Data are as follows:

<table>
<thead>
<tr>
<th>( q )</th>
<th>( 1/q )</th>
<th>( 1/c )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.026</td>
<td>0.0040</td>
<td>38.5</td>
</tr>
<tr>
<td>0.053</td>
<td>0.0087</td>
<td>18.9</td>
</tr>
<tr>
<td>0.075</td>
<td>0.019</td>
<td>13.33</td>
</tr>
<tr>
<td>0.082</td>
<td>0.027</td>
<td>12.19</td>
</tr>
<tr>
<td>0.123</td>
<td>0.044</td>
<td>8.13</td>
</tr>
<tr>
<td>0.129</td>
<td>0.045</td>
<td>7.75</td>
</tr>
</tbody>
</table>

First try Langmuir equation, Eq. (12.1-3): \( q = \frac{q_0 c}{K + c} \)

Plot \( 1/q \) as follows.

(Note: A plot of \( \log q \) vs \( \log c \) for the Freundlich Eq. (12.1-2) where \( q = K c^n \) is not a straight line. Hence, data do not follow this Eq.)

The data give a straight line and follow the Langmuir equation.

\[
\frac{K}{q_0} = \text{slope of line} = 0.120
\]

The intercept is \( 1/q_0 = 6.9 \). Hence, \( q_0 = \frac{1}{6.9} = 0.145 \)

\[
K = 0.120 q_0 = 0.120 \times 0.145 = 0.0174
\]

\[
q = \frac{0.145}{0.0174 + c}
\]

334
\[ S = 2.5 \text{ m}^3 \text{ solution}, \ M = 3.0 \text{ kg carbon}, \ c_F = 0.25 \text{ kg phenol/m}^3 \]

\[ Q_F = 0 \]

**Eq. (12.2-1)**

Material balance:

\[ Q_F M + C_F S = Q H + C \]

\[ 0 \times 3.0 + 0.25 \times 2.5 = 4 \times 3.0 + C(2.5) \]

\[ 0.625 = 3.0C + 2.5C \]

**Plot this straight line. Plot isotherm \( q = 0.199 \) for \( x = 0.229 \)**

At intersection:

\[ C = 0.106, \ q = 0.120 \]

**% extraction = \( \frac{0.25 - 0.106}{0.25} \times 100 \)**

\[ \% \text{ extraction} = 57.67\% \]

---

**From Eq. 12.3-1,**

\[ T_x \text{ (total cycle at feed)} = 5.16 \text{ h}, \ T_x = 6.95 \text{ h} \]

\[ T_{hl} \text{ (usable cycle to break feed)} = 3.65 \text{ h}, \ T_{nl} \text{ (break feed)} = 3.65 \text{ h} \]

\[ H_{UNB} \text{ (unused feed)} = 4.1 \text{ cm}, \ H_B \text{ (length used feed)} = 9.9 \text{ cm}, \ \theta_1 = 3.65 \theta_n = 1.51 \text{ h} \]

**(a)**

For the new tower, \( T_x = 8.5 \text{ h} \)

New \( H_B \) is proportional to \( T_x \).

\[ H_B \text{ (new)} = \frac{8.5}{3.65} \times 9.9 = 23.1 \text{ cm} \]

**Eq. (12.3-5)**

\[ H_{\text{total}} = H_{UNB} + H_B \text{ (new)} = 4.1 + 23.1 = 27.2 \text{ cm} = H_T \]

New \( T_x = 9, \ \theta_1 = 8.50 + 1.51 = 10.01 \text{ h} \)

\( T_{hl} \) (usable to break feed) = 8.5 h

\[ T_{hl}/T_x = \frac{8.5}{10.01} = 0.849 \text{ per usable cycle} \]

**Some diameter**

**(b)** New C.S. area = \( \frac{2000}{7.54} \) (old C.S. area)

\[ \frac{\pi D^2}{4} = \frac{2000}{7.54} (\frac{\pi}{4} 4.2) \]

\[ D = 6.52 \text{ cm} \]

All other values as in (a)
Values of $c/c_0 = c/9.26 \times 10^{-6}$ are calculated and plotted.

<table>
<thead>
<tr>
<th>$t/A$</th>
<th>0</th>
<th>9</th>
<th>9.2</th>
<th>9.6</th>
<th>10.0</th>
<th>10.4</th>
<th>10.8</th>
<th>11.2</th>
<th>11.5</th>
<th>12.0</th>
<th>12.5</th>
<th>13.0</th>
<th>13.5</th>
<th>14.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>$c/c_0$</td>
<td>1.00</td>
<td>0.964</td>
<td>0.998</td>
<td>1.028</td>
<td>1.049</td>
<td>1.062</td>
<td>1.075</td>
<td>1.088</td>
<td>1.099</td>
<td>0.629</td>
<td>0.729</td>
<td>0.829</td>
<td>0.929</td>
<td>0.799</td>
</tr>
</tbody>
</table>

At $c/c_0 = 0.02$, $t_c = 9.58\, \text{h}$

Area $A_1$ by graphical integration:

$A_1 = \int_0^{t_c} (1 - c/c_0)\, dt = 9.58$, $A_2 = \int_0^{t_0} (1 - c/c_0)\, dt = 1.334$

$H_T = 0.268\, \text{m}$

Note: $t_m = 9.58\, \text{h}$

Total $c = A_1 + A_2 = 9.58 + 1.334 = 10.91\, \text{h} = t_T$

Eq. (12.3-4) $H_{UNB} = (1 - t_m/t_T) H_T = (1 - 9.58/10.91) H_T = 0.033\, \text{m}$

$H_{UNB} = 0.033\, \text{m}$

Frac. of bed used $= t_m/t_T = 9.58/10.91 = 0.878$ = frac. bed used

Satn loading case:

Mass vol $N_2$ gas = 4052 kg/m$^3$ h

For bed $= 712.8\, \text{kg/m}^3$. Take 1 m$^2$ of bed $= 0.268\, \text{m}^2$.

Mass $= 1(0.268\, \text{m}^2)(712.8\, \text{kg/m}^3) = 191.0\, \text{kg solid}$.

In $t_c = 10.91\, \text{h}$,

Amount adsorbed $= 4852\, \text{kg} N_2 (10.91\, \text{h}) (9.26 \times 10^{-6}\, \text{kg H}_2\text{O} = 40.94\, \text{kg H}_2\text{O}$

$\text{kg H}_2\text{O/kg solid} = 40.92/191.0 = 0.2194 = \text{satn loading}$

($b$) $H_T = 0.40\, \text{m}$, $H_{UNB} = 0.033\, \text{m}$, $H_B = H_T - H_{UNB} = 0.40 - 0.033 = 0.367\, \text{m}$

$t = H_B / t_m = t_c = 6.367/0.235 = 9.58 = (t_T)^c$

Frac. used of bed $= 0.367/0.400 = 0.918$