```
{Example 2.5}
{Based on assumptions, T_s=25 C, and concentration of CO2 at s surface is zero.}
MM_v=18.
MM_air=29.
MM_CO2=44
D_d=0.55e-3
U_d=2.
T_G=25.+273.
T_L=25.+273.
P_G=1.0133e5
phi=0.6
P_sat=P_sat(Water, T=T_G)
P_v=phi*P_sat
X_v=P_v/P_G
m_v=X_v*MM_v/(X_v*MM_v+(1.-X_v)*MM_air)
X_vs=P_sat/P_G
m_vs=X_vs*MM_v/(X_vs*MM_v+(1.-X_vs)*MM_air)
mu_G=viscosity(AIR,T=T_G)
rho_G=density(AIR,T=T_G,P=P_G)
k_G=conductivity(AIR,T=T_G)
nu_G=mu_G/rho_G
C_PG=cp(STEAM,T=T_G,x=1)
D_12=(1.97e-5)*(101330./P_G)*((T_G/256.)^(1.685))
Sc_G=nu_G/D_12
Pr_G=prandtl(AIR,T=T_G)
Sh_G=2.
Sh_G=K_massG*D_d/(rho_G*D_12)
Nus_G=2.
Nus_G=H_G*D_d/k_G
{Part a:  First neglect the blowing effect}
m_dd_va1=K_massG*(m_vs-m_v)
{Now include blowing effect}
B_mG=(m_v-m_vs)/(m_vs-1.)
m_dd_va=K_massG*ln(1.+B_mg)
{Part b: Now we have heat transfer as well.  However, by fixing T_s at 50 C, evaporation rate will also be fixed, and will be decoupled from HT}
T_sb=273+50
P_vsb=P_sat(water, T=T_sb)
X_vsb=P_vsb/P_G
m_vsb=X_vsb*MM_v/(X_vsb*MM_v+(1.-X_vsb)*MM_air)
B_mGb=(m_v-m_vsb)/(m_vsb-1.)
m_dd_vb=K_massG*ln(1.+B_mgb)
{c:  This time we deal with CO2 mass transfer rate. Let us solve for case (a)}
m_CO2s=0.0
X_CO2G=500.e-6
m_CO2G=X_CO2G*MM_CO2/(X_CO2G*MM_CO2+X_v*MM_v+(1-X_v-X_CO2G)*MM_air)
D_aCO2=0.16e-4
Sh_G=K_massCO2*D_d/(rho_G*D_aCO2)
{First without the blowing effect:}
m_ddCO2=K_massCO2*(m_CO2s-m_CO2G)
{Now with blowing}
m_ddtot=m_dd_va+m_ddCO2b
B_mGCO2=(m_CO2G-m_CO2s)/(m_CO2s-(m_ddCO2b/m_ddtot))
m_ddCO2b=m_ddtot*m_CO2s+K_massCO2*(ln(1.+B_mGCO2)/B_mGCO2)*(m_CO2s-m_CO2G)
```

$MM_v = 18$

$MM_{air} = 29$

$MM_{CO2} = 44$

$D_d = 0.00055$

$U_d = 2$

$T_G = 25 + 273$

$T_L = 25 + 273$

$P_G = 101330$

$\phi = 0.6$

$P_{sat} = \mathbf{P}_{sat}\left[\text{'Water'}, T = T_G\right]$

$P_v = \phi \cdot P_{sat}$

$$X_v = \frac{P_v}{P_G}$$

$$m_v = X_v \cdot \left[\frac{MM_v}{X_v \cdot MM_v + (1 - X_v) \cdot MM_{air}}\right]$$

$$X_{vs} = \frac{P_{sat}}{P_G}$$

$$m_{vs} = X_{vs} \cdot \left[\frac{MM_v}{X_{vs} \cdot MM_v + (1 - X_{vs}) \cdot MM_{air}}\right]$$

