Warmup:

• (From Callister) A sheet of steel 2.5 mm thick has nitrogen atmospheres on both sides at 900 °C and is permitted to achieve a steady-state diffusion condition. The diffusion coefficient for nitrogen in steel at this temperature is $1.2 \times 10^{-10} \text{ m}^2/\text{s}$, and the diffusion flux is found to be $1.0 \times 10^{-7} \text{ kg/m}^2\cdot\text{s}$. Also, it is known that the concentration of nitrogen in the steel at the high-pressure surface is 2 kg/m$^3$. How far into the sheet from this high pressure side will the concentration be 0.5 kg/m$^3$? Assume a linear concentration profile.

• Nitrogen from a gaseous phase is to be diffused into pure iron at 675 °C.
  a. If the surface concentration is maintained at 0.2 wt% N, what will be the concentration 2 mm from the surface after 25 hours? The diffusion coefficient for nitrogen in iron at 675 °C is $1.9 \times 10^{-11} \text{ m}^2/\text{s}$.
  b. How long will it take to achieve the same concentration profile at 900 °C? The diffusion rate is for nitrogen in steel at this temperature is $1.2 \times 10^{-10} \text{ m}^2/\text{s}$.

• The diffusion coefficients for nickel in iron are given at two temperatures.
  a. Determine the values of $D_0$ and $Q_d$.
  b. What is the magnitude of $D$ at 1300 °C?

<table>
<thead>
<tr>
<th>T(K)</th>
<th>D (m$^2$/s)</th>
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<tbody>
<tr>
<td>1473</td>
<td>2.2x10$^{-15}$</td>
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<tr>
<td>1673</td>
<td>4.8x10$^{-14}$</td>
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1. An FCC iron-carbon alloy initially containing 0.55 wt-% C is exposed to an oxygen-rich and virtually carbon-free atmosphere at 1325 K (1052 °C). The carbon diffuses from the alloy and reacts at the surface with the oxygen; the carbon concentration at the surface is maintained essentially at 0 wt% C. (This process of carbon depletion is known as decarburization.)
   a. At what position will the concentration be 0.25 wt% after a 10 hour treatment?
      The value of $D$ at 1325 K is $4.3 \times 10^{-11}$ m$^2$/s.
   b. The diffusion barrier is 148 kJ/mol (1.53 eV/atom). What is the diffusion rate at 1225 K?

2. Carbon is allowed to diffuse through a steel plate 10 mm thick. The concentrations of carbon at the two faces are 0.85 and 0.40 kg/cm$^3$, which are maintained constant. The preexponential and activation energies for diffusion are $6.2 \times 10^{-7}$ m$^2$/s and 80,000 J/mol, respectively.
   a. What is the diffusion rate of carbon in steel at 600 °C?
   b. Compute the temperature at which the steady-state diffusion flux is $6.3 \times 10^{-10}$ kg/(m$^2$·s).

3. A solution of Fick's 2nd law for a plate of thickness $L$ is
   $$C(x) = C(0) + x J_0 + A \exp(-t/\tau) \sin(\pi x/L)$$
   where $J_0 = [C(L)-C(0)]/L$. Find an equation for $\tau$. Estimate the value of $\tau$ for the above problem at 600 °C.

4. If pure Cu and pure Ni are in contact, and held at 1000 °C for approximately 15 minutes, voids will form in the Cu-rich region but not in the Ni-rich reason.
   a. What is the diffusion mechanism? Explain your answer.
   b. Which diffuses faster: Cu or Ni? Explain your answer.
   c. If pure Fe is put in contact with Fe that has a high concentration of interstitial C, could the same phenomenon be observed? Explain your answer.