Home Assignments for ME6203

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Chapter 2

Question 8

The twin bulb method of measuring diffusion is shown in Fig. P 2.3. The bulbs, which are stirred and equal volume, initially contain binary gas mixtures of different compositions. At time zero, the valve is opened; at time t, the valve is closed, and the bulk contents are analyzed. Explain how is information can be used to calculate the diffusion coefficients in this binary gas mixture.

Solution:

Assumptions: 1. There is a infinite thin diaphragm at the middle of the bulb

2. The flux across the diaphragm reaches steady state quite quickly.

Suppose the gas in the left bulb is called gas A, the right called gas B

$$j_1 = [\frac{D}{l}](C_{1,left} - c_{1,right})$$

$$V_{left}\frac{dC_{1,left}}{dt} = -Aj_1$$

$$V_{right}\frac{dC_{1,right}}{dt} = Aj_1$$

from above equations, we get

$$\frac{d}{dt}(C_{1,left} - C_{1,right}) = D\beta(C_{1,left} - C_{1,right})$$

where

$$\beta = \frac{A}{l}(\frac{1}{V_{left}} + \frac{1}{V_{tight}})\ V_{left} = V_{right} = V \quad \text{then} \quad \beta = \frac{2A}{Vl}$$

t=0, $C_{1,left} - C_{1,right} = C^0{}_{1,left} - C^0{}_{1,right}$

then

$$\frac{C_{1,left} - C_{1,right}}{C^0{}_{1,left} - C^0{}_{1,right}} = e^{-\beta Dt}$$

then

$$D = \frac{1}{\beta t}\ln(\frac{C^0{}_{1,left} - C^0{}_{1,right}}{C_{1,left} - C_{1,right}})$$

From A to B,

$$D_{AB} = \frac{1}{\beta t}\ln(\frac{C^0{}_{1,Aleft} - C^0{}_{1,Aright}}{C_{1,Aleft} - C_{1,Aright}})$$

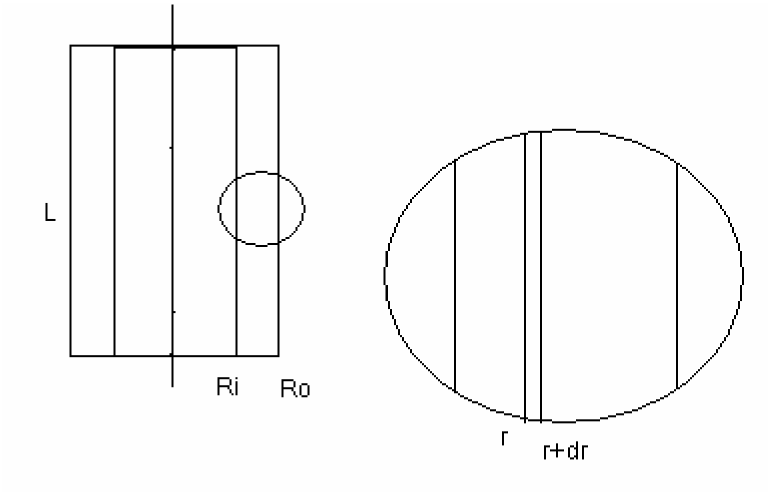
From B to A

$$D_{BA} = \frac{1}{\beta t}\ln(\frac{C^0{}_{1,Bright} - C^0{}_{1,Bleft}}{C_{1,Bright} - C_{1,Bleft}})$$

we can measure the time t and the concentrations, we can also measure the variables and get β, then we can get the diffusion coefficients.

9.

9. Find the steady-state flux out of a pipe with a porous wall. The pipe has an inner radius R_i and an outer radius R_0. The solute has a fixed, finite concentration c_{1i} inside of the pipe, but is essentially at zero concentration outside. As a result, solute diffuses through the wall with a diffusion coefficient D. When you have found the result, compare it with the results for steady-state diffusion across a thin slab and away from a dissolving sphere.



