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REVIEW QUESTIONS ON MASS TRANSFER

1. There are several analogies between mass, heat, and momentum transfer. How do they arise? Why are those between mass and heat transfer easier to use than mass and momentum?

2. What is the difference between diffusivity and mass transfer coefficient?

3. Give 3 important dimensionless groups for mass transfer and their significance.

4. Is mass flux from a liquid into a gas higher or lower if the gas is soluble in the liquid? (as compared to an insoluble gas).

5. Derive the mass transfer boundary layer equation.

6. Estimate the rate of evaporation of an organic liquid puddle.

ANSWERS

① General equations of transport

mass $N = -\mathcal{D}\frac{dc}{dy}$ (Fick's Law)

heat $q = -k\frac{dT}{dy}$ (Fourier's Law)

momentum $\tau = -\mu\frac{dv}{dy}$ (Newton's Law)

From here you can see that ~~[illegible]~~ mass, temperature, and velocity profiles will have similar forms. Also, problems in each transport area will be approached the same way (shell balances or by using equations of motion & energy, etc.)

Mass and momentum transfer analogies are more difficult to follow because momentum is a vector quantity while mass and temperature are scalar. Also, mass and heat transfer ~~are~~ follow more analogous driving force laws

② Diffusivity is a molecular property and describes flux in terms of local (differential) concentration gradients. It is a function of T, P, and the components only.

Mass transfer coefficients deal with measureable concentration differences. It is a function of the system's geometry and flow conditions. Usually it concerns flux at a boundary

(3) Very important ones

Peclet (for mass) $= vL/\mathcal{D} =$ m.t. by flow / m.t. by diffusion

Sherwood $= k_m L/\mathcal{D} =$ concentration gradient at boundary / gradient from bulk to boundary

Schmidt $= \mu/\rho\mathcal{D} =$ molecular diffusivity of momentum / mass

Others (less important)

Psychrometric Ratio = heat transfer by convection / ht. by m.t.

Damkohler Number = max rxn rate / max m.t. rate

Thiele parameter = rxn rate / diffusion rate.

(4). The flux is higher for insoluble gases.

The two extremes are diffusion through a stagnant medium →

$$N_A = -\mathcal{D}_{AB}\frac{dC_A}{dx} + x_A N_A$$

$$N_A = -\frac{1}{x_B}\mathcal{D}\frac{dC_A}{dx}$$

and equimolar counterdiffusion →

$$N_A = -N_B$$

$$N_A = -\mathcal{D}\frac{dC_a}{dx}$$

$\frac{1}{x_B} > 1$, so stagnant film diffusion is faster. This is the case if the gas is insoluble and just sits there. Soluble gas would have diffusion to the liquid, which decreases N_A.

(5). See B.S. & L. page 605.

(6). - Assume puddle rapidly reaches equilibrium with ambient temp.
- Assume gas adjacent to surface in equilibrium with liquid and has a liquid concentration C_0. (For a breezy day $C_0 = 0$)

Flux $N_A = k_g (c - C_0)$ $\quad$ k_g = mass transfer coeff in gas

$Q = k_g A (C - C_0)$ $\quad$ A = puddle area.

- For a day without a breeze use diffusion through stagnant medium

$$\frac{\partial c}{\partial t} = -\frac{\partial N_A}{\partial x} = \mathcal{D} \frac{\partial^2 c}{\partial x^2}$$

$C = C_0$ at $x = 0$

$C = 0$ at $x \to \infty$

Find an expression for $C(x,t)$

Evaporation rate $= N_A = -\mathcal{D} \left.\frac{\partial c}{\partial x}\right|_{x=0}$