Problem 2.5

The assumptions mentioned regarding the droplet are met with $T_s = 25°C$ and $m_{CO2,s} = 0$.

Define

① → vapor

② → air

③ → CO_2

a) $T_L = T_G = T_s = 25°C = 298\ K$

$\phi = 0.6$

$P_1 = \phi P_{sat} = (0.6)(3141\ Pa) = 1884\ Pa$

$P_0 = 101330\ Pa$

$X_{1,G} = P_1 / P_0 = 0.0186$

$$m_{1,G} = \frac{X_1 M_1}{X_1 M_1 + (1 - X_1) M_2} = 0.01163$$

$$X_{1s} = P_{sat}\big|_{T_s} / P = 3141/101330 = 0.031$$

$$m_{1s} = \frac{X_{1s} M_1}{X_{1s} M_1 + (1 - X_{1s}) M_2} = 0.0195$$

From Appendix E

$$D_{12} = (1.97 \times 10^{-5}\ m^2/s)\left(\frac{101330}{P_0}\right)\left(\frac{T_G}{256}\right)^{1.685}$$

$$= 2.545 \times 10^{-5}\ m^2/s$$

$$Sh_G = \frac{K_G D}{\rho_G D_{12}} = 2$$

As an approximation use

$$\rho_G = \rho_{air} = 1.185 \; kg/m^3$$

Also, $D = 5.5 \times 10^{-4} \, m$

$$\Rightarrow K_G = 0.11 \; kg/m^2 s$$

Without consideration for the blowing effect, we will have

$$m_1'' = K_G (m_{1,s} - m_{1,G}) = 0.00088 \; kg/m^2 s$$

With the blowing effect included, then

$$B_{m,G} = \frac{m_{1,G} - m_{1,s}}{m_{1,s} - 1} \approx 0.0086$$

$$m_1'' = K_G \ln(1 + B_{m,G}) = 0.000873 \; kg/m^2 s$$

b) $T_{s,b} = 323 \, K$

$$P_{1,sb} = P_{sat}\Big|_{T_{s,b}} = 1.225 \times 10^4 \, Pa$$

$$X_{1,sb} = P_{1,sb} / P_0 = 0.1209$$

$$\Rightarrow m_{1,sb} = 0.0787$$

$$B_{mG,b} = \frac{m_{1,G} - m_{1,sb}}{m_{1,sb} - 1} = 0.07276$$

$$m_{1,b}'' = K_G \ln(1 + B_{mG,b}) = 0.0077 \; kg/m^2 s$$

c) We will do this for Part a only.

$$m_{3,s} = 0$$

$$X_{3,G} = 500 \times 10^{-6}$$

$$m_{3,G} = \frac{X_{3G} M_3}{X_{3G} M_3 + X_{1G} M_1 + (1 - X_{1G} - X_{3G}) X_2} = 7.64 \times 10^{-4}$$

For diffusion coefficient, let us assume diffusivity of CO_2 with respect to the mixture is equal to D_{13} for simplicity.

$$D_{13} = 1.6 \times 10^{-5} \ m^2/s$$

$$Sh_{G,CO_2} = \frac{K_{G,CO_2} D}{\rho_G D_{13}} \Rightarrow K_{G,CO_2} = 0.0689 \ kg/m^2 s$$

$$m_{3,s} = 0$$

$$B_{mG} = \frac{m_{3,G} - m_{3,s}}{m_{3,s} - \frac{m''_{CO_2}}{m''_{tot}}} \qquad (1)$$

$$m''_3 = m''_{tot} m_{3,s} + K_{G,CO_2} \frac{\ln(1 + B_{mG})}{B_{mG}} \cdot (m_{3,s} - m_{3,G}) \qquad (2)$$

$$m''_{tot} = m''_3 + m''_1 \qquad (3)$$

Solution of (1) ~ (3) gives

$$m''_3 = -0.0000523 \ kg/m^2 s.$$