Chap 3. Water purification process in natural systems

ⅰ) physical process … dilution, sedimentation, filtration, gas-transfer, heat-transfer

ⅱ) chemical process … 산화-환원, dissolution-preapitation

ⅲ) Biochemical process … biological metabolism

3.4 Gas transfer

ⅰ) pure water와 gas의 closed system

ⅱ) gas → liquid (absorption)

ⅲ) 일부 desorption

ⅳ) 궁극적으로 saturated

↓

'solubility를 구한다'

by Henry's law $\chi = \frac{P}{H}$

χ : 평형상태에서 dissolved gas의 molar fraction\

$$= \frac{gas \quad moles(n_g)}{gas \quad moles(n_g) + liquid \quad moles(n_l)}$$

H : Henry's coefficient [atm/mol fraction]

P : gas pressure

by Dalton's law $P=\Sigma P_i$

$$\chi_i = \frac{P_i}{H_i} \begin{matrix} (i \text{ 성분의 } Partial \ pressure) \\ (i \text{ 성분의 } henry \text{ 상수}) \end{matrix}$$

* gas transfer rate

ⅰ) liquid phase 에서의 gas 농도 변화율

$$\frac{dC}{dt} = K_L \frac{A}{V}(C_s - C)$$

K_L : 물질 이동 계수 [$L\Theta^{-1}$]　　C_s : saturated 농도

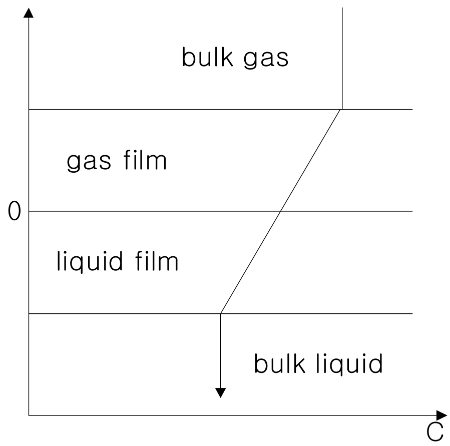
A : 표면적 [L^2]　　C : actual 농동

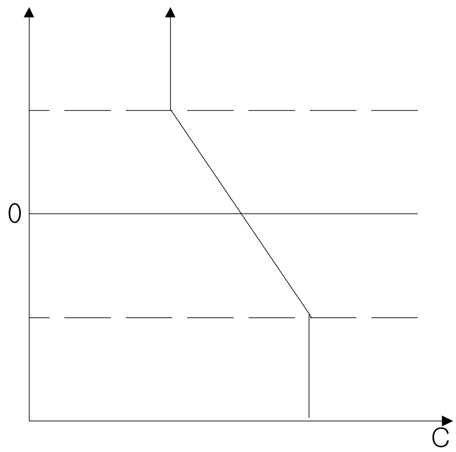
V : volume [L^3]

