CE 407 Separations

Mass transfer interfacial concentrations and overall mass transfer coefficients

n-octane undergoes mass transfer from a bulk gas phase,where its mole fraction y is 0.05, to a bulk liquid phase, where its mole fraction is x is 0.01, through a gas-liquid interface. Temperature and pressure are 60 °C and 1.0 atm; mass transfer coefficients are as follows:

$$k_y = 6.0 \times 10^{-6} \text{ mol/cm}^2\text{s};$$
$$k_x = 1.5 \times 10^{-6} \text{ mol/cm}^2\text{s}.$$

Assuming validity of Raoult's law for the equilibrium relation,

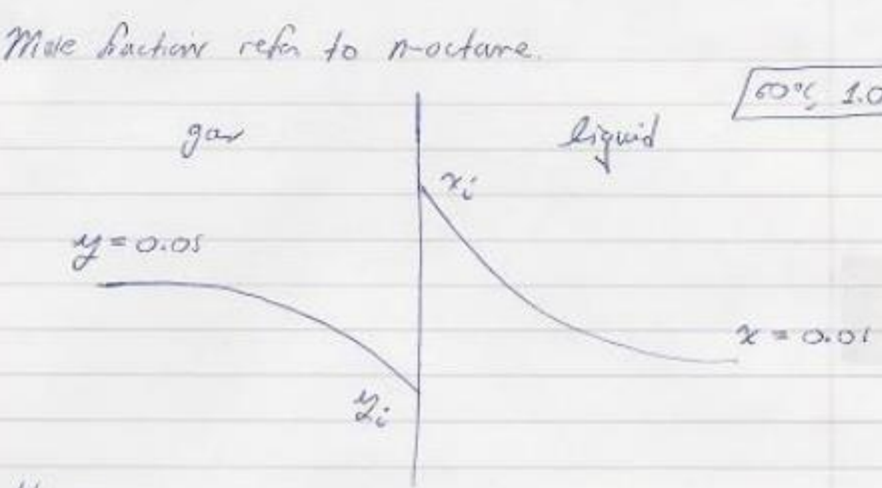
(a) what are the interfacial mole fractions y_i and x_i;

(b) what is the flux of n-octane from vapor to liquid; and

(c) what are the overall mass-transfer coefficients K_x and K_y?

Mole fraction refer to n-octane.

60°C, 1.0 atm



Have

Flux (bulk gas → interface) = Flux (interface → bulk liquid)

and

Equilibrium at interface.

∴

$$N = k_y (y - y_i) = k_x (x_i - x)$$

and $y_i = \left(\frac{P^{sat}}{P}\right) x_i$ ← assuming validity of Raoult's law for octane

$m = 0.11$ since P^{sat} of octane is 0.11 atm at 60°C, from Fig. 22.1 on p. 739

(a) Solve for y_i:

x_i from 2nd eq.

$$k_y (y - y_i) = k_x \left(\frac{y_i}{m} - x\right)$$

or

$$y_i = \frac{k_x x + k_y y}{k_x/m + k_y} = \frac{(1.5)(0.01) + (6.0)(0.05)}{(1.5)/(0.11) + 6.0}$$

Then

$y_i = 0.01604$

$x_i = y_i / m = 0.1458$

(b) $N = k_y(y - y_i) = (6.0\times10^{-6}\ mol/cm^2 s)(0.05 - 0.01604)$

$= 2.038\times10^{-7}\ mol/cm^2 s$

based on gas-phase mass transfer

or

$N = k_x(x_i - x) = (1.5\times10^{-6}\ mol/cm^2 s)(0.1458 - 0.01)$

$= 2.037\times10^{-7}\ mol/cm^2 s$

$\boxed{N = 2.038\times10^{-7}\ mol/cm^2 s}$ (same answer to within round-off error.)

(c)
$$K_y = \left(\frac{1}{k_y} + \frac{m}{k_x}\right)^{-1}$$
$$= \left(\frac{1}{6.0\times10^{-6}\ \frac{mol}{cm^2 s}} + \frac{0.11}{1.5\times10^{-6}\ \frac{mol}{cm^2 s}}\right)^{-1}$$

$$\boxed{K_y = 4.167\times10^{-6}\ \frac{mol}{cm^2 s}}$$

$$K_x = \left(\frac{1}{k_x} + \frac{1}{m k_y}\right)^{-1}$$
$$= \left(\frac{1}{1.5\times10^{-6}\ \frac{mol}{cm^2 s}} + \frac{1}{(0.11)(6.0\times10^{-6}\ \frac{mol}{cm^2 s})}\right)^{-1}$$

$$\boxed{K_x = 0.4583\times10^{-6}\ \frac{mol}{cm^2 \cdot s}}$$

Not required:

... or

$y^*(x) = mx$

$$N = K_y (y - y^*)$$
$$= \left(4.167\times10^{-6}\ \frac{mol}{cm^2 s}\right)(0.05 - 0.11(0.01))$$
$$= 2.038\times10^{-7}\ mol/cm^2 \cdot s$$

(vapor → liquid)

... or

$x^*(y) = \frac{y}{m}$

$$N = K_x (x^* - x)$$
$$= \left(0.4583\times10^{-6}\ \frac{mol}{cm^2 \cdot s}\right)\left(\frac{0.05}{0.11} - 0.01\right)$$
$$= 2.037\times10^{-7}\ mol/cm^2 \cdot s$$

∴ all four methods

$$N = \begin{cases} k_y (y - y_i) \\ k_x (x_i - x) \\ K_y (y - y^*) \\ K_x (x^* - x) \end{cases}$$

(vapor → liquid)

give the same answer!