Yield Coefficient

$$Y_{X/S} = \frac{\Delta X}{\Delta S} = -\frac{dX}{dS}$$

$$\Delta S = \Delta S_{\text{assimilation into biomass}} + \Delta S_{\text{assimilation into an extracellular product}} + \Delta S_{\text{growth energy}} + \Delta S_{\text{maintenance energy}}$$

$$Y_{X/O2} = \frac{\Delta X}{\Delta O_2} \qquad Y_{P/S} = \frac{\Delta P}{\Delta S}$$

Growth Yield

- For organisms growing aerobically on glucose
  - $Y_{X/S} = 0.4 – 0.6$ g/g
  - $Y_{X/O2} = 0.9 – 1.4$ g/g

- In most cases the yield of biomass on a carbon-energy source is 1.0 ± 0.4 g biomass/g of carbon consumed.

Maintenance Coefficient

$$m \equiv \frac{[dS/dt]_m}{X}$$

- Maintenance
  - To repair damaged cellular components
  - To transfer some nutrients and products
  - For motility
  - To adjust the osmolarity

Product Formation

- Growth-associated product formation
  - Specific rate of product formation

$$q_p = \frac{1}{X}\frac{dP}{dt} = Y_{p/x}\,\mu$$

$$\frac{dP}{dt} = Y_{p/x}\frac{dX}{dt}$$

- Nongrowth-associated product formation

$$q_p = \beta = \text{constant}$$

  - Ex) many secondary metabolites such as antibiotics

Product Formation

- Mixed-growth-associated product formation
  - Specific rate of product formation

$$q_p = \alpha \mu + \beta$$

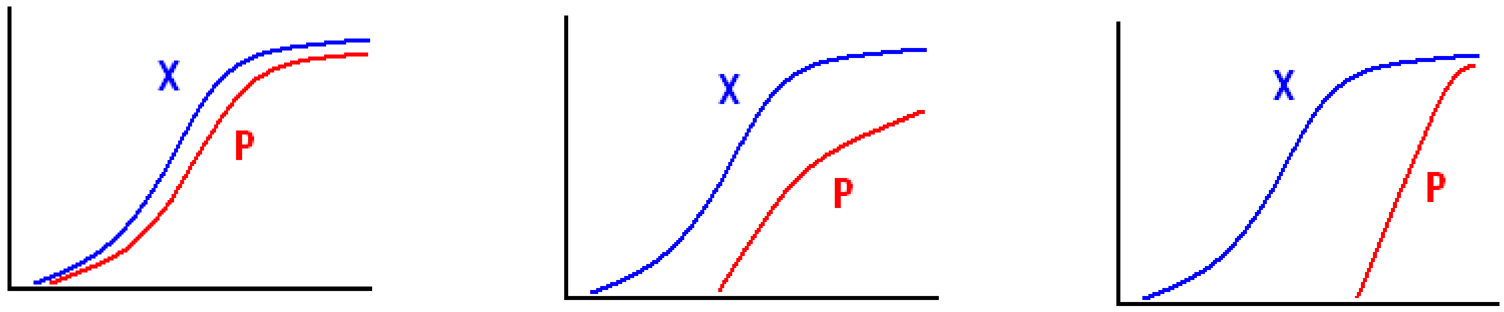
$$\frac{dP}{dt} = \alpha \frac{dX}{dt} + \beta X$$

(Luedeking-Piret Equation)

- Ex) lactic acid, xanthan gum, some secondary metabolites

Kinetic Pattern of Product Formation

- Fig. 6.6



(a) growth-associated

(b) mixed-growth-associated

(c) nongrowth-associated

6.2.3. How Environmental Conditions Affect Growth Kinetics

- Effect of Temperature
  - Eqs. (6.19) and (6.20)
    - E_a: activation energy for growth (10-20 kcal/mol)
    - E_d: activation energy for thermal death (60-80 kcal/mol)
  - Thermal death is more sensitive to temperature changes than microbial growth.

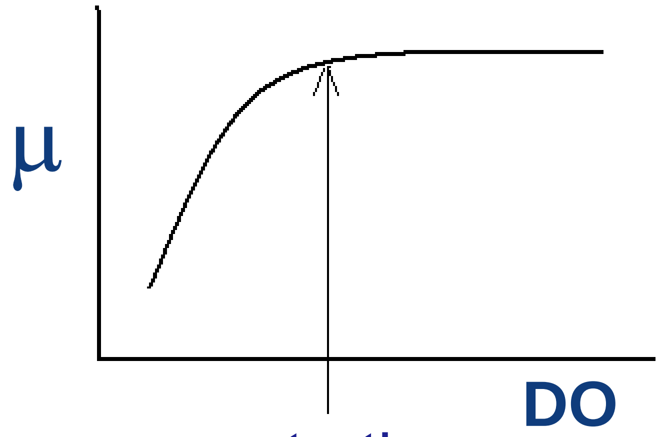
- Fig. 6.7

Effect of pH

- pH optimum
  - Bacteria: 3~8
  - Yeast: 3~6
  - Mold: 3~7
  - Plant cell: 5~6
  - Animal cell: 6.5~7.5
- Fig. 6.8
- pH controller

Effect of DO (dissolved oxygen)

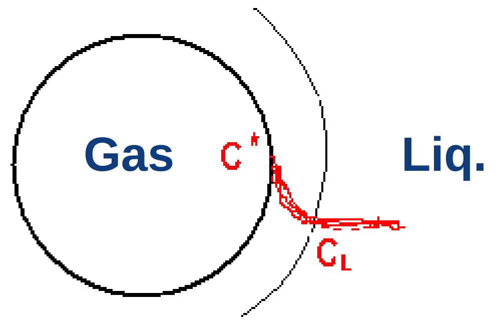
- Fig. 6.9



- Critical oxygen concentration
  - The growth rate is independent of DO above a critical oxygen concentration.
    - Bacteria and yeasts: 5%~10% of the saturated DO
    - Molds: 10~50% of the saturated DO
      (depending on the pellet size of molds)
  - Saturated DO in H_2O at 25^{o}C and 1 atm ≈ 7ppm
    - Salts and organic material alter the saturation value.

Oxygen Transfer Rate (OTR)

- OTR from gas to liquid



$$OTR = N_{O2} = k_L\ a\ (C^* - C_L)$$

- N_{O2} : OTR (mg O_2 / L / h)
- k_L : oxygen transfer coefficient (cm/h)
- a : gas-liquid interfacial area (cm^2/cm^3)
- k_L a : volumetric oxygen transfer coefficient (1/h)
- C* : saturated DO concentration (mg/L)
- C_L : DO concentration in the broth (mg/L)

Oxygen Uptake Rate (OUR)

- OUR from liquid to cell

  $$OUR = q_{O_2} X = (\mu X) / Y_{X/O_2}$$

  - q_{O_2} : specific rate of oxygen consumption (mg O_2/g cell/h)
  - Y_{X/O_2} : oxygen yield coefficient (g cell/g O_2)

- When oxygen transfer is the rate-limiting step,

$$OTR (\rightarrow) = OUR (\rightarrow)$$

$$(\mu X) / Y_{X/O_2} = k_L a (C^* - C_L)$$

$$d X / dt = Y_{X/O_2} k_L a (C^* - C_L)$$