CHAPTER 8

Classifying Chemical Compounds

Chapter Preview

Early chemists had determined that all chemical compounds in the world could be placed in one of two categories: chemical compounds that existed as part of living things (organisms), and those that did not. These two groups were called organic and inorganic compounds. Subsequently, chemists were able to make chemical compounds in the laboratory that were previously thought only to exist in living things. This changed their understanding of organic and inorganic compounds, although a form of this classification exists today.

In this chapter, you will learn how ionic and molecular compounds can be further classified by examining chemical formulas and molecular structures.

KEY IDEAS

- **All chemical compounds are either organic or inorganic.**
- **Inorganic compounds can be molecular or ionic (acids, bases, or salts).**
- **Lewis diagrams (electron dot) can explain how molecular compounds form as a result of bonding pairs of electrons.**
- **Organic compounds are molecular and contain carbon and hydrogen.**

TRY THIS: Classifying Compounds

Skills Focus: classifying

All compounds can be classified into one of two groups: organic or inorganic. For this activity, you will use the older, and partly correct, meaning of "organic," which states that organic compounds are present in or result from living organisms. For example, a strand of your hair would contain an organic compound. An inorganic compound is simply one that is not organic. An example of an inorganic compound is a rusted iron nail.

1. Think about the matter in the world around and within you, and consider which matter would contain organic compounds and which would contain inorganic compounds.
2. Make two lists: one with five examples of matter that contains organic compounds, and one with five examples of matter that contains inorganic compounds.

A. Which list was easier to create? Why do you think this is the case?

B. Beside each organic example, state the original living organism that contained the organic compound.

8.1 Classifying Inorganic Compounds

You know that compounds can be ionic or molecular based on how their elements are bonded. But all compounds can also be organic or inorganic, depending on the kinds of elements within. Inorganic or organic, what's the difference? An organic chemical was originally believed to come from a living organism (Figure 1). However, a significant discovery was made in the mid-1800s when "organic" compounds were synthesized in the lab from non-living compounds. Today, compounds that have a high percentage of carbon by mass are classified as **organic compounds**; otherwise they are considered to be **inorganic compounds**.

LEARNING TIP

Identifying key words helps readers determine the most important concepts in a section. To help you determine key words, look for words that are bolded, used in headings, or repeated.

Figure 1 Organic compounds were first thought to exist only in living organisms.

Almost all of the compounds you have studied so far—such as water, salt, carbon dioxide, iron(III) oxide (rust), sodium carbonate (washing soda)—are inorganic compounds. All of the compounds for which you have learned to name and write formulas are inorganic. Yes, some of these compounds contain carbon atoms, but the carbon is not considered present in a high percentage. What then is high percentage carbon? We will answer this question later in this chapter.

In Chapter 7 you learned that inorganic compounds can be ionic or molecular based on the bonds that join them together internally. In this chapter, you will delve further into the study of all compounds and learn more about their behaviours.

As you investigate the nature of these chemicals, you will realize the significance of the bonding types involved (Figure 2).

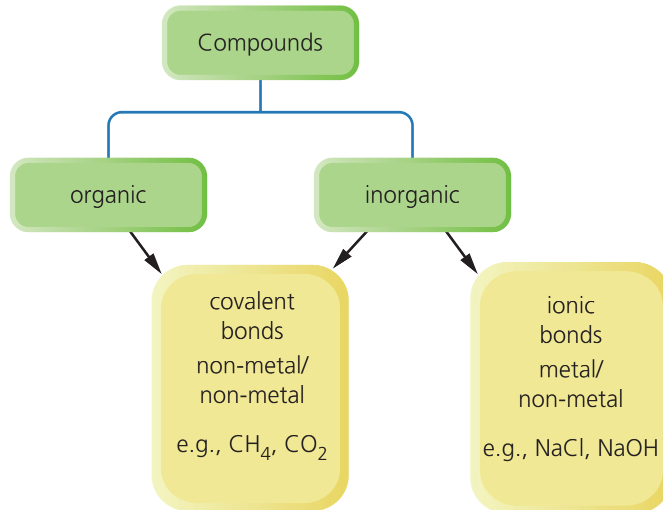


Figure 2 Bonding plays a key role in the behaviour and, therefore, in the classification of compounds. From this diagram, you can see that covalent bonds can be present in both organic and inorganic compounds, while ionic bonds are only present in inorganic compounds.

Inorganic Molecular Compounds

Compounds in this class are

- inorganic, so they contain little (at least not in a high percentage) or no carbon
- molecular, so they have a non-metal bonded to a non-metal to form molecules

There are some examples of inorganic molecular compounds that are quite common, but the number of examples is small: water (H_2O), ammonia (NH_3), carbon dioxide (CO_2, considered low percentage carbon), and laughing gas (N_2O). Can you think of some other common everyday examples that fit this classification? There are not many, are there? Most inorganic compounds are ionic.

Inorganic Ionic Compounds

The classification of inorganic ionic compounds has a long history of development. 8A *Investigation*

By the 1500s, early chemists (the alchemists) recognized that one group of substances shared a common property—a sour taste. These substances possessed other properties as well. They were called acids from the Latin word *acidus*, meaning sour. Another group of substances, called alkalis (or bases), was prepared from the ashes of wood. Bases had a slippery feel and were discovered to be effective cleaners.

In the 1600s, the alchemists realized that bases could react with acids and neutralize or destroy them. The resulting solution contained a new substance that tasted salty. When the water was evaporated from these solutions, a crystalline solid remained. These products were appropriately called salts.

Advances in the study of acids, bases, and salts were made when scientists started looking at the components of acids and bases to conceptually explain their classification.

8A *Investigation*

Classifying Solutions of Ionic Compounds

To perform this investigation, turn to page 224.

In this investigation, you will look for some fundamental similarities and differences among a number of ionic compounds.

In the 1800s, the Swedish chemist Svante Arrhenius recognized the presence of ions in solution and their relationship to acids and bases. These studies led to what is understood as the Arrhenius definitions of acids, bases, and salts: **acids** are substances that release H^+ ions in solution; **bases** are substances that release OH^- ions in solution; **salts** are substances that release positive ions and negative ions *other than* H^+ and OH^- in solution. These Arrhenius definitions hold true today for ionic compounds.

It is a common understanding that, unless otherwise stated, the term "solution" means that substances are dissolved in water. These water solutions often are referred to as **aqueous** (from Latin *aqua*, water) solutions and have the designation of (aq). For example, NaCl (aq) represents a solution formed when sodium chloride (table salt) is dissolved in water.

To learn more about Arrhenius and his contributions, go to **www.science.nelson.com**

General Properties of Acids, Bases, and Salts

As you may know from experience, acids like lemon juice taste sour, and bases like soap taste bitter (Figure 3). Salts, like table salt, do not taste anything like acids or bases. *For obvious safety reasons, when testing for acids, bases, or salts in a laboratory, you should never rely on taste tests.* Chemists instead use properties like those described in Table 1.

Figure 3 Acids and bases are common household chemicals. Generally speaking, most food products are acids and most bases make good cleansing agents.

To test your knowledge of common household acids and bases, go to **www.science.nelson.com**

Table 1 General Properties of the Water Solutions of Acids, Bases, and Salts

Acids	Bases	Salts
• conduct an electric current • cause chemical indicators to change colour (for example, litmus turns red) • react with certain metals to produce hydrogen gas	• conduct an electric current • cause chemical indicators to change colour (for example, litmus turns blue) • do not react with certain metals to produce hydrogen gas	• conduct an electric current • have no effect on chemical indicators (for example, litmus does not change colour) • do not react with certain metals to produce hydrogen gas

Chemical indicators are commonly used in school laboratories to test for acids and bases. Chemical indicators are molecular compounds that have a specific colour. They can change if they interact with an acid or base and turn into a slightly different compound with a different colour. Table 2 shows a list of common indicators and their colours in acids and bases. A colour chart of indicators can also be found in Appendix C6.

