13. A stream of air at 100 kPa pressure and 300 K is flowing on the top surface of a thin flat sheet of solid naphthalene of length 0.2 m with a velocity of 20 m/sec. The other data are:

Mass diffusivity of naphthalene vapor in air = 6 * 10^{-6} m^2/sec
Kinematic viscosity of air = 1.5 * 10^{-5} m^2.sc
Concentration of naphthalene at the air-solid naphthalene interface = 1 * 10^{-5} kmol/m^3

Calculate:

(a) the overage mass transfer coefficient over the flat plate
(b) the rate of loss of naphthalene from the surface per unit width

Note: For heat transfer over a flat plate, convective heat transfer coefficient for laminar flow can be calculated by the equation.

$$Nu = 0.664\ \mathrm{Re}_L^{1/2}\ \mathrm{Pr}^{1/3}$$

you may use analogy between mass and heat transfer.

Solution:

Given: Correlation for heat transfer

$$Nu = 0.664\ \mathrm{Re}_L^{1/2}\ \mathrm{Pr}^{1/3}$$

The analogous relation for mass transfer is

$$Sh = 0.664\ \mathrm{Re}_L^{1/2}\ Sc^{1/3} \text{ --(1)}$$

where

Sh = Sherwood number = kL/D_{AB}
Re_L = Reynolds number = L$\upsilon\rho/\mu$
Sc = Schmidt number = μ / (ρ D_{AB})
k = overall mass transfer coefficient
L = length of sheet
D_{AB} = diffusivity of A in B
υ = velocity of air
μ = viscosity of air
ρ = density of air, and
μ/ρ = kinematic viscosity of air.

Substituting for the known quantities in equation (1)

$$\frac{k(0.2)}{6 * 10^{-6}} = 0.664 \left(\frac{(0.2)(20)}{1.5 * 10^{-5}} \right)^{1/2} \left(\frac{1.5 * 10^{-5}}{6 * 10^{-6}} \right)^{1/3}$$

k = 0.014 m/sec

Rate of loss of naphthalene = k (C_{Ai} – $C_{A\infty}$)
= 0.014 (1 * 10^{-5} – 0) = 1.4024 * 10^{-7} kmol/m^2 sec

Rate of loss per meter width = (1.4024 * 10^{-7}) (0.2) = 2.8048 * 10^{-8} kmol/m.sec
= 0.101 gmol/m.hr