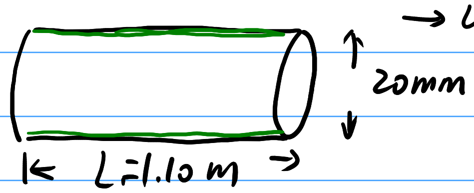
CHE 318 L19

Dimensionless number examples

Case 1



$D_{AB} = 6.92 \times 10^{-6}\ m^2/s$ $\quad p_{Ai} = 74.0\ Pa$ $\quad \begin{cases} \mu = 1.932 \times 10^{-5}\ Pa \cdot s \\ \rho = 1.114\ kg/m^3 \end{cases}$

Gas !

1) $$N_{Re} = \frac{D \cdot U_m \cdot \rho}{\mu} = \frac{0.020 \times 0.80 \times 1.114}{1.932 \times 10^{-5}} = 922.6$$

$$N_{Sc} = \frac{\mu}{\rho D_{AB}} = \frac{1.932 \times 10^{-5}}{1.114 \times 6.92 \times 10^{-6}} = 2.506$$

Laminar gas flow. Need to use "rod-like"

x-axis $$\frac{W}{D_{AB} \cdot \rho \cdot L} = N_{Re} \cdot N_{Sc} \cdot \frac{D}{L} \cdot \frac{\pi}{4}$$

$$= 922.6 \times 2.506 \times \frac{0.020}{1.10} \cdot \frac{3.1416}{4} = 33.02$$

How to get W ? $$W = \frac{[kg]}{[s]} = \rho \cdot U \cdot A_{tube} = \rho \cdot U_m \cdot \frac{\pi D^2}{4}$$

$$= 1.114 \times 0.80 \times 3.1416 \times (0.020)^2 / 4$$

$$= 2.80 \times 10^{-4}\ kg/s$$

(the same if use $W = 33.02 \times \rho \times D_{AB} \times L$)

Use plot, $\begin{cases} \text{x-axis} = 33.02 \\ \text{y-axis} = 0.55 \end{cases}$ $$\frac{C_A - C_{A0}}{C_{Ai} - C_{A0}} = 0.55 \quad (C_{A0} \approx 0)$$

$C_A = C_{Ai} \cdot 0.55 = 2.799 \times 10^{-5} \times 0.55 = 1.539 \times 10^{-5}\ kg\ mol/m^3$

$C_{Ai} = P_{Ai} / RT = 74.0/8314/318 = 2.799 \times 10^{-5}\ kg\ mol/m^3$

2) How will result change if we double v?

x-axis $N_{Re} N_{Sc} \frac{D}{L} \frac{\pi}{4} \propto v_m$

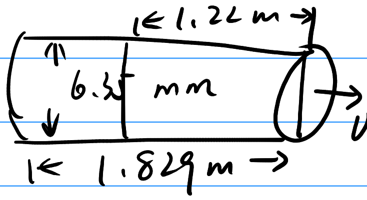
$v_m' = 2 \times v_m \Rightarrow$ x-axis becomes doubled

search x → axis → y-axis, read out C_A

3) If $D_{AB} \downarrow$ $\frac{W}{D_{AB} \rho L} \uparrow \Rightarrow$ Lower outlet conc ✓

Case 1-2 $T = 28.1°C$ $\rho = 996\ kg/m^3$

$\mu = 8.71 \times 10^{-4}\ Pa \cdot s$



$V_m = 0.0305\ m/s$

$C_{A,i} = 0.02948\ kg\ mol/m^3$ $D_{AB}\ (liq) = 1.245 \times 10^{-9}\ m^2/s$

C_A at outlet ?

Please use the cheatsheet !

1) $N_{Re} = \frac{L_D \cdot V_m \cdot \rho}{\mu} = \frac{0.00635 \times 0.0305 \times 996}{8.71 \times 10^{-4}} = 221.4$

It's laminar flow

$N_{Sc} = \frac{\mu}{\rho D_{AB}} = \frac{8.71 \times 10^{-4}}{996 \times 1.245 \times 10^{-9}} = 702.41$

$W = \rho \cdot V_m \cdot \frac{\pi D^2}{4} = 996 \times 0.0305 \times 3.1416 \times (6.35 \times 10^{-3})^2 / 4 = 9.616 \times 10^{-4}$ kg/s

x-axis $N_{Re} \cdot N_{Sc} \cdot \frac{D}{L} \cdot \frac{\pi}{4} = 634.4$

↑ use 1.22 m, not 1.829 m !

x-axis > 400 , follow the parabolic line

$\frac{C_A - C_{A0}}{C_{A,i} - C_{A0}} = \frac{C_A - 0}{0.02948 - 0} = 5.5 \times 634.4^{-\frac{2}{3}}$

$C_A = 2.196 \times 10^{-3}\ kg\ mol/m^3$