Prof. Shunkal
Lec 7 (17/10/...)

BioChemical & Environmental Reaction Engineering

Respiration

Nitrogen fixation.

Photosynthesis.

Nitrification.

Denitrification.

ENZYME KINETICS

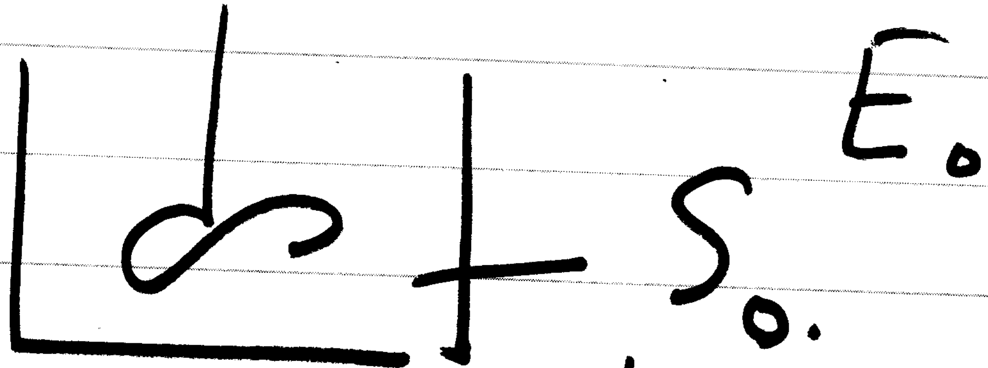
1) ENZYMES ARE PROTEINS.

2) ACTIVE SITES ARISE FROM THREE DIMENSIONAL CONFIGURATION.