Table 2 Some Common Chemical Indicators and Their Colours

Chemical indicator	Colour in acid	Colour in base
methyl orange	red	yellow
methyl red	red	yellow
bromothymol blue	yellow	blue
litmus	red	blue
phenolphthalein	colourless	pink
indigo carmine	blue	yellow

Acidity

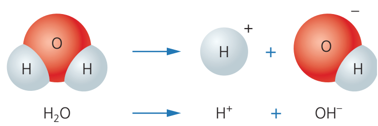


Figure 4 A few water molecules form H^+ and OH^- ions (about one in a million).

Solutions are said to be acidic, basic, or neutral based on the relative amounts of H^+ and OH^- ions that they contain. Pure water is always neutral because it always has an equal number of H^+ and OH^- ions. This happens because water is slightly ionic; a very few water molecules still have a tendency to produce a very small number of H^+ and OH^- ions, always in equal amounts. For this reason, chemists sometimes find it helpful to think of water as HOH rather than H_2O (1 HOH produces 1 H^+ ion and 1 OH^- ion) (Figure 4). Thus, a conductivity test of pure water will show a very small flow of electric current.

If an acid (H^+) is added to water, the $H^+ = OH^-$ balance in water is disrupted and we end up with more H^+ than OH^-. The resulting solution is said to be acidic. Similarly, if a base (OH^-) is added to water, we end up with more OH^- than H^+ in solution and the solution is considered to be basic. Adding salt (containing no H^+ or OH^-) does not affect the $H^+ = OH^-$ balance in water, so the solution remains neutral.

TRY THIS: Electrical Conductivity Tests

Skills Focus: interpreting data

You learned in Chapter 7 that solutions of ionic compounds conduct electricity, whereas molecular compounds do not. You have also learned that water (H_2O) is a molecular compound. In an investigation, conductivity tests were conducted on water as well as other compounds in solution. An ammeter was added to the test circuit to measure current flow in milliamperes (mA) (Figure 5). The light bulb used was one that required very little power to illuminate.

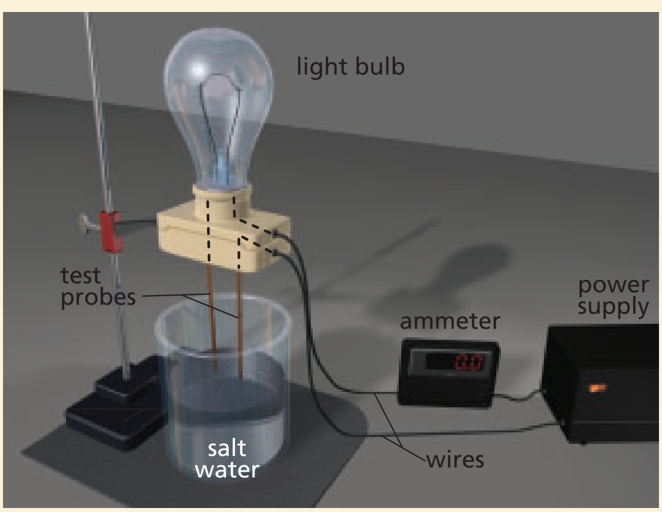


Figure 5

1. The electrical conductivity tester was used by inserting the test probes in a variety of materials. The water used was pure or distilled water (all minerals removed). The conductivity test results appear in Table 3.

Table 3

Compound tested	Light bulb	Current (mA)
table salt (NaCl) in water	very bright	400 mA
table sugar ($C_{12}H_{22}O_{11}$) in water	very dim	0.0040 mA
water	very dim	0.0040 mA
methanol (CH_4O), a liquid alcohol (no water present)	off	0 mA

A. Based on the results of the conductivity tests, which compounds would you classify as completely ionic or molecular?

B. Should pure water be classified as completely molecular? Explain.

C. How do you explain the conductivity of the sugar solution?

Table 4 summarizes the method in which solutions are classified as acidic, basic, or neutral.

Table 4 Classifying Solutions as Acidic, Basic, or Neutral

Solution classification	Relative ion count	Examples
acidic	$H^+ > OH^-$	HCl (aq) provides extra H^+
neutral	$H^+ = OH^-$	H_2O, NaCl (aq)
basic	$H^+ < OH^-$	NaOH (aq) provides extra OH^-

Acidity is described, then, as a measure of the relative amounts of H^+ and OH^- in a solution. It follows that the higher the relative number of H^+ ions, the higher the acidity.

LEARNING TIP

When you are reading difficult text, it is a good habit to paraphrase (say in your own words) difficult passages. Ask yourself, "Am I making good use of the tables and figures provided and remembering to stop and reread difficult passages?"

Measuring Acidity (The pH Scale)

Is hydrochloric acid a hazardous chemical? It all depends on how much hydrochloric acid is present in a given amount of water. A large amount of HCl in water (concentrated hydrochloric acid) will cause severe skin burns, and this same acid exists in your stomach for digestive purposes, but in a less concentrated form. How can we measure these differences in acidity?

Chemists have developed an acidity scale called the **pH scale**. The normal range of pH is from 0 to 14, with a pH of 7 being neutral. Solutions with a pH lower than 7 are acidic, whereas solutions with a pH greater than 7 are basic. Hydrochloric acid in the stomach has a pH of 1, while concentrated hydrochloric acid (1M) has a pH of 0. Therefore, concentrated HCl is more acidic. It is possible to have an extremely acidic solution with a pH lower than 0 (negative pH value), or an extremely basic solution with a pH greater than 14. The pH values for a variety of substances are given in Figure 6.

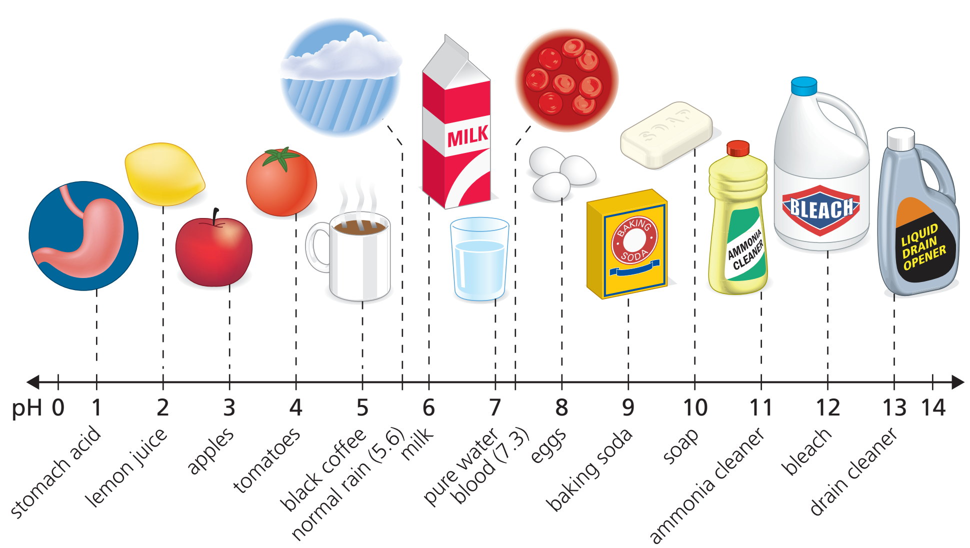


Figure 6 The pH scale allows chemists to quickly determine the acidity of solutions.

Did You KNOW?

