LED Assessment

Teacher Guide

Name _____

Date _____ Hour ____

Matching

Match the word with the best definition.

__F__ 1. LED

__M__ 2. doping

__H__ 3. solid solution

__N__ 4. semiconductor

__I__ 5. band gap

__L__ 6. conduction band

__C__ 7. insulator

__E__ 8. metal

__B__ 9. valence band

__K__ 10. energy band

__J__ 11. orbital

__G__ 12. isoelectronic

__A__ 13. electronegativity

__D__ 14. biasing

a. the attraction of an atom for electrons

b. the highest energy filled band that lies at the bottom of the band gap

c. a type of material that is a poor conductor of electricity

d. applying a voltage, often done to alter electrical and optical output of a device

e. a material with a partially filled energy band

f. a semiconductor p-n junction that is optimized to release light of about the band gap energy when electrons fall from the conduction band to the valence band under forward bias

g. containing the same number of electrons

h. a homogeneous solid in which one type of atom (or ion) has been substituted for a similar atom (or ion) in a structure

i. the energy separation between the top of the valence band and the bottom of the conduction band

j. a region of the atom where electrons are most likely to be found when they have a particular energy

k. a collection of orbitals closely spaced in energy

l. a band that when partially occupied by mobile electrons, permits their net movement in a particular direction

m. process by which atoms in a semiconductor are replaced with other atoms having more or less valence electrons, which leads to an excess of mobile electrons or holes, respectively

n. a substance conducting only a slight electrical current at room temperature

Multiple Choice

Choose the best answer.

__C__ 15. An example of a solid that possesses the zinc blende structure is

a. NaCl
b. CsCl
c. GaAs
d. Zn

__D__ 16. Energies of the electrons *within any one isolated atom* exhibit all these characteristics **EXCEPT**

a. At most, only two electrons may occupy any one orbital.
b. Electrons within the same orbital must "spin" in opposite directions.
c. Electrons fill the lowest energy levels first.
d. Electrons occupy spaces in between energy levels.

__B__ 17. Although the alkaline earth metals have their s orbitals filled and the p orbitals empty, overlapping occurs because

a. a "bridge" exists between the two types of orbitals.
b. the lowest levels of the p band are lower in energy than the upper levels of the s band.
c. the highest levels of the p band are lower in energy than the upper levels of the s band.
d. the lowest levels of the p band are higher in energy then the upper levels of the s band.

__D__ 18. If a material has a band gap in the ultraviolet portion of the spectrum, it will appear

a. black
b. red
c. violet
d. colorless

__B__ 19. A semiconducting solid solution used in manufacturing an LED has the zinc blende structure and the chemical formula $Al_xGa_{0.35}As_yP_{0.80}$, where

a. x = 0.80 y = 0.35
b. x = 0.65 y = 0.20
c. x = 1.00 y = 0.00
d. x = 0.20 y = 0.65

__A__ 20. For electrical conductivity two conditions are necessary, namely

a. the presence of charged particles and their ability to move.
b. the presence of charged particles and their stability.
c. the presence of neutral atoms and their ability to move.
d. the presence of neutral atoms and their stability.

__D__ 21. As the size of atoms increase in a solid, the accompanying orbital overlaps

a. are increased, and the resulting energy gaps get larger.
b. are increased, and the resulting energy gaps get smaller.
c. are reduced, and the resulting energy gaps get larger.
d. are reduced, and the resulting energy gaps get smaller.

True/False

If the statement is true, write true on the line. If the statement is false, correct the underlined word and place that on the line.

_____Top___ 22. Only electrons near the bottom of the filled orbitals of a band contribute to electrical conductivity

.

_____True___ 23. LEDs last longer, are brighter, and are more efficient than incandescent lights.

_____True___ 24. Solids having atoms of comparable sizes and forming the zinc blende structure can be combined to form solid solutions.

countless # of_ 25. Solid solutions can be formed in a few stoichiometries, which allows the "tuning" of band gap energies.

