

*Design and analysis of biological reactor

Fed Batch operation. \rightarrow

$f(t)$ = flowrate
of entering
feed stream

$C_f(t)$ = conc. of i
in the feed
stream

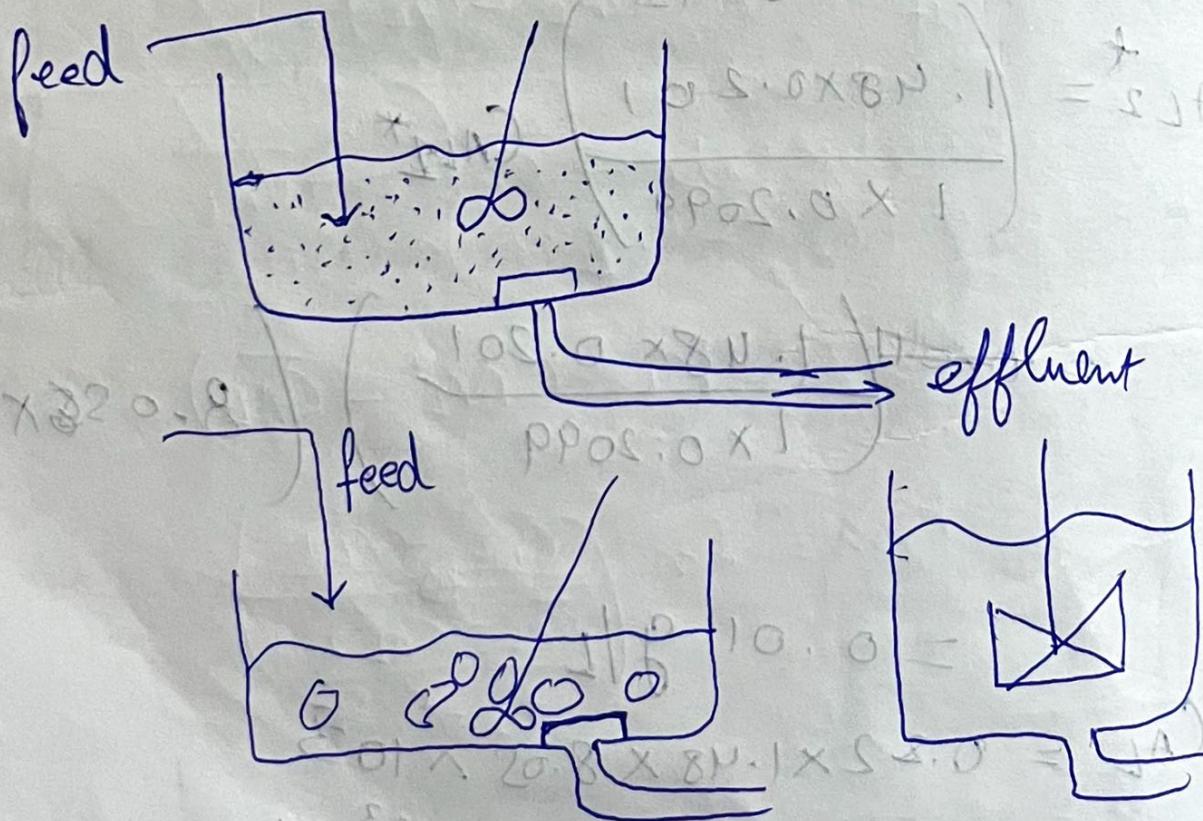
$$\frac{d}{dt} (V_R, C_i) = V_R \cdot r_{fi} + f(t) C_{if} \quad | \quad f = \text{const.}$$

