

Self-Assessment Exam Electronic Materials

Solution Key

Write your answers on these pages.

State your assumptions and show calculations that support your conclusions.

**RESOURCES PERMITTED: PERIODIC TABLE OF THE ELEMENTS, TABLE OF CONSTANTS,
AN AID SHEET (ONE PAGE 8½" × 11"), AND A CALCULATOR.**

NO BOOKS OR OTHER NOTES ALLOWED.

Exam 2, Problem #3

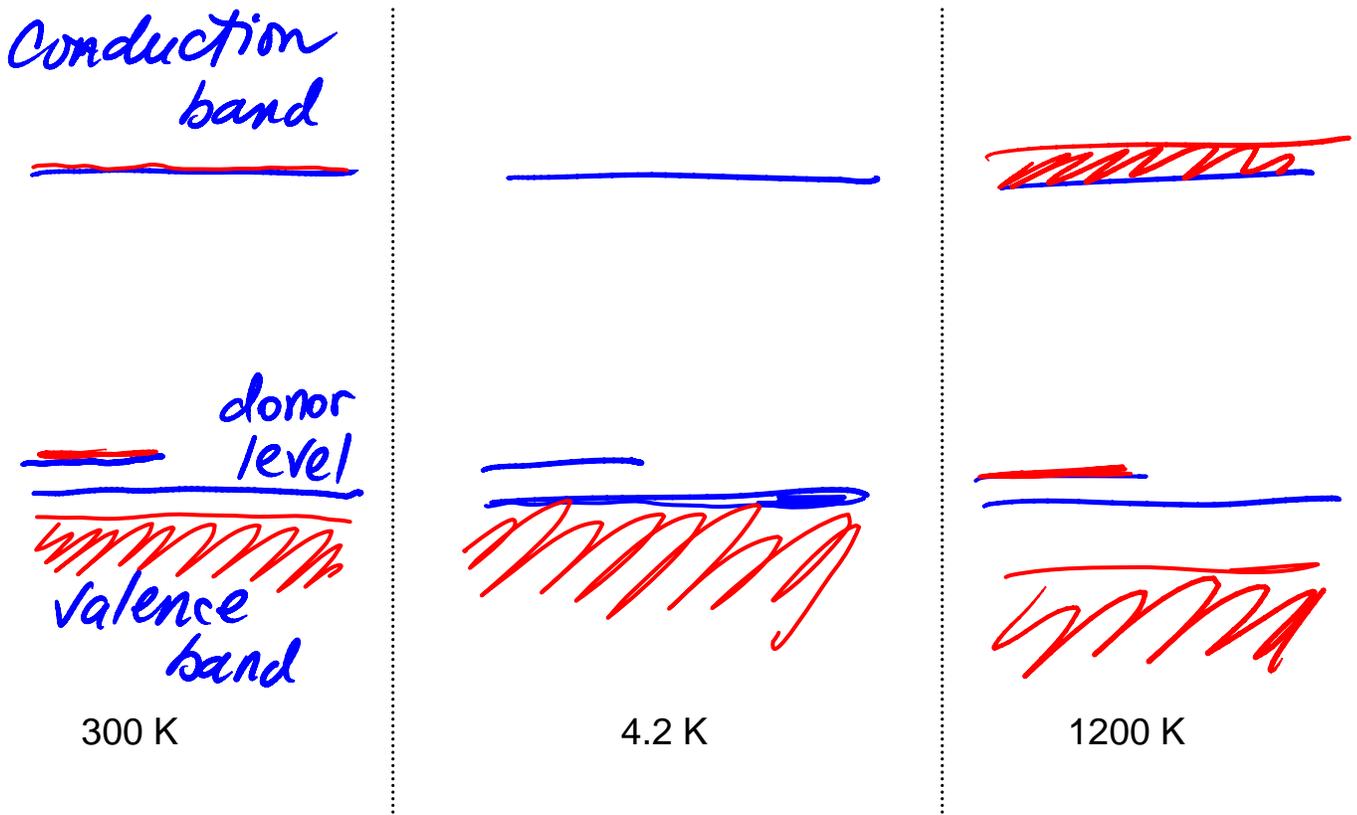
- (a) Germanium (Ge) is a semiconductor with a band gap energy, E_g , of 0.7 eV. Determine the amount (in grams) of gallium (Ga) that substitutionally incorporated into 1 kg of Ge will establish a charge-carrier concentration of 3.091×10^{17} carriers/cm³. You may assume that the temperature is sufficiently high that all of the doping states are fully ionized.

