

MS 115a, Problem Set #8

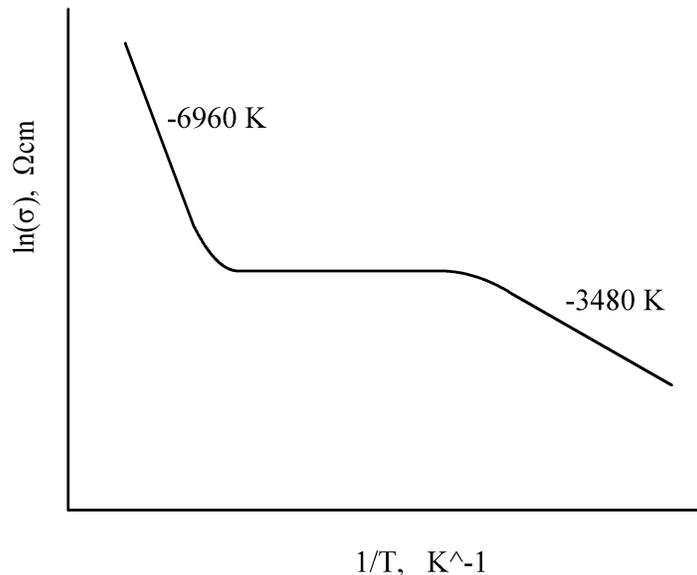
assigned 11/21/12

due 11/28/12

1. Show that the concentration of holes in the valence band of an intrinsic semiconductor is

$$\eta_h = 2 \left( \frac{2\pi m k}{h^2} \right)^{3/2} T^{3/2} \exp\left( \frac{-\epsilon_F}{k_b T} \right)$$

2. Explain why nonstoichiometric III-V compounds (where III implies Al, Ga or In and V implies P, As or Sb) are typically extrinsic semiconductors. Consider the common defects that occur in the diamond structure type.
3. The band gap energy of silicon is 1.11 eV and that of germanium is 0.67 eV. How pure do these elements need to be in order to observe intrinsic conductivity at room temperature? Assume impurities are donor species contributing one electron per atom (fully ionized) at room temperature.
4. Silicon is doped with equal concentrations of  $P^{5+}$  and  $Al^{3+}$ . How does its conductivity compare with pure Si? Explain using a density of states diagram,  $E$  (as ordinate, vertical axis) vs.  $N(E)$  (as abscissa, horizontal axis).
5. The resistivity of pure copper is  $1.72 \times 10^{-6} \Omega\text{cm}$  (273 K) and its Fermi energy 7.02 eV. (a) Estimate the electron mobility, (b) estimate the time between electron scattering events, (c) estimate the velocity of the electrons with (kinetic) energy  $E_F$ , (d) estimate the mean free path between scattering events.
6. The electrical conductivity of a p-type semiconductor has been measured and behaves as shown to the right. The numbers on the plot indicate the slope of  $\ln(\sigma)$  vs.  $1/T$ . Label the regions of this graph. Draw a schematic band diagram for this material in the form of  $E$  vs.  $N(E)$ . Indicate as many energy terms as you can (in units of eV).



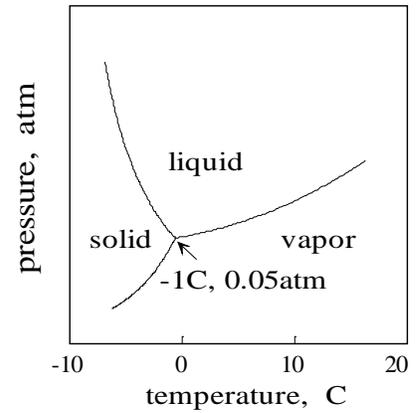
7. The phase diagram of H<sub>2</sub>O is shown to the right.

a) For T<sub>1</sub> = -5°C plot schematically

G<sub>solid</sub>, G<sub>liquid</sub> and G<sub>vapor</sub> as functions of P.

b) Do the same for T<sub>2</sub> = 10°C.

c) What is  $\left(\frac{\partial G}{\partial P}\right)_{T, \{N_i\}}$  ?



8. Show that the entropy (per mole) due to mixing of A and B atoms is given by

$$\Delta S^{\text{mix}} = -RX_A \ln X_A - RX_B \ln X_B.$$

a) Begin with the statistical definition of entropy,  $S = k_b \ln \Omega$ ,

b) Compare the entropies of the mixed and unmixed solutions (having N<sub>o</sub> atoms)

c) Use Stirling's approximation,  $\ln(N!) \sim N \ln(N) - N$  for large N, to evaluate S

d) Note the relationship between k<sub>b</sub>, R and N<sub>o</sub>.