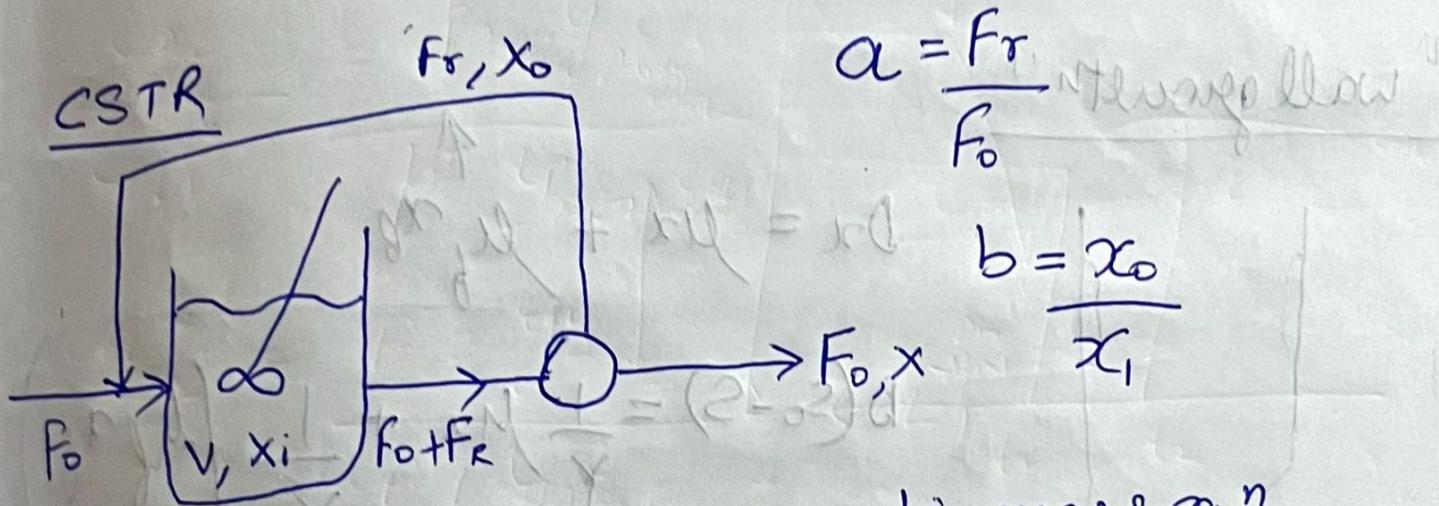
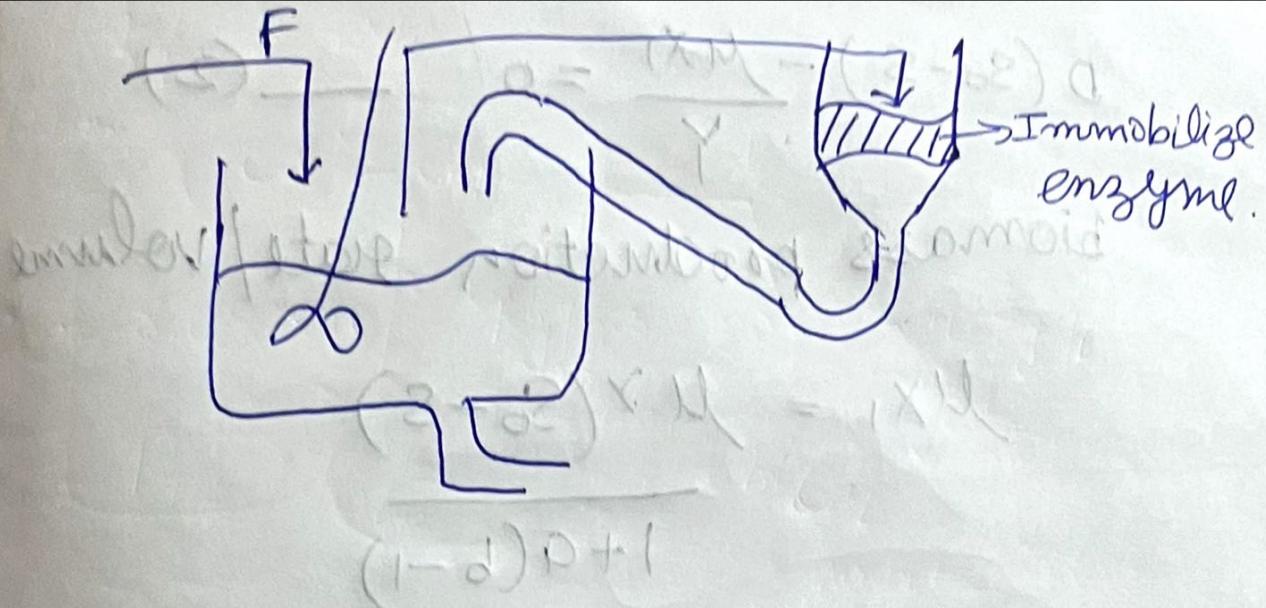
$$\frac{dC_i}{dt} = \frac{f(t)}{V_R} [C_{if} - C_i]$$

Mass balance:

$$\frac{d}{dt} [f V_R] = f F(t)$$

$$\Rightarrow \frac{dV_R}{dt} = F(t)$$





$$a = \frac{Fr}{F_0}$$

"flowing flow"

$$b = \frac{x_0}{x_i}$$

Steady state: bio mass eq^n

$$Fr, x_0 + \mu x_i, V_R - (F_0 + F_r)x_i = 0$$

$$\Rightarrow (F_0 + F_r)x_i - Frx_0 = \mu x_i V_R$$

$$\Rightarrow (1+a) - ab = \frac{\mu V_R}{F_0} = \frac{\mu}{D}$$

$$D = \frac{\mu}{1 - a(b-1)}$$

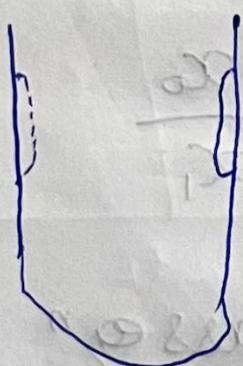
①

$$D(S_0 - S) - \frac{\mu X_1}{Y} = 0 \quad (2)$$

biomass production rate / volume

$$\mu X_1 = \frac{\mu Y(S_0 - S)}{1 + a(b - 1)}$$

"wall growth"