Protecting the Stomach

Your stomach has mechanisms to stop it from being damaged by the high acidity of the hydrochloric acid in it. The stomach wall is protected by a fairly thick coat of mucus. The cells in this mucus secrete a base that neutralizes the acid. If hydrochloric acid gets through to the stomach wall, a person can develop gastric ulcers.

Did You KNOW?

The pH Scale

The pH scale was developed in 1909. The symbol "pH" was chosen to represent the "power of Hydrogen," to describe the concentration of H^+ ions in solution. Think of the pH scale as a "backwards" scale—the lower the pH, the higher the number of H^+ ions, and the higher the acidity.

The pH scale for measuring acidity has mathematical similarities to the Richter scale that is used for measuring earthquakes. Both scales are based on logarithms (powers of 10) so that every 1 point move on the Richter or pH scale represents 10 times more or less shaking force or acidity, respectively. A solution with a pH of 4 has 10 times more H^+ ions (10 times more acidic) than one with a pH of 5. A solution with a pH of 3 is 100 times more acidic than a pH of 5 (Table 5).

Table 5 Acidity and pH

Substance	pH	Relative acidity (compared with water)
pure water	7	neutral
human saliva	6	10 (10^1) times more acidic than water
black coffee	5	100 (10^2) times more acidic than water
tomato juice	4	1000 (10^3) times more acidic than water
soft drink	3	10 000 (10^4) times more acidic than water
lemon juice	2	100 000 (10^5) times more acidic than water
stomach acid	1	1 000 000 (10^6) times more acidic than water

Figure 7 A pH meter can be used to accurately measure the acidity of a solution.

A solution's pH can be directly measured with an electronic instrument called a pH meter (Figure 7) or with pH paper. The pH paper will display a certain colour when immersed in a solution. When that colour is matched to a colour chart for the pH paper, the solution's pH can be approximated (Figure 8).

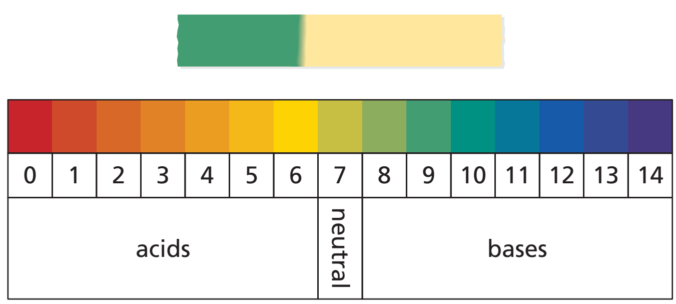


Figure 8 The left side of this strip of pH paper was immersed in a solution. The strip has turned green and indicates that the solution's pH is close to 9. GO

To learn how to make a pH test chemical at home, go to **www.science.nelson.com** GO

Naming Acids

Many of the commercial acids you encounter in the chemistry lab originate as manufactured gases. Gases are denoted by using (g) after their formulas. These particular gases readily dissolve in water and become acidic solutions. Some examples appear in Table 6.

The examples in Table 6 suggest that a system exists for naming acids. Some names include the term "hydro"; some do not. Some names end in "ic"; some end in "ous."

Table 6 Names for Some Common Acids and Their Gas Origins

Acid name	Gas	Chemical name of gas	Gas dissolved in water to form acid	Chemical name of solution
hydrochloric acid	HCl (g)	hydrogen chloride	HCl (aq)	hydrogen chloride
nitric acid	NO_2 (g)	nitrogen dioxide	HNO_3 (aq)	hydrogen nitrate
sulfurous acid	SO_2 (g)	sulfur dioxide	H_2SO_3 (aq)	hydrogen sulfite

As with all chemical compounds, the acid names are derived from the acids' chemical formulas. The rules for naming acids are summarized in the flow chart in Figure 9.

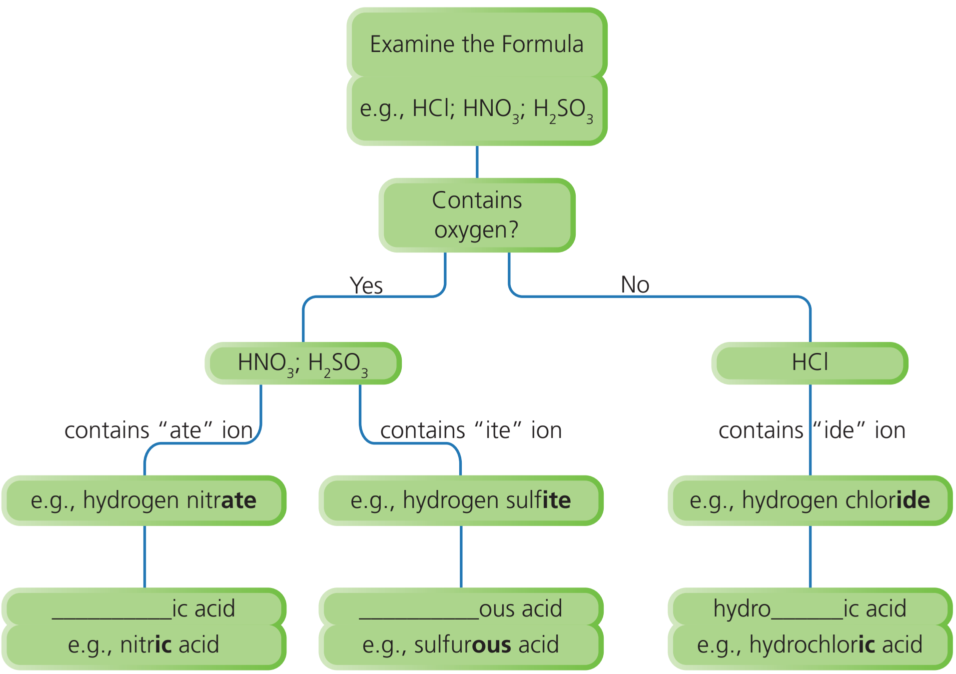


Figure 9 An acid's name is derived from the acid's chemical formula.

Notice that the negative ions in hydro ____ ic acids are "ide" ions, and these ion names become "ic" as in hydrochloric acid. There is no general rule as to how much of the ion name is retained. For example, the nitrate ion in HNO_3 leads to nitric acid, whereas the sulfite ion in H_2SO_3 leads to sulfurous acid, not sulfous acid. Furthermore, an acid such as HI is named hydriodic acid, simply because it is easier to say than hydroiodic acid. Do not be concerned with these little quirks, as long as you can follow the general rules and write the proper prefixes and suffixes for acid names.

Did You KNOW?

Phase Designations

Chemists use symbols after chemical formulas to describe the phases of matter when it is relevant. Some common phase designations are:

(s) solid: NaCl (s) (table salt crystals)
(l) liquid: NaCl (l) (liquid table salt, melted; not common)
(g) gas: He (g) (helium gas)
(aq) aqueous: NaCl (aq) (table salt dissolved in water)

LEARNING TIP

As you read Figure 9, create a picture in your mind. Cover the figure and recall your picture. Compare your picture with the information in Figure 9. Did you leave out any important information? If so, repeat the strategy.

Naming Bases and Salts

You have already learned the IUPAC rules for naming bases and salts when you learned about naming ionic compounds. Some examples appear in Table 7.

Table 7 Ionic Compound Naming Rules for Bases and Salts

Ionic compound	Classification	Chemical name
$NaNO_3$	salt	sodium nitrate
KCl	salt	potassium chloride
NaOH	base	sodium hydroxide
$Ca(OH)_2$	base	calcium hydroxide

TRY THIS: Metal and Non-Metal Oxide Solutions (A Periodic Trend)

Skills Focus: interpreting data, classifying

Oxygen is reactive with many of the elements in the Periodic Table. We observe this on a daily basis with metals such as iron and copper. Once reacted with oxygen, these metals join a class of compounds called oxides, so in these cases, iron(II) oxide and copper(II) oxide are formed. Non-metals also react both naturally and in commercial situations with oxygen to form oxide compounds such as carbon dioxide and sulfur dioxide.