3). COFACTORS ENABLE THE ENZYMES TO EXHIBIT THE 3D STRUCTURE

$$E + S \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} ES$$

$$ES \xrightarrow{k_2} P + E$$



$$\frac{d\, Vs}{dt} = r_s V \quad \Bigg| \quad \frac{d\, V(es)}{dt} = r_{es} V$$

$$-r_s = k_1(e)(s) - k_{-1}(es)$$

$$r_{es} = k_1(e)(s) - k_{-1}(es) - k_2(es)$$

$$\frac{d}{dt}(V\,es) = r_{es}\,V$$

$$e_0/s_0 \ll 1$$

$$r_{es} = 0$$

QSSA

$$e_0 = e + es$$

$$0 = k_1 (e)(s) - k_{-1}(es) - k_2 (es)$$

$$es\left[k_{-1} + k_2\right] = k_1 \left[e_0 - es\right] s$$

$$es\left[k_{-1} + k_2 + k_1 s\right] = k_1 e_0 s$$

$$es = \frac{k_1 e_0 s}{k_{-1} + k_2 + k_1 s}$$

$$E + S \rightleftharpoons ES$$

$$Es \xrightarrow[2]{} P + E$$

$$r_p = k_2 (es)$$

$$r_p = k_2 (es)$$

$$r_p = \frac{k_2 \left[k_1 e_0 s \right]}{k_{-1} + k_2 + k_1 s}$$

$$= \frac{k_2 e_0 s}{(k_{-1} + k_2)/k_1 + s}$$

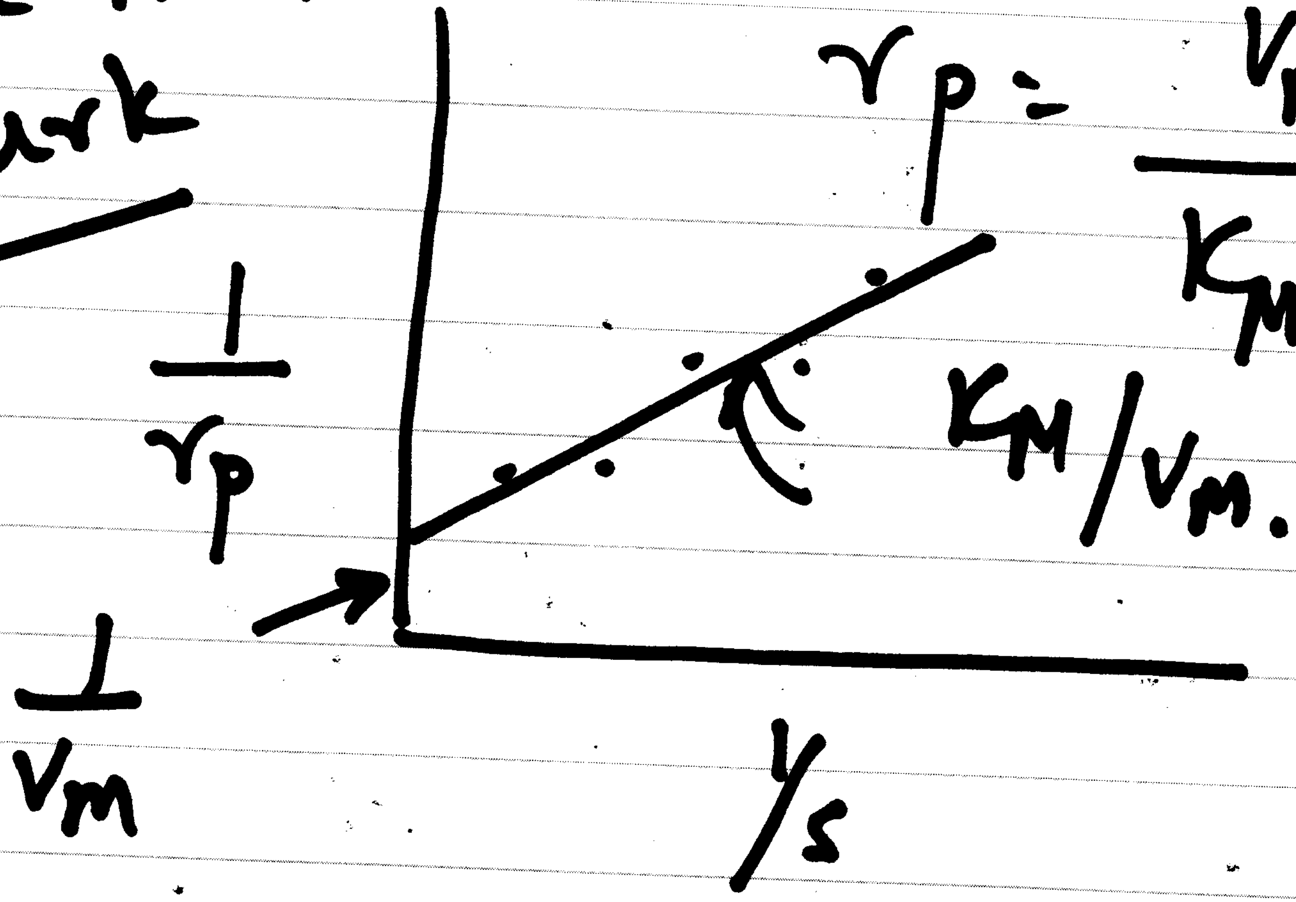
$$E + S \underset{-1}{\overset{1}{\rightleftharpoons}} ES$$

