(e) $\cdot\ddot{\underset{\cdot}{\mathrm{Sb}}}\cdot$

(f) $:\ddot{\underset{\cdot\cdot}{\mathrm{Kr}}}:$

(g) $\dot{\mathrm{Ba}}\cdot$

5. (a) H^+
   (b) K^+
   (c) F^-
   (d) Mg^{2+}
   (e) S^{2-}
6. (a) $[\mathrm{H}]^+$
   (b) $[\mathrm{K}]^+$
   (c) $[:\ddot{\underset{\cdot\cdot}{\mathrm{F}}}:]^-$
   (d) $[\mathrm{Mg}]^{2+}$
   (e) $[:\ddot{\underset{\cdot\cdot}{\mathrm{S}}}:]^{2-}$

   All the Lewis symbols have full outer shells (consisting of eight electrons). Positive ions have emptied their outermost shells, and negative ions have filled their outermost shells. The rule that is being followed is the octet rule.
7. (a) $\mathrm{K}^{\times} + \cdot\ddot{\underset{\cdot\cdot}{\mathrm{Cl}}}: \rightarrow \mathrm{K}{}^{\times}_{\cdot}\ddot{\underset{\cdot\cdot}{\mathrm{Cl}}}:$
   (b) $\overset{\times}{\mathrm{Mg}}{}^{\times} + \cdot\dot{\underset{\cdot\cdot}{\mathrm{S}}}: \rightarrow \mathrm{Mg}{}^{\times}_{\times}\overset{\times}{\underset{\cdot\cdot}{\mathrm{S}}}:$

Applying Inquiry Skills

8. (a) Obtain a small sample of an ionic solid, such as a piece of chalk (calcium carbonate, $CaCO_{3(s)}$). Use a low-voltage conductivity apparatus to test the electrical conductivity of the sample. Record your observations.
   (b) In liquid form, ionic compounds conduct electricity.
   (c) Ionic compounds are solids at room temperature. As solids, they are nonconductors of electricity. However, as liquids, they conduct electricity quite well. Some examples of molten ionic compounds are sodium chloride (melts at 801°C) and aluminum oxide, Al_2O_3 (melts at 2000°C). When dissolved in water, ionic compounds produce solutions that conduct electricity.
   (d) In the solid state, ionic compounds do not conduct electricity. In ionic solids, the ions are tightly held in the crystal structure, so they are not free to move and carry electric charge. When an ionic compound is melted, or dissolved (dissociated) in water, the attractive forces are overcome and the crystal breaks up. The ions are now free to move and carry electric charge.

1.12 COVALENT BONDING

PRACTICE

(Page 39)

Understanding Concepts

1. The two bromine atoms are placed side by side.

   $:\ddot{\underset{\cdot\cdot}{\mathrm{Br}}}\cdot\ \ {}^{\times}\overset{\times\times}{\underset{\times\times}{\mathrm{Br}}}{}^{\times}_{\times}$

   Electron pairs are arranged so that each bromine atom is surrounded by eight electrons, satisfying the octet rule. There is one shared pair of electrons.

   $:\ddot{\underset{\cdot\cdot}{\mathrm{Br}}}{}^{\cdot}_{\times}\overset{\times\times}{\underset{\times\times}{\mathrm{Br}}}{}^{\times}_{\times}$

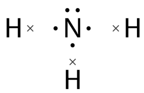
   A line is drawn to represent the shared pair of electrons between the two bromine atoms.

   $:\ddot{\underset{\cdot\cdot}{\mathrm{Br}}} — \overset{\times\times}{\underset{\times\times}{\mathrm{Br}}}{}^{\times}_{\times}$

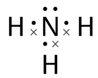
   The final chemical equation is

   $:\ddot{\underset{\cdot\cdot}{\mathrm{Br}}}\cdot + {}^{\times}\overset{\times\times}{\underset{\times\times}{\mathrm{Br}}}{}^{\times}_{\times} \rightarrow :\ddot{\underset{\cdot\cdot}{\mathrm{Br}}} — \overset{\times\times}{\underset{\times\times}{\mathrm{Br}}}{}^{\times}_{\times}$

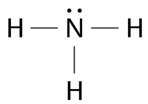
2. The nitrogen atom is placed in the centre of the molecule, surrounded by three hydrogen atoms.



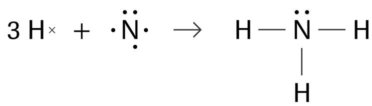
Electron pairs are arranged so that the nitrogen atom is surrounded by eight electrons, satisfying the octet rule. Hydrogen only requires two electrons in order to be stable. There is one shared pair of electrons between each hydrogen atom and the nitrogen atom.