$$Dx = \mu x + \mu_f x_f$$

$$D(S_0 - S) = \frac{1}{Y} D_x + \frac{1}{Y_f} (\mu_f x_f)$$

Beall

$$2XN = \rho S_d - \rho (S_d + d)$$

$$\frac{d}{d} = \frac{2XN}{\rho} = d \Rightarrow (D + 1)^{-1}$$

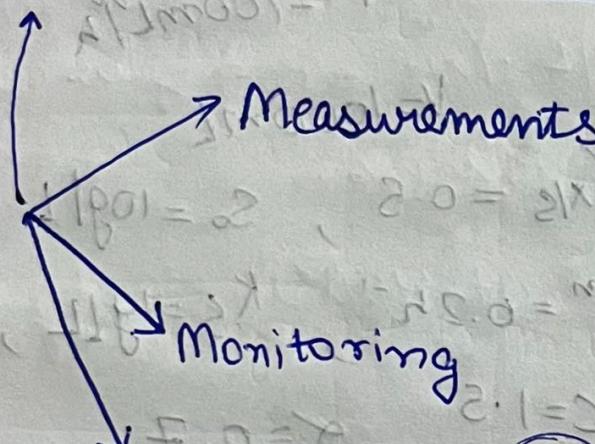
①

$$\frac{D}{(1-d)D - 1} = 1$$

$$X_1 = \frac{D(S_0 - S)}{\mu} \gamma_{x13} = \frac{(0.1)(10 - 0.48)0.5}{0.065}$$

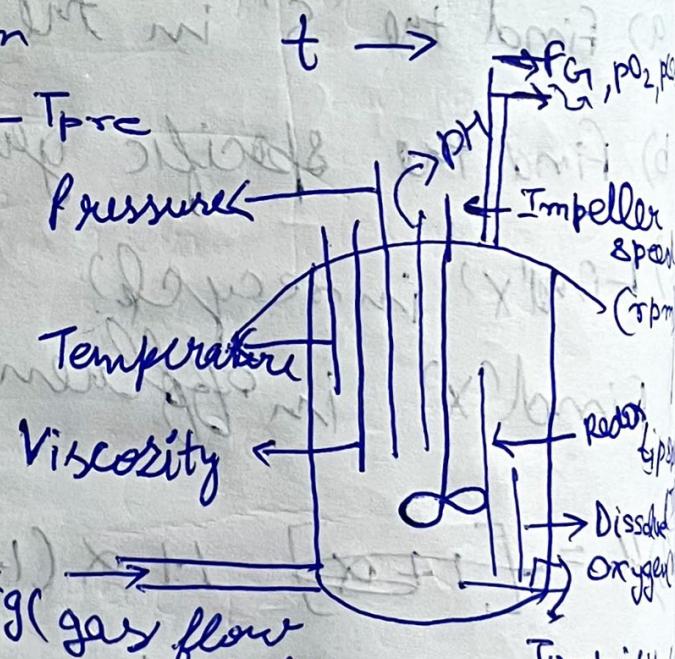
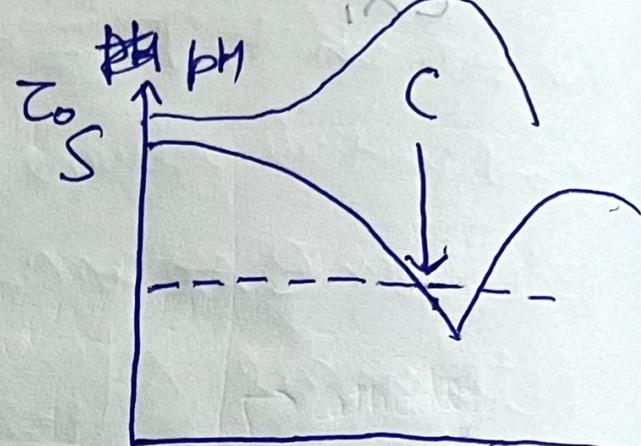
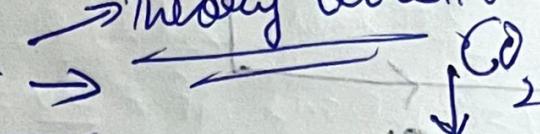
$$\Rightarrow 7.3 \text{ g/L}$$

Instrumentations and Control



Control $\Rightarrow \Delta E_{\min} = T_{set} - T_{prec}$

Theory Questions



Theory

"Glucose"
Ethanol +
 NH_4^+ , Mg^{2+} , K^+ , Na^+ , Ca^{2+} , PO_4^{3-}
DNA | RNA | NADPH

Temperature Sensor

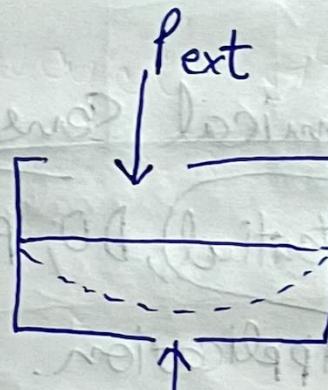
i) Thermistors → Semiconductors
 $(25-45^{\circ}\text{C})$