Interestingly, these commonly produced oxides often are open to the environment and are then exposed to water as water vapour or rain. What happens next? Are new substances created once again? If so, do they exhibit familiar properties?

1. Tests were done on various solutions with bromothymol blue indicator solution and the results are recorded in Table 8.

Table 8

Oxide in water	Bromothymol blue test	Classification
MgO	blue	
CaO	blue	
SO_2	yellow	
NO_2	yellow	

2. Complete Table 8 by classifying each solution as acidic, basic, or neutral. (See Table 2 on page 203 for indicator colours.)

A. Examine the classifications in Table 8 and locate the elements involved in the Periodic Table. State a simplified periodic trend that appears to exist with solutions of metal and non-metal oxides.

B. Write the chemical formula for carbon dioxide. If you tested a solution of carbon dioxide with bromothymol blue, would the solution be acidic, basic, or neutral?

C. Write the chemical formula for sodium oxide. If you tested a solution of sodium oxide with bromothymol blue, would the solution be acidic, basic, or neutral?

8.1

CHECK YOUR Understanding

1. In the early years of chemistry, why were certain compounds considered to be organic?
2. Give an example of a substance that would fit the original definition of an organic chemical.
3. State a modern definition of an organic compound.
4. (a) What property do acids, bases, and salts have in common?
   (b) What is the effect of an acid on blue litmus paper?
   (c) What is the effect of a base on blue litmus paper?
   (d) What would you expect to happen if an iron nail were placed in hydrochloric acid?
5. Give the Arrhenius definitions for acids, bases, and salts.
6. Classify each of the following substances as an acid, a base, or a salt.
   (a) $LiOH$
   (b) KNO_3
   (c) $Sr(OH)_2$
   (d) HBr
   (e) KCl
   (f) H_2SO_4
   (g) $Ca(OH)_2$
   (h) HNO_3
7. (a) Which two ions are present in very small amounts in any sample of pure water?
   (b) What is a good alternative chemical formula for water, rather than H_2O? Why?
   (c) With respect to ion count, why is water considered to be neutral?
8. How do the number of H^+ and OH^- ions compare after
   (a) HI is added to water?
   (b) KBr is added to water?
   (c) KOH is added to water?
9. You test a solution with bromothymol blue indicator solution and the indicator turns yellow. What can you conclude about the relative H^+ and OH^- ion count?
10. Give some examples of where the term pH is used in your everyday life.
11. Make a sketch of the pH scale and label it with pH values. Show the areas that represent acidic, basic, and neutral solutions.
12. What would you expect the pH value for grapefruit juice to be? (>7, 7, <7)
13. Write the acid name for each of the following ionic compounds.
    (a) HI
    (b) H_2CO_3
    (c) $HClO$
    (d) HNO_2
14. Write the chemical formula for each of the following acids.
    (a) hydrocyanic acid
    (b) oxalic acid
    (c) chlorous acid
    (d) nitric acid
15. Write the acid name or chemical formula for each of the following.
    (a) HBr
    (b) sulfurous acid
    (c) $HClO_4$
    (d) phosphoric acid
16. First, classify each of the following substances as an acid, a base, or a salt. Then, write the name or chemical formula. If the substance is an acid, write the acid name.
    (a) potassium hydroxide
    (b) KNO_3
    (c) $Mg(OH)_2$
    (d) HI
    (e) sodium sulfate
    (f) $HClO_4$
    (g) aluminum hydroxide
    (h) H_2CrO_4

8.2 Another Look at Bonding—Lewis Diagrams

You have learned that bonding types (ionic and covalent) can be used to classify all compounds. Ionic compounds can be further classified as acids, bases, and salts based on their compositions. Molecular compounds can be further classified based on their atomic arrangements or structures. In order to gain an understanding of how atoms are arranged in molecules, we will investigate Lewis diagrams.

In the early 1900s, the American G.N. Lewis developed a system of arranging dots around the symbol of an element to represent an atom's valence electrons as it prepares to bond. Lewis reasoned that, for studies of bonding, there was no need to represent any of the other subatomic particles (protons, neutrons, or other electrons) as only valence electrons are involved in bonding. Looking at the atomic model proposed by Bohr and the Lewis diagram, you will notice striking similarities (Figure 1). GO

To learn more about the work of G.N. Lewis, go to **www.science.nelson.com** GO

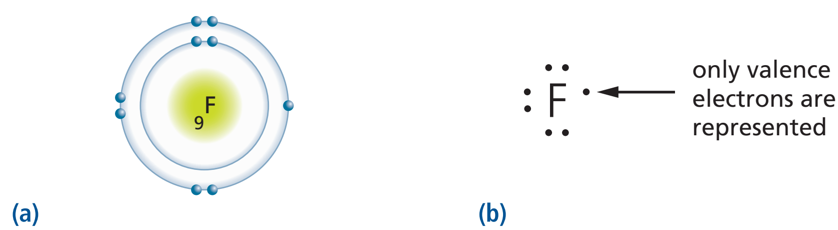


Figure 1 (a) A Bohr diagram of the fluorine atom is very similar to (b) a Lewis diagram.

LEARNING TIP

Are you able to explain the similarities and differences between Bohr's and Lewis's atomic models? If not, re-examine Figures 1 and 2. What type of bonding are Lewis diagrams useful for representing?

Lewis Diagrams and Covalent Bonds

You might consider a **Lewis diagram** as a simpler version of a Bohr diagram that has only valence electrons illustrated. However, there is a subtle (slight) difference in how the valence electrons are arranged. The Bohr model describes an atom in its natural state, whereas a Lewis model describes an atom as it prepares to bond with other atoms. The Lewis model shows that when an atom prepares to form a covalent bond, its valence electrons arrange themselves as single electrons whenever possible. A single electron is then able to pair with another single electron from another atom to form a shared pair, or **bonding pair**, of electrons**.** Lewis diagrams are also called **electron dot diagrams** since the valence electrons are designated by dots. However, symbols other than dots are used if they provide a better understanding of bonding between atoms.

A Lewis diagram for an oxygen atom shows the 6 valence electrons as dots surrounding the symbol for oxygen, with 2 single valence electrons (Figure 2(a)). An atom of argon (noble gas) has a complete valence shell of 8 valence electrons so it has no single valence electrons (Figure 2(b)).

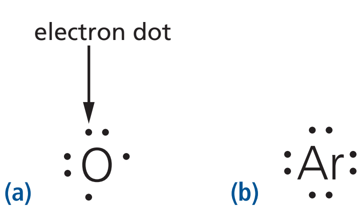


Figure 2 Lewis diagrams showing electron dots for the valence electrons of (a) oxygen and (b) argon atoms

Lewis Diagrams for Atoms

Drawing Lewis diagrams for atoms is easy by following a few steps.

Example 1: A Lewis diagram for a chlorine atom.

1. Determine the number of valence electrons. The number of valence electrons can easily be determined from the group (family) number in the Periodic Table. Since we will restrict ourselves to the first 20 elements, we can use the following method:
   (a) Elements in Groups 1 and 2 have 1 or 2 valence electrons, respectively.
   (b) Elements in Groups 1**3** through 1**8** have 3 to 8 valence electrons based on the group number. For example, an element such as chlorine in group 1**7** has 7 valence electrons.
2. Arrange the valence electrons as dots around the atom's symbol. First place 2 valence electrons together as paired electrons and then place up to 3 valence electrons as unpaired electrons equally around the valence shell. If there are more valence electrons, then begin to double up the unpaired electrons to make paired electrons (Figure 3).