$$\frac{dC1}{dt} = (C_s - C)k_a \quad ; \quad k_a = f(T)$$

ⅱ) two film theory

㉠ $C_s > C$ … absorption　　㉡ $C_s < C$ … desorption





ⅲ) stagnant situation ~ mass transfer는 only dependant in diffusion

ⅳ) bulk phase에 internal movement가 있는 경우

→ turbulent & eddy diffusion

→ gas transfer rate는 film에 의해 지배

ⅴ) gas film controlled ~ gas film의 상대적 저항이 크며, 용해도 大

liquid film controlled ~ liquid film의 상대적 저항이 크며, 용해도 小

mixed film controlled ~ 각 film resistance가 같다. 용해도 中

* Fick's 1st law of diffusion

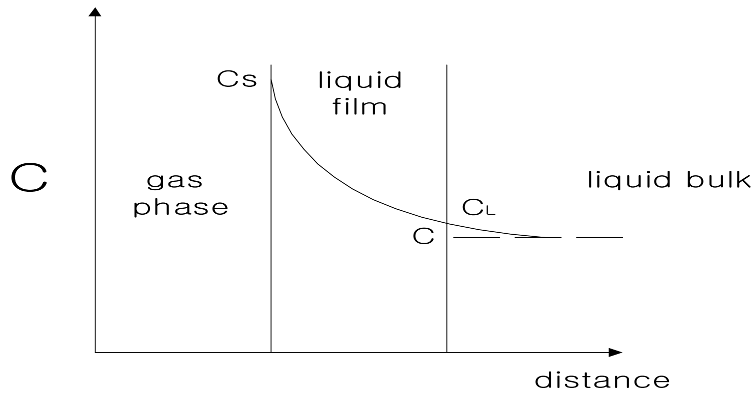
i) $J_A = -D_{AB}\frac{\partial c}{\partial x}$ ------ ①

JA : mass flux $[\frac{mass}{area \cdot time}]$

DAB : diffusivity [㎡/s]

$\frac{\partial c}{\partial x}$: *concentration graidient*

ii) Stationary liquid film theory



<gas transfer through stationary liquid film>

C_S : saturation concentration of the gas in the liquid

C : gas 농도 in the liquid bulk

C_L : gas 농도 at the film / bulk boundary

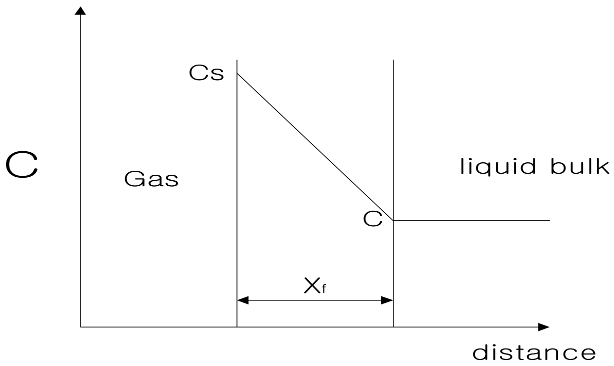
x_f : liquid film thickness

$\frac{\partial M}{\partial t} = -D_{AB} \cdot A\frac{\partial C}{\partial x_f}$ ------ ②

↑ mass transfer rate

iii) the liquid film thickness (x_f) is small (only a few molecular thick)

assumption $\frac{\partial C}{\partial x_f} \fallingdotseq \frac{C_S - C}{x_f}$ ------ ③



<Linear approximation of gas transfer through stationary liquid film>

from ②③ $\frac{\partial M}{\partial t} = -D_{AB} \cdot A \frac{C_s - C}{X_f}$ ------ ④

$$\frac{\partial C}{\partial t} = -D_{AB} \cdot \frac{A}{V} \frac{C_s - C}{X_f} \text{ ------ ④}'$$

ⅳ) $K_L = \frac{D_{AB}}{X_f}$ ------ ⑤

↑ gas transfer coefficient [length/time]