$$ES \xrightarrow[2]{} P + E$$

$$\left(\frac{k_{-1} + k_2}{k_1}\right) = K_M \; ; \; k_2 e_0 = V_m$$

$$v_p = \frac{V_m S.}{K_M + S}$$

Line Weaver Burk



$$r_p = \frac{V_m S}{K_M + S.}$$

LB Plot

$$\frac{1}{r_p} = \frac{K_M}{V_m S} + \frac{1}{V_M}$$

$$\frac{1}{r_p} = \frac{K_M}{V_M} S + \frac{1}{V_M}$$

$$r_p = \bar{r}_p + \epsilon$$

$$r_p = \frac{V_m S}{K_m + S}$$

Competitive Inhibition	$E + I = EI$
	$E + S = ES$
	$ES \rightarrow P + E$

$$S + E \underset{-1}{\overset{1}{\rightleftharpoons}} ES$$

$$I + E \underset{-2}{\overset{2}{\rightleftharpoons}} EI$$

$$ES \xrightarrow[3]{} P + E$$

$$0 = r_{es} = k_1 (e)(s) - k_{-1}(es) - k_3 (es)$$

$$0 = r_{eI} = k_2 (e)(I) - k_{-2}(eI)$$

$$(es)\left[k_{-1} + k_3\right] = k_1 \left[e_0 - es - eI\right]$$

$$-r_S = k_1 (e)(s) - k_{-1} (es)$$

~~$-k_3 (es)$~~

$$k_2\left[e_0 - es - e1\right] I = k_{-2}(eI)$$

$$(eI) = \frac{\left[e_0 - es - eI\right] k_2 / k_{-2}}{I}$$

$$(eI) = (e_0 - es - eI)(k_2)$$

$$K_{-2} = k_{-2} / k_2$$

$$k_2[e_0 - es - e1]I$$

$$= k_{-2}(e1).$$

$$e1[k_{-2} + k_2 I] = k_2 I[e_0 - es].$$

$$e1 = \quad k$$

$$r_{e1} = 0 = k_2 [e_0 - e1 - es] I - (e1) k_{-2}$$

$$e1 [k_2 I + k_{-2}] = k_2 I [e_0 - es].$$

$$0 = \cancel{d}_{es} = k_1(e)(s) - k_{-1}(es) - k_3(es)$$

$$0 = k_1(e_0 - es - eI) - k_{-1}(eI) - k_3(es).$$

$$r_p = \frac{V_M S}{S + K_m\left[1 + \frac{I}{K_i}\right]}.$$

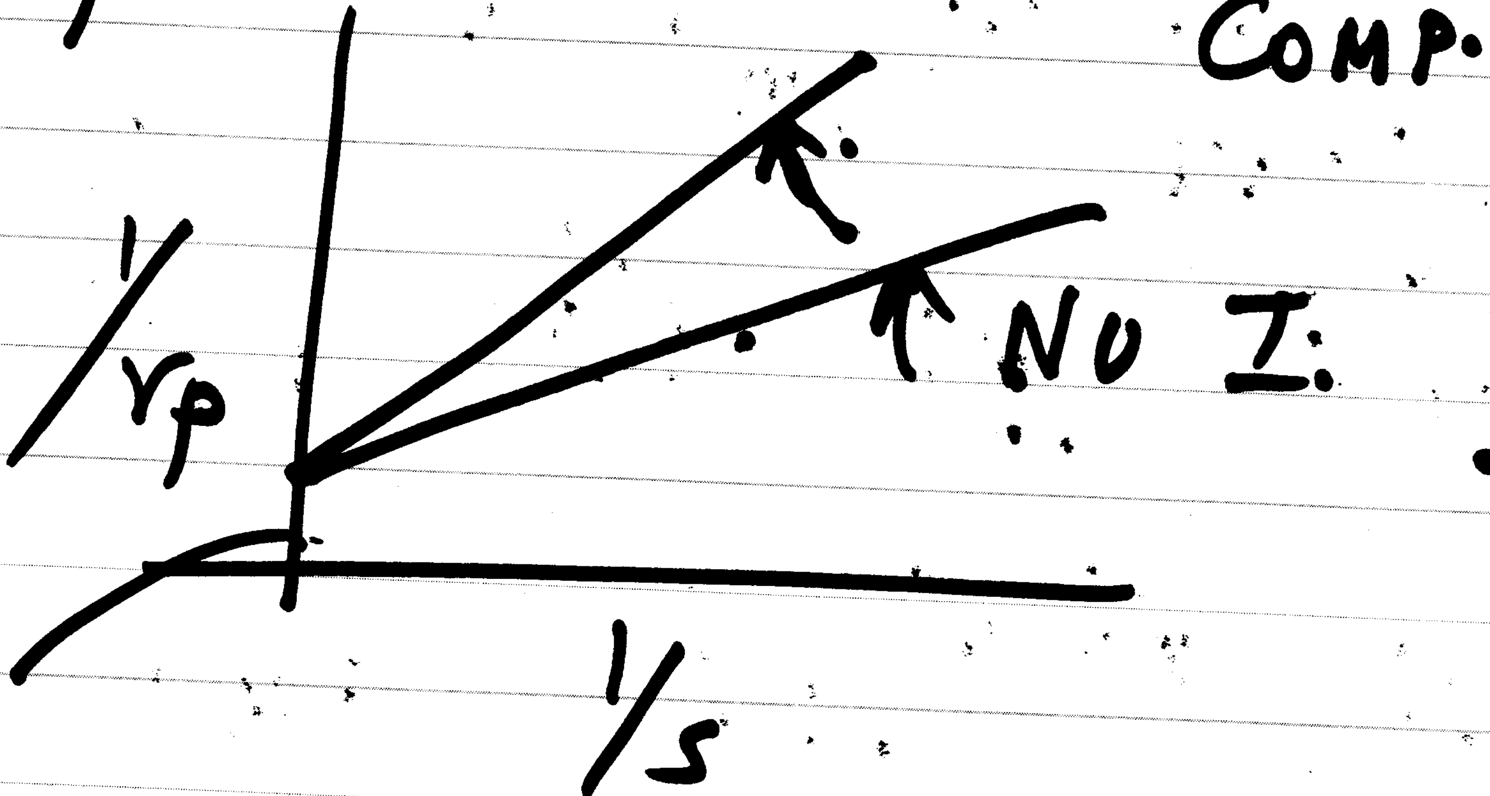
$$K_i = k_{-2} / k_2$$

$E + S \rightleftharpoons ES$

$E + I \rightleftharpoons EI.$

$$K_m = (k_{-1} + k_3) / k_1.$$

$$\frac{1}{r_p} = \frac{1}{V_M} + \frac{K_M}{V_{MS}}\left[1 + I/K_i\right]$$



UN COM

$$E + S \rightleftharpoons ES$$

$$I + ES \rightleftharpoons IES$$

$$ES \rightarrow P + E$$

$$r_p = \frac{V_M S}{K_m + S(1 + I/K_i)}$$

COM.

