Vapor-Liquid Interface Problem

Monday, September 11, 2017 9:20 AM

Liquid benzene (C6H6) at 298 K is contained in a 1-cm-diameter glass tube and maintained at a level 10 cm below the top of the tube, which is open to the atmosphere. The following properties of benzene are given:

T_{boil}	353 K @ 1 atm
h_{fg}	393 kJ/kg @ Tboil
MW_{C6H6}	78.108 kg/kmol
MW_{air}	28.85 kg/kmol
ρ_l	897 kg/m^3
$D_{C6H6\text{-}air}$	0.88 x 10^{-5} m^2/s @ 298 K

A) Determine the mass evaporation rate (kg/s) of the benzene.

B) How long does it take to evaporate 1 cm^3 of benzene?

A) $\dot{m}_{C_6H_6}$

$$\dot{m}'' = \bar{\rho} \, D_{C_6H_6-air} \, \ln\left(\frac{1 - Y_{C_6H_6,\infty}}{\ldots}\right)$$

$\cdot \quad _{C_6H_6} \quad \overline{} \quad \frac{}{L} \quad \cdots (1 - Y_{C_6H_6,i})$

$\bar{\rho}$:

$$\frac{n}{V}$$

$$\bar{\rho} = \frac{P}{(R_u/MW)T}$$

$Y_{C_6H_6,i}$:

$$Y_{C_6H_6,i} = X_{C_6H_6,i} \frac{MW_{C_6H_6}}{MW_{mix,i}}$$

$$\rightarrow X_{C_6H_6,i} = \frac{P_{sat}(T_{liq,i})}{P}$$

C.C.:

$$\frac{dP}{P} = \frac{h_{fg}}{R_u/MW_{C_6H_6}} \frac{dT}{T^2}$$

ref: $T = 353 \quad P_{sat} = 1$

wanted: $T = 298 \quad P_{sat} = ?$

$$\int_{1atm}^{P_{sat}} \frac{dP_{sat}}{P} = \frac{h_{fg}}{R_u/MW_{C_6H_6}} \int_{353}^{298} \frac{dT}{T^2}$$

$$\ln\left(\frac{P_{sat}}{1atm}\right) = \frac{-h_{fg}}{R_u/MW_{C_6H_6}} \left(\frac{1}{298} - \frac{1}{353}\right)$$

$$P_{sat} = 0.145 \text{ atm} \quad @ \ 298K$$

$X \quad P_{sat} \quad 0.145 \quad \cdots$

$$x_{C_6H_6,i} = \frac{P_{sat}}{P} = \frac{\;}{1} = \underline{0.145}$$

$$MW_{mix,i} = 0.145\, MW_{C_6H_6} + (1-0.145)\, MW_{air}$$
$$= 35.99 \text{ kg/kmol}$$

$$\Rightarrow Y_{C_6H_6,i} = 0.145 \frac{(78.108)}{(35.99)} = 0.3147$$

$$\Rightarrow \overline{MW} = \frac{1}{2}\left(MW_{mix,i} + MW_{mix,\infty}\right)$$
$$\hookrightarrow 32.42 \text{ kg/kmol}$$

$$\bar{\rho} = \frac{P}{(R_u/\overline{MW})T} = 1.326 \text{ kg/m}^3$$

$$\boxed{D_{AB} \propto T^{3/2} P^{-1}}$$

$$D_{AB_{T=298}} \propto 298^{3/2}\, 1^{-1}$$
$$D_{AB_{T=353}} \propto 353^{3/2}\, 1^{-1}$$

$$\frac{D_{AB,353}}{353^{3/2}} = C = \frac{D_{AB,298}}{298^{3/2}}$$

$$D_{AB,383K} = D_{AB,298} \left(\frac{353}{298}\right)^{3/2}$$

(298)

$$\dot{m}''_{C_6H_6} = \frac{\bar{\rho} D_{C_6H_6}}{L} \ln\left(\frac{1 - Y_{C_6H_6,\infty}}{1 - Y_{C_6H_6,i}}\right)$$

$$= 4.409 \times 10^{-5}\ kg/s\text{-}m^2$$

$$\dot{m} = \dot{m}''\left(\frac{\pi D^2}{4}\right) = 3.46 \times 10^{-9}\ kg/s$$

B)

$$t = \frac{m_{evap}}{\dot{m}_{C_6H_6}} = \frac{\rho_{liq} V}{\dot{m}_{C_6H_6}} = 2.54 \times 10^5$$

70.6 hr