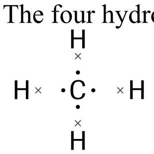
Lines are drawn to represent the shared pair of electrons between the hydrogen atoms and the nitrogen atom.



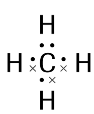
The final chemical equation is



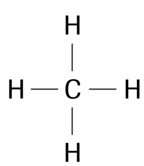
3. The four hydrogen atoms surround the lone carbon atom in the centre.



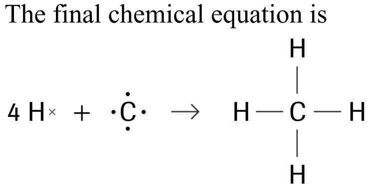
Electron pairs are arranged so that the carbon atom is surrounded by eight electrons, satisfying the octet rule. Each hydrogen atom is also stable, with two electrons.



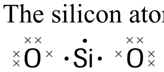
A line is drawn to represent the shared pair of electrons between the four hydrogen atoms and the carbon atom.



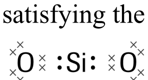
The final chemical equation is



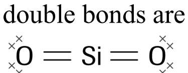
4. The silicon atom is placed between the two oxygen atoms.



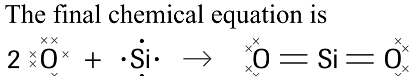
Electron pairs are arranged so that both oxygen atoms and the silicon atom are surrounded by eight electrons, satisfying the octet rule. There are two shared pairs of electrons between each oxygen atom and the silicon atom.



Lines are drawn to represent the shared pair of electrons between the oxygen atoms and the silicon atom. Two double bonds are formed.



The final chemical equation is

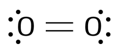
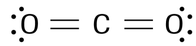
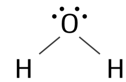
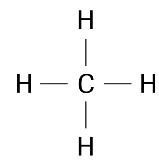
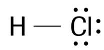
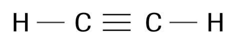
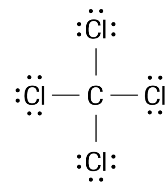


TRY THIS ACTIVITY: BUILDING MOLECULAR MODELS

(Page 44)

(a)

Table 2 Lewis Structures

O_2	CO_2	H_2O	CH_4
			
H_2	**HCl**	**C_2H_2**	**CCl_4**
			

(b) O_2—linear
CO_2—linear
H_2O—bent
CH_4—tetrahedral
H_2—linear
HCl—linear
C_2H_2—linear
CCl_4—tetrahedral

(c) The holes in the round pieces represent the unpaired (bonding) electrons in the atom. The pegs or springs represent the shared electron pairs (the bonds).

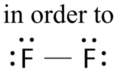
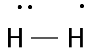
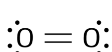
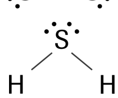
(d) The molecules that contain single bonds are H_2O, CH_4, H_2, HCl, and CCl_4. The molecules that contain double bonds are O_2 and CO_2. The molecule that contains a triple bond is C_2H_2.

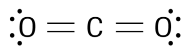
(e) The polar molecules are H_2O and HCl. Both these molecules consist of two or more atoms with electronegativities that differ such that one atom has a stronger attraction for the shared pair of electrons than the other atom. Opposite charges are found at opposite ends of each molecule, making it polar.

SECTION 1.12 QUESTIONS

(Page 45)

Understanding Concepts

1. (a) Sulfur and oxygen form two covalent bonds. Both elements are nonmetals. Since each element has six electrons in its outermost shell, to satisfy the octet rule, they must share electrons.
   (b) Sodium and iodine form an ionic bond. Sodium has one electron in its outermost shell and is a metal, whereas iodine has seven electrons in its outermost shell and is a nonmetal. Sodium loses its valence electron to become stable, and iodine gains an electron in its outermost shell. Each atom follows the octet rule.
   (c) Bromine and bromine form covalent bonds because bromine is a nonmetal and each atom must share electrons in order to satisfy the octet rule.
2. (a) 
   (b) 
   (c) 
   (d) 

(e) 

