POD 21

How to get K_L^o

$$K_L^o a = \frac{1}{\frac{1}{K_L a} + \frac{1}{H K_g a}}$$

So we need H, K_L, K_g & a

a should be a_w – wetted area/vol

vs. a_t = total area/vol

Onda correlation:

$$\frac{a_w}{a_t} = 1 - \exp\left[-1.45\left(\frac{\sigma_c}{\sigma_L}\right)^{0.75} \times (Re_L)^{0.1}(Fr)^{-0.05}(We_L)^{0.2}\right]$$

σ_c : critical packing tension

σ_L : liquid surface tension

$$Re_L = \left(\frac{\rho_L L}{a_t \mu_L}\right)$$

L = liquid superficial velocity $\left(\frac{\text{length}}{\text{time}}\right)$

$= \dfrac{Q}{A}$ ← vol flow rate (Q); ← column area (A)

ρ_L = density of liquid

a_t = total packing area/vol

μ_L = liquid viscosity

$$Fr = \frac{L^2 a_t}{g} \quad \text{(Froude \#)}$$

g = gravity

$$We = \text{Weber \#} = \left(\frac{L^2 \rho_L}{\sigma_L a_t}\right)$$

Now for k_L:

$$k_L = 0.0051 \left(\frac{\mu_L g}{\rho_L}\right)^{1/3} Re^{2/3} Sc^{-1/2} (a_t d_p)^{0.4}$$

$$Sc = \text{Schmidt \#} = \frac{\nu_L}{D_L}$$

D_L = liquid diff, $\nu_L = \dfrac{\mu_L}{\rho_L}$

$a_t d_p$ is a packing (shape) factor:

d_p = nominal packing size

Note that $\left(\frac{\mu_L g}{\rho_L}\right)^{1/3}$ has units of velocity, as is K_L

And for the gas phase:

$$K_G = C\, a_t\, D_G \left(\frac{G \rho_G}{a_t \mu_G}\right)^{0.7} \left(\frac{\mu_G}{\rho_G D_G}\right)^{1/3} (a_t d_p)^{-2}$$

$C = 2.0$ if $d_p < 15\,mm$, 5.3 $d_p > 15\,mm$

D_G = gas phase diffusivity

G = Gas superficial velocity

ρ_G = Gas density

μ_G = Gas viscosity

So we need:

Packing prop.

- Packing type/size:
- a_t, ℓ_p, σ_c (packing tension)

liquid prop.

- Liquid surface tension σ_L
- Liquid density ρ_L
- Liquid viscosity μ_L

Gas prop.

- Gas density ρ_G
- Gas viscosity μ_G

solute prop.

- Solute Dif in Gas D_G
- Solute Dif in Liquid D_L
- Henry's law Coef (vol basis) H

operating param.

- Liquid superficial vel. L
- Gas superficial vel. G

Let's look at stripping chloroform out of water at 25°C

We propose to use 1" Pall rings (~~plastic~~ steel).

From the manufacturer,

$d_p = 25\,mm = 2.5\,cm$

$a_t = 209\ m^2/m^3 = 2.09\ 1/cm$

so $a_t d_p = 5.22$

For ~~plastic~~ steel $\sigma_c = 0.075\ N/m = 75\ dynes/cm$

Liquid properties: (water)

$\sigma_L = 70\ dynes/cm$ (clean water)

$\rho_L = 1\ g/cm^3$

$\mu_L = 0.01$ poise $\left(\frac{g}{cm\,s}\right)$

$\nu_L = 0.01\ cm^2/s$

Gas properties : air at 1 Atm, 25°C

$\rho_G = 1.18 \times 10^{-3}\ g/cm^3$

$\mu_G = 1.85 \times 10^{-4}$ poise

$\nu_G = 0.156\ cm^2/s$

Solute Properties (Chloroform)

$D_G = 0.090\ cm^2/s$

$D_L = 1.0 \times 10^{-5}\ cm^2/s$

$H = 10\text{^}\left[4.673 - \frac{1627}{T}\right] = 0.163$

Operating Parameters

$L = 1.53\ cm/s$ ($= 22.6\ gpm/ft^2$)

$G = 43\ cm/s$ ($= 84\ cfm/ft^2$)

$R = \frac{HG}{L} = 4.6$

So:

$$\sigma_c / \sigma_L = \frac{75}{70} = 1.07$$

$$Re_L = \frac{(1.53\ \text{cm/s})(1\ \text{g/cm}^3)}{(2.09\ \text{1/cm})(0.01\ \text{g/cm s})} = 73.2$$

$$Fr = \frac{(1.53\ \text{cm/s})^2 (2.09\ \text{1/cm})}{980\ \text{cm/s}^2} = 0.0050$$

$$We_L = \frac{(1.53\ \text{cm/s})^2 (1\ \text{g/cm}^3)}{(70\ \text{dyne/cm})(2.09\ \text{1/cm})} = 0.016$$

$$\therefore \frac{a_w}{a_t} = 1 - \exp\left[-1.45 (1.07)^{0.75} \times (73.2)^{0.1} \times (0.0050)^{-0.05} \times (0.016)^{0.2}\right]$$

$$= 0.74$$

So for these conditions we're only 3/4 wetted! Note that if σ_L is <u>lower</u> then it changes a lot.

Now for K_L:

$Re_L = 73.2$ $\qquad a_t d_p = 5.22$

$$Sc = \frac{0.01 \ cm^2/s}{1 \times 10^{-5} \ cm^2/s} = 1000$$

$$\frac{\mu_L g}{\rho_L} = \nu_L g = 0.01 \ cm^2/s \cdot 980 \ cm/s^2 = 9.8 \ cm^3/s^3$$

$$\therefore K_L = 0.0051 \times \left(9.8 \ cm^3/s^3\right)^{1/3} \times (73.2)^{2/3} \times (1000)^{-1/2} \times (5.22)^{0.4}$$

$$= 0.0117 \ cm/s$$

And for K_G

$$\frac{G \rho_g}{a_t \mu_G} = \frac{43 \ cm/s}{(2.09 \ 1/cm)(0.156 \ cm^2/s)} = 132$$

$$\frac{\mu_G}{\rho_G D_G} = \frac{0.156 \ cm^2/s}{0.090 \ cm^2/s} = 1.73$$

$C = 5.3$ $\quad (d_p = 25 mm > 15 mm)$

So:

$$K_G = (5.3)(2.09\ ^1/_{cm})(0.09\ ^{cm^2}/_s)$$

$$\times (132)^{0.7} (1.73)^{1/3} (5.22)^{-2}$$

$$= 1.34\ ^{cm}/_s$$

$$\text{so } K_L^o = \frac{1}{\frac{1}{K_L} + \frac{1}{H K_G}}$$

$$= \frac{1}{\frac{1}{0.0117} + \frac{1}{(1.34)(0.163)}} = 0.0111\ ^{cm}/_s$$

Almost same as K_L!

$$\text{and } K_L^o a_w = 0.0172\ s^{-1}$$

$$\text{w/ } H_{ox} = \frac{L}{K_L^o a_w} = \frac{1.53\ ^{cm}/_s}{0.0172\ ^1/_s} = 89\ cm$$

$$= 0.89\ m$$

This, coupled w/ Nox, would give you the height of the tower!