from ④′⑤

$$\frac{\partial C}{\partial t} = -K_L \frac{A}{V}(C_s - C)$$

↓

high 농도 region → low 농도

→ when the gas concentration increase with time the asration operation

$\frac{\partial C}{\partial t} = K_L \frac{A}{V}(C_s - C)$ ------ ⑥′

ⅴ) A is difficult to determine

$K_{La} = K_L \frac{A}{V}$ ------ ⑦

K_{La} : overall gas transfer coefficient $[\Theta^{-1}]$

from ⑥′⑦

$$\frac{\partial C}{\partial t} = K_{La}(C_s - C)$$

ex) Gas concentration change in a liquid as a function of time

$$\frac{dc}{dt} = K_L \frac{A}{V}(C^* - C)$$

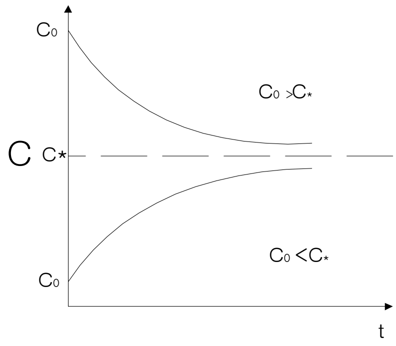
┌ t = 0　　C = C_0 ┐
└ t = t　　C = C_t ┘

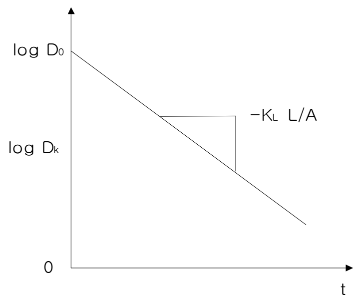
$$\int_{C_0}^{C_t} \frac{dc}{C^* - C} = K_L \frac{A}{V} \int_0^t dt$$

$$\ln \frac{C^* - C_t}{C^* - C_0} = \ln \frac{D_t}{D_0} = -K_L \frac{A}{V} t$$

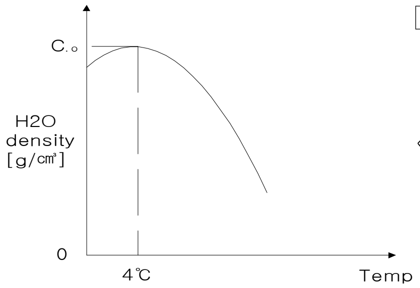
$$D_t = D_0 \quad \exp\left\{ \quad (-K_L \frac{A}{V}) t \quad \right\}$$

D_0, D_t = saturation deficit at t=0, t=t





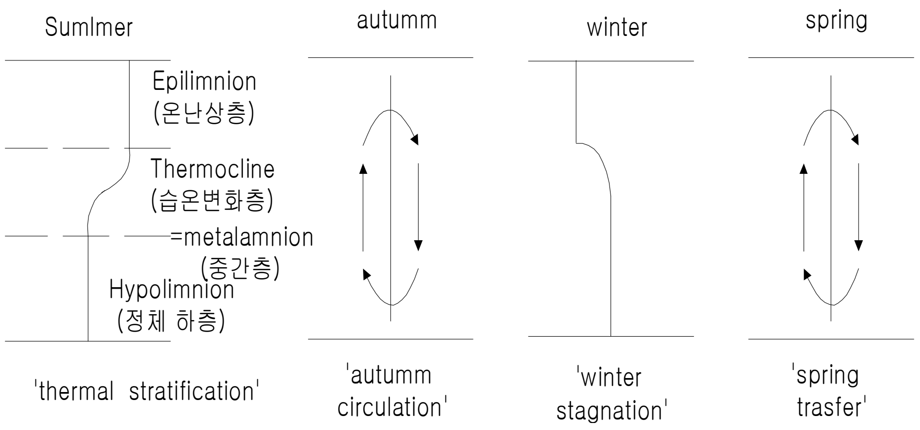
heat transfer



4 thermal regimes

- homogeneous regime
  - ~ no vertical temperature gradient
- heterogeneous regime

* 깊이에 따른 temperature profile (heterogeneous regime)



③ Biochemical process ~ self purification process에서 chemical process는 대부분 biological에 의한다.

3-7 metabolic process

(가) metabolism (대사)

ⅰ) catabolism (이화작용) ~ new cell 합성 또는 cell 유지에 필요한 energy를 공급

ⅱ) anabolism (동화작용) ~ new cell을 만든다

ⅲ) Endogenous catabolism (내생 이화 작용)

~먹이가 없을 때 자기 자신을 이용하여 energy 생산

(나) enzyme

$$E + S \underset{k_a'}{\overset{k_a}{\rightleftharpoons}} ES \xrightarrow{k_b} E + P$$

