**HW#5 Answer Key MSEG 302 Spring 2018.**

**1). A differential nitrogen pressure exists across a 2-mm thick steel furnace wall. After some time, steady-state diffusion of nitrogen is established across the wall. Given that the nitrogen concentration on the high-pressure side of the wall is 2 kg/m3, and on the low pressure side is 0.2 kg/m3, calculate the flow of nitrogen through the wall (in kg/m2-hr) if the diffusion coefficient for nitrogen in this steel is 1.0 x 10-10 m2/s at the furnace operating temperature.**

Steady-state, so use Fick’s first law… J = -D dC/dx

dC/dx = (Ca-Cb)/(xa-xb) = (2 – 0.2) kg/m3 / (2 x 10-3 m) = 900 kg/m4

J = 1 10-10 m2/s (900 kg/m2) (3600 s/hr) = 3.24 x 10-4 kg/m2-hr

**2). The activation energy for the diffusion of copper in silver is 193 kJ/mol. Calculate the diffusion coefficient at 927 C, given that the diffusion coefficient at 727 C is 1.0 x 10-14 m2/s.**

D = Do exp(-Qd/RT)

Qd = 193 kJ/mol, R=8.31 J/mol-K

If T=927 C, T=(927+273)=1200 K

If T=727 C, T=(727+273)=1000 K

1.0 x 10-14 m2/s = Do exp(-193000/8.31/1000), so Do = 1.22 10-4 m2/s

D(1200) = 1.22 x 10-4 m2/s exp(-193000/8.31/1200) = 4.80 10-13 m2/s

Value is higher than at 1000 K, which makes sense.

**3). From information available in Tables in Chapter 5 of the Callister text (or elsewhere), determine the diffusion coefficient for magnesium in aluminum at 450 C. What time would be required at 550 C to produce the same diffusion result (in terms of concentration at a specific point) as for 15 hrs at 450 C?**

From Table 5.2, D = Do exp[-Qd/RT], with Do = 1.2 10-4 m2/s, Qd = 130000 J/mol

So D = 1.2 10-4 m2/s exp[-130000/8.31/(450+273) = 4.81 10-14 m2/s

D = x2/t, so to get a certain extent of diffusion x need to find x = Sqrt[D t]. Setting these equal gives Sqrt[D1 t1] = Sqrt[D2 t2], or D1 t1 = D2 t2, or t2 = t1 (D1 / D2).

At 550 C, D=1.2 10-4 m2/s exp[-130000/8.31/(450+273) = 6.67 10-13 m2/s

So t2 = 15 hrs (4.81 10-14/6.67 10-13) = 1.08 hrs

**4). An FCC iron-carbon alloy initially containing a uniform concentration of 0.55 wt% carbon is put into an oxygen-rich, decarburizing furnace at 1052 C. Under these conditions carbon is completely oxidized at the surface, so the surface concentration of carbon is 0 wt%. At what position from the surface will the carbon concentration be 0.25 wt% after a 10 hr heat treatment? The diffusion coefficient for carbon in iron 1052 C is 3.3 x 10-11 m2/s.**

Non-steady state, so need Fick’s second law. Boundary conditions match those given in the text and lecture, where solution of concentration as a function of time are given by:

with erf() the Gaussian error function (native to Mathematica, or given in Tables such as 5.1 in the text).

d = 3.3 10^-11 m^2/s

t = 10 hr\*3600 s/hr

Solve[(0.25 - 0.55)/(0 - 0.55) == 1 - Erf[x/(2 Sqrt[d t])], x]

x = 9.3 10-4 m = 0.93 mm

Plotting the concentration profile at this point to check:

x = 0.00093 (m)

d = 3.3 10^-11 (m2/s)

t = 36000 (s)

Rearrange equation to solve for Cx and plot:

Plot[0.55 + (0 - 0.55) (1 - Erf[x/(2 Sqrt[d t])]), {x, 0, 0.005}]



Here y-axis is concentration in wt%, x-axis is distance in meters