MATE 313

Fall 2019

Homework # 3

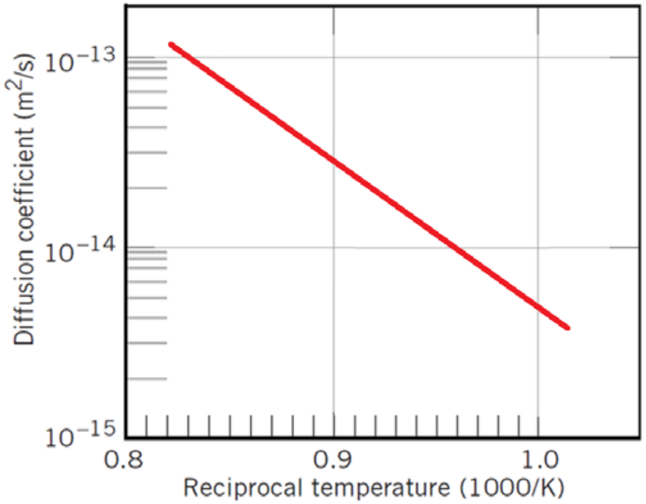
Due: November 4th, 2019

Note: This homework weighs twice the weight of other homeworks.

Group submission (up to 3 students per group) is allowed.

Question 1

Using the plot given below, determine the activation energy (Q) and preexponential (D_o) for the diffusion of Au in Ag.



D versus 1000/T plot for the diffusion of Au in Ag

Question 2

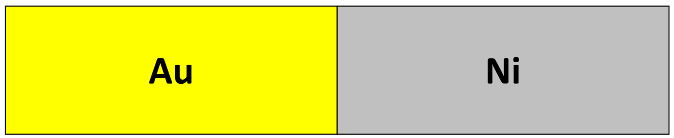
A diffusion couple including inert wires was made by plating pure copper on to a block of α-brass with a composition Cu-30 wt% Zn. After *56* days at 785°C the marker velocity was determined as 2.6×10^{-8} mm/s. Microanalysis showed that the composition at the markers was $X_{Zn} = 0.22$, $X_{Cu} = 0.78$, and that $\delta X_{Zn}/\delta x$ was -0.089 mm^{-1}. From an analysis of the complete penetration curve interdiffusion coeff (*D"*) at the markers was calculated as 4.5×10^{-13} m^2/s. Use this data to calculate D^{α}_{Zn} and D^{α}_{Cu} in brass at 22 at% Zn. Marker velocity is expressed as

$$v = -(D^{\alpha}_{Zn} - D^{\alpha}_{Cu}) \frac{\delta X_{Zn}}{\delta x}$$

Question 3

Interdiffusion in Au–Ni alloys occurs by the vacancy mechanism, and the intrinsic diffusivity of Au is always larger than that of Ni in this system. At 900°C, the interdiffusivity drops by about two orders of magnitude on going from pure Au to pure Ni.

Suppose a one-dimensional diffusion couple was made up consisting of pure Au on the left and pure Ni on the right and that inert markers were placed at the interface prior to any interdiffusion. Then the diffusion couple was heated at 900°C for a long time to allow significant interdiffusion to occur.



Question 3

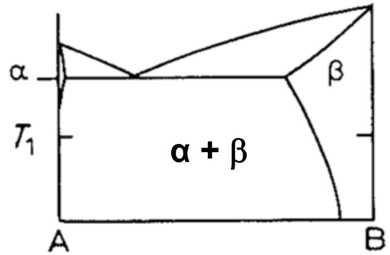
(a) Draw a schematic diagram illustrating the expected shape of the concentration of Ni vs. distance across the interdiffusion zone. Justify the shape of the curve you have drawn.

(b) Which way would the inert markers placed at the original interface move as a result of the interdiffusion? By what mechanism would they move?

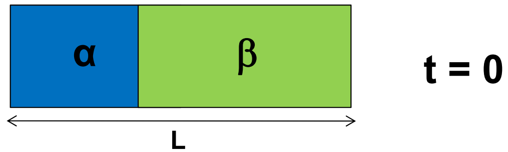
(c) The lattice constants of Au and Ni are about 0.4 and 0.36 nm, respectively (both elements are f.c.c. and there is continuous solid solubility at 900°C). Would you expect the resulting atomic size difference to contribute to the marker motion? Explain your reasoning.

Question 4

- Below is a hypothetical phase diagram for the A-B system.
- At temperature T_1 B is practically insoluble in A, whereas B can dissolve 15 atomic % A.



- A diffusion couple made by welding together pure A and pure B is annealed at T_1.



a) Show by a series of sketches how the concentration profiles and α/β interface position will vary with time.

b) If the overall composition of the couple is 65 atomic %B, what will be the maximum displacement of the α/β interface in terms of L? (Assume α and β have equal molar volumes.)

Question 5

Considering only the nearest neighbors, estimate the surface energy (J/m^2) for the {110} planes of Au.
Atomic radius of Au is 0.144 nm and its heat of sublimation is 368.4 kJ/mole. State any assumptions you make.

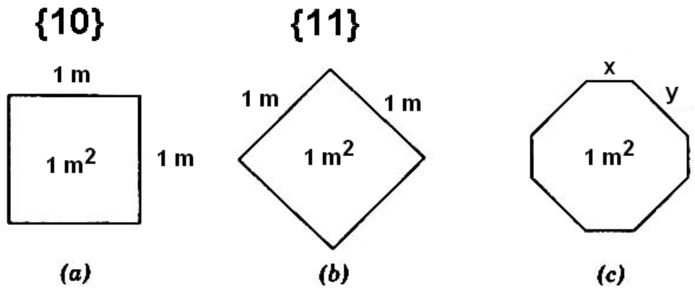
Question 6 (*20 pts*)

Consider a 2 dimensional crystal where the energies of the {10} and {11} planes (planes that are perpendicular to the paper) are 0.250 and 0.225 J/m^2, respectively.

Find

a) the values of x, y and
b) the total boundary energy

corresponding to the equilibrium shape of 1 m^2 surface area.



Question 7

Estimate the distance between dislocations in a tilt boundary of aluminum if the misorientation angle is 5º.
Lattice parameter of Al = 0.405nm. Crystal structure is FCC.

Question 8

Consider a two-phase alloy where β precipitates are to be embedded within a α matrix. Calculate the angle θ to form at the junction where two α grains meet a β grain when,

a) $5\gamma_{\alpha\alpha} = \gamma_{\alpha\beta}$

b) $\gamma_{\alpha\alpha} = 5\gamma_{\alpha\beta}$

Question 9

A steel sample with an inital average grain diameter of 8.6 µm was kept in a heat treatment furnace at 975°C for 2 hours. Metallographic examination showed that the average grain diameter increased to 18.2 µm as a result of this heat treatment.

a) <u>How much additional time</u> at the same temperature <u>is necessary</u> for the average grain size to increase to 30.5 µm?

b) If you are asked to limit the grain size at 30.5 µm by forming stable precipitates of 500 nm average diameter within this steel, what volume fraction of them do you need?