inflow or outflow**

**$F_{A0} = F_A = 0$**

**- Assumptions, well mixed**

$$\int^V r_A dV = r_A V$$

$$\frac{dN_A}{dt} = r_A V$$



**- Rearranging and Integrating**

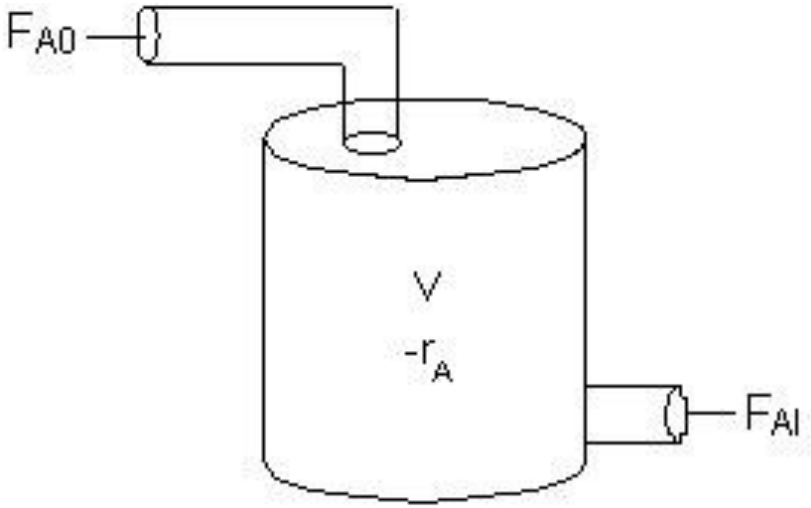
$$t_1 = \int_{N_{A1}}^{N_{A0}} \frac{dN_A}{-r_A V}$$