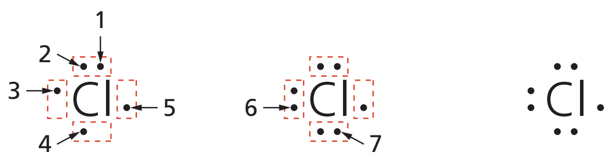


Figure 3 Placing 7 valence electrons for Cl in a Lewis diagram

Example 2: A Lewis diagram for a boron atom.

1. Boron has 3 valence electrons.
2. Place 2 valence electrons together as paired electrons and the third as an unpaired electron. This illustrates boron in its natural state. But Lewis diagrams show electrons ready to bond, so wherever possible, electrons are placed singly. Therefore, one of the paired valence electrons is moved to show all 3 valence electrons as unpaired (single) electrons, ready for bonding (Figure 4). This model of "changing places" closely resembles the modern atomic theory studied in more advanced courses.

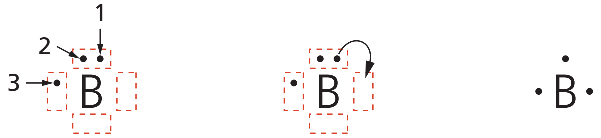


Figure 4 Placing 3 valence electrons for B in a Lewis diagram

STUDY TIP

Summarizing helps you to monitor your understanding of what you read. As you read Example 1, identify the main point in each step. Complete the statement, "This step tells me to..." Write each step in a point-form note on a study card. Include a visual on the back of your study card. You can use this study card later to help you prepare for a chapter test.

A quick method is to place electrons singly equally around the shell until 4 are placed, after which they are seated in pairs. This method works, but it is not supported by modern atomic theory.

Lewis Diagrams for Molecules

As you learned earlier, each atom has a tendency to complete its valence shell when bonding. A complete valence shell is one that matches its nearest noble gas. All noble gases have 8 valence electrons, except helium, which has 2. This is known as the **octet rule**.

To draw a Lewis diagram for a molecule, you must first be given the molecular formula. Atoms are then connected to one another by pairs of shared electrons, or bonding pairs. Consider the example for water (Figure 5). The molecular formula is H_2O. Each of the 2 hydrogen atoms has 1 valence electron. The oxygen atom has 6 valence electrons. (Note that "x" is used rather than dots for the hydrogen electrons. This is done simply to differentiate between the hydrogen and oxygen electrons.) By following the octet rule, the Lewis diagram shows how the 2 hydrogen atoms bond with the oxygen atom.

LEARNING TIP

When forming Lewis diagrams for molecules, it helps to visualize the dots arranged in pairs with the bonding pairs placed between the atoms that they connect and the lone pairs at different sides of the atomic symbol.

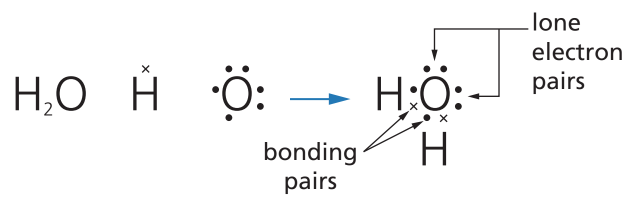


Figure 5 A Lewis diagram for water (H_2O)

The purpose of a Lewis diagram is to illustrate that the formation of these covalent molecules is possible. In Figure 5, you can see that arranging the bonding atoms in this manner leads to all atoms having complete valence shells as a result of bonding pairs of electrons. Oxygen ends up complete with 8 valence electrons (with 2 bonding pairs), and each hydrogen atom ends up complete with 2 valence electrons (with 1 bonding pair). As a result, the octet rule is satisfied for all atoms. Each bonding pair of electrons forms a **covalent chemical bond**. Note that the other pairs of electrons are not involved. These **lone electron pairs** do not form bonds.

To practise interpreting Lewis diagrams, go to **www.science.nelson.com**

Other carefully selected covalent molecules such as ammonia (NH_3) can be represented by Lewis diagrams (Figure 6).

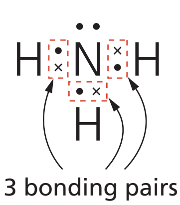


Figure 6 In the Lewis diagram for NH_3 each N atom obtains 8 valence electrons and each H atom obtains 2 valence electrons, thereby satisfying the octet rule.

For simplification, the bonding pair of electrons is often replaced by a line to represent a single covalent bond (Figure 7).

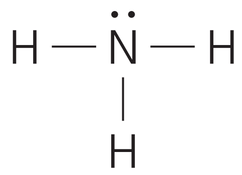


Figure 7 A simplified Lewis diagram for NH_3 shows each bonding pair of electrons as a line representing a covalent bond.

Common covalent molecules such as carbon dioxide require an introduction to double bonds, which is beyond the scope of our studies.

Lewis Diagrams for Ionic Compounds

Lewis diagrams can also be drawn for ionic compounds, but they simply mimic (imitate) the electron transfer that can be shown in a Bohr diagram (Figure 8). Since formulas for ionic compounds are predictable based on ion charge, we seldom rely on Lewis diagrams to help us understand the ionic bonds that exist. Lewis diagrams are more commonly used to explain covalently bonded compounds whose formulas cannot be predicted.

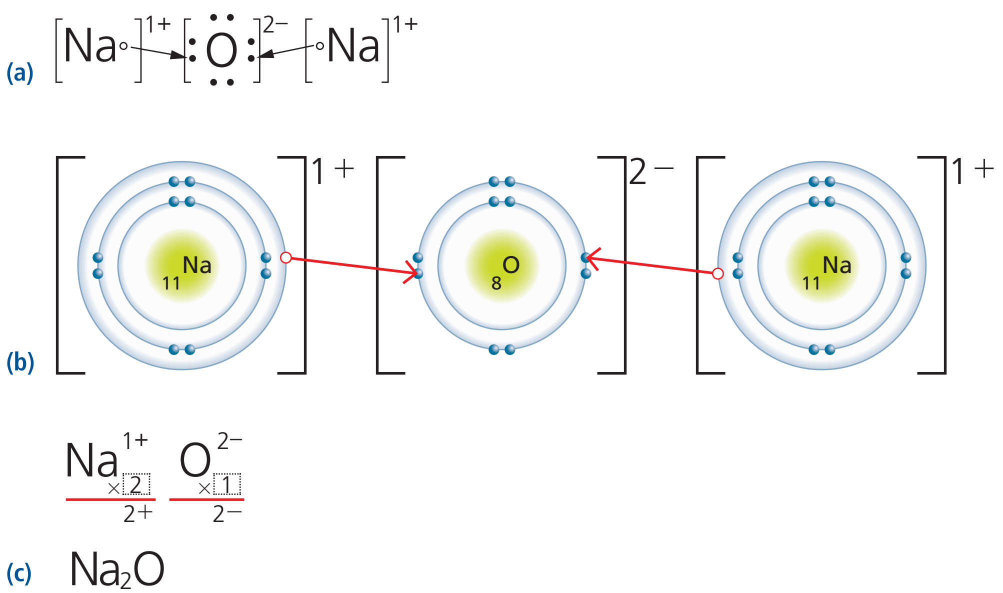


Figure 8 (a) A Lewis diagram for ionic compounds shows how the valence shells are completed by electron transfer. (b) This same transfer is shown in the Bohr diagram. (c) However, formulas for ionic compounds can be predicted from the combining ion charges.

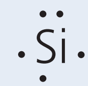
8.2 CHECK YOUR Understanding

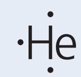
1. What type of bonding are Lewis diagrams useful for representing?
2. State the number of valence electrons for each of the following elements:
   (a) carbon (C)
   (b) argon (Ar)
   (c) lithium (Li)
   (d) magnesium (Mg)
   (e) hydrogen (H)
   (f) helium (He)
   (g) sulfur (S)
   (h) phosphorus (P)
3. Copy Table 1 in your notebook, leaving large spaces for drawing the diagrams. Complete the second and third columns for all of the elements. Complete the fourth column for those elements that will form ions.

