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CH18B020

AMT TUTORIAL - 7

① Freundlich isotherm:

$$q = K C^{1/n} \quad ; \text{parameters: } q \text{ and } n.$$

Model is fit using nlinfit function in MATLAB.

$K = \underline{5.655}$ $\quad n = \underline{2.176}$

$$\Rightarrow q = 5.655\, C^{0.4596}.$$

Mean Squared error = $\underline{30.467}$

Langmuir Isotherm:

$$q = \frac{q_m K C}{1 + KC} \quad ; \text{parameters: } q_M \text{ and } K.$$

Model is fit using nlinfit function in MATLAB.

$\underline{K = 0.0433}$, $q_M = 52.002$

$$\Rightarrow q = \frac{2.252\, C}{1 + 0.0433C}$$

Mean squared error = $\underline{0.801}$.

By comparing the mean squared errors as well as the visual examination of the ~~atta~~ adsorption isotherm plots, we find that Langmuir isotherm best fits the data.

($K = \cancel{5.655}$ 0.0433, ~~$n = 2.176)$~~ $q_M = 52.002$)

(2) a) At minimum Adsorbent condition,

$$\frac{W_{min}}{L} = \frac{Y_0 - Y_1}{X_1 - X_0}$$

$Y_0 = 3.5\ mg/L \quad Y_1 = 0.1\ mg/L$

$X_0 = 0$ and X_1 is in eqbm with Y_1

$$\Rightarrow X_1 = 50(0.1)^{0.32}$$

$$= 23.932\ mg\ compound/g\ charcoal$$

$L = 10$ Litres

$$\Rightarrow W_{min} = \frac{10 \times (3.5 - 0.1)}{23.932}$$

$$\Rightarrow \boxed{W_{min} = 1.4207\ g\ charcoal}.$$

b) $$Sh = \frac{k_L \times (\text{diameter of particle})}{D_{AB}}$$

$D_{AB} = 1.5 \times 10^{-5}\ cm^2/s = 1.5 \times 10^{-9}\ m^2/s$

$Sh = 30.$; particle diameter $= 2 \times 10^{-3}\ m.$

$$\therefore k_L = \frac{1.5 \times 10^{-9} \times 30}{2 \times 10^{-3}} = 2.25 \times 10^{-5}\ m/s.$$

$W = 2\ W_{min} = 2.841\ g$

Adsorbate Balance :

$$-\frac{\partial c}{\partial t} = k_L a (c - c^*)$$

c is the concentration of adsorbate in the solution at any time t.

a is the surface area of charcoal per unit volume of solution.

$$\Rightarrow a = 5\, m^2/\text{kg charcoal} \times \frac{(2.841\times10^{-3}\ \text{kg charcoal})}{10\times10^{-3}\ m^3\ \text{solution}}$$

$$= 1.421\ m^2/m^3\ \text{solution}.$$

c^* is the eqbm concentration of adsorbate in solution

$$\Rightarrow c^* = \left(\frac{(c_i - c)L}{wK}\right)^n \quad mg/L$$

From the given isotherm,

$$n = \frac{1}{0.32} = 3.125, \quad K = 50$$

Substituting all the values in the eqn,

$$-\frac{\partial c}{\partial t} = k_L a\left(c - \left(\frac{(c_i - c)L}{wK}\right)^n\right)$$

$$\Rightarrow \int_0^t dt = \int_{3.5}^{0.1} \frac{-dc}{\left(k_L a\left(c - \left(\frac{(c_i-c)L}{wK}\right)^n\right)\right)}$$

$$= \int_{0.1}^{3.5} \frac{dc}{k_L a\left(c - \left(\frac{(c_i-c)L}{wK}\right)^n\right)}$$

