CSTR – continuous / batch ??

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Reaction engineering

total time the reactant has spent in the reactor – residence time

time required to pass a molecule through a reactor

→ kinetics, thermodynamics
how fast → feasibility

→ rate ∝ rate of consumption of reactants
∝ rate of formation of product

→ flexible – can know the minute details – like temp, pressure
→ **Batch** :- We add the reactants and after the completion of reaction the products are removed
small scale

→ continuous → continuous flow of reactants and products
→ large scale

→ residence time :- time taken for the conversion → (design parameter)

$t_{batch} = t_{ran} + t_{charge} + t_{discharge} + t_{clean}$

→ CSTR, batch, plug
large residence time → gas → small residence time → otherwise long pipe will be required.
isothermal condition

→ Input – out + gen = accumulation.

Batch :- $\frac{dC_A}{dt} = (-r_A)V$

$\frac{dC_A}{dt} = (-r_A)V$

$$X_A = \frac{C_{A0} - C_A}{C_{A0}}$$

$$t = C_{A0} \int_0^{X_A} \frac{dX_A}{(-r_A)V}$$

$$V = V_0(1 + \varepsilon_A X_A)$$

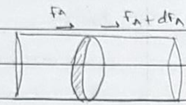
→ **Plug flow** :- each and every particle will spend same time in the plug flow reactor
– try to maintain flat velocity profile
– mixing is not always good → ✓

→ residence time = l/v → velocity

→ CSTR < PFR → less conversion
→ residence time of plug = batch
→ No accumulation in plug flow

$$\boxed{F_{A0} - F_{Af} + (-r_A)V = 0}$$

$$F_{Af} = F_{A0}(1 - X_A)$$



$$\frac{V}{F_{A0}} = \tau$$

$$F_A - (F_A + dF_A) + (-r_A)dV = 0$$

→

$$-dF_A = (-r_A)dV$$

$$F_{A0}\frac{dX_A}{dV} = (-r_A)$$

$$\frac{\tau}{C_{A0}} = \int_0^{X_{A_f}} \frac{dX_A}{-r_A}$$

CSTR (steady state)

$$F_{A0} - F_{Af} - (-r_A)V = 0$$

$$F_{A0}X_A = (-r_A)V$$

$$\frac{V}{F_{A0}} = \frac{X_A}{(-r_A)}$$

const residence time

→ rate of mass transfer = rate of reaction → $\boxed{\text{heterogeneous}}$
→ To increase conversion → series
→ production rate → llel

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residence time $= \frac{V_R}{V_0}$ → volumetric flow rate of feed entering the reactor

Conversion $= \frac{\text{moles of A reacted}}{\text{moles of A supplied}}$

Batch reaction

$$\frac{dN_A}{dt} = -(r_A V)$$

$$C_{A0}\frac{dX_A}{dt} = -r_A$$

$\frac{-1}{r_A}$ v/s X_A → to find volume or residence time by area under the curve

→ CSTR

$$V_0 C_{A0} - V_0 C_A + r_A V = \frac{d}{dt}(C_A V)$$

$F_{A0} = V_0 C_{A0}$ → molar

$$V_0(C_{A0} - C_A) = -r_A V$$

$$\tau_m = \frac{V}{V_0} = \frac{C_{A0} - C_A}{(-r_A)}$$ → design eqn

→ PFR

$$F_A - (F_A + dF_A) + r_A dV = 0$$

$$\frac{-dF_A}{dV} = (-r_A)$$

$$\frac{F_{A0} - F_A}{F_{A0}} = X_A$$

$$\tau = \frac{V}{V_0} = C_{A0}\int_0^{X_f} \frac{dX_A}{(-r_A)}$$

→ $V_A = V_{0A}(1 + \varepsilon_A X_A)$

$$\boxed{\varepsilon_A = \frac{V_{X_A=1} - V_{X_A=0}}{V_{X_A=0}}}$$ → for complete conversion

ε_A ✗

ε_A = fractional volume change

$$\frac{\Delta V}{V_0}$$

how much time it is taking to treat 1 reactor volume

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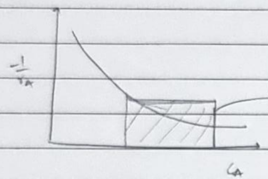
τ = space time → $\tau = V/v_0$ time required to process one reactor volume of the feed — design parameter

— Amt of time spent by the particle until it exits the reactor →

→



$(C_{A0} - C_{Af})\left(\frac{-1}{r_A}\right) = \tau$ — CSTR

to find the volume of the reactor

$F_{A0} = F_{A0}(1 - X_A) + (-r_A)V$

$F_{A0} X_A = (-r_A)V$

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

avg residence time = space time

$\frac{V C_{A0}}{F_{A0}} = \frac{C_{A0} - C_{Af}}{(-r_A)}$

$\tau = \frac{V}{v_0}$

— $C_{A0}^{n-1} k \tau$ — Damkohler number — n = order

↳ relates reaction time scale to convection

$\frac{k C_0^n}{C_0/\tau}$ → reaction rate

→ tells about conversion

convective mass transport rate

$\frac{C_0 v_0}{V}$

Da > 10 | X > 0.9

~~Da~~

Da < 0.1 | X < 0.1

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Recycle reactor → to increase mixing → in plug flow

① autocatalytic reaction → when product acts as catalyst

② maintain isothermal

③ promote certain selectivity of a product

R = $\frac{\text{returned}}{\text{leaving}}$

— Performance of a reactor can be judged on the basis of $-1/r_A$ v/s X (area) → it will give an estimate about τ and eventually V.

→ low conversion → mixed

→ high conversion → plug

→