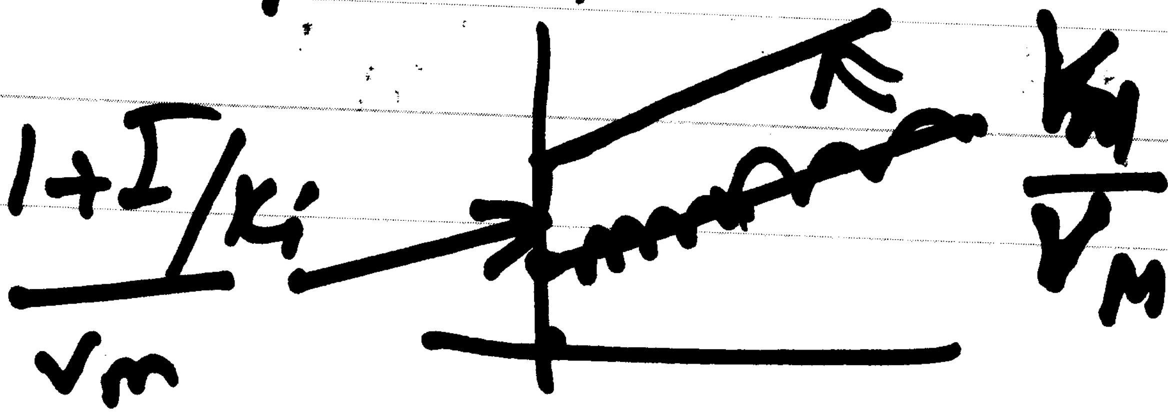
$$E + S \rightleftharpoons ES$$

$$E + I \rightleftharpoons EI$$

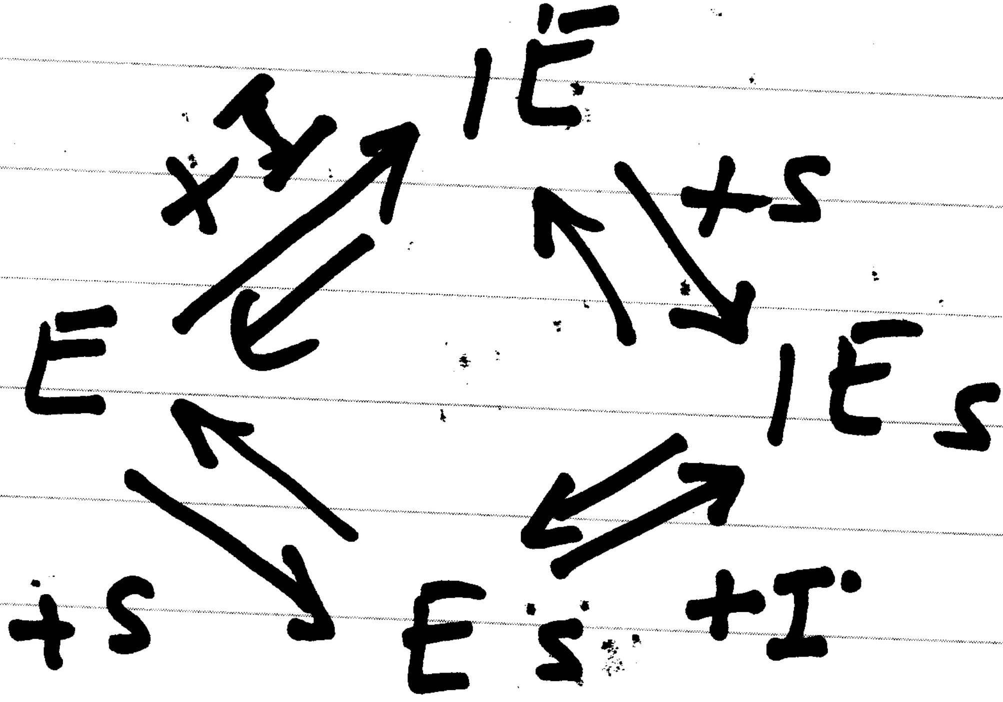
$$ES \rightarrow P + E$$

$$r_p = \frac{V_m S}{K_M + S\left(1 + \frac{I}{K_i}\right)}$$

$$\frac{1}{r_p} = \frac{K_M}{V_m S} + \frac{1 + I/K_i}{V_m \cancel{(1 + I/K_i)}}$$



UNCOM.



$r_{eI} = 0$

$r_{Ies} = 0$

$r_{es} = 0$

$$r_p = \frac{V_m S}{(S + K_M)(1 + I/K_i)}$$

$$E + S \underset{-1}{\overset{1}{\rightleftharpoons}} ES$$

$$ES + S \underset{-2}{\overset{2}{\rightleftharpoons}} SES$$

$$ES \xrightarrow{3} P + E.$$

$$e_0 = e + es + ses$$

$$0 = \dot{es} = k_1(e)(s) - k_{-1}(es) + k_{-2}(ses) - k_2(s)(es) - k_3(es)$$

