Homework 5.0

Carefully review chapter 5 lecture slides and, if time allows, read textbook sections (Askeland chapter 5) and give an honor statement confirming the reading

Homework 5.1

- Explain briefly, in your own words, the difference between self-diffusion and inter-diffusion

- Compare briefly, in your own words, interstitial diffusion mechanism versus substitutional diffusion via vacancy exchange mechanism

Homework 5.2

Calculate the mass of H_2 gas that passes in five hour through a 2-mm thick Pd metal membrane with area of 0.25 m^2 at 500°C.

Known H_2 diffusion coefficient through Pd is ~1.0×10^{-4} cm^2/s, while concentrations at two sides of the membrane are 3.0 and 0.5 kg of H_2 per cubic meter of Pd metal

Assume steady-state condition, i.e., constant H_2 diffusion flux and constant H_2 concentration gradient

Total flow of H_2

$$\Delta m = |J| \cdot A \cdot \Delta t = D\frac{\Delta C}{\Delta x} \cdot A \cdot \Delta t = ?\times?\times?\times?\times? = \mathbf{0.05625}\ \boldsymbol{g}$$

Homework 5.3

The diffusion coefficients for aluminum in copper is 5.81×10^{-12} cm^2/s at 600°C and 4.05×10^{-10} cm^2/s at 800°C. Please:

1) Determine the values of pre-exponential term D_0 and diffusion activation energy Q_d.
2) What is the diffusion coefficient at 700°C?

1) Knowing,

$$5.81 \times 10^{-12} \frac{cm^2}{s} = D_0 \exp\left(-\frac{Q_D}{8.314 \frac{J}{mol \cdot K} \times 873K}\right)$$

$$4.05 \times 10^{-10} \frac{cm^2}{s} = D_0 \exp\left(-\frac{Q_D}{8.314 \frac{J}{mol \cdot K} \times 1073K}\right)$$

Take ratio,

$$? = \exp[??]$$

Activation energy

$$Q_D = \frac{?}{??} = \mathbf{165300} \frac{\boldsymbol{J}}{\boldsymbol{mol}}$$

Pre-exponential term

$$D_0 = ? \exp\left(\frac{??}{???}\right) = \cdots = \mathbf{0.045} \ \frac{\boldsymbol{cm^2}}{\boldsymbol{s}}$$

Homework 5.3 (2)

2) Diffusion coefficient at 700°C

$$D_{700C} = ? \exp\left(-\frac{??}{???}\right) = \cdots$$

$$D_{700C} = \mathbf{6.02 \times 10^{-11}\ \frac{cm^2}{s}}$$

Homework 5.4

An FCC iron-carbon alloy initially containing 0.20 wt% C is carburized at an elevated temperature and in an atmosphere that gives a surface carbon concentration constant at 1.2 wt%. If after 50 h the concentration of carbon is 0.4 wt% at a position 0.5 cm below the surface, please determine the diffusion coefficient.

For local concentration in carburization

$$C(x,t) = C_S - (C_S - C_0)\text{erf}\left(\frac{x}{2\sqrt{Dt}}\right)$$

Based on information provided,

$$??=?-(???-????)\text{erf}\left(\frac{x}{2\sqrt{Dt}}\right) \qquad \text{erf}\left(\frac{x}{2\sqrt{Dt}}\right) = \cdots = \mathbf{0.8}$$

From interpolation or Excel "Goal Seek" or others $\frac{x}{2\sqrt{Dt}} = ???$

Diffusion coefficient:

$$D = \frac{?}{??} = \cdots = \mathbf{4.23 \times 10^{-7}\,\frac{cm^2}{s}}$$

Homework 5.5

The diffusion coefficient for Al in Cu at 400 and 500 ^{o}C are 6.69x10^{-15} and 3.05x10^{-13} cm^2/s, respectively. Determine the approximate time at 400 ^{o}C that will produce the same diffusion result (i.e., diffusion length) as a 10 hour heat treatment at 500 ^{o}C.

Note that diffusion length $x \approx \sqrt{Dt}$

Essentially the diffusion length at the two temperatures are the same

$$x \approx \sqrt{D_{400C} t_{400C}} = \sqrt{D_{500C} t_{500C}}$$

$$?? = ???$$

Time needed at 400^{o}C to produce the same effect:

$$t_{400C} = \frac{?}{??} ??? = \cdots = \mathbf{462\ h}\ \text{or}\ \mathbf{\sim 19\ days}$$