# CSTR

- **General Mole Balance on System Volume V**

$$\text{In} - \text{Out} + \text{Gen.} = \text{Accum.}$$

$$F_{A0} - F_A + \int^V r_A dV = \frac{dN_A}{dt}$$




**- Assumptions**

**• steady state** $\dfrac{dN_A}{dt} = 0$

**• well mixed** $\int^V r_A dV = r_A V$

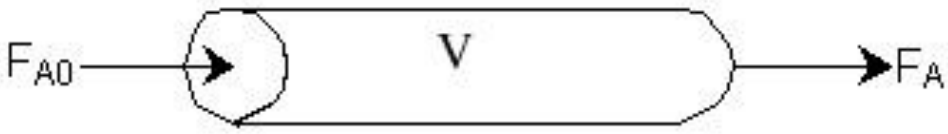
**- Rearranging**

$$V = \frac{F_{A0} - F_A}{-r_A}$$

# PFR

- **General Mole Balance on System Volume V**

$$\text{In} - \text{Out} + \text{Gen.} = \text{Accum.}$$




$$F_{A0} - F_A + \int^V r_A dV = \frac{dN_A}{dt}$$

**- Assumptions, steady state** $\dfrac{dN_A}{dt} = 0$

**- Design equation for PFR**

$$F_{A0} - F_A + \int^V r_A dV = 0$$

**- Differential w.r.t V** $0 - \dfrac{dF_A}{dV} = -r_A \qquad \dfrac{dF_A}{dV} = r_A$

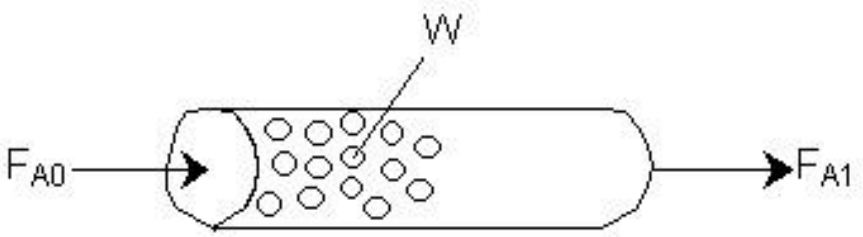
**- Rearranging and integrating**

$$V_1 = \int_{F_{A1}}^{F_{A0}} \frac{dF_A}{-r_A}$$

# PBR

- **General Mole Balance on Catalyst W**

$$\text{In} - \text{Out} + \text{Gen.} = \text{Accum.}$$




$$F_{A0} - F_A + \int^{W} r'_A dW = \frac{dN_A}{dt}$$

**- Assumptions, steady state** $\dfrac{dN_A}{dt} = 0$

**- Design equation for PFR**

$$F_{A0} - F_A + \int^{W} r'_A dW = 0$$

**- Differential w.r.t V** $0 - \dfrac{dF_A}{dW} = -r'_A \qquad \dfrac{dF_A}{dW} = r'_A$

**- Rearranging and integrating**

$$W_1 = \int_{F_{A1}}^{F_{A0}} \frac{dF_A}{-r'_A}$$

# Self Test

1. Which equation is used in arriving at the design equation for a batch reactor?
   - A. $G_j = V*r_j$
   - B. $dN_j/dt = 0$
   - C. $F_{jo} = F_j = 0$
   - D. $E = mc^2$
2. What assumptions are made when modeling an ideal tubular reactor?
   - A. Steady sate and no radial variations
   - B. Plug flow and liquid systems
   - C. Gas flow and steady state
   - D. That the reactor will photograph well

# Self Test II

**3. What does the mole balance for a CSTR become if $r_j = -k*C_j$?**

**A. $C_j = (F_{jo} - F_j)/V$**

**B. too complicated**

**C. $V = (F_{jo} - F_j)/(k*C_j)$**

**D. $V = (F_{jo} - F_j)/k$**

**4. Which reactor is modeled by the equation $V = (F_{jo} - F_j)/(k*C_j)$ if $r_j = -C_j*k$?**

**A. CSTR**

**B. The red one with polka dots**

**C. Batch reactor**

**D. Tubular reactor**

# Self Test III

**5. What is the name for any chemical compound or element with a given identity?**

**A. Ion**

**B. Atom**

**C. Alfred**

**D. Chemical species**

**6. Which of the following is a combination type reaction?**

**A. 53 left: 37 right: 5 left**

**B. $A + B \rightarrow C$**

**C. $A_2 \rightarrow 2A$**

**D. $A \rightarrow B$**

# Self Test IV

**7. What happens during a combination reaction?**

**A. A molecule breaks down into smaller molecules**

**B. You get a burger, fries and a soft drink**

**C. Two or molecules combine**

**D. Species  molecular configuration changes only**

**8. What happens during a decomposition reaction?**

**A. Species  molecular configuration changes only**

**B. A molecule rots**

**C. Two molecules combine to give one molecule**

**D. A molecule breaks down into smaller molecules**

# Self Test V

**9. What assumption is made when studying an IDEAL CSTR?**

**A. Innocent until proven guilty**

**B. Adiabatic operation**

**C. Perfect mixing**

**D. Constant volume**

**10. Which of the following reactors usually have the easiest temperature control?**

**A. Blue reactors**

**B. CSTRs**

**C. Tubular reactors**

**D. Batch reactors**

# Self Test VI

11. A packed bed reactor is also known as a fluidized bed reactor.

A. Only when using an alias

B. Depends on the catalyst used

C. True

D. Always false

12. What is the rate of appearance of B in the reaction $A \rightarrow B$?

A. very slow

B. $r_B = r_A$

C. $r_B = - r_A$

D. $r_B = (r_B - r_A)$

# Self Test VII

**13. What type of mathematical equation is used to express the rate law?**

**A. Irreversible equation**

**B. Differential equation**

**C. Unsolvable equation**

**D. Algebraic equation**

**14. What are the dimensions of k in the equation $r_A = k C_A$?**

**A. moles$^2$/volume$^2$/time**

**B. time/mole/volume**

**C. three**

**D. 1/time**