E : enzyme

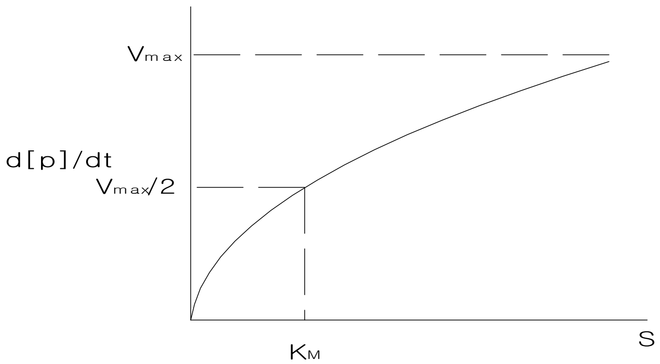
S : substrate

P : product

$$\frac{d[p]}{dt} = \frac{V_{max}[S]}{K_M + [S]}$$ 'Michaelis Mentan eq'

$$K_M = \frac{k_a' + k_a}{k_a}$$

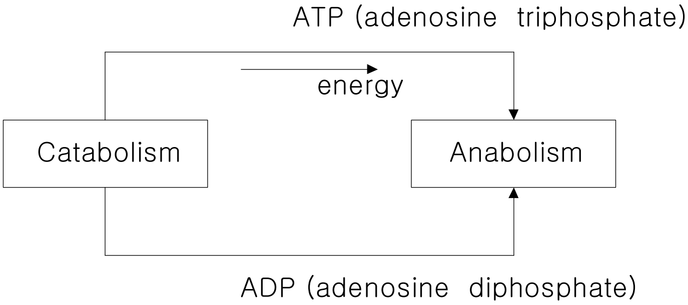
V_{max} = maximum 생성속도



ⅰ) constitutive ~ enzyme이 cell의 일부

ⅱ) adaptive enzyme ~ 미생물이 특별한 환경에 접했을 때 적응할 수 있는 효소를 만든다

(다) metabolism에서의 energy transfer



ATP → ADP + P (anabolism에서 energy 소비)
ADP + P → ATP (catabolism에서 energy 생산)

(라) metabolic process
ⅰ) aerobic ~ end product는 low energy, stable
C component → CO_2
N component → NH_3 → NO_2^- → NO_3^-
nitrite nitrate
S component → H_2S → S → SO_4^{2-}
sulfide sulfur sulfate
ⅱ) anaerobic ~ end product는 high energy, unstable
C → organic acid → CH_4 + CO_2
N → NH_3
S → H_2S

Microorganism

(가) bacteria

ⅰ) autotroph (독립영양생물) … inorganic source로 energy를 얻음

ex) 폐타이어 분해 미생물 (S 성분)

ex) S성분의 脫黃

'4대 냄새 S성분' · H_2S

· methyl sulfide (MS) : $(CH_3)_2S$

· dimethyl disulfide (DMDS)

· methyl merchaptan : CH_3SH

ⅱ) hetrotroph (종속영양생물) … organic 분해

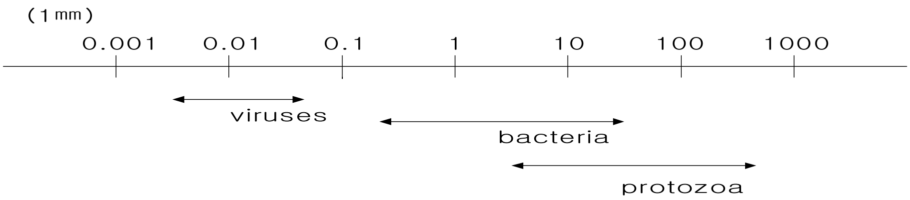
ⅲ) phototroph (광 영양생물) … sunlight로부터 energy 공급

* 유기물 분해 bacteriadp 있어서 O_2 有無에 따라

ⅰ) aerobic hetrotroph

ⅱ) anaerobic hetrotroph

ⅲ) facultative hetrotroph



(나) Protozoa

ⅰ) 절대 호기성

ⅱ) hetrotroph bacteria처럼 organic 분해로 energy 化

(다) Algae

ⅰ) autotrophic & photosynthetic organism

ⅱ) hetrotroph bacteria의 waste product (CO_2, NO_3^-, PO_4^{-7})을 利化