produces a ***p*-type** semiconductor in which positive **holes** carry the current. The energy level of impurity atoms lies slightly below the conduction band in an *n*-type semiconductor, and acts as a **donor** from which electrons readily pass into the conduction band. The energy level of impurity atoms in a *p*-type semiconductor lies slightly above the valence band and acts as an **acceptor** level, since electrons from the valence band easily reach it, leaving holes behind to act as charge carriers.

A semiconductor **diode** consists of a ***pn* junction** and allows current to flow in one direction only; it can be used as a **rectifier** to change ac to dc. Common **transistors** consist of three semiconductor sections, either as ***pnp*** or ***npn***. Transistors can amplify electrical signals and find many other uses. An integrated circuit consists of a tiny semiconductor crystal or **chip** on which many transistors, diodes, resistors, and other circuit elements have been constructed using careful placement of impurities.

Questions

*1. What type of bond would you expect for (*a*) the N_2 molecule, (*b*) the HCl molecule, (*c*) Fe atoms in a solid?

*2. Describe how the molecule $CaCl_2$ could be formed.

*3. Does the H_2 molecule have a permanent dipole moment? Does O_2? Does H_2O? Explain.

*4. Although the molecule H_3 is not stable, the ion H_3^+ is. Explain, using the Pauli exclusion principle.

*5. The energy of a molecule can be divided into four categories. What are they?

*6. Would you expect the molecule H_2^+ to be stable? If so, where would the single electron spend most of its time?

*7. Explain why the carbon atom ($Z = 6$) usually forms four bonds with hydrogen-like atoms.

*8. If conduction electrons are free to roam about in a metal, why don't they leave the metal entirely?

*9. Explain why the resistivity of metals increases with temperature whereas the resistivity of semiconductors may decrease with increasing temperature.

*10. Figure 29–33 shows a "bridge-type" full-wave rectifier. Explain how the current is rectified and how current flows during each half cycle.

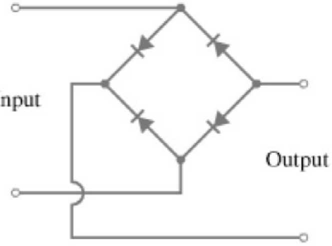

FIGURE 29–33 Question 10.

*11. Compare the resistance of a *pn* junction diode connected in forward bias to its resistance when connected in reverse bias.

*12. Explain how a transistor could be used as a switch.

*13. What is the main difference between *n*-type and *p*-type semiconductors?

*14. Describe how a *pnp* transistor can operate as an amplifier.

*15. In a transistor, the base–emitter junction and the base–collector junction are essentially diodes. Are these junctions reverse-biased or forward-biased in the application shown in Fig. 29–32?

*16. A transistor can amplify an electronic signal, meaning it can increase the power of an input signal. Where does it get the energy to increase the power?

*17. A silicon semiconductor is doped with phosphorus. Will these atoms be donors or acceptors? What type of semiconductor will this be?

*18. Do diodes and transistors obey Ohm's law? Explain.

*19. Can a diode be used to amplify a signal? Explain.

Problems

*29–1 to 29–3 Molecular Bonds

*1. (I) Estimate the binding energy of a KCl molecule by calculating the electrostatic potential energy when the K^+ and Cl^- ions are at their stable separation of 0.28 nm. Assume each has a charge of magnitude 1.0*e*.

*2. (II) The measured binding energy of KCl is 4.43 eV. From the result of Problem 1, estimate the contribution to the binding energy of the repelling electron clouds at the equilibrium distance $r_0 = 0.28$ nm.

*3. (II) Estimate the binding energy of the H_2 molecule, assuming the two H nuclei are 0.074 nm apart and the two electrons spend 33% of their time midway between them.

*4. (II) Binding energies are often measured experimentally in kcal per mole, and then the binding energy in eV per molecule is calculated from that result. What is the conversion factor in going from kcal per mole to eV per molecule? What is the binding energy of KCl ($= 4.43$ eV) in kcal per mole?

*5. (III) (*a*) Apply reasoning similar to that in the text for the $S = 0$ and $S = 1$ states in the formation of the H_2 molecule to show why the molecule He_2 is *not* formed. (*b*) Explain why the He_2^+ molecular ion *could* form. (Experiment shows it has a binding energy of 3.1 eV at $r_0 = 0.11$ nm.)

*29–4 Molecular Spectra

*6. (I) Show that the quantity $\hbar^2/I$ has units of energy.

*7. (II) The so-called "characteristic rotational energy," $\hbar^2/2I$, for N_2 is 2.48×10^{-4} eV. Calculate the N_2 bond length.

*8. (II) (*a*) Calculate the characteristic rotational energy, $\hbar^2/2I$, for the O_2 molecule whose bond length is 0.121 nm. (*b*) What are the energy and wavelength of photons emitted in a $L = 2$ to $L = 1$ transition?

*9. (II) The equilibrium separation of H atoms in the H_2 molecule is 0.074 nm (Fig. 29–8). Calculate the energies and wavelengths of photons for the rotational transitions (*a*) $L = 1$ to $L = 0$, (*b*) $L = 2$ to $L = 1$, and (*c*) $L = 3$ to $L = 2$.