1 carrier / Ga dopant atom
 \therefore we need 3.091×10^{17} Ga atoms/cm³ Ge
 $\Rightarrow (3.091 \times 10^{17} / N_{Av} \text{ moles Ga}) \times 69.723 \frac{\text{g}}{\text{mole}} = 3.58 \times 10^{-5} \frac{\text{g Ga}}{\text{cm}^3 \text{ Ge}}$
 Volume of 1 kg Ge = $\frac{1000 \text{ g}}{5.35 \text{ g/cm}^3} = 187 \text{ cm}^3$
 \therefore mass of Ga dopant req'd = $3.58 \times 10^{-5} \times 187 = \underline{\underline{6.69 \times 10^{-3} \text{ g}}}$

- (b) Name the dominant charge carrier in Ga-doped Ge, and specify whether the material is *p*- or *n*-type.

h^+ (hole) \therefore *p*-type

- (c) Draw the schematic energy-level diagram of Ga-doped germanium indicating electron occupancy at: 300 K (room temperature); 4.2 K (cooled in liquid He); 1200 K (heated near the melting point of Ge) Label the (1) valence band, (2) conduction band, (3) energy gap, and (4) any energy levels associated with the presence of the dopant. Show electron occupancy by shading.



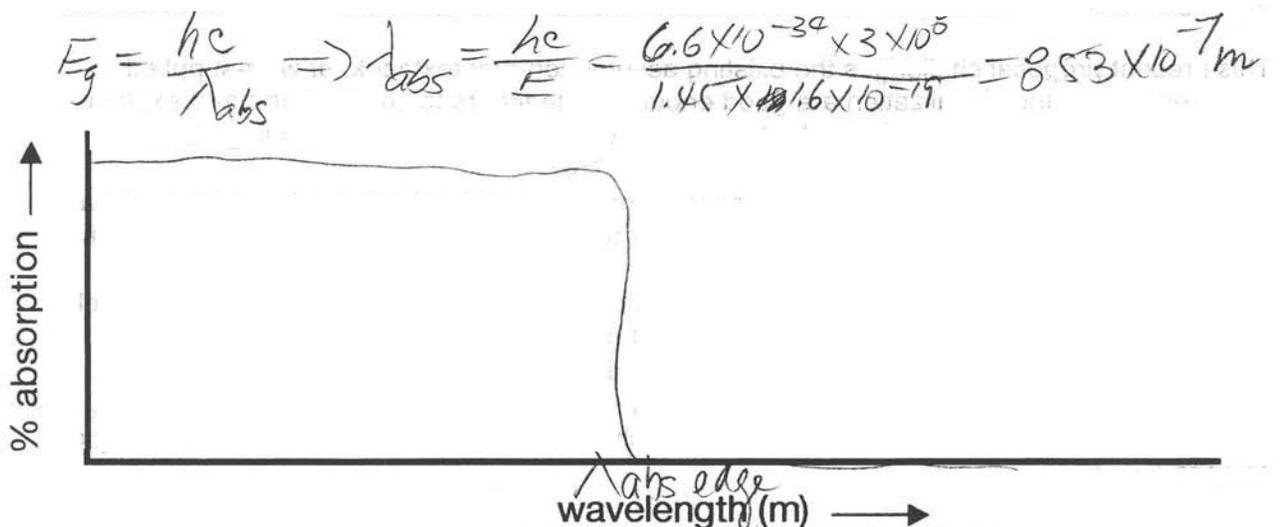
Exam 2, Problem #4

- (c) Aluminum arsenide (AlAs) is a compound semiconductor with a band gap energy, E_g , of 2.3 eV. The value of E_g can be decreased by mixing AlAs with a compound semiconductor that has a smaller band gap energy. Name one such compound semiconductor and justify your choice by making reference to the operative chemical bonding.

To produce a smaller band gap, we want a similar compound to AlAs, but with a weaker bond. One way to do this is with greater internuclear separation. So we look in group 13 (below Al) and find Ga and In; in group 15 (below As) we find Sb. Substituting these into the original lattice, three possible compounds would be: GaAs, InAs, AlSb.

Final Exam, Problem #12

- (a) Cadmium telluride (CdTe) is a semiconductor with a band gap, E_g , of 1.45 eV. On the graph below sketch the absorption spectrum of this material. Label the absorption edge and give its value.



- (b) Cadmium sulfide (CdS) is also a semiconductor. Do you expect the band gap of this material to be greater than or less than the band gap of CdTe? Explain.

Greater. S is smaller than Te, so the Cd-S bond is stronger, leading to a larger E_g .

MIT OpenCourseWare
<http://ocw.mit.edu>

3.091SC Introduction to Solid State Chemistry
Fall 2009

For information about citing these materials or our Terms of Use, visit: <http://ocw.mit.edu/terms>.