$$0 = \dot{ses} = K_2(es)(s) - k_{-2}(ses)$$

$$r_p = \frac{k_3 (e_0) \cancel{k_1} S}{\cancel{k_1} S + \left(\frac{k_{-1} + k_3}{\cancel{k_1} k_1}\right) + \frac{\cancel{k_1} k_2 S^2}{k_{-2} \cancel{k_1}}}$$

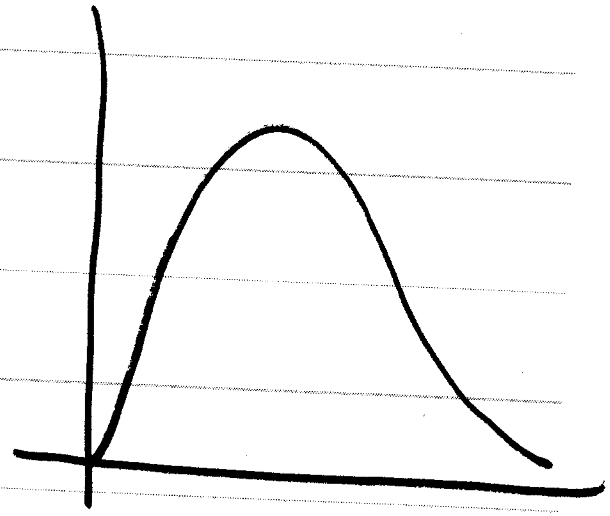
$$r_p = \frac{k_3 e_0 S}{\left[S + \left\{ \frac{k_{-1} + k_3}{k_1} \right\} + \frac{k_2 S^2}{k_{-2}} \right]}$$

$$r_p = \frac{V_M S}{1 + \frac{K_2}{S} + \frac{S}{K_1}}$$

$$\left(\frac{dr_p}{dS}\right) = 0$$

$$K_1 = \left[k_{-2} / k_2\right]$$

$$K_2 = \left[\frac{k_{-1} + k_3}{k_1}\right]$$



$$\frac{dr_p}{ds} = 0.$$

$$\boxed{s_{opt} = \sqrt{K_1 K_2}}$$

pH ~~Re~~ EFFECTS.

