10.302
Fall 2004
Discussion Problem for Recitation on
Tuesday, November 23, 2004

The Drückelhammer Brewing Company is contemplating a switch from one-liter glass bottles to one-liter plastic bottles for their famous beer. This will obviously result in a lighter bottle that will not break when dropped. However, they are concerned that the beer will go "flat" during storage. You have therefore been asked to estimate the rate at which CO_2 is lost from the beer. For estimation purposes, it is agreed that the following properties and assumptions may be used:

Bottle

The bottle may be treated as a simple right circular cylinder. The diameter is 8.5 cm and the height is 18.5 cm. The bottle is filled to a height of 17.5 cm with 1 cm of "gas space" above the liquid. The thickness of the plastic (polyethylene terephthalate) will be 0.75mm. For transport calculations, use an area of 580 cm^2.

Beer

Initial concentration of CO_2 = 0.25 moles/L

$h_m = 10^{-4}$ cm/s for that portion of the bottle which is "wet" by the beer

$h_m = 1$ cm/s for that portion of the bottle which is not "wet" by the beer, i.e. for the gas space above the beer

Ambient

In the surrounding air, the concentration of CO_2 is 20 x 10^{-6} moles/L

$h_m = 1$ cm/s

Plastic

$$D_{co_2} = 1 \times 10^{-9} \, cm^2 / s$$

Thickness = 0.75 mm

Unless stated otherwise, you may assume that the concentration profile in the plastic has attained steady state.

Partition Coefficients for CO_2

$S_{air/beer} = 0.5$ $S_{plastic/air} = 3$

A. Sketch the CO_2 concentration profile that would exist at very long times when equilibrium with respect to the ambient has been achieved (i.e. at $t = \infty$, after the beer is completely "flat").

Beer   Plastic   Air

C = 20 x 10^{-6} moles/L

C = 0
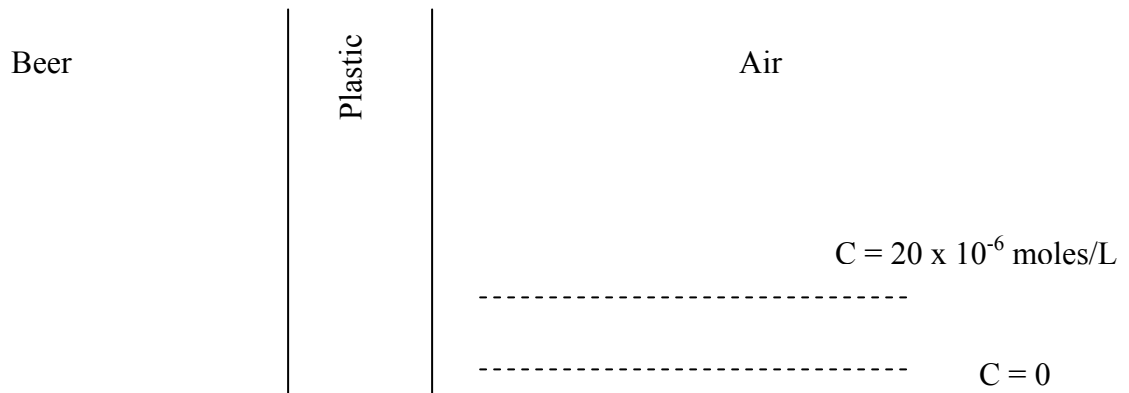
B. What is the value of the overall mass transfer coefficient for the transport of CO_2 from the liquid to the air? Use the beer-phase concentration to describe the driving force.

C. How will the flux of CO_2 from the gas phase (top of the bottle) compare with that from the rest of the bottle? In other words, which flux is larger? Why?

D. What fraction of the CO_2 will be lost to the ambient air during one month of storage?