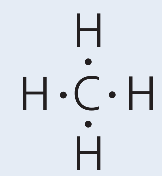
Table 1

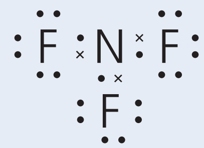
Element	Bohr diagrams for atoms	Lewis diagrams for atoms	Lewis diagrams for ions
hydrogen			
magnesium			
oxygen			
sulfur			
carbon			
boron			
beryllium			
potassium			
helium			
nitrogen			

4. Draw Lewis diagrams for each of the following molecules. Use "x" to represent electrons for the second element.
   (a) HCl
   (b) F_2
   (c) H_2O
   (d) carbon tetrachloride
   (e) sulfur difluoride
   (f) nitrogen trichloride
5. In your notebook, draw Lewis diagrams that will correct the errors in the following Lewis diagrams.

   (a) 

   (b) 

   (c) CH_4 

   (d) NF_3 

6. Why is it uncommon to draw Lewis diagrams for ionic compounds?
   A. Lewis diagrams can only illustrate covalent bonding.
   B. Ionic compounds cannot be represented by Lewis diagrams.
   C. Ionic compounds involve electron transfer, not electron sharing.
   D. Formulas for ionic compounds are predictable and understandable based on ion charges.

8.3 Organic Compounds

Early chemists believed that certain chemicals were only found in living organisms. These chemicals were appropriately called organic chemicals since they came from organisms. It was later discovered that some of these "organic" chemicals could be synthesized in the lab from non-living things. Nevertheless, the name "organic" stuck.

It was the German chemist Friedrich Wöhler (Figure 1) who, in the 1800s, first converted an inorganic chemical into urea, $(NH_2)_2CO$. Urea is a compound that can be isolated from urine. Urea was recognized as organic by all chemists and was believed to be manufactured only by living organisms.

Today, the sheer number of known organic compounds is staggering! Chemists estimate that 10 million compounds have been discovered so far, and 9 million of those are organic compounds. Living things are made up of thousands of different organic compounds. After studying organic compounds from nature, chemists and engineers often attempt to duplicate these compounds in the laboratory. The result is a wide variety of synthetic chemicals that have become part of our daily lives, such as fuels, fabrics, plastics, and medicines. An estimated 250 000 new organic compounds are synthesized in research laboratories every year.

Modern **organic chemistry** is often described as the chemistry of carbon compounds. Organic compounds are molecular compounds that have carbon atoms as their basis. Organic molecules contain C, H, and sometimes O, N, and other non-metals, and they have covalent bonds. A few examples of organic compounds are listed in Table 1. Notice that carbon and hydrogen atoms are always present.

Table 1 A Few Common Organic Compounds

Organic compound	Name	Use
CH_4	methane, natural gas	house heating
C_4H_{10}	butane	lighter fluid
C_8H_{18}	octane	gasoline component
CH_3OH	methanol	windshield washer antifreeze
C_2H_5OH	ethanol	alcoholic beverages, gasoline additive

Not all compounds that contain carbon are organic. Thus, carbon dioxide (CO_2) with no H, and sodium bicarbonate ($NaHCO_3$) with the metal Na, are both inorganic compounds. On the other hand, methane (CH_4) and ethanol (C_2H_5OH) are both examples of organic compounds.

Figure 1 Friedrich Wöhler (Germany) is considered the "father" of modern organic chemistry.

Did You KNOW?

What Is Organic?

The term "organic" has different meanings depending on the context in which it is used. Today you hear phrases such as "organic fruit and vegetables." In this case the term "organic" is not used as a chemistry term. An organic apple suggests that the conditions in which the apple was grown were controlled to avoid the use of manufactured fertilizers. However, a chemist might say that all apples are organic since they contain organic compounds.

Sometimes it is sufficient to say that organic compounds have a high percentage of carbon, but there is no hard-and-fast rule as to what constitutes a high percentage. Here are some percentages for the above examples, using mass numbers:

CO_2	$\frac{12}{44} \times 100\ \% = 27\ \%\ C$	inorganic
$NaHCO_3$	$\frac{12}{84} \times 100\ \% = 14\ \%\ C$	inorganic
CH_4	$\frac{12}{16} \times 100\ \% = 75\ \%\ C$	organic
C_2H_5OH	$\frac{24}{46} \times 100\ \% = 52\ \%\ C$	organic

In most cases, if you notice C and more than one H in the formula, along with no metals, you can expect the compound to be organic.

Did You KNOW?

Silicon

The only element with similar bonding abilities to carbon is the element silicon (Si). This is evident in the fact that silicon appears in the many compounds contained in dirt, soil, sand, and rocks. Notice its position in the Periodic Table in relation to carbon.

What's So Special About Carbon?

Carbon has the unique ability to form several bonds with other atoms as well as with itself. This is due to the fact that carbon has 4 valence electrons. The 4 valence electrons allow carbon atoms to form chains of various lengths, and these chains can then have all types of branches. Each unpaired valence electron in carbon is capable of pairing up with another single electron from a different atom such as hydrogen. This bonding pair of electrons forms a covalent chemical bond (Figure 2).

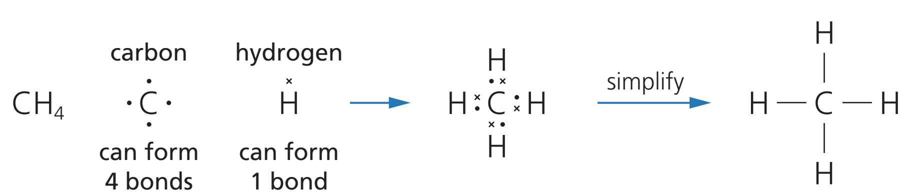


Figure 2 Valence electron dots for C and H show how these elements can be arranged and bond to form a methane molecule, CH_4. Since all bonds are shared electron pairs, it follows that all organic compounds are molecular.

Structural Formulas

Simplified Lewis diagrams, also called **structural formulas**, can be drawn to help visualize organic molecules (Figure 3). Chemists find that structural formulas are very useful for studying organic compounds. These formulas not only show the number of atoms in each organic molecule, but also the arrangement of these atoms. In many cases, the structure of the molecule helps chemists understand that particular compound's properties and behaviour.

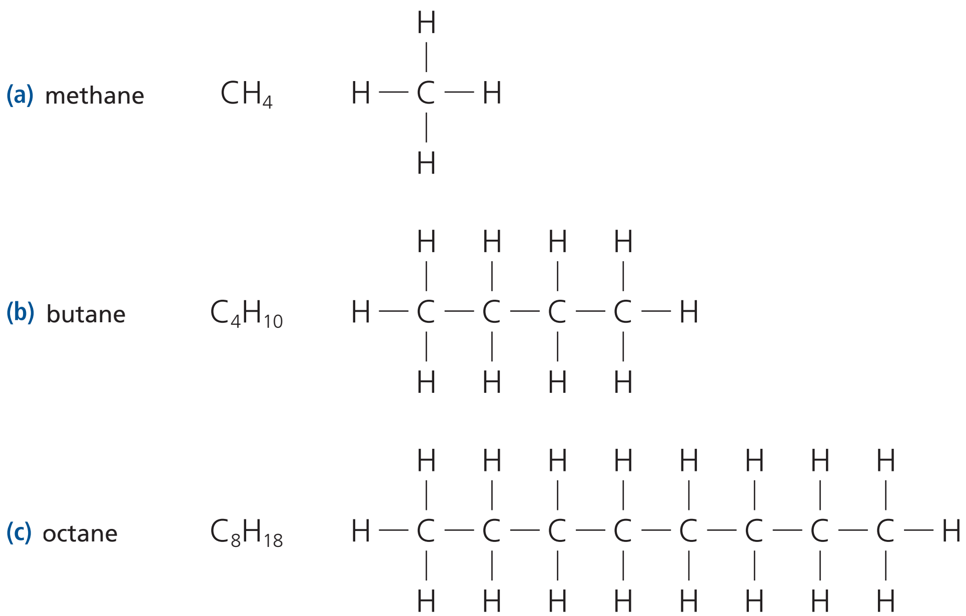


Figure 3 Structural formulas for (a) methane, (b) butane, and (c) octane

> ***LEARNING TIP***
> Keep in mind this set of basic rules by which you can form Lewis structures. Bonds are pairs of electrons shared between two atoms. Most covalently bonded atoms (except hydrogen) have a filled octet of balanced electrons.

