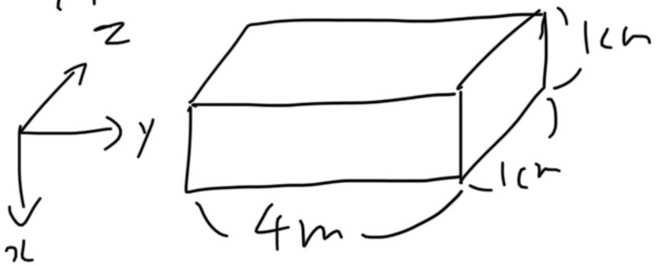
1.



heated to 1000K

$D = 4 \times 10^{-7}\ cm^2/s$

(a) neglect Nitrogen loss from bottom & edge

$\Rightarrow$ x-direction I 2=|

$$\frac{\partial \rho}{\partial t} = D \frac{\partial^2 \rho}{\partial x^2}$$

Boundary condition & initial condition

$$\begin{cases} \rho(x<0, t=0) = 100, \quad \rho(x>0, t=0) = 5 \\ \rho(x=0, t) = 5 \end{cases}$$

(b) Consider the case as a thin film source case

$$\Rightarrow \rho_i = \frac{\rho_0}{\sqrt{4\pi D t}} \exp\left(-\left(\frac{x-\alpha_i}{\sqrt{4Dt}}\right)^2\right) dx$$

$$\left.\begin{array}{l} \rho_0 = 5 \ (a_i < 0) \\ \rho_0 = 100 \ (a_i \geq 0 \end{array}\right\} \Rightarrow \rho(x,t) = \sum_i^{\infty} \rho_i$$

$$= \int_0^{\infty} \frac{5}{\sqrt{4\pi D t}} \exp\left(-\frac{(x-a_i)^2}{4Dt}\right) da$$

$$+ \int_{-1}^{0} \frac{100}{\sqrt{4\pi D t}} \exp\left(-\frac{(x-a_i)^2}{4Dt}\right) da$$

$$\left[z = \frac{x-\alpha}{\sqrt{4Dt}} \right] \nearrow$$

$$e(x,t) = -\frac{5}{\sqrt{\pi}} \int_{\frac{x}{2\sqrt{Dt}}}^{-\infty} e^{-z^2}\, dz$$

$$- \frac{100}{\sqrt{\pi}} \int_{\frac{x+1}{2\sqrt{Dt}}}^{\frac{x}{2\sqrt{Dt}}} e^{-z^2}\, dz$$

$$\Rightarrow \frac{5}{\sqrt{\pi}} \left(\int_{-\infty}^{0} e^{-z^2}\, dz + \int_{0}^{\frac{x}{2\sqrt{Dt}}} e^{-z^2}\, dz \right) + \frac{100}{\sqrt{\pi}} \int_{\frac{x}{2\sqrt{Dt}}}^{\frac{x+1}{2\sqrt{Dt}}} e^{-z^2}\, dz$$

$$\therefore \Rightarrow \frac{5}{2} \left(\mathrm{erf}\left(\frac{x}{2\sqrt{Dt}} + 1 \right) \right) + 50 \left(\mathrm{erf}\left(\frac{x+1}{2\sqrt{Dt}} \right) - \mathrm{erf}\left(\frac{x}{2\sqrt{Dt}} \right) \right)$$

(C) $\int_{-1}^{0} \rho(x,t)\,dx$

$$= \int_{-1}^{0} \frac{5}{2}\left(\mathrm{erf}\left(\frac{x}{2\sqrt{Dt}}\right)+1\right)\Bigg) + 50\left(\mathrm{erf}\left(\frac{x+1}{2\sqrt{Dt}}\right)\right.$$

$$\left. - \mathrm{erf}\left(\frac{x}{2\sqrt{Dt}}\right)\right)$$

$$\int \mathrm{erf}(x)\,dx = x\,\mathrm{erf}(x) + \frac{e^{-x^2}}{\sqrt{\pi}} + C$$

$$\int \mathrm{erf}\left(\frac{x}{2\sqrt{Dt}}\right)dx = \frac{2\sqrt{Dt}}{\sqrt{\pi}} \cdot e^{-\frac{x^2}{4Dt}}$$

$$+ x\,\mathrm{erf}\left(\frac{x}{2\sqrt{Dt}}\right) + C$$

$$\int \mathrm{erf}\left(\frac{x+1}{2\sqrt{Dt}}\right)dx = \frac{2\sqrt{Dt}}{\sqrt{\pi}} \exp\left(-\frac{(x+1)^2}{4Dt}\right)$$

$$+ (x+1)\,\mathrm{erf}\left(\frac{x+1}{2\sqrt{Dt}}\right) + C$$

$$\Rightarrow \int_{-1}^{0} \rho(x,t)\,dx = \int_{-1}^{0} \left(\frac{5}{2} - \frac{95}{2} \operatorname{erf}\left(\frac{x}{2\sqrt{Dt}} \right) + 50 \operatorname{erf}\left(\frac{x+1}{2\sqrt{Dt}} \right) \right) dx$$

$$\Rightarrow \frac{5}{2} - \frac{195}{2} \left(\frac{2\sqrt{Dt}}{\sqrt{\pi}} - \frac{2\sqrt{Dt}}{\sqrt{\pi}} \exp\left(-\frac{1}{4Dt}\right) - \operatorname{erf}\left(\frac{1}{2\sqrt{Dt}} \right) \right)$$

when $t=0 \Rightarrow \operatorname{erf}(\infty) = 1$

$$\left[\int_{-1}^{0} \rho(x,t)\,dx = 100 \right]$$

$$\Rightarrow \int_{-1}^{0} \rho(x,t)\,dx = 50$$

$t \Rightarrow 621106$ 초

(d) As D increases, $\int_{-1}^{0} \rho(x,t)\,dx$ decreases. thus, the time it takes to be 50% is reduced.

2. (a)

At 1173 K temperature

=) Injection time (h) : injection distance (μm)

0	0
2.4	70
4.8	100
7.2	120
9.5	140
11.9	155
14.3	170

=) $l \propto \sqrt{t}$

(b) At 2.4 h

Temperature	Injection distance
1173 K	170 μm
1273 K	126 μm
1373 K	210 μm
1473 K	338 μm

$$\Rightarrow T \propto \sqrt{l}$$

(C) $l \propto \sqrt{t}$

$$\frac{\partial c}{\partial t} = D\frac{\partial^2 c}{\partial x^2}$$ → Injection distance $\sqrt{Dt}$ 에 비례

$$\Rightarrow l = k\sqrt{Dt}$$

$D_0 \exp\left(-\frac{Q}{RT}\right)$ activation E

$t = 2.4\ h \quad T = 1173K$

$t = 2.4\ h \quad T = 1273K$

$$\Rightarrow 170 \times 10^{-6} = k\sqrt{D_0 \exp\left(-\frac{Q}{R \times 1173K}\right)}$$

$$126 \times 10^{-6} = K\sqrt{D_0 \exp\left(-\frac{Q}{R \times 1273\,K}\right)}$$

$$\Rightarrow \quad \underline{Q = 145944\,J \approx 147723}\ J$$