## Question 1

$$F_{j0} - F_j + \int^V r_j \, dV = 0$$ (CSTR, steady state, no accumulation)
(No spatial variation in rate)

⊙ $r_j = \rho_b r_j' \left[\frac{\text{mass catalyst}}{\text{volume}}\right]\left[\frac{\text{moles } j}{\text{time} \cdot \text{mass catalyst}}\right]$ ($\rho_b \to$ bulk density of catalyst)

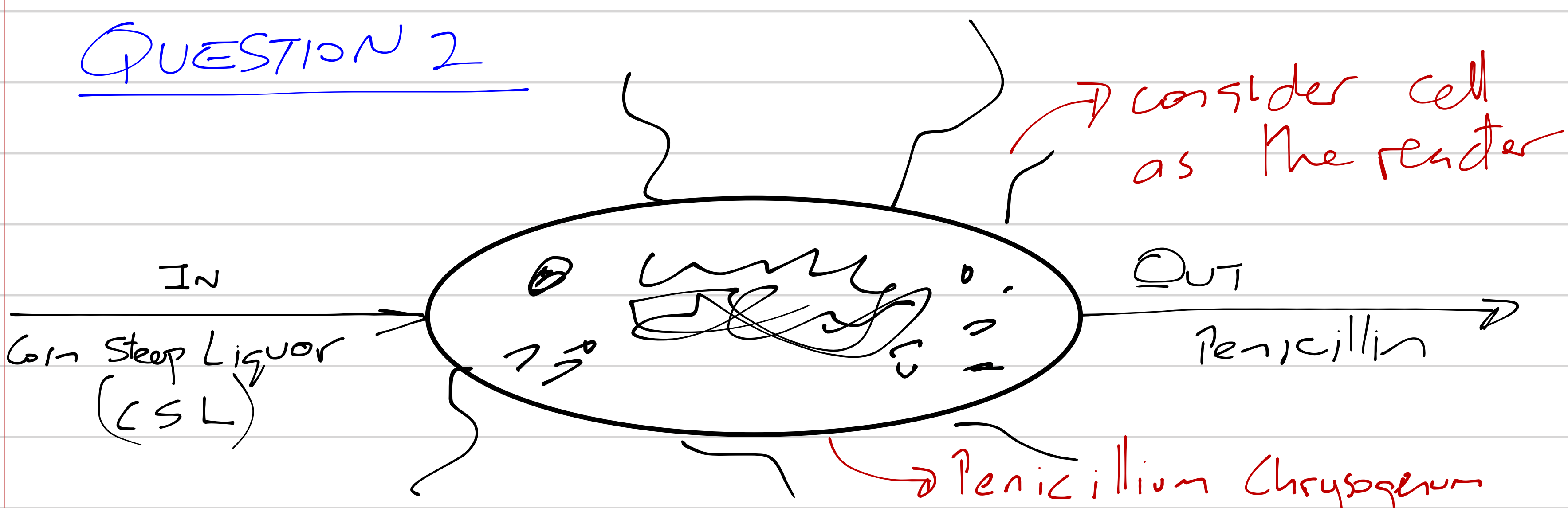
also $W = V\rho_b \ [\text{Volume}]\left[\frac{\text{mass catalyst}}{\text{Volume}}\right]$

$$\Rightarrow 0 = F_{j0} - F_j + \int r_j' \rho_b \, dV$$

$$\hookrightarrow 0 = F_{j0} - F_j + r_j' W$$

$$\Rightarrow W = \frac{F_{j0} - F_j}{-r_j'}$$

## QUESTION 2




- Assume cell is well mixed and RNA remains inside cell

Corn Steep Liquor + Penicillium → amino acids + RNA + DNA

Gen. mole balance: $F_{j0} - F_j + \int_0^V r_j \, dV = \frac{dN_j}{dt}$

let $M_j$ = molecular weight of species $j$

$\Rightarrow F_{j0} M_j = w_{j0}$ (mass flow rate of $j$ into reactor)

also $\Rightarrow N_j M_j = m_j$ (mass of species $j$ in reactor)

$\hookrightarrow F_{j0} M_j - F_j M_j + M_j \int^V r_j \, dV = M_j \frac{dN_j}{dt}$

$\hookrightarrow \omega_{j0} - \omega_j + \int_0^V M_j r_j \, dV = \frac{dm_j}{dt}$

a) Unsteady mass balance on Corn Steep Liquor, C:

$C \rightarrow P$ (P: product)

- Corn Steep liquor is consumed and not generated
- Unsteady state so $\frac{dN_C}{dt} \neq 0$

$$F_{C0} - F_C + \cancel{\int^V r_C \, dt}^{\,0} = \frac{dN_C}{dt}$$

$$\Rightarrow N_C = (F_{C0} - F_C)\, t$$

b) Unsteady mass balance on RNA

- RNA is not expelled
- RNA is generated but not introduced
- let RNA be defined by R

$$\cancel{F_{R0}}^{\,0} - \cancel{F_R}^{\,0} + \int_0^V r_R \, dV = \frac{dN_R}{dt}$$

$$N_R = r_R V t$$

c) Unsteady mass balance for Penicillin

let P represent Penicillin

$$\cancel{F_{P0}}^{0} - F_P + \int^V r_P \, dV = \frac{dN_P}{dt}$$

$$r_P V - F_P = \frac{dN_P}{dt}$$

$$\underline{N_P = (r_P V - F_P) t}$$

## QUESTION 3:

$$2A \xrightarrow{k_1} B \quad \{ k_1 = 0{,}03 \, dm^3 / (mol \cdot s) \}$$

* CSTR ASSUMPTION: - Steady State
- perfect mixing (no variation in $r_j$)
- liquid-phase reaction (incompressible)

i) Mole Balance:

$$F_{A0} - F_A - \int^V r_A \, dV = \cancel{\frac{dN_A}{dt}}^{0}$$

$$F_{A0} - F_A - r_A V = 0$$

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

* But $F_A = v C_A$ and $F_{A0} = v_0 C_{A0}$ {volume is constant}

$$\therefore \quad V = \frac{v_0 C_{A0} - v C_A}{-r_A} \qquad \text{where } v = v_0 = 3\,dm^3/s$$

$$= \frac{v_0 C_{A0} - v C_A}{k C_{A0}^2}$$

$$F_{A0} = v_0 C_{A0} = \left(3\,\frac{dm^3}{s}\right)\left(\frac{2\,mol}{dm^3}\right) = \underline{6\,\frac{mol\,A}{s}}$$

$$F_A = v C_A = \left(\frac{3\,dm^3}{s}\right)\left(\frac{0{,}1\,mol\,A}{dm^3}\right) = 0{,}3\,\frac{mol\,A}{s}$$

$$\Rightarrow \quad V = \frac{(6 - 0{,}3)\,\frac{mol}{s}}{\left(\frac{0{,}03\,dm^3}{mol.s}\right)\left(\frac{2\,mol\,A}{dm^3}\right)^2} = \underline{47{,}5\,dm^3}$$