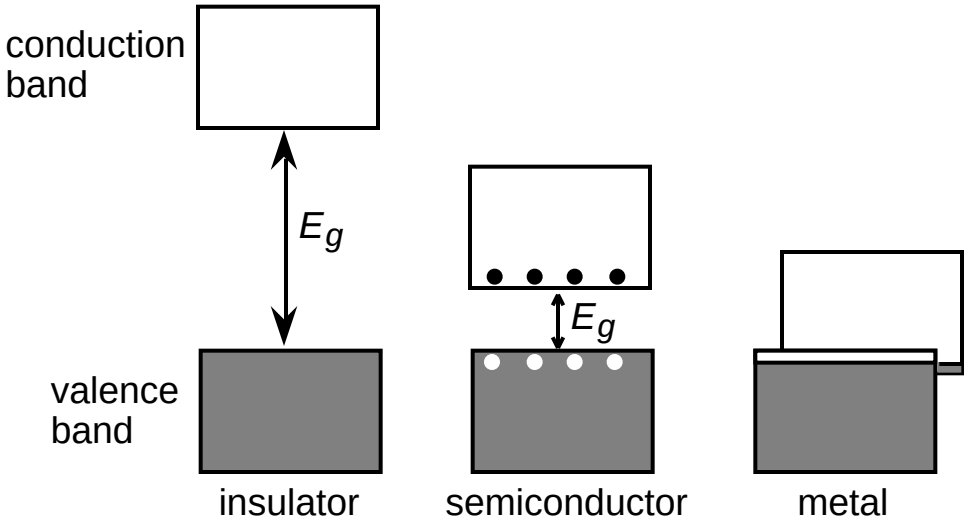
__the same #__ 26. Elements having the zinc blende structure contain different numbers of valence electrons.

Problems

27. Suppose you want to create a red cutoff filter (of all the colors in the visible region of the spectrum, the filter will transmit only red light). What should the band gap be to make such a filter out of a semiconductor?

If red light is to be transmitted (not absorbed), then the material should have a band gap that allows it to absorb in the orange region. (This corresponds to a band gap energy of ~2.0 eV.

28. Sketch the band-structure diagrams for an insulator, a semiconductor, and a metal.



Schematic band-structure diagrams for an insulator, a semiconductor, and a metal. The band gap, E_g, shown as the double-headed arrow, is the separation between the top of the valence band and the bottom of the conduction band. The size of the band gap energy decreases in passing from an insulator to a semiconductor to a metal. Electron–hole pairs are shown for a semiconductor as filled circles in the conduction band (electrons) and open circles in the valence band.

29. Name two solids with the zinc blende structure that are isoelectronic with α-Sn, and predict how their band gaps will compare to that of α-Sn.

InSb and CdTe are isoelectronic with α-Sn. α-Sn is metallic with a small band gap. Ionic character increases with the difference in electronegativity between atoms A and Z. As ionic character increases, so does E_g. The expected trend in band-gap energies is Sn < InSb < CdTe

30. Suggest a two-element (binary) compound that is isoelectronic with diamond; such a material might be expected to rival diamond in hardness.

BN is isoelectronic with diamond and is also extremely hard.

31. Explain why $CdSnP_2$ has the same valence electron count as GaAs.

Phosphorus has the same number of valence electrons as arsenic, so substitution of As with P does not change the valence count. Cadmium has one less valence electron than gallium, but tin has one more electron than gallium. Substituting one half of the Ga atoms with Cd and the other half with Sn leads to the same valence count $Cd_{0.5}Sn_{0.5}P = CdSnP_2$.

32. Which contain partially filled bands and why: Mg, Si, and NaCl?

Mg: Mg is an example of a metal. The Mg 3s band is filled but overlaps the Mg 3p band to create a partially filled band.

Si: Si is an example of a semiconductor. At relatively low temperatures few electrons would be in the conduction band, whereas at higher temperatures a greater fraction of the electrons are promoted from the valence band to the conduction band; thus, partially filled bands are created.

NaCl: NaCl is an example of an ionic insulator. Due to the large band gap energy in NaCl, this insulator contains bands that are either full or empty of electrons.

33. Some LED materials can be prepared by combining Ga, In, As, and P in the zinc blende structure. If the formula of one such solid is $Ga_{0.4}In_xAs_yP_{0.7}$, what are x and y equal to, and how would you interpret this formula based on the zinc blende structure?

x = 0.6; y = 0.3 the gallium and indium atoms occupy positions equivalent to zinc in the zinc blende; the arsenic and phosphorus atoms occupy positions equivalent to sulfur in zinc blende. The 1:1 stoichiometry of Zn:S dictates that the sum of the Ga and In must be equal to the sum of As and P atoms present in the solid.