Integrating this expression numerically in MATLAB,

$$t = 1.1428\times10^5\ s$$

$$= \boxed{31.743\ \text{hours}}$$

(3) a) $L_{expt} = 0.2\ m.$

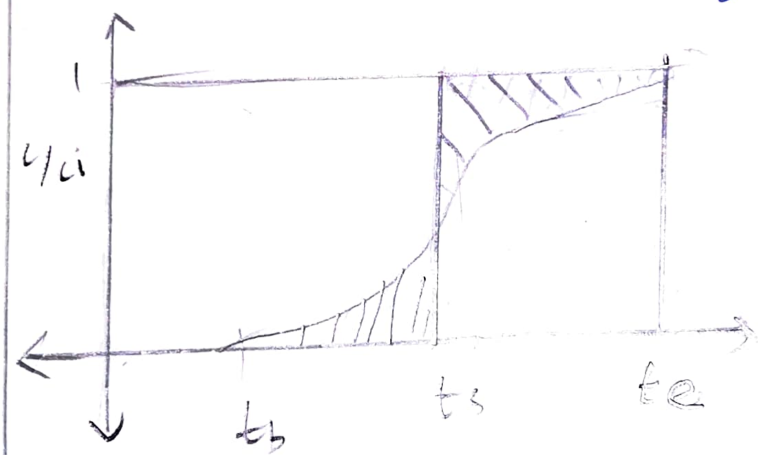
$u_{superficial} = 0.29\ m/s$

$c_i = 0.11\ gmol/m^3.$

Breakthrough time : time at which $\frac{c}{c_i} = 0.03.$

$\Rightarrow \boxed{t_b = 20.626 \text{ minutes}}$

(Obtained using Spline interpolation in MATLAB)



At stoichiometric time Area above curve = Area below the curve

$$\Rightarrow \int_{t_b}^{t_s} \frac{c}{c_i}\,dt = 1 \times (t_e - t_s) - \int_{t_s}^{t_e} \frac{c}{c_i}\,dt$$

$$\Rightarrow \int_{t_b}^{t_s} \frac{c}{c_i}\,dt + \int_{t_s}^{t_e} \frac{c}{c_i}\,dt = (t_e - t_s)$$

$$\Rightarrow (t_e - t_s) - \int_{t_b}^{t_e} \frac{c}{c_i}\,dt.$$

t_e is the saturation time - the bed is fully used up. ($c/c_i = 1$)

$\Rightarrow$ from the data $t_e = 108.6$ minute

Performing the integration numerically,

$t_s = 45.18$ minutes

$$u_s = \frac{L}{t_s} = \frac{0.2}{45.18} = 4.427 \times 10^{-3} \text{ m/min}$$

$$\Rightarrow u_s = 0.2656 \text{ m/h.}$$

$$LUB = L \times \left(1 - \frac{t_b}{t_s}\right).$$

$$= 0.2 \times \left(1 - \frac{20.63}{45.18}\right)$$

$$\Rightarrow \boxed{LUB = 0.1087 \text{ m}} = 0.109 \text{ m}.$$

Since the curve is not symmetric ($\frac{c}{c_i}$ vs t curve)

we can't use $MTZ = 2 \times LUB$.

Instead we use the general expression,

$$MTZ \text{ Length of mass transfer zone} = L \times \left(1 - \frac{t_b}{t_e}\right)$$

$$\Rightarrow \text{Length of mass transfer zone} = \boxed{0.162 \text{ m}}$$

(Note: If the curve was symmetric,

$MTZ = 2 \times LUB$)

b) $\dot{V} = 3000\ m^3/h.$

$= \dfrac{3000}{3600}\ m^3/s$

$\Rightarrow \dot{V} = 0.833\ m^3/s$; $u_{superficial} = 0.29\ m/s$

$\text{Area of Bed} = \dfrac{\dot{V}}{u_{superficial}}$.

$\Rightarrow$ Diameter of bed $= \sqrt{\dfrac{4\dot{V}}{\pi u_{superficial}}}$

$= 1.913\ m.$

Adsorption cycle, $t = 8$ hours

$\Rightarrow$ length of used bed $= u_s \times t$

$= 2.125\ m$

LUB and length of mass transfer zone will remain the same before and after scale up because the wavefront is the same.

$\Rightarrow$ Length of bed = Length used + Length unused (LUB)

$\Rightarrow L = 2.125 + 0.1087$

$\Rightarrow L_{total} = 2.233\ m.$

Weight of adsorbate adsorbed till break through, $w = \dot{V} \times c_i \times t_b$.

($\because$ Cenit 40)

$\Rightarrow W = \underline{2640 \text{ gmol}} = \underline{190.37 \text{ kg}}$

($MW = 72.11 \text{ g mol}^{-1}$)

$$\text{Average loading} = \frac{\text{Mass of adsorbate}}{\text{Mass of bed}}$$

$$= \frac{\text{Mass of adsorbate}}{\rho_{bed} \frac{\pi D^2}{4} L_{total}}$$

$= \underline{0.5876 \text{ gmol/kg bed}}$

$= \underline{0.0424} \text{ kg adsorbate /kg bed.}$

$$\text{Maximum loading} = \frac{\text{Mass of adsorbate}}{\text{mass of } \underline{\text{used part of bed}}}$$

$$= \frac{W}{\rho_{bed} \frac{\pi D^2}{4} L_{used}}$$

$\therefore$ Maximum loading $= \underline{0.6177 \text{ gmol}}$ MEK /kg bed

$= \underline{0.0445}$ kg MEK/kg Bed.