$$\bar{E} = \overset{-}{E} + H^{+} = \overset{-2}{E} + 2H^{+}$$

$$\left(\frac{e^{-}}{e_0}\right)$$

$$K_1 = \frac{e^{-}\, H^{+}}{e}$$

$$K_2 = \frac{e^{-2}(H^{+})^{2}}{(e^{-})(H^{+})}$$

$$e_0 = e + e^- + e^{-2}$$

$$e_0 = \frac{e^- H^+}{K_1} + e^- + K_2(e^-)/H^+$$

$$e^-\left[\frac{H^+}{K_1} + 1 + \frac{K_2}{H^+}\right] = e_0$$

$$\left(\frac{e^-}{e^0}\right) = \frac{1}{\left[1 + \frac{H^+}{K_1} + \frac{K_2}{H^+}\right]}$$

~~H^+~~ $\left(\frac{e^-}{e_0}\right)$

$$H^+ = \sqrt{K_1 K_2}$$

$$r_p = \frac{V_M S.}{K_M + S.}$$

(H^+)

$$V_M = (k_2 e_0)(y)$$

$E + S = \overline{ES}$

$ES \xrightarrow[k_2]{} P + E$

$$y = \frac{\bar{e}}{e_0}$$

MICROBIAL REACTION.

$$r_x = \mu x$$

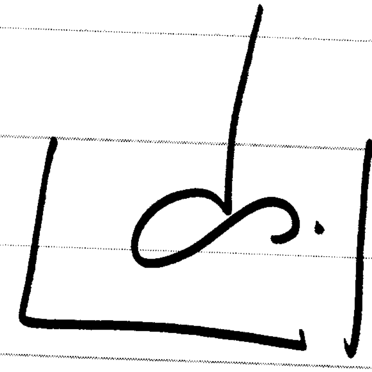
μ = Sp. Growth Rate.

$$\mu = \frac{\mu_m S}{K_S + S}$$

K_S : MONOD CONSTANT.

μ_m : MAX. GROWTH RATE.

$$v \frac{dx}{dt} = \eta_x \cdot V$$



$$v \frac{ds.}{dt} = \eta_s \cdot V$$

$$\left(\frac{dx}{ds}\right) = \frac{\eta_x}{\eta_s} = -(\gamma)$$

$$x - x_i = \gamma (s_i - s)$$

$$\frac{dx}{ds} = \frac{r_x}{r_s} = -Y$$

$$(x - x_i) = (Y_q)[s_i - s].$$

Yield Coeff

$$\frac{dx}{dt} = r_x \; \%L \cdot S.$$

$$(\%L \cdot S = [\mu \; x].$$

$$\frac{dx}{dt} = \left[\frac{\mu_m \; S}{K_S + S}\right][x].$$

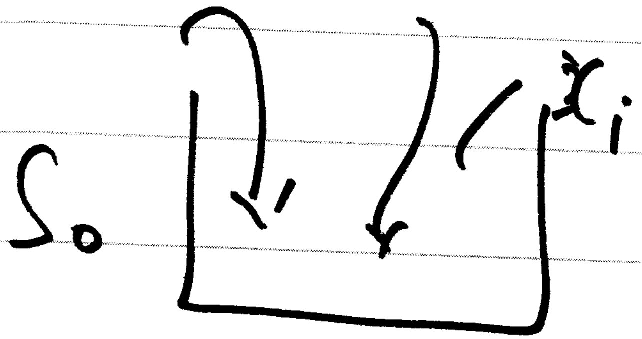
$$\frac{d}{dt}\left[\begin{array}{c} y(S_i - S) \\ + x_i \end{array}\right] = \frac{\mu_m S.}{K_s + S}\left[x_i + y(S_i - S)\right].$$

