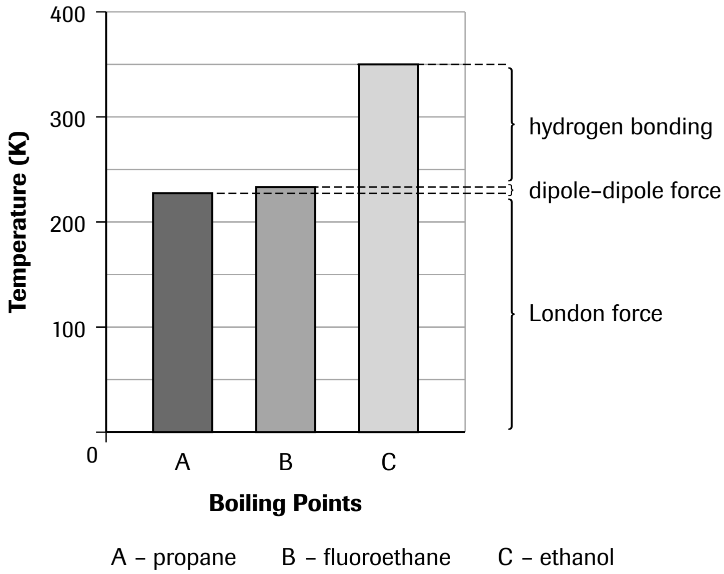
Extensions

15. The London force is affected by the shape and structure of adjacent molecules. The key variables are the distance between charge points, and the number of charge points that can approach closely. Molecules that have a shape that allows them to pack closely together have attractions that are stronger because the distances separating charges are less. Molecules with shapes closer to planar (like a sheet of paper) than spherical (like a ball) will attract more strongly.
16. (a)



(b) Based on the boiling point graph for these isoelectronic liquids, London force contributes most to intermolecular attraction, hydrogen bonding is usually less significant (about one-half in this example), and dipole–dipole force is almost insignificant.

4.6 THE STRUCTURE AND PROPERTIES OF SOLIDS

PRACTICE

(Page 273)

Understanding Concepts

1. The main factors that determine the hardness of a solid are the strength and direction of bonds between its entities.
2. (a) covalent bonding covalent network crystal
   (b) ionic bonding ionic crystal
   (c) covalent bonding molecular crystal
   (d) covalent bonding covalent network crystal
   (e) metallic bonding metallic crystal
   (f) ionic bonding ionic crystal
3. The melting point of a solid is proportional to the attractive forces between the entities of the solid. Strong bonds like covalent bonds will result in very high melting points, while much weaker bonds like London forces will result in lower melting points.
4. Metals are generally malleable, ductile, and flexible because the bonding between atoms in metals is nondirectional—so changing the position of the atoms (shape of the solid) does not “break” the bonding.
5. (a) Aluminum is a light, soft, flexible, silvery metal solid, with a fairly low melting point for metals. Aluminum oxide is a very hard network crystalline solid with an extremely high melting point. In aluminum, the bonding is metallic bonds of a lower-than-average strength for metals. In aluminum oxide, very strong ionic bonds lock the aluminum and oxygen ions in a rigid three-dimensional network.
   (b) Carbon dioxide is a soft molecular solid with a very low boiling point. Silicon carbide is a very hard network crystal solid with an extremely high boiling point. In carbon dioxide, the molecules are held together by relatively weak nondirectional London forces only. In silicon carbide, the silicon and carbon atoms are locked in a three-dimensional network by very strong covalent bonds.

6. (a) The blade must be oriented in the same direction as the plane of the atoms (or ions) in the crystal because the crystal can only break along these “cleavage” planes.
   (b) To cleave a sodium chloride crystal, the knife blade should be perpendicular to a crystal face because the crystal is a cube and planes of ions are at 90° to each other.
   (c) The crystal will shatter into small pieces if struck incorrectly.
   (d) Diamonds and other precious stones are cut into smaller gemstones by this technique before they are polished.
7. (a) high melting point, conducts electricity — vanadium, $V_{(s)}$
   (b) low melting point, soft — phosphorus pentoxide, $P_2O_{5(s)}$
   (c) high melting point, soluble in water — sodium bromide, $NaBr_{(s)}$
   (d) very high melting point, non-conductor — silicon dioxide, $SiO_{2(s)}$

Applying Inquiry Skills

8. (a) It seems logical to assume that conductivity of electric current and of heat are related.
   (b) Thick wires of equal diameter and length, made of several common metals, are tested for electrical conductivity with an electrical multimeter. The same wires are tested for heat conduction by heating one end and recording the time for the other end to reach a specified temperature. The independent variable is the type of metal; the dependent variables are the electrical conductivity and time to heat; and the controlled variables are length, diameter, initial temperature, final temperature, and heat source.
   (A common laboratory device has spokes of different metals with a concave end to attach a blob of wax. The relative heat conductivity can be determined by noting the order or time for the wax to fall off each metal.)