\downarrow
 Persistence $\propto T$

- ii) Pt Platinum resistance sensors
- iii) Thermometer Bulb
- iv) Thermocouples

'P' Sensors:

Diaphragm gauge

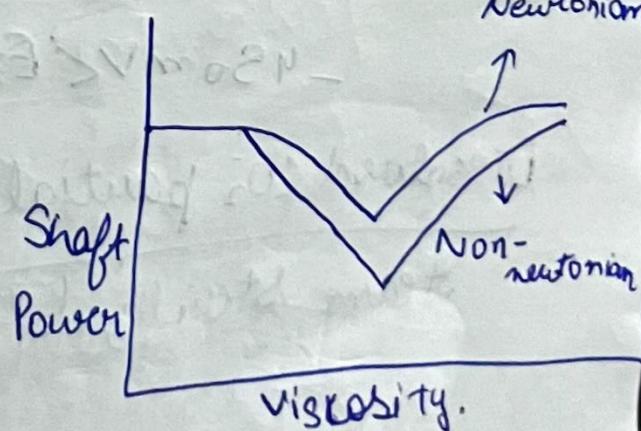


$$\Delta P = P_{ext} - P_{ref}$$

Shaft Power input

Torsion dynamometer

↓
 measure the torque or the force with which something rotates.



Dynamic method

Temperature sensors

Flow rate of gases/Liq

Rotameter

Thermal mass flow meter

ΔT in front of mass flow rate

* Medium Chemical Sensors

pH, redox potential, DO, PCO_2

↓ Application.

Monitoring low content of 'DO'

(< 1 ppm) \Rightarrow anaerobic process

$$-450mV < E_n < -150mV$$

Dissolved CO_2 partial pressure

Steam sterilizable electrochemical probe \rightarrow pH

separated from process fluid

pH change
of standard bica

Biosensors

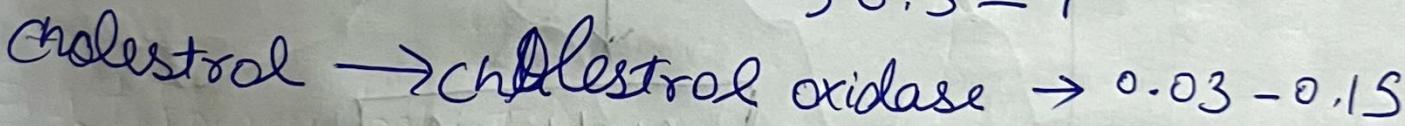
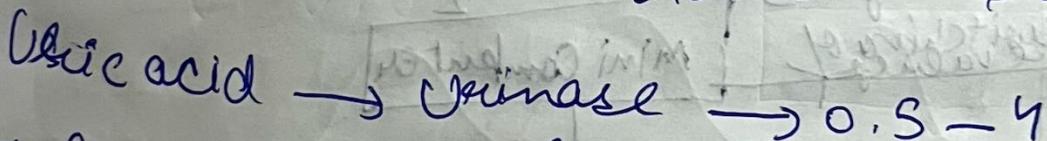
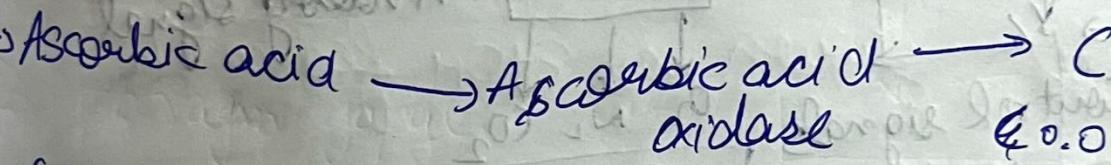
↓ based on