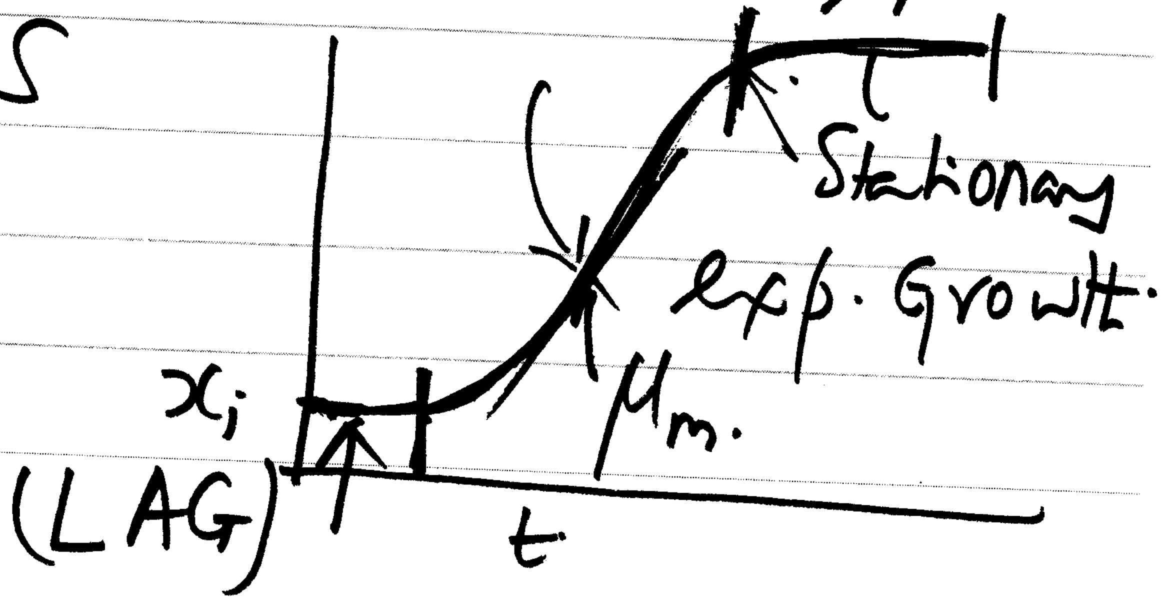
$$-y\frac{dS.}{dt} = \frac{\mu_m S.}{(K_s + S)}\left[x_i + y\left[S_i - S\right)\right].$$

S_0

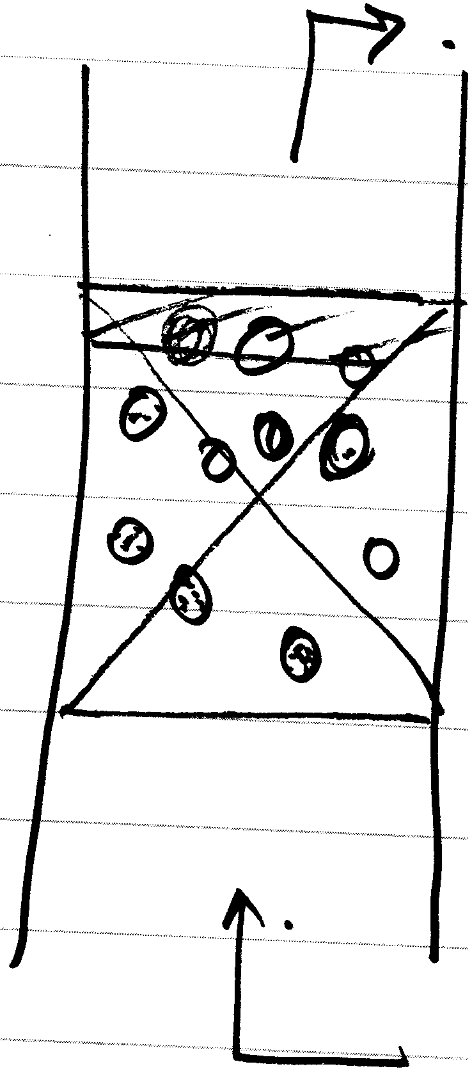
$$\left(x_i + Y K_s + Y S_i\right) \ln\left[\frac{x_i + Y S_i - Y S}{x_i}\right] \Bigg|_{x_0}^{x} \Bigg|_{S_0}^{S}$$

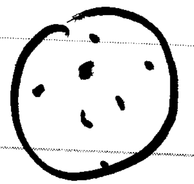
$$= Y K_s \ln \frac{S_i}{S} = \left(x_i + Y S_i\right) \mu_m t.$$