3. H_2S is a polar molecule because it has polar covalent bonds and a bent shape, with opposite charges at opposite ends. All the other molecules are nonpolar. Due to their symmetry, any polar bonds are cancelled out, or there are no polar bonds (e.g., H_2).
4. In a covalent bond, two atoms share a pair of electrons. Ionic bonds form as a result of the transfer of electrons from one atom to another. As a result, one atom becomes a cation while the other atom becomes an anion. The electrostatic force of attraction between the oppositely charged ions results in the formation of an ionic bond. In both ionic and covalent bonds, the octet rule is satisfied: all atoms end up with a full outer shell.
5. (a) Beryllium has a higher electronegativity than strontium because beryllium is in period 2, whereas strontium is in period 5. Beryllium has a smaller atomic radius than strontium and therefore a stronger pull on its valence electrons than strontium.
   (b) Chlorine has a higher electronegativity than sodium because chlorine has a higher atomic number and therefore more protons in its nucleus than sodium. It therefore has a stronger pull on its valence electrons than sodium.
6. (a) H—F
   (b) C—O
   (c) O—H
   (d) P—Cl
   (e) N—H
   (f) P—O
   (g) C—N
7. If the polar bonds are identical and arranged symmetrically around a central atom, their combined pulls cancel each other and the molecule is nonpolar. There are no opposite charges at opposite ends.
8. (a) An intermolecular bond is a bond between two or more molecules.
   (b) Dipole–dipole forces form between polar molecules because the slightly positive end of one molecule is attracted to the slightly negative end of a neighbouring molecule. London dispersion forces form between polar and nonpolar molecules due to temporary imbalances in the positions of electrons in the atoms that make up the molecules.
9.

Table 3 Intermolecular Forces

Molecule	Intermolecular force(s) (LDF, DDF, or both)
hydrogen, H_2	LDF
carbon tetrachloride, CCl_4	LDF
hydrogen sulfide, H_2S	LDF, DDF

10. The boiling point of methane is much lower than the boiling point of hydrogen bromide because methane in a nonpolar molecule whereas hydrogen bromide is polar. The intermolecular bonds that form between methane molecules (LDFs) are fewer and weaker than the intermolecular bonds that form between hydrogen bromide molecules (LDFs and DDFs). Less energy is required to break the bonds between methane molecules, resulting in a lower boiling point.

Applying Inquiry Skills

11. **Prediction**
   (a) The molecules that will be affected by the charged object are NCl_3 and H_2O because these molecules are polar.

   Observations
   (b) Samples 1 and 2 could be Br_2 and CCl_4. Samples 3 and 4 could be NCl_3 and H_2O.

   Analysis
   (c) A charged object attracts or repels a thin stream of liquids composed of polar molecules, NCl_3 and H_2O, but it has no effect on liquids composed of nonpolar molecules, Br_2 and CCl_4.

   Synthesis
   (d) The polar molecules, NCl_3 and H_2O, are slightly positively charged at one end and slightly negatively charged at the other end due to their shape and the presence of polar covalent bonds. Thus, the end of the polar molecule that has the opposite charge of the charged object will move toward the charged object.

(e) The liquids were affected by both positive and negative charges because the polar molecules of the liquids are positively charged at one end and negatively charged at the other end. A positively charged object attracts the negatively charged end of the polar molecule, while a negatively charged object attracts the positively charged end of the polar molecule.

1.13 INVESTIGATION: CLASSIFYING SOLIDS USING PHYSICAL PROPERTIES

(Pages 46–47)

Prediction

(a) Potassium iodide and sodium chloride are ionic compounds, whereas sucrose and camphor are molecules.

Hypothesis

(b) Potassium iodide and sodium chloride are ionic compounds because they each consist of a cation and an anion, and are therefore held together by ionic bonds. Sucrose and camphor are both molecular solids because they consist of nonmetal atoms that are held together by covalent bonds.

Observations

Table 1 Physical Properties of Different Compounds

Compound	**Part 1: Solubility (dissolves/ does not dissolve)**	**Part 2: Conductivity (conducts electricity/ does not conduct electricity)**	**Part 3: Hardness (descriptive)**	**Hardness (ranking)**	**Part 4: Melting point (°C)**
potassium iodide, $KI_{(s)}$	dissolves	solution conducts electricity	brittle, fair amount of pressure placed on crystal	2	686
sodium chloride, $NaCl_{(s)}$	dissolves	solution conducts electricity	brittle, large amount of pressure placed on crystal	1	801
sucrose, $C_{12}H_{22}O_{11(s)}$	dissolves	solution does not conduct electricity	not too hard to break	3	185
camphor, $C_{10}H_{16}O_{(s)}$	dissolves slightly	solution does not conduct electricity	soft	4	177
Part 5: Unidentified solid	[Answer will vary depending on sample]	[Answer will vary depending on sample]	[Answer will vary depending on sample]	Not applicable	[Answer will vary depending on sample]

Analysis

(c) According to the results, sodium chloride and potassium iodide belong to one category while sucrose and camphor belong in the second category.

(d) Sodium chloride and potassium iodide both dissolve in water, have high melting points, a high level of hardness, and their solutions conduct electricity. Camphor and sucrose are relatively soft, have low melting points, and do not conduct electricity when dissolved in water.

(e) Sodium chloride and potassium iodide are ionic compounds. Ionic compounds are soluble in water, exhibit a high level of hardness, have a high melting point, and their solutions conduct electricity. Molecular solids, such as sucrose