(g) Two more classification schemes that might be used are: models that have the same elements bonding (O_2), and models that have different elements bonding (HCl); models with a carbon atom (CH_4), and models without a carbon atom (H_2O). (Students are likely to discover quickly the variety of compounds that can be formed using carbon atoms.) The rationale for this classification is that once again, clear distinctions can be made between such bonding arrangements.

2.1 CLASSIFYING COMPOUNDS

PRACTICE

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Understanding Concepts

1. (a) A metal element and a nonmetal element combine to form an ionic compound.
   (b) A nonmetal element and a nonmetal element combine to form a molecular compound.
2. Electrical conductivity can be used as a diagnostic test for an ionic compound. Ionic compounds (many of which dissolve readily in water) form solutions that conduct electricity.

Applying Inquiry Skills

3. **Experimental Design**
   Solubility: Obtain a small amount of the unknown substance. Observe and record its state at the ambient temperature. Add a small quantity of the substance to about 10 mL of distilled water. Stir the mixture with a stirring rod and note whether the chemical dissolves. Many ionic compounds readily dissolve in water.
   Conductivity: Obtain a small sample of distilled water in a beaker. Use a low-voltage conductivity apparatus to test the electrical conductivity of the sample. The apparatus should indicate a reading of zero. Test the electrical conductivity of the mixture from the above solubility procedure and record observations. Ionic compounds form solutions that conduct electricity.
4. • Compound A is ionic — its solution conducts electricity.
   • Compound B is molecular — it is a liquid at SATP, and its solution does not conduct electricity.
   • Compound C is molecular — it is a gas at SATP.
   • Compound D is ionic — its solution conducts electricity.
   • Compound E is molecular — its solution does not conduct electricity.

2.2 IONIC BONDING

PRACTICE

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Understanding Concepts

1. The properties of ionic compounds that suggest ionic bonds are strong are: they are solids at SATP, they have hard surfaces, and they have high melting and boiling points.
2. Metal elements and nonmetal elements form ionic bonds with each other.
3. Groups 1, 2, and 3 (13), tend to lose electrons to become positive ions. Groups 15, 16, and 17 tend to gain electrons to form negative ions.
4. The minimum number of different ions in the formula of an ionic compound is 2. This is because the smallest unit of an ionic compound that would still have the properties of the compound is a 1:1 ratio of the different ions, with the general formula MX.
5. (a) S^{2-} (f) K^+
   (b) Ba^{2+} (g) P^{3-}
   (c) Br^- (h) Rb^+
   (d) Cl^- (i) Be^{2+}
   (e) Ca^{2+}

Applying Inquiry Skills

6. (a) **Experimental Design**

Conductivity of an Ionic Solid: Obtain a small sample of 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.

Alternatively, fill a 100-mL beaker about one-third full with crystals of sodium chloride. Use a low-voltage conductivity apparatus to test the electrical conductivity of the sample. Record your observations.

(b) The student is to research the conductivity of molten (liquid) ionic compounds. The student will discover that 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).

(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 an electrical current. When an ionic compound is melted, the attractive forces are overcome and the crystal collapses. The ions are now free to move and carry an electrical current, as they are in solution.

PRACTICE

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Making Connections

7. The student is to use the Internet to research and report upon the importance of one of the ions that make up the human body, and comment on whether supplements of the ion are recommended. There are many ions from which to choose.

GO TO www.science.nelson.com, Chemistry 11, Teacher Centre.

PRACTICE

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Understanding Concepts

8. (a) The electron dot diagrams of metal ions differ from those of nonmetal ions in that the diagrams of metal ions have vacant valence orbitals, and no lone pairs, and show a positive charge outside the square bracket, while the diagrams of nonmetal ions have no vacant valence orbitals, have lone pairs, and show a negative charge outside the square bracket.

(b) Electron dot diagrams of metal ions are similar to those of nonmetal ions in that both diagrams show a total charge that is equal in value but opposite in sign, and both diagrams represent an ion that has full outer orbits of electrons — a configuration exactly the same as that of the nearest noble gas.