Action of immobilized enzyme
coupled with an analytic device

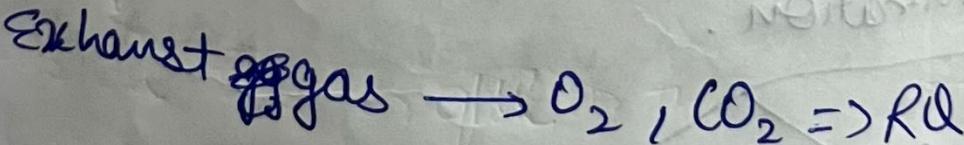
Enzyme thermistors

↓ based on

measures of
heat released



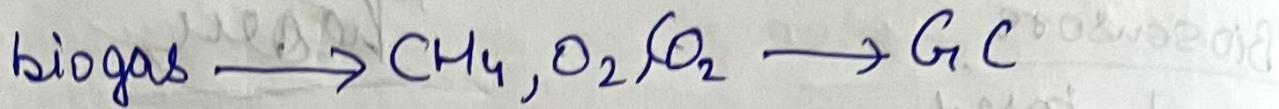
Gas analysis



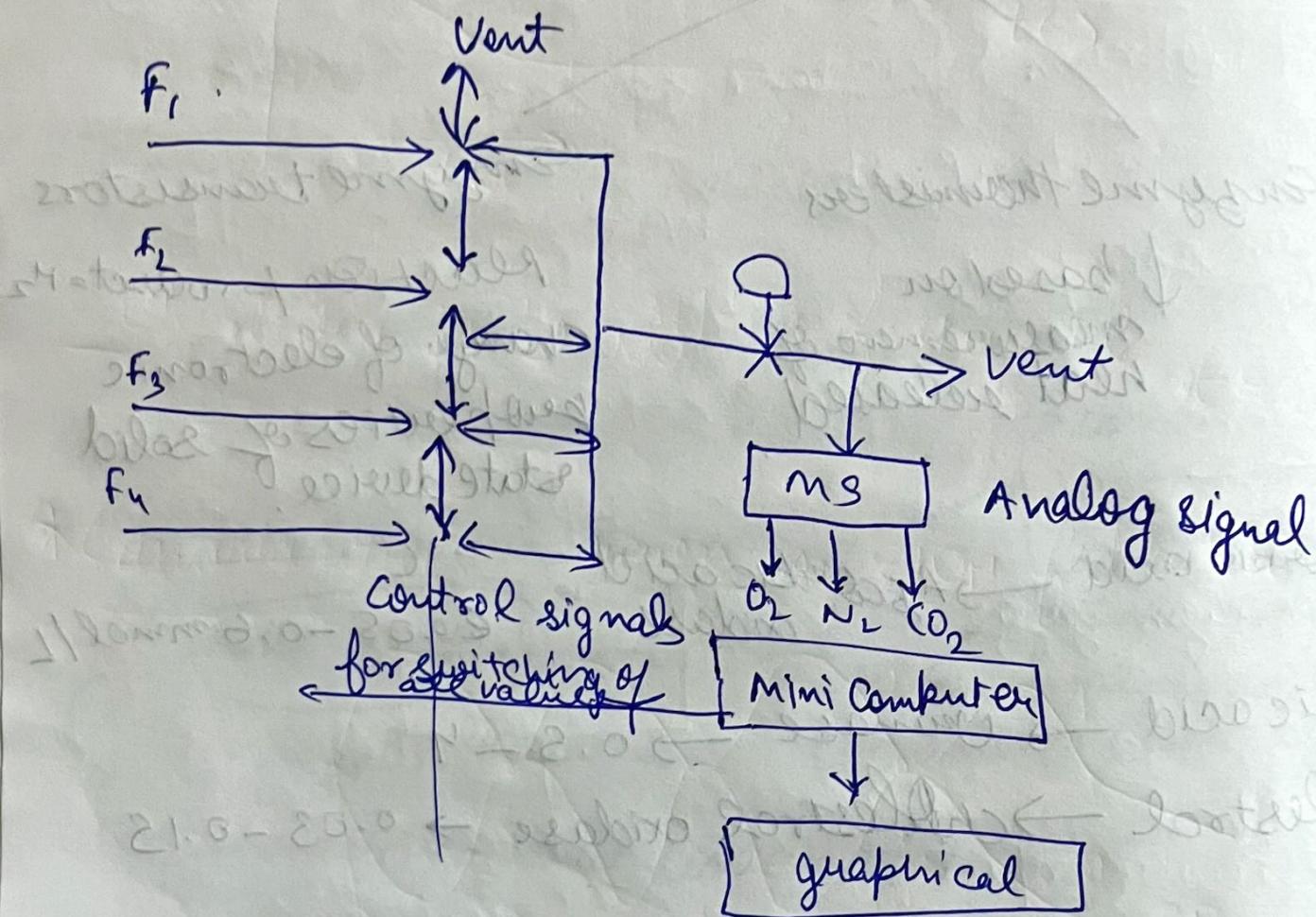
O₂ → Infrared spectrophotometer
GC

O₂ → MS → rapid response time (<1min)
high sensitivity ($\sim 10^{-5}$ M)