Making Connections

9. Graphite may be better than oil in lubricating moving parts of a machine because it is a powdered solid—a dry lubricant that will not stick to dirt, or cake or build up on moving parts. Graphite may also be more stable at higher temperatures than an oil.
10. Nitinol is a nickel-titanium mixture in about a 55%–45% proportion by mass. It has two distinct crystalline structures, called martensitic and austenitic after crystal structure first observed in steels. It exhibits unique properties of “shape memory” and “superelasticity.” It can be deformed easily in the martensitic form, and will return to its original shape upon heating. In its austenitic form, it is extremely elastic, allowing it to be bent severely without breaking or changing the shape to which it returns. Superelasticity is used in making eyeglass frames, cell phone antennas, orthodontic wires and surgical probes that are far more flexible than if made with other metals. Thermal “memory” has a host of medical applications for devices that take final shape only after they are inserted in the body, like vertebral spacers, and heart valve instruments that can be shaped to a patient for an operation, and then returned to original shape later for reuse.
11. (a) Moissanite has a refractive index of 2.67±2, dispersion of 0.104, hardness of 9.25, and specific gravity of 3.21. Diamond has a refractive index of 2.42, dispersion of 0.044, hardness of 10, and specific gravity of 3.52.
   (b) In theory, any of these properties could distinguish the two materials, given precise measuring equipment and time. Finding specific gravity, for example, requires very precise measure of mass and volume for very small objects.
   (c) Jewellers normally distinguish diamonds from other stones by thermal conductivity, but this doesn’t work with moissanite. The only device that can currently distinguish diamond from moissanite uses absorption of UV light as its operating principle. The stone is first tested for thermal conduction to ensure that it is either diamond or moissanite, and then is tested with the UV sensor device. Diamond transmits certain UV frequencies which moissanite absorbs.

Extension

12. If graphite did not conduct electricity, one might assume that it was composed of double sheets of carbons bonded together, explaining why there are no free electrons. The double sheets should slide over each other still, because they would not be bonded except by London forces.

CAREERS IN CHEMISTRY

PRACTICE

(Page 275)

Making Connections

1. (Reports will vary, but almost all universities provide excellent web site biographical information on faculty members. In Ontario, Dr. LeRoy (Waterloo) and Drs. Gillespie and Bader (McMaster) are examples already used in this course.)

SECTION 4.6 QUESTIONS

(Page 276)

Understanding Concepts

1. Ionic substances do not conduct while solid because all ions are locked in position. Upon melting, the ions are free to move and the substance conducts freely. In aqueous solution, the ions are also free to move and the solution will conduct more or less well, depending on concentration.
2. A substance conducts electricity when its particles have a charge and are free to move, meaning the particles must be held only by weak forces.
3. In calcium oxide, the ions have double the charge that the ions in sodium chloride have, creating a significantly greater interionic attraction.
4. In solid carbon dioxide, the bonding consists of London forces between molecules. These relatively weak forces result in very low melting and boiling points, and make the solid a soft substance. By contrast, in silicon dioxide, the bonding consists of a continuous network of covalent bonds between atoms. These very strong forces result in very high melting and boiling points, and make the solid a very hard, brittle substance.
5. Most metals have a relatively high density because their atoms are closely packed together in solid form, held together strongly by mobile valence electrons that are dispersed throughout a structure of positive ions.
6. Covalent network structures have the highest hardnesses and also the highest melting and boiling points, indicating that covalent bonds are the strongest. Molecular structures have the lowest values for these properties, indicating that intermolecular bonding forces are the weakest. Metals and ionic compound properties fall between these first two, but the values for both metals and ionic compounds vary widely, depending on the specific substance.
7. Rubbing your zipper with your pencil will coat it with graphite which will act as a lubricant. Graphite crystals form in layers one atom thick held to each other only by very weak London force, so they slide very easily over each other.
8. Diamond is composed of carbon atoms bonded four times each in a three-dimensional covalent network. It is a colourless solid, extremely hard, and a nonconductor. Its main use is as an abrasive; pure crystals are used as gemstones.

   Graphite is composed of carbon atoms bonded three times each in a two-dimensional covalent network resulting in layers one atom thick which are held to each other by London force. It is a grey-black solid, very soft and slippery, and a good electrical conductor because of the mobility of the delocalized, unbonded fourth electron of each carbon atom. It has a myriad of uses in industry, most of which have to do with its high melting point and lubricant properties.

Applying Inquiry Skills

9. XCl_a must be an ionic compound. The high melting point suggests that it has very strong bonding holding the entities together, but is water soluble, so it is not likely a covalent network crystal.

   YCl_b must be a molecular compound. The melting and boiling points are low, indicating London forces holding the entities together. The solubility argues that the molecules are nonpolar.

Making Connections

10. (Note: Many answers are possible.)

