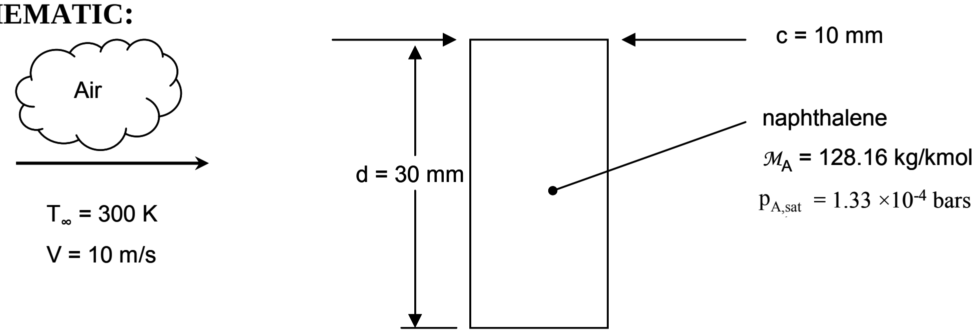
PROBLEM 6.63

KNOWN: Dimensions of rectangular naphthalene rod. Velocity and temperature of air flow. Molecular weight and saturation pressure of naphthalene.

FIND: Mass loss after 30 minutes.

SCHEMATIC:



ASSUMPTIONS: (1) Constant properties, (2) Mass loss is small, so dimensions remain unchanged, (3) Viscosity of air-naphthalene mixture is approximately that of air.

PROPERTIES: Table A-4, Air (300 K): $\nu = 15.89 \times 10^{-6}\ m^2/s$. Table A-8, Naphthalene in air, (300 K): $D_{AB} = 0.62 \times 10^{-5}\ m^2/s$, $Sc = \nu/D_{AB} = 2.56$.

ANALYSIS: We will use the heat and mass transfer analogy, with the Nusselt number correlation known from Problem 6.10 to be of the form

$$Nu_d = CRe_d^m Pr^{1/3}$$

Then invoking Equation 6.59,

$$Sh_d = CRe_d^m Sc^{1/3} = h_m d / D_{AB}$$

Now $Re_d = Vd/\nu = 10\ m/s \times 0.03\ m/15.89\times10^{-6} m^2/s = 18{,}880$. We find the values of C and m from Problem 6.10 with c/d = 0.33, for the front, sides, and back of the rod:

	C	m	Sh_d	h_m(m/s)
front	0.674	1/2	126.7	0.0262
sides	0.153	2/3	148.5	0.0307
back	0.174	2/3	168.8	0.0349

The average mass transfer coefficient is

$$\overline{h}_m = (h_{m,front}d + 2h_{m,side}c + h_{m,back}d)/(2d + 2c)$$

$$= \frac{0.0262\ m/s \times 0.03\ m + 2 \times 0.0307\ m/s \times 0.01\ m + 0.0349\ m/s \times 0.03\ m}{2 \times 0.03\ m + 2 \times 0.01\ m}$$

$$= 0.0306\ m/s$$

Then the mass loss can be found from

$$\Delta m = n_A \Delta t = \overline{h}_m A_{tot} (\rho_{A,s} - \rho_{A,\infty})\Delta t$$

Continued…

Here $\rho_{A,\infty} = 0$ and $\rho_{A,s}$ can be found from the saturation pressure, using the ideal gas law:

$$\rho_{A,s} = \frac{p_{A,sat}}{R_i T_s} = \frac{p_{A,sat}\mathcal{M}_A}{\mathcal{R} T_s}$$

$$= \frac{1.33 \times 10^{-4} \text{ bar} \times 128.16 \text{ kg/kmol}}{8.314 \times 10^{-2} \text{ m}^3 \cdot \text{bar/kmol} \cdot \text{K} \times 300 \text{ K}}$$

$$= 6.83 \times 10^{-4} \text{ kg/m}^3$$

Thus, finally,

$$\Delta m = 0.0306 \text{ m/s} \times (2 \times 0.03 \text{ m} + 2 \times 0.01 \text{ m}) \times 0.5 \text{ m}$$

$$\times (6.83 \times 10^{-4} - 0) \text{ kg/m}^3 \times 30 \text{ min} \times 60 \text{ s/min}$$

$$= 1.50 \times 10^{-3} \text{ kg}$$ <

COMMENTS: The average depth of surface recession is given by $\delta = \overline{h_m}(\rho_{A,s} - \rho_{A,\infty})\Delta t/\rho_{A,sol}$ where $\rho_{A,sol}$ is the density of solid naphthalene, $\rho_{A,sol} = 1025 \text{ kg/m}^3$. Thus $\delta = 37\ \mu\text{m}$ and the assumption that the dimensions remain unchanged is good.