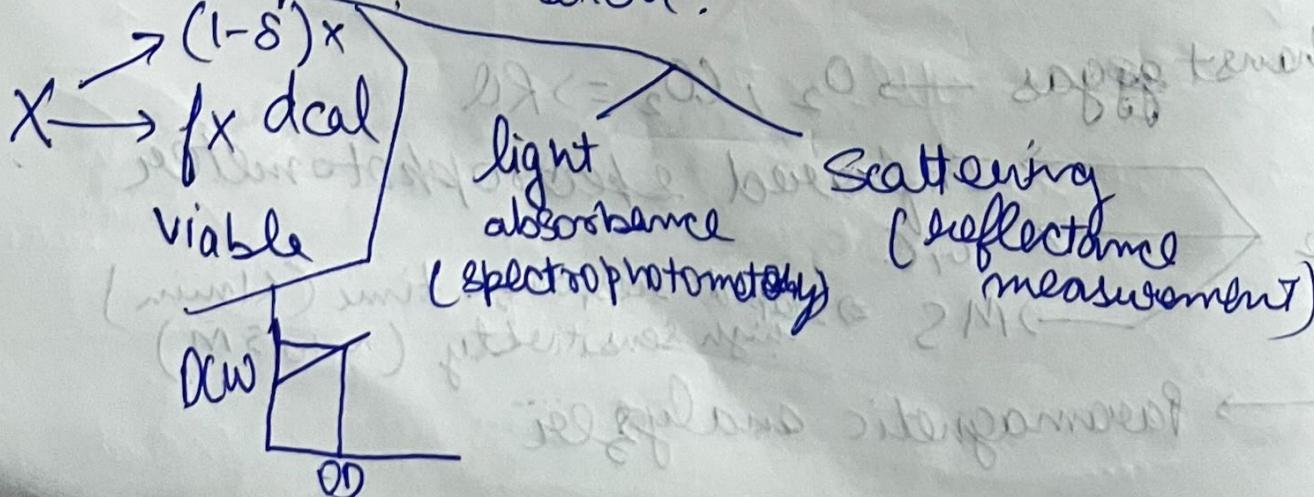
O₂ → Paramagnetic analyzer



gas phase partial pressure of volatile components
e.g. ethanol, acetaldehyde

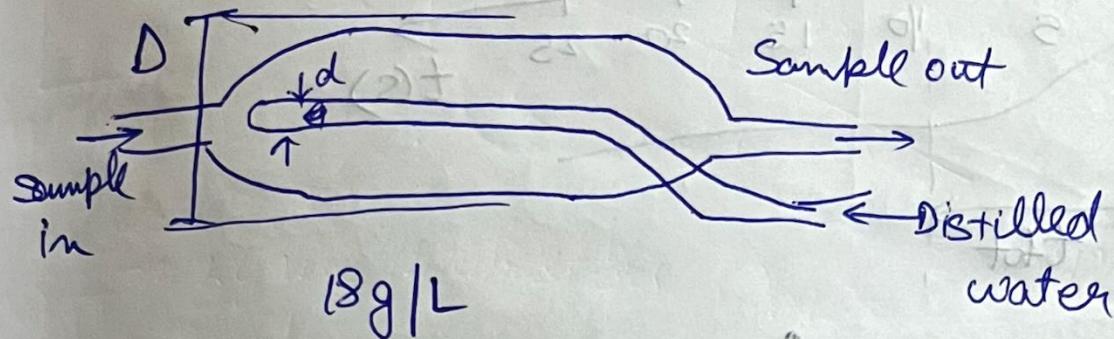


Online sensors for cell properties Total biomass content / concentration.



Solution

Sample stream dilution
flows through cuvette



Online monitoring of biochemical or metabolic state of the cell population

I⁻ IN SITU FLUOROMETRY:

X: UV light @ 366 nm is directed into the culture

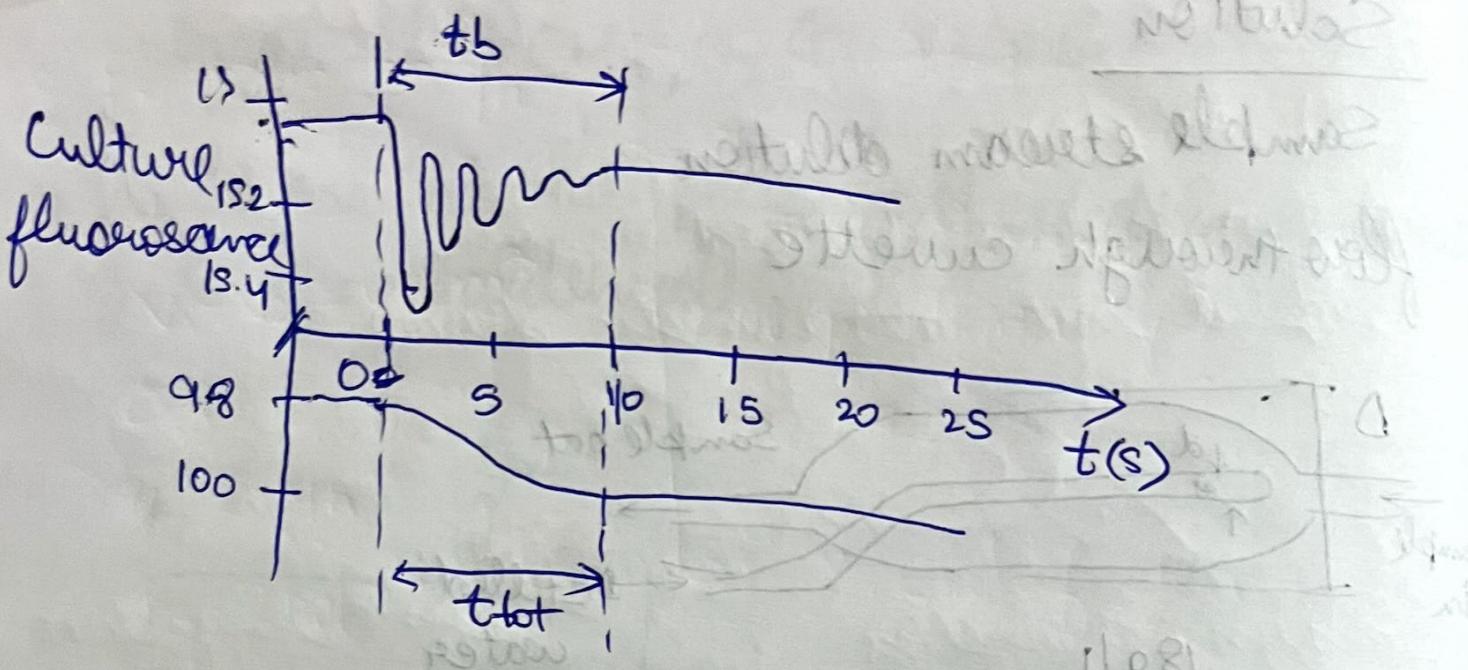
fluorescence is measured
photodiode
photomultipliers.

