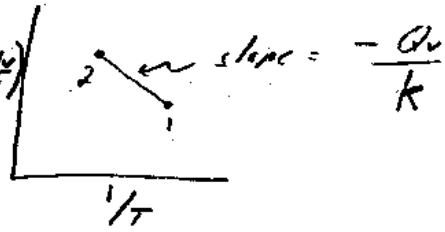
ENGR 240 HW #5

$T_1 = 450\ ^\circ C = 723\ K$, $\left(\frac{N_v}{N}\right)_1 = 1.0 \times 10^{-6}$

$T_2 = 475^\circ C = 748\ K$, $\left(\frac{N_v}{N}\right)_2 = 2.2 \times 10^{-6}$

- could solve 2 ways:

① ARRHENIUS PLOT



slope $= -\frac{Q_v}{k}$

OR

② 2 EQUATIONS, 2 UNKNOWNS...

$$\left(\frac{N_v}{N}\right)_2 = A_0 \exp\left(\frac{-Q_v}{kT_2}\right)$$

$$\left(\frac{N_v}{N}\right)_1 = A_0 \exp\left(\frac{-Q_v}{kT_1}\right)$$

→ divide: $\frac{(N_v/N)_2}{(N_v/N)_1} = \exp\left[\frac{-Q_v}{k}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)\right]$

$$\frac{2.2}{1.0} = \exp\left[\frac{-Q_v}{k}\left(\frac{1}{748K} - \frac{1}{723K}\right)\right] \rightarrow \frac{Q_v}{k} = 17{,}000\ K$$

(Kelvin)

$$Q_v = 17{,}000\ K\ (1.38 \times 10^{-23}\ J/K) = \boxed{2.3 \times 10^{-19}\ J}$$

- Also, w/ $2.2 \times 10^{-6} = A_0 \exp\left(-17{,}000/748K\right)$, $\left(\frac{Q_v}{k}\right)$ $\boxed{A_0 = 16{,}000}$

b) At $500\ ^\circ C = 773\ K$,

$$\frac{N_v}{N} = 16{,}000 \exp\left(\frac{-17{,}000}{773}\right) = 4.5 \times 10^{-6}$$

or

$\boxed{4.5 \text{ out of } 1{,}000{,}000}$

2) Unsteady-State Diffusion (semi-infinite slab)

$D = 7.0 \times 10^{-17}\ m^2/s$

$x = 1.0 \times 10^{-6}\ m$

$C_s = 0.00100$

$C_0 = 0$ (pure Si)

$C_x = 0.00035$

a) $\frac{C_x - C_0}{C_s - C_0} = \frac{0.00035}{0.00100} = 0.35$

$\downarrow$

$= 1 - \text{erf}\left(\frac{x}{2\sqrt{Dt}}\right)$

from hand-out (or table 5.1),

$$\frac{x}{2\sqrt{Dt}} \doteq 0.65 = \frac{1 \times 10^{-6}\,m}{2\left(7.0 \times 10^{-17}\,\frac{m^2}{s} \cdot t\right)^{1/2}}$$

$\downarrow$

$$\boxed{t = 8450\ s}$$

(2 hr. 20 min)

b)

x (m)	$\frac{x}{2\sqrt{Dt}}$	$\frac{C_x - 0}{C_s - 0}$	C_x (mol. fract. 6a)
0.25×10^{-6}	0.16	0.80	0.00080
0.50×10^{-6}	0.33	0.63	0.00063
0.75×10^{-6}	0.49	0.48	0.00048

$\uparrow$ from handout

c) Basis: 1 mole of ALLOY

$$0.00035 \text{ mol Ga} \left(\frac{69.72 \text{ g}}{\text{mol}}\right) = 0.024 \text{ g Ga}$$

$$0.99965 \text{ mol Si} \left(\frac{28.09 \text{ g}}{\text{mol}}\right) = 28.08 \text{ g Si}$$

$$\frac{0.024}{28.08 + 0.024} = \boxed{0.00085 \text{ wt. fract. Ga}}$$

d) $D = D_0 \exp\left(\frac{-E_A}{RT}\right)$

at 1100 °C (1373 K),

$$7.0 \times 10^{-17} \frac{m^2}{s} = D_0 \exp\left(\frac{-330{,}000 \text{ J/mol}}{8.314 \text{ J/mol-K}\,(1373 \text{ K})}\right)$$

$$D_0 = 2.5 \times 10^{-4} \frac{m^2}{s}$$

so, solve for...

$$5.0 \times 10^{-16} = 2.5 \times 10^{-4} \exp\left(\frac{-330{,}000}{8.314\,T}\right)$$

$$\boxed{T = 1473 \text{ K} = 1200 \text{ °C}}$$