    Molecular research in the medical and pharmaceutical fields has produced materials such as human insulin for diabetics, and diagnostic devices such as MRI scans. The plastics industry has produced new contact lens materials and many new fabrics and containers and construction materials. The electronics industry has created new products like rechargeable NiMH batteries, fuel cells, and LEDs for traffic lights.
11. Clay is a term that refers to a general class of minerals produced by long-term weathering of igneous rock into very tiny particles—usually less than a few micrometres in size. The predominant compound present (of a very complex mixture)—in the clays that can be heated to produce pottery—is normally kaolinite, $Al_2Si_2O_5(OH)_{4(s)}$. In general, all clays may be thought of as hydrated aluminum silicates with varying amounts of other atoms, such as K, Mg, Fe, and Ca included in the mineral's crystal structure. All clays contain at least some tiny particles of SiO_2 and Al_2O_3.

    Ceramic is a term that refers to any manufactured materials that have essentially a network crystalline structure. This includes abrasives, porcelain, china, refractories (heat-shielding materials), structural clay products (brick and pottery), electrical ceramics (for electronics), and glasses. Glasses account for nearly half of all ceramic production.

    Clay, when wet, is a soft, slippery plastic material. It is easily moulded into shapes, because the tiny particles are attracted to each other by low-strength London forces and hydrogen bonds. By heating these silicaceous minerals at very high temperatures, new bonds form to change the material into a very hard, brittle network solid. The networks are mostly covalent—but also somewhat ionic—in crystalline character. The bonding structure is extremely complex, but may be thought of as a tetrahedral silicon-oxygen network modified with many substituted atoms and ions, all held together within an overall glass structure. All glasses have a crystal structure that is unique—the arrangement of atoms in glasses is like the arrangement in liquids—because there is no regular repetitive pattern to the structure.

12. Boron nitride, $BN_{(s)}$, is a network covalent compound with unique properties. It has very high melting and boiling points, conducts heat well, is a soft slippery solid like graphite, but unlike graphite, is a nonconductor of electricity. It is used as an additive to plastics, ceramic mixes, and lubricants, where it adds lubricating and thermal transmission properties and, to ceramics, increased strength. It can be used as a dry lubricant in powdered form. The network structure is planar hexagonal sheets, much like graphite, except that the hexagon corners are alternating B and N atoms. As in graphite, the atoms within a single crystal sheet of boron nitride are strongly bonded with covalent bonds, while each sheet is attracted to the next only by London force.
13. Biological computers have been a scientific dream for years. The progressive technology of miniaturization is driven by the fact that the more transistors one can place on a microchip, the faster and more powerful the processor will be. The logical limit to miniaturization is at the level where individual switches would be molecular (or even atomic) in size. Current mechanical computers depend on a huge number of possible circuits through microscopic transistor "switches" engraved photographically on silicon-based semiconducting microchips.

    Recently, Dr. Ehud Shapiro, working at the Weismann Institute in Israel, constructed a different kind of mechanical computer that is designed along the theoretical lines of proposed biological computers. The key point here is that such a computer operates as a continuous ribbon of individual information "cells." These cells are scanned by a read/write head that moves along the ribbon from cell to cell, reading symbols, writing symbols, and changing its control state as it goes. Alan Turing created such a concept on paper in 1936, and the system has been called a Turing Machine ever since. Biologists believe that ribosomes operate in a somewhat similar fashion—they may be thought of as biological computers preprogrammed by messenger RNA to assemble proteins.

    Scientists theorize that someday the ability to build such computers from biological components might result, for example, in microscopic devices that could be programmed to adjust any desired chemical levels within the body. Perhaps they might also produce needed proteins on demand, and replace many or most medical treatments now in existence. The possibilities seem endless, and will certainly include applications not yet dreamed of.

CHAPTER 4 LAB ACTIVITIES

ACTIVITY 4.3.1 SHAPES OF MOLECULES

(Page 277)

Prediction

(a) According to the VSEPR theory,

CCl_4 should be tetrahedral, with 4 bond pairs around the carbon atom.

C_2Cl_4 should be trigonal planar at each end, with three groups of electrons (one double bond and two single bonds) around each carbon atom. The overall molecule should be flat (i.e., in one plane).

C_2F_2 should be linear around each carbon atom, with two groups of electons (a triple bond and a single bond) around each carbon atom. The overall shape of the molecule should also be linear.

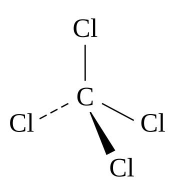
NCl_3 should be pyramidal, with 3 bond pairs and 1 lone pair around the nitrogen atom.

OF_2 should be V-shaped, with 2 bond pairs and 2 lone pairs around the oxygen atom.

NH_2OH should be pyramidal around the nitrogen, with 3 bond pairs and 1 lone pair around the nitrogen atom; and V-shaped around the oxygen, with 2 bond pairs and 2 lone pairs around the oxygen atom. There is no simple description of the overall shape of the whole molecule.

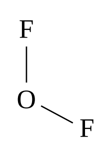
Evidence/Analysis

(b)

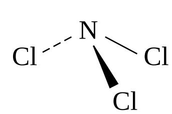


tetrahedral

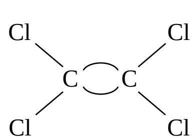
linear



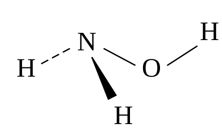
V– shape



pyramidal



trigonal planar



pyramidal (N)
V– shape (O)