When oxygen bonds within organic molecules it requires 2 bonds (2 bonding pairs) in order to fill its valence shell. The Lewis diagrams and structural formulas for the oxygen-containing compounds methanol and ethanol are shown in Figure 4. Notice that structural formulas do not show any non-bonding electron dots such as those on O atoms. In structural formulas, it is understood that the valence shells are complete for each atom.

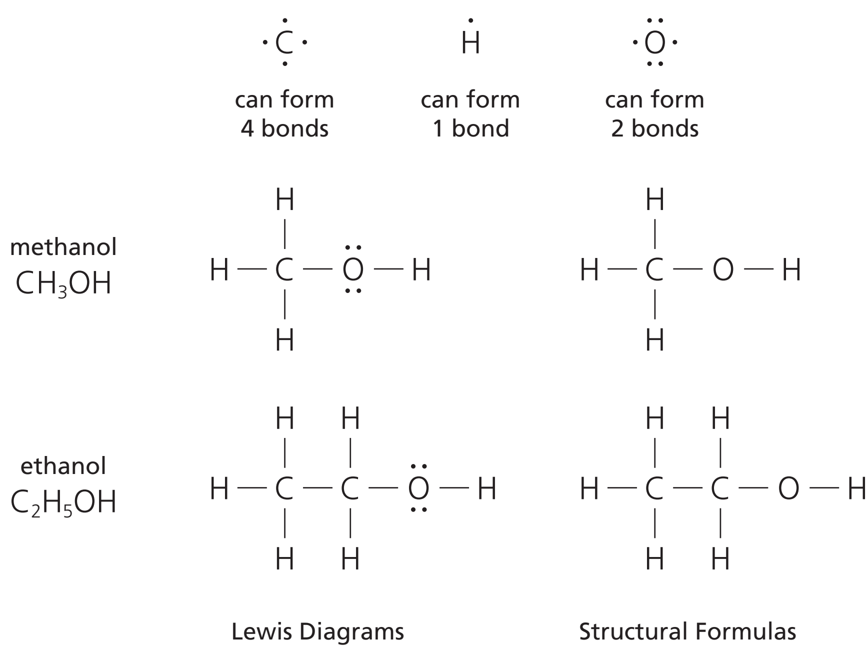


Figure 4 Structural formulas leave out the non-bonding electron dots.

To learn how the organic compound ethanol could help fuel the future, listen to the audio clip at
www.science.nelson.com

Chemists reason that different compounds have different properties and should have different compositions. Usually the composition of a compound is described by its chemical formula. But sometimes the chemical formula does not help describe differences in organic compounds. For example, ether and ethanol both have the same chemical (molecular) formula (C_2H_6O). Ether is a highly explosive liquid, and can be used as an anesthetic. Ethanol is the alcohol found in alcoholic beverages. They are from different organic families and have quite different properties. How can they both be C_2H_6O?

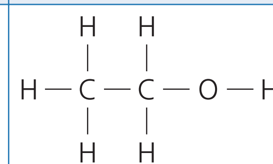
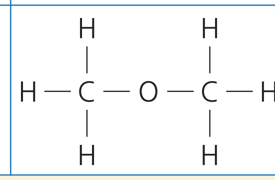
TRY THIS: *Structural Formulas*

Skills Focus: creating models

Organic chemists rely on structural formulas to better describe composition and properties of organic molecules. A structural formula uses a bond line to show a bonding pair of electrons, as shown in the structural formulas for ethanol and ether in Table 2.

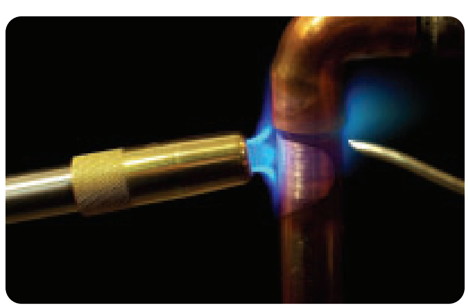
1. Sketch structural formulas for the following organic compounds. Recall that each C atom has 4 bond lines, each O atom has 2, and each H atom has 1.
   (a) C_3H_8
   (b) CH_4O
   (c) C_4H_{10} (sketch two different structures)
   (d) C_3H_8O (sketch three different structures)
   (e) $C_4H_{10}O$ (sketch seven different structures)

Table 2

Organic compound	Molecular formula	Structural formula	Organic molecular formula
ethanol	C_2H_6O		CH_3CH_2OH
ether	C_2H_6O		CH_3OCH_3

Classifying Organic Compounds

A very elaborate scheme has been developed for classifying organic compounds. The classification of these compounds into families is based on their properties and molecular structures. Only a few of these families are illustrated in Table 3. The simplest of all organic compounds are the **hydrocarbons** since, as their name suggests, they only contain the elements hydrogen and carbon. You may have heard of methane, propane, butane, and octane (Figure 5). Note the similarities in their names.

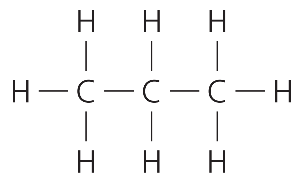
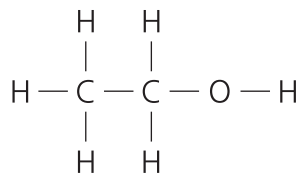
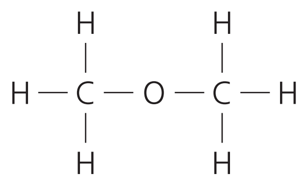


(a)

(b)

Figure 5 Some of the hydrocarbons may be familiar to you. (a) Propane torches are used when soldering pipes. (b) Octane is an important component of gasoline.

Table 3 Some Families of Organic Compounds

Family name	Sample compound name	Structural formula
hydrocarbons	propane	
alcohols	ethanol	
ethers	dimethyl ether	

Sources of Organic Compounds

Organic compounds are naturally occurring or synthetic. Many natural organic compounds are produced by plants during photosynthesis. The plants take in carbon dioxide, CO_2 (the source of the carbon for the carbon compounds) from the air. They react CO_2 with H_2O to produce organic molecules. You know these organic compounds as carbohydrates, sugars, proteins, and fats. Animals then eat the plants and manufacture more organic compounds in more chemical reactions. Humans eat both carbon-containing plants and animals and eventually return the carbon to the ground and the air. This cycle of carbon starting in the air and eventually returning to the air is called the carbon cycle.