NADH / NADPH excited

NADH / NADPH fluoresce with max intensity @ 400 nm

= f (cell density avg cell metabolic state,
light absorption in medium)

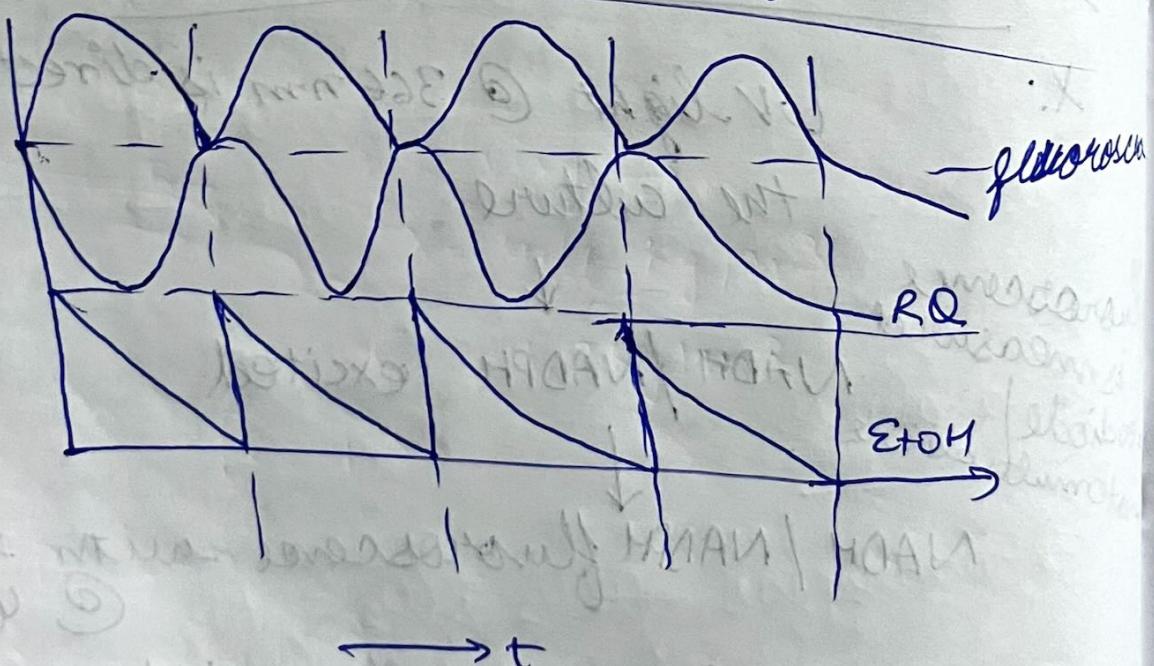
biomass X, $\frac{1}{2}$ O₂ + transfer
mixing time Substrate exhaustion.



a) after a pulse addition of quinide

state of addition to the membrane of gain in to $0.5 \text{ M H}_2\text{S}$

**Candida utilis* grown on EtOH fed batch



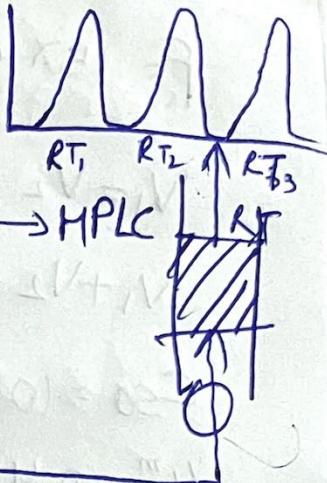
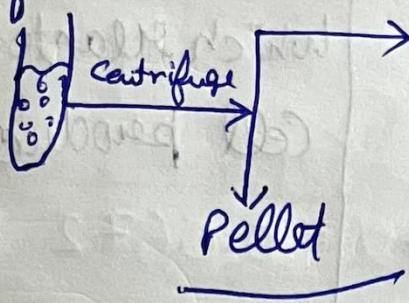
Offline analytic method