$\mu_G = \mathbf{Visc}\left[\text{'Air'}, T = T_G\right]$

$\rho_G = \rho\left[\text{'Air'}, T = T_G, P = P_G\right]$

$k_G = \mathbf{k}\left[\text{'Air'}, T = T_G\right]$

$$\nu_G = \frac{\mu_G}{\rho_G}$$

$C_{PG} = \mathbf{Cp}\left[\text{'Steam'}, T = T_G, x = 1\right]$

$$D_{12} = 0.0000197 \cdot \frac{101330}{P_G} \cdot \left[\frac{T_G}{256}\right]^{1.685}$$

$$Sc_G = \frac{\nu_G}{D_{12}}$$

$Pr_G = \mathbf{Pr}\left[\text{'Air'}, T = T_G\right]$

$Sh_G = 2$

$$Sh_G = K_{massG} \cdot \frac{D_d}{\rho_G \cdot D_{12}}$$

$$Nus_G = 2$$

$$Nus_G = H_G \cdot \frac{D_d}{k_G}$$

$$m_{dd,va1} = K_{massG} \cdot [m_{vs} - m_v]$$

$$B_{mG} = \frac{m_v - m_{vs}}{m_{vs} - 1}$$

$$m_{dd,va} = K_{massG} \cdot \mathbf{ln}[1 + B_{mG}]$$

$$T_{sb} = 273 + 50$$

$$P_{vsb} = \mathbf{P}_{sat}['Water', T = T_{sb}]$$

$$X_{vsb} = \frac{P_{vsb}}{P_G}$$

$$m_{vsb} = X_{vsb} \cdot \left[\frac{MM_v}{X_{vsb} \cdot MM_v + (1 - X_{vsb}) \cdot MM_{air}}\right]$$

$$B_{mGb} = \frac{m_v - m_{vsb}}{m_{vsb} - 1}$$

$$m_{dd,vb} = K_{massG} \cdot \mathbf{ln}[1 + B_{mGb}]$$

$$m_{CO2s} = 0$$

$$X_{CO2G} = 0.0005$$

$$m_{CO2G} = X_{CO2G} \cdot \left[\frac{MM_{CO2}}{X_{CO2G} \cdot MM_{CO2} + X_v \cdot MM_v + (1 - X_v - X_{CO2G}) \cdot MM_{air}}\right]$$

$$D_{aCO2} = 0.000016$$

$$Sh_G = K_{massCO2} \cdot \frac{D_d}{\rho_G \cdot D_{aCO2}}$$

$$m_{ddCO2} = K_{massCO2} \cdot [m_{CO2s} - m_{CO2G}]$$

$$m_{ddtot} = m_{dd,va} + m_{ddCO2b}$$

$$B_{mGCO2} = \frac{m_{CO2G} - m_{CO2s}}{m_{CO2s} - \frac{m_{ddCO2b}}{m_{ddtot}}}$$

$$m_{ddCO2b} = m_{ddtot} \cdot m_{CO2s} + K_{massCO2} \cdot \frac{\mathbf{ln}[1 + B_{mGCO2}]}{B_{mGCO2}} \cdot [m_{CO2s} - m_{CO2G}]$$

SOLUTION

Unit Settings: [J]/[K]/[Pa]/[kg]/[degrees]

$B_{mG} = 0.007998$ $B_{mGb} = 0.07276$ $B_{mGCO2} = 0.01198$

C_{PG} = 1887
D_{12} = 0.00002545
D_{aCO2} = 0.000016
D_d = 0.00055
H_G = 92.72
k_G = 0.0255
$K_{massCO2}$ = 0.06893
K_{massG} = 0.1096
MM_{air} = 29
MM_{CO2} = 44
MM_v = 18
μ_G = 0.00001848
m_{CO2G} = 0.0007638
m_{CO2s} = 0
m_{ddCO2} = -0.00005265
m_{ddCO2b} = -0.00005233
m_{ddtot} = 0.000821
$m_{dd,va}$ = 0.0008733
$m_{dd,va1}$ = 0.0008597
$m_{dd,vb}$ = 0.007699
m_v = 0.01163
m_{vs} = 0.01947
m_{vsb} = 0.07866
Nus_G = 2
ν_G = 0.0000156
ϕ = 0.6
Pr_G = 0.7281
P_G = 101330
P_{sat} = 3141
P_v = 1884
P_{vsb} = 12253
ρ_G = 1.185
Sc_G = 0.613
Sh_G = 2
T_G = 298
T_L = 298
T_{sb} = 323
U_d = 2
X_{CO2G} = 0.0005
X_v = 0.0186
X_{vs} = 0.031
X_{vsb} = 0.1209

6 potential unit problems were detected.