Sol: Select a thin volume as shown above, and write the mass balance equation in this volume:

(solute accumulation in volume dv) = (rate of diffusion into layer at r)-

(rate of diffusion out of the layer r+dr)

For it is steady state,

$$0 = 2\pi rL\cdot j_1|_r - 2\pi rL\cdot j_1|_{r+dr}$$

$$0 = \frac{\partial(r\cdot j_1)}{\partial r}$$

For $j_1 = -D\frac{\partial C}{\partial r}$, so

$$0 = -\frac{\partial(rD\frac{\partial c}{\partial r})}{\partial r} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

And the boundary conditions are :

$r = R_i \qquad C = C_{1i}$ ………………………………(2)

$r = R_0 \qquad C = 0$ ………………………………(3)

Integrate (1), we get $C = \frac{a}{D} Inr + b$ …………………(4)

a and b are constants,

Substitute (2) and (3) to (4)

We get $a = \frac{C_{1i} D}{In \frac{R_i}{R_0}} \qquad b = -\frac{C_{1i} InR_0}{In \frac{R_i}{R_0}}$

So $C = \frac{C_{1i}}{In \frac{R_i}{R_0}} Inr - \frac{C_{1i} InR_0}{In \frac{R_i}{R_0}}$

And $j_1 |_r = -D \frac{\partial C}{\partial r} = \frac{DC_{1i}}{rIn \frac{R_0}{R_i}}$

The flux out of a pipe, $j_1 |_{r=R_0} = -D \frac{\partial C}{\partial r} = \frac{DC_{1i}}{R_0 In \frac{R_0}{R_i}}$

The flux across a thin slab is $j_1 = \frac{D}{L}(C_{10} - C_{1l})$ as shown in 2.2., which is a constant.

The flux away from a dissolving sphere is

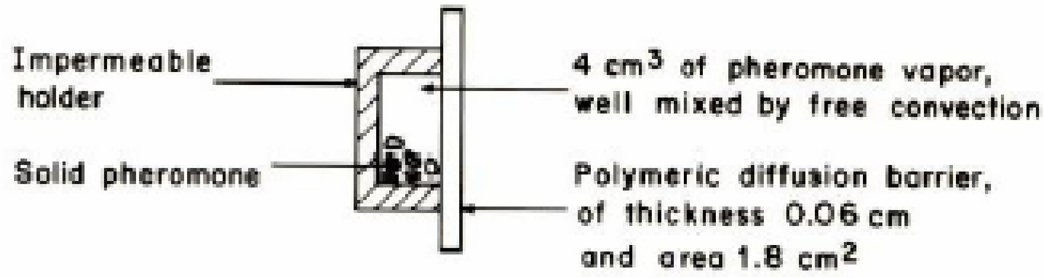
$j_1 = \frac{D}{R_0} C_{sat}$ as shown in 2.4.2. While the radius is doubled, the flux will be a half of the original one.

10.

10. Controlled release is important in agriculture, especially for insect control. One common example involves the pheromones, sex attractants released by insects. If you mix this attractant with an insecticide, you can wipe out all of one sex of a particular insect pest. A device for releasing one pheromone is shown schematically in Fig. P2.4. This pheromone does not sublime instantaneously, but at a rate of

$$r_0 = 6 \cdot 10^{-17}[(1 - 1.10 \cdot 10^7 \text{ cm}^3/\text{mol})c_1] \text{ mol/sec}$$

where c_1 is the concentration in the vapor. The permeability of this material through the polymer (DH) is $1.92 \cdot 10^{-12}$ cm²/sec. Its concentration of pheromone outside of the device is essentially zero. (a) What is the concentration (mol/cm³) of pheromone in the vapor? (b) How fast is the pheromone released by this device?



Sol: Write the accumulation equation in the holder,

(pheromone accumulation in the holder)=(pheromone sumblimed)-(pheromone diffused out)

Pheromone sumblimed at a rate of

r = $6\cdot10^{-7}\left[1-(1.1\square10^{7}cm^{3}/molC_{1})\right]mol/\sec$

And the pheromone diffused out is

Q= $j_1 A$ where A is the area of the barrier

It is steady state, so

r = $j_1 A$

$6\cdot10^{-7}\left[1-(1.1\square10^{7}cm^{3}/molC_{1})\right]mol/\sec$ = - $1.92\square10^{-12}cm^{2}/\sec$ $\frac{0-C_1(mol/L)}{0.06cm}x1.8cm^{2}$

Thus get C_1=0.836x$10^{-7}mol/cm^{3}$

So the rate diffused out of the holder is

Q=-$1.92\square10^{-12}cm^{2}/\sec$ $\frac{0-C_1(mol/L)}{0.06cm}x1.8cm^{2}$=4.82X$10^{-18}mol/\sec$