IM





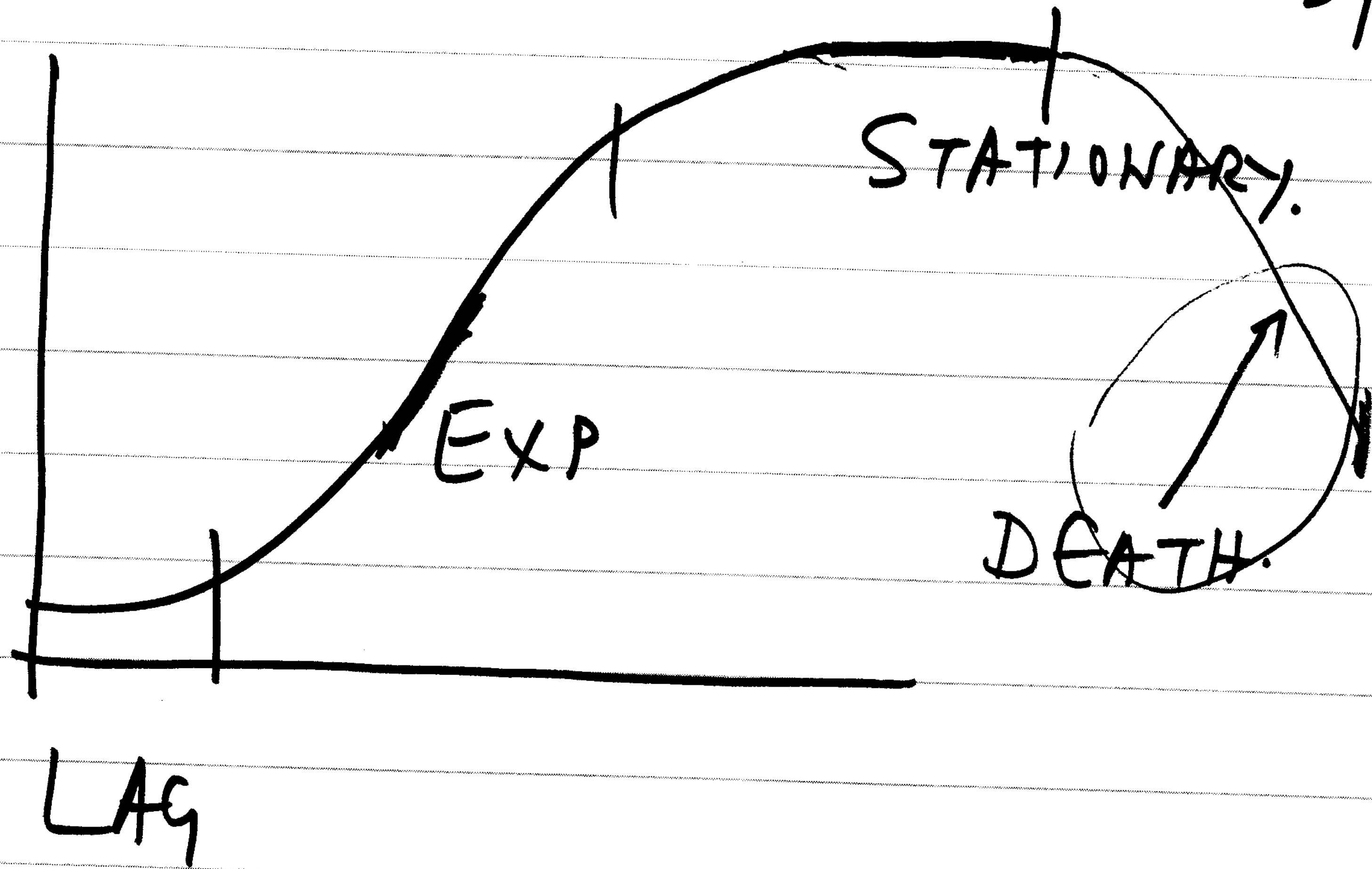
IMM. MICRO PELLETS.

x_i

$$(x_i) + x_o + Y(S_o - S)$$

S_o

(x_o)


STATIONARY.
EXP
DEATH.
LAG

ICR

$$\left(x_0 + x_i + Y K_s + Y s\right) \ln\left[\frac{x_0 + x_i + Y S_0 - Y s}{x_0 + x_1}\right]$$

$$+ \; Y K_s \ln \frac{S_0}{s}$$

V/F.

$$= \left(x_0 + x_i + Y S_0\right)\left(1 - \epsilon_s - \epsilon_g\right)\left(\mu_m\right)\tau.$$

ALCOHOL

PLUG FLOW

$$\frac{dx}{dV} = r_x - \mu x$$

$$\frac{dx}{(1-\epsilon_g-\epsilon_e)\,dV} = \frac{\mu_m\left[x_i + x_o + Y(S_o - S)\right]}{K_s + S}$$

$$V_e = V\left[1 - \epsilon_g - \epsilon_e\right)$$