Measurement of medium properties

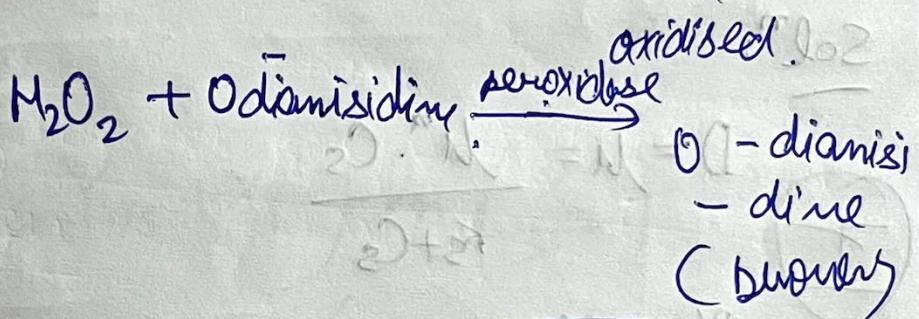
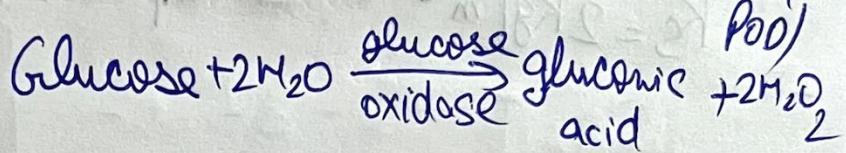
Absorption

refraction

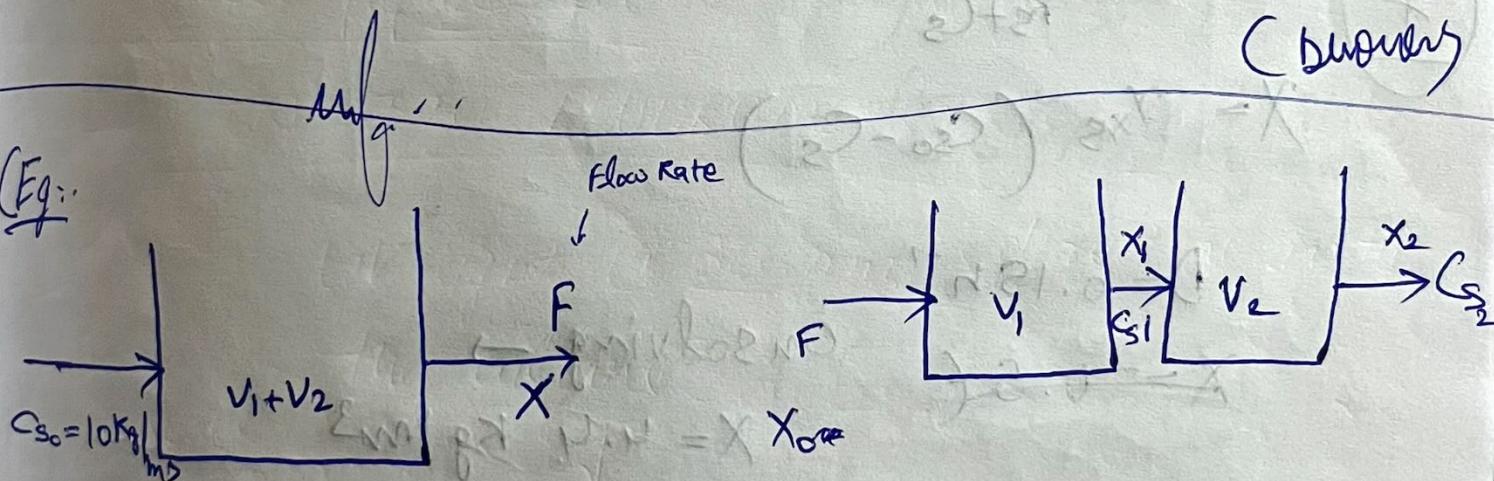
fluorescence



Chemical analysis (GOD/POD)

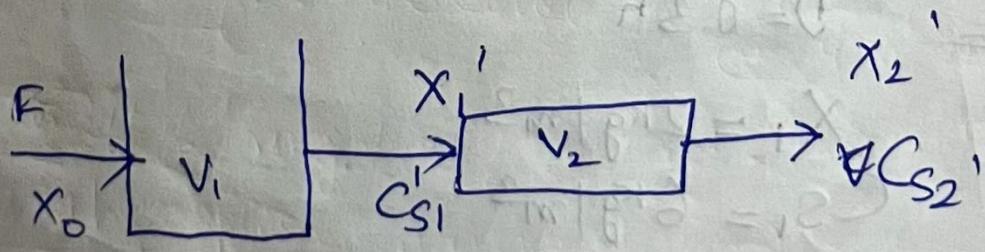


(Eq.:



$X_0 = 0$ Config-I

C_{S0} Config-II



Config III