9. (a) lithium iodide $Li\cdot + :\ddot{\underset{..}{I}}: \rightarrow [Li]^+ [:\ddot{\underset{..}{I}}:]^-$

$Li + I \rightarrow [Li]^+ [I]^-$

(b) barium chloride $\cdot Ba\cdot + 2:\ddot{\underset{..}{Cl}}: \rightarrow [:\ddot{\underset{..}{Cl}}:]^- [Ba]^{2+} [:\ddot{\underset{..}{Cl}}:]^-$

(c) potassium oxide $2\,K\cdot + :\ddot{\underset{.}{O}}\cdot \rightarrow [K]^+ [:\ddot{\underset{..}{O}}:]^{2-} [K]^+$

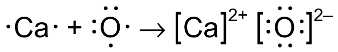
(d) calcium fluoride $\cdot Ca\cdot + 2:\ddot{\underset{..}{F}}: \rightarrow [:\ddot{\underset{..}{F}}:]^- [Ca]^{2+} [:\ddot{\underset{..}{F}}:]^-$

10. (a) nitrogen $\cdot\ddot{N}\cdot$ (e) lithium $Li\cdot$

(b) sulfur $:\ddot{\underset{.}{S}}\cdot$ (f) cesium $Cs\cdot$

(c) argon $:\ddot{\underset{..}{Ar}}:$ (g) calcium $\cdot Ca\cdot$

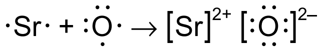
(d) iodine $:\ddot{\underset{..}{I}}:$ (h) sodium Na

11. (a) $Ca + O \rightarrow [Ca]^{2+} [O]^{2-}$ 

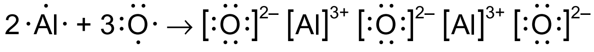
The two elements will combine in a ratio of 1:1. The formula is CaO.

(b) $2\ Rb + O \rightarrow [Rb]^{1+} [O]^{2-} [Rb]^{1+}$ 

The two elements will combine in a ratio of 2:1. The formula is Rb_2O.

(c) $Sr + O \rightarrow [Sr]^{2+} [O]^{2-}$ 

The two elements will combine in a ratio of 1:1. The formula is SrO.

(d) $2\ Al + 3\ O \rightarrow [O]^{2-} [Al]^{3+} [O]^{2-} [Al]^{3+} [O]^{2-}$ 

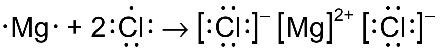
The two elements will combine in a ratio of 2:3. The formula is Al_2O_3.

12. 

The electron dot diagrams for the five halogens are identical. Elements in the same chemical family have the same number of valence electrons, and will thus be represented by the same electron dot diagram.

13. (a) A magnesium atom has two valence electrons. By transferring the two electrons to chlorine atoms, the resulting magnesium ion will have a stable octet with the same electron configuration as neon.

A chlorine atom has seven valence electrons. By attracting an electron from a magnesium atom, the resulting chlorine ion will have a stable octet with the same electron configuration as argon. Two chlorine atoms will attract one electron each from a single magnesium atom.

$Mg + 2\ Cl \rightarrow [Cl]^{-} [Mg]^{2+} [Cl]^{-}$ 

The formula is $MgCl_2$.

(b) A sodium atom has one valence electron. By transferring this electron to a sulfur atom, the resulting sodium ion will have a stable octet with the same electron configuration as neon.

A sulfur atom has six valence electrons. By attracting two electrons from sodium atoms, the resulting sulfur ion will have a stable octet with the same electron configuration as argon. One sulfur atom will attract one electron each, from two separate sodium atoms.

$2\ Na + S \rightarrow [Na]^{+} [S]^{2-} [Na]^{+}$ 

The formula is Na_2S.

(c) An aluminum atom has three valence electrons. By transferring the three electrons to oxygen atoms, the resulting aluminum ion will have a stable octet with the same electron configuration as neon.

An oxygen atom has six valence electrons. By attracting two electrons from aluminum atoms, the resulting oxygen ion will have a stable octet, also with the same electron configuration as neon. Three oxygen atoms will attract two electrons each, from two separate aluminum atoms.

$2\ Al + 3\ O \rightarrow [O]^{2-} [Al]^{3+} [O]^{2-} [Al]^{3+} [O]^{2-}$ 

The formula is Al_2O_3.

(d) A barium atom has two valence electrons. By transferring the two electrons to chlorine atoms, the resulting barium ion will have a stable octet with the same electron configuration as xenon.

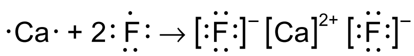
A chlorine atom has seven valence electrons. By attracting an electron from a barium atom, the resulting chlorine ion will have a stable octet with the same electron configuration as argon. Two chlorine atoms will attract one electron each from a single barium atom.

