24.6

a. $\vec{N}_A + \vec{N}_B = c\vec{V}$

(Sol) $\vec{N}_A + \vec{N}_B = C_A\vec{v}_A + C_B\vec{v}_B$

$$= C\left(\frac{C_A\vec{v}_A + C_B\vec{v}_B}{C}\right) = c\vec{V}$$

b) $\vec{n}_A + \vec{n}_B = \rho\vec{V}$

(Sol) $\vec{n}_A + \vec{n}_B = \rho_A\vec{v}_A + \rho_B\vec{v}_B$

$$= \rho\left(\frac{\rho_A\vec{v}_A + \rho_B\vec{v}_B}{\rho}\right) = \rho\vec{V}$$

(c) $\vec{\vec{J}}_A + \vec{\vec{J}}_B = 0$

(Sol) $\vec{\vec{J}}_A + \vec{\vec{J}}_B = -\rho D_{AB}\vec{\nabla}\omega_A - \rho D_{BA}\vec{\nabla}\omega_B$

for binary system $D_{AB} = D_{BA}$

$$\Rightarrow \vec{\vec{J}}_A + \vec{\vec{J}}_B = -\rho D_{AB}\left(\vec{\nabla}\omega_A + \vec{\nabla}\underbrace{\omega_B}_{1-\omega_A}\right)$$

$$= -\rho D_{AB}\left(\vec{\nabla}\omega_A - \vec{\nabla}\omega_A\right) = 0$$

24.12.

$$SiCl_4(g) + 2H_2(g) \rightarrow Si(s) + 4HCl(g)$$

40 mol% 40 mol% 20 mol%

$800^\circ C = 1073\ K$

$1.5\times10^5\ Pa = 1.5\times10^5\ kg/m\cdot s$

$\sigma_{SiCl_4} = 5.08\ A^\circ = 5.08\times10^{-10}\ m$

for $\begin{cases}\sigma_{H_2} = 2.97\ A^\circ \\ \sigma_{HCl} = 3.31\ A^\circ\end{cases}$ are known. $\begin{cases}= 2.97\times10^{-10}\ m \\ = 3.31\times10^{-10}\ m\end{cases}$

$M.W._{SiCl_4} = 169.9\ g/mol = 0.1699\ kg/mol$

$M.W._{H_2} = 2\ g/mol = 0.002\ kg/mol$

$M.W._{HCl} = 36.5\ g/mol = 0.0365\ kg/mol$

(a)
$$D_{SiCl_4,H_2} = \frac{2T^{3/2}N^{1/2}k^{3/2}\left(\frac{1}{2M.W._{SiCl_4}} + \frac{1}{2M.W._{H_2}}\right)^{1/2}}{3\pi^{3/2}P\left(\frac{\sigma_{SiCl_4}+\sigma_{H_2}}{2}\right)^2}$$

$$= \frac{2\cdot(1073)^{3/2}K^{3/2}(6.02\times10^{23})^{1/2}(1/mol)^{1/2}(1.38\times10^{-23})^{3/2}(kg\cdot m^2/s^2\cdot K)^{3/2}\left(\frac{1}{2\times0.1699}+\frac{1}{2\times0.002}\right)^{1/2}(mol/kg)^{1/2}}{3\pi^{3/2}\cdot1.5\times10^5\ kg/m\cdot s^2\left(\frac{5.08\times10^{-10}+2.97\times10^{-10}}{2}\right)^2 m^2}$$

$$= 1.94\times10^{-4}\ m^2/s = 1.94\ cm^2/s$$

(b) $$D_{SiCl_4.HCl} = \frac{2T^{3/2}N^{1/3}k^{3/2}\left(\frac{1}{2M.W._{SiCl_4}} + \frac{1}{2M.W._{HCl}}\right)^{1/2}}{3\pi^{3/2}p\left(\frac{\sigma_{SiCl_4} + \sigma_{HCl}}{2}\right)^2}$$

$$= \frac{2\cdot(1073)^{3/2}(6.02\times10^{23})^{1/3}(1.38\times10^{-23})^{3/2}\left(\frac{1}{2\times0.1699} + \frac{1}{2\times0.0365}\right)^{1/2}}{3\pi^{3/2}\cdot1.5\times10^{5}\left(\frac{5.08\times10^{-10} + 3.31\times10^{-10}}{2}\right)^2}$$

$$= 4.585\times10^{-5}\ m^2/s = 0.459\ cm^2/s$$

(c) $$\frac{1}{D_{SiCl_4,mixture}} = \frac{\frac{y_{H_2}}{1-y_{SiCl_4}}}{D_{SiCl_4,H_2}} + \frac{\frac{y_{HCl}}{1-y_{SiCl_4}}}{D_{SiCl_4,HCl}}$$

$$= \frac{\frac{0.4}{1-0.4}}{D_{SiCl_4.H_2}} + \frac{\frac{0.2}{1-0.4}}{D_{SiCl_4,HCl}}$$

$$= \frac{0.667}{1.94\ cm^2/s} + \frac{0.333}{0.459\ cm^2/s} = 1.071\ s/cm^2$$

$$\Rightarrow D_{SiCl_4.mixture} = 0.934\ cm^2/s$$