2016 Fall Qualify Exam. (Engineering Material)

1. Define (a) atomic number, (b) atomic mass unit (amu), (c) mass number, and (d) Avogadro's number. (5%)

2. Sterling silver contains 92.5 wt % silver and 7.5 wt % copper. Copper is added to silver to make the metal stronger and more durable. A small sterling silver spoon has a mass of 100 g. Calculate the number of copper and silver atoms in the spoon. (10%)


3. Calculate the lattice energy for the formation of solid NaCl if the following information is given. What does the calculated lattice energy tell you about the material (hint: Hess law)? (10%)
    (i) 109 kJ is required to convert solid Na to gaseous Na
    (ii) 121 kJ is required to convert gaseous Cl2 to two monatomic Cl atoms
    (iii) 496 kJ is required to remove the 3s1 electron of Na (form Na+ cation)
    (iv) -570 kJ of energy (energy is released) to add an electron to the Cl
    (v) -610 kJ of energy to form gaseous NaCl (heat of formation of NaCl)

4. Draw the following crystallographic planes in an FCC unit cell, and list the position coordinates of the atoms whose centers are intersected by each of the planes: (10%)
    (a) (100), (b) (110), and (c) (111)

5. A sheet of aluminum alloy is cold-rolled 25 percent to a thickness of 0.2 cm. If the sheet is then cold-rolled to a final thickness of 0.16 cm, what is the total percent cold work done? (10%)

6. (a) Calculate the equilibrium concentration of vacancies per cubic meter in pure aluminum at 550°C. Assume that the energy of formation of a vacancy in pure aluminum is 0.74 eV. (b) What is the vacancy fraction at 500°C? (use $\frac{n_v}{N} = Ce^{\frac{-E_v}{K.T}}$, $N = 6.02 \times 10^{28} atoms/m^3$, Boltzmann's constant $k = 8.62 \times 10^{-5} eV/K$, and assume $C=1$) (5%)

7. A diffusion couple shown below is prepared using two hypothetical metals A and B. After a 24-h heat treatment at 750°C (and subsequently cooling to room temperature) the concentration

of B in A is 3.0 wt% at the 4.0-mm position within metal A. If another heat treatment is conducted on an identical diffusion couple, only at 900°C for 24 h, at what position will the composition be 2.5 wt% B? Assume that the preexponential and activation energy for the diffusion coefficient are 1.5×10^{-4} m²/s and 125,000 J/mol, respectively. (use the gas constant, 8.31 J/mol-K) (10%)
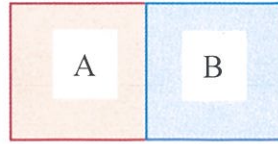
8. Consider a metal single crystal oriented such that the normal to the slip plane and the slip direction are at angles of 30° and 45° respectively, with the tensile axis. If the critical resolved shear stress is 7.5 MPa, will an applied stress of 15 MPa cause the single crystal to yield? If not, what stress will be necessary? (10%)

9. A structural component in the form of a wide plate is to be fabricated from a steel alloy that has a plane strain fracture toughness of 100 MPa·m$^{0.5}$ and a yield strength of 900 MPa. The flaw size resolution limit of the flaw detection apparatus is 5.0 mm. If the design stress is one-half of the yield strength and the value of Y is 1.0, determine whether or not a critical flaw for this plate is subject to detection. (10%)

10. For a lead–tin alloy of composition 70 wt% Sn–30 wt% Pb and at 150°C, (a) determine the mass fractions of α and β phases and (b) determine the mass fractions of primary β and eutectic microconstituents. (10%)
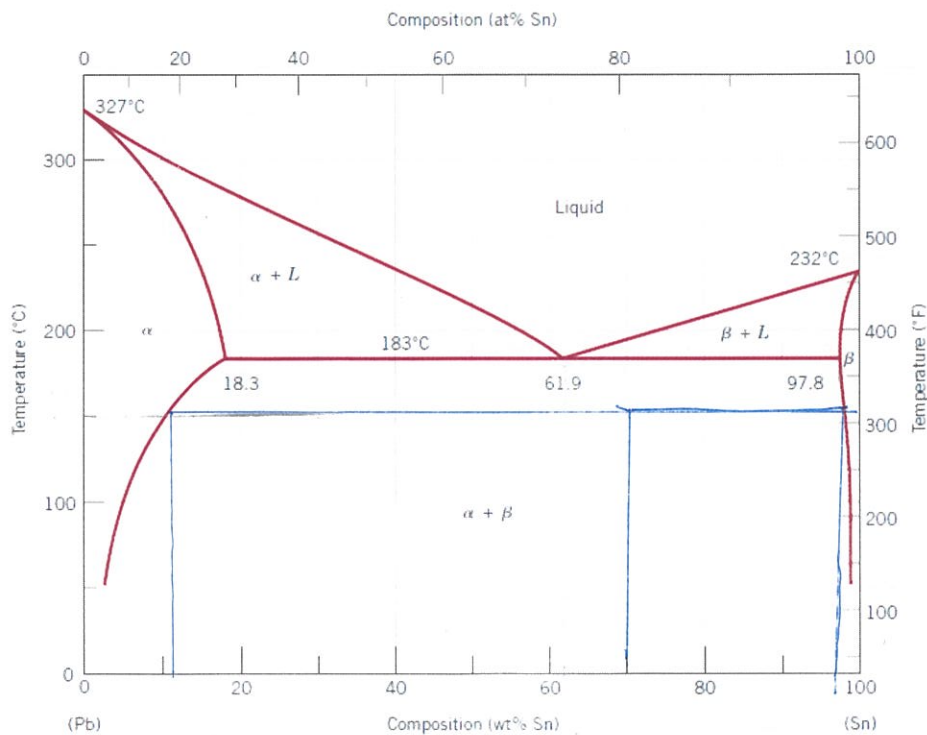
11. It is known that the kinetics of recrystallization for some alloys obey the Avrami equation, and that the value of n in the exponential is 2.5. If, at some temperature, the fraction recrystallized is 0.25 after 120 min, determine the rate of recrystallization at this temperature. (10%)