$Ba + 2\ Cl \rightarrow [Cl]^{-} [Ba]^{2+} [Cl]^{-}$ 

The formula is $BaCl_2$.

(e) A calcium atom has two valence electrons. By transferring the two electrons to fluorine atoms, the resulting calcium ion will have a stable octet with the same electron configuration as argon.

A fluorine atom has seven valence electrons. By attracting an electron from a calcium atom, the resulting fluorine ion will have a stable octet with the same electron configuration as neon. Two fluorine atoms will attract one electron each from a single calcium atom.

$Ca + 2\ F \rightarrow [F]^{-} [Ca]^{2+} [F]^{-}$ 

The formula is CaF_2.

(f) A sodium atom has one valence electron. By transferring this electron to an iodine atom, the resulting sodium ion will have a stable octet with the same electron configuration as neon.

An iodine atom has seven valence electrons. By attracting an electron from a sodium atom, the resulting iodine ion will have a stable octet with the same electron configuration as xenon.

$Na + F \rightarrow [Na]^+ [F]^-$ $\quad \mathrm{Na}\cdot + :\underset{\cdot\cdot}{\dot{\mathrm{F}}}: \rightarrow [\mathrm{Na}]^+ [:\underset{\cdot\cdot}{\ddot{\mathrm{F}}}:]^-$

The formula is NaF.

(g) A potassium atom has one valence electron. By transferring this electron to a chlorine atom, the resulting potassium ion will have a stable octet with the same electron configuration as argon.

A chlorine atom has seven valence electrons. By attracting an electron from a potassium atom, the resulting chlorine ion will have a stable octet with the same electron configuration as argon.

$K + Cl \rightarrow [K]^+ [Cl]^-$ $\quad \mathrm{K}\cdot + :\underset{\cdot\cdot}{\dot{\mathrm{Cl}}}: \rightarrow [\mathrm{K}]^+ [:\underset{\cdot\cdot}{\ddot{\mathrm{Cl}}}:]^-$

The formula is KCl.

14. (a) baking soda
    (b) table salt
    (c) limestone or chalk
    (d) slaked lime — used to make mortar and plaster

SECTION 2.1- 2.2 QUESTIONS

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Understanding Concepts

1. With respect to periodic trends, elements within a chemical family (group) tend to participate in similar chemical reactions, producing ionic compounds with the same general formula. With respect to electronegativity, Group 1 and 2 metals, which have low electronegativities, will readily react with the elements in Group 17, which have high electronegativities, to form ionic compounds. As most Group 1 and 2 metals and Group 17 elements are relatively abundant in nature, it makes sense that the ionic compounds that these elements form would also be abundant in nature.
2. To reach a stable state with a full outer orbit of electrons, oxygen must gain two electrons. To reach a stable state with a full outer orbit of electrons, lithium must lose one electron. Thus, for lithium and oxygen to combine, there must be two lithium atoms for every one oxygen atom, with each lithium atom donating one electron to a single oxygen atom — a ratio of two lithium atoms for every one oxygen atom.
3. Ion formation shows periodic trends. Elements within a chemical family (group) tend to produce similar ions, and to participate in similar chemical reactions, producing ionic compounds with the same general formula.
4. (a) calcium carbonate
   (b) calcium hydroxide
   (c) sodium chloride
   (d) sodium bicarbonate
5. (a) $Cs + F \rightarrow [Cs]^+ [F]^-$ $\quad \mathrm{Cs}\cdot + :\underset{\cdot\cdot}{\dot{\mathrm{F}}}: \rightarrow [\mathrm{Cs}]^+ [:\underset{\cdot\cdot}{\ddot{\mathrm{F}}}:]^-$
   (b) CsF
   (c) An ionic compound (an ionic halide).
   (d) Solid at SATP, with a hard surface, is brittle, has a high melting point, and forms a solution that conducts electricity.
   (e) The properties of the compound are due to the strong, simultaneous forces of attraction between the positive and negative ions, which hold the ions firmly in a rigid structure. The solid state, hardness, brittleness, and the high melting point result from the strong attractions, which occur in the crystal structure. And because the ionic bonds break down in water, the resulting ions are free to move in solution and conduct electricity.
   (f) Cs has a low first ionization energy, and F has a high electron affinity, so it makes sense that the reaction would be a vigorous one. With the alkali metals, reactivity increases moving down the group, due to increasing atomic radii and decreasing first ionization energies. With the halogens, reactivity increases moving up the group, due to decreasing atomic radii and increasing electron affinity.