Another major source of natural organic compounds comes from deep within Earth. Crude oil and natural gas deposits formed millions of years ago when plant and animal remains were subjected to enormous forces of heat and pressure. These natural deposits contain mixtures of organic compounds that are nowadays separated into their component parts at gas processing plants and oil refineries (Figure 6). Many of the components in these mixtures are simple hydrocarbons such as methane, propane, butane, and octane. They are primarily separated to be used as fuels, but often these simple molecules are used as building blocks by chemists to synthesize larger, more complex molecules. These small molecules are like pieces of LEGO to a chemist! GO

Figure 6 An oil refinery

To learn more about how oil refineries work, go to
www.science.nelson.com GO

8.3 CHECK YOUR Understanding

1. State a modern definition of organic chemistry.
2. Why was the term "organic" originally chosen? Give an example of an original organic substance.
3. For each photo below, consider the substances that make up the object. List those substances that you think are organic and those that you think are inorganic.

(a)

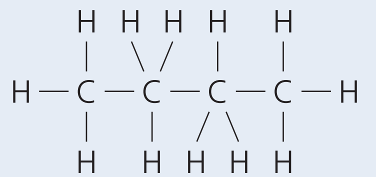
(b)

(c)

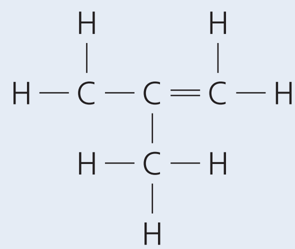
(d)

4. What two elements are always common to organic compounds?
5. Is washing soda (Na_2CO_3) considered to be organic? State two reasons why or why not.
6. Explain what makes carbon special when it bonds with other elements.
7. Draw a Lewis diagram of carbon, and a Lewis diagram of hydrogen.
8. (a) Draw a Lewis diagram to illustrate how a molecule of propane (C_3H_8) can exist.
   (b) Draw a structural formula for a molecule of propane.
9. Draw five different structural formulas for C_6H_{14}.
10. Identify the errors in the following structural formulas. In your notebook, draw the correct structural formulas.

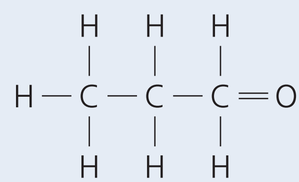
(a) C_4H_{10}



(b) C_4H_{10}



(c) C_3H_8O



11. What is a major source of organic molecules?
12. What type of industrial plant (factory) is used to separate mixtures of organic compounds?

Science **WORKS**

SPIDER CHEMISTS

The world around us is made of many different materials with distinct chemical structures. Some are natural, such as starch, wool, and silk, while others are synthetic, such as plastic pop bottles, latex paint, and superglue. What they have in common is that they are all made of giant molecules!

All life is made possible because of giant molecules called polymers. A polymer consists of long chains composed of small repeating molecular units called monomers. Polymers usually consist of thousands of monomers covalently bonded together. They can be many millions of times larger than simple molecules such as water or carbon dioxide. There are three major types of biological giant molecules: proteins, carbohydrates, and nucleic acids. Proteins are long chains of amino acids, such as keratins that form our fingernails and hair. Carbohydrates are chains of sugars that form substances such as cotton, cellulose (the wood fibre of trees), or starches for storing energy. Nucleic acids are chains of nucleotides that take the form of DNA or RNA.

Scientists have also created a large variety of synthetic polymers such as nylon, plastic, and rubber. Of particular interest to chemists today, is how to produce a synthetic equivalent of spider silk. Spider silk is a fine protein polymer that is known for its strength and elasticity. It is one of the strongest natural fibres, and gram for gram, is six times stronger than steel (Figure 1).

Chemists have already created materials that are either very strong or very stretchy, but have not been able to achieve both qualities in the same material. Recently, chemists have determined that the secret behind the combined strength and flexibility of spider silk lies in the arrangement of the amino acids.

Moreover, chemists are fascinated with the spider's ability to create different types of silk that serve different functions. Spiders start a web with dragline silk that creates an incredibly strong framework. The web is then rewoven with a slightly more flexible and sticky molecular structure called capture silk. Once the prey is captured in the web, the spider produces another type of polymer to wrap around the trapped insect (Figure 2).

Spider silk may hold lots of promise for creating tear-resistant textiles and high-strength fibres needed for lightweight bulletproof gear. More interestingly, spider silk is chemically unreactive, water insoluble, and resistant to bacteria and fungi. This makes it ideal for biomedical applications, including sutures, artificial tendons and ligaments, and biomedical devices. Synthetic fibres are often used in place of natural materials, since they are strong, light, elastic, and inexpensive.

Figure 1 Individual fibres of spider silk

Figure 2 A spider uses a third type of silk to wrap its captured prey.

8.4

Explore an Issue

DECISION MAKING SKILLS

- ○ Defining the Issue
- ● Researching
- ○ Identifying Alternatives
- ● Analyzing the Issue
- ● Defending a Decision
- ● Communicating
- ○ Evaluating

The Great Organic Debate: Healthier—Yes or No?

The term "organic" has different meanings even within the scientific community. An organic chemist believes that organic compounds are defined as carbon based, whereas an agricultural scientist identifies organic foods as naturally grown according to certain specifications. But even after settling on a common definition, scientists still cannot agree on the role of organic food production in modern agriculture.

The Issue: Naturally Grown Foods Are Healthier

What role do synthetic chemicals play in food production and how do these foods affect your health? The world population is constantly increasing and travel is much more accessible than in the past. As a result, scientists are not only faced with the challenge of providing an adequate food supply, but also with controlling disease. Naturally grown foods are safe to produce and consume, but are they healthier and can their rate of production meet world needs? What are the alternatives and are they safe?

Statement

People should eat only organic foods.

Background to the Issue

Organic Farming

All foods contain organic compounds, but an organic food is one that has been grown in certain soil conditions. "Organic farming" refers to crops that have been grown without using any synthetic fertilizers or pesticides (Figure 1). Organic farming is often considered the most natural way to farm in the sense that it relies solely on natural fertilizers (manure) and natural methods of controlling pests and disease. Organic farming also includes growing plants, whose fibres are used in clothing, and the growing of grapes, which are used to make organic wines.

Farmers can grow certified organic crops by meeting strict standards, including proper buffer fields between the organic field and any non-organic fields (preventing non-organic pollen from fertilizing organic crops). All crops that are to be sold as organic must be inspected and certified.

Figure 1 Produce labelled "organic" is grown using only natural fertilizers and methods.

Non-Organic Farming

According to public attitudes, organic food is the healthy option, both for people and the environment. But is organic food really as good as we think? One argument is that organic farming can lead to the risk of contamination with dangerous natural bacteria and mould toxins. Increased levels of natural pesticide found in organic produce could even be as dangerous as synthetic chemicals.

Conventional (non-organic) farming has utilized synthetic chemicals such as fertilizers and pesticides since their development (Figure 2). Fertilizers containing elemental nitrogen, phosphorus, and potassium have been manufactured for the past one hundred years. Plants depend on nitrogen for leaf and stem growth, phosphorus for root development and blooms, and potassium for roots and general vigour.

Figure 2 In conventional farming, synthetic fertilizers are sprayed on crops to help their growth.

Take a Position

1. Carefully read the statement and background information.
2. Your teacher will assign you to a group. Your group will then be divided into two subgroups: one that will support the statement and one that will oppose it.
3. With your subgroup, research the topics of organic and non-organic foods and how chemistry is involved in agriculture. Sources of information could include newspaper or journal articles, textbooks, library references, and the Internet.

   www.science.nelson.com GO

Communicate Your Position

1. Prepare a presentation that supports your position on organic versus non-organic foods. Prepare a list of pros and cons, and establish an argument for how your pros outweigh your cons. Consider, for example:
   (a) What types of chemicals are used and what are their benefits and hazards?
   (b) What effects do organic and inorganic foods have on human health?
   (c) What effects do the organic and inorganic farming practices have on human and environmental health?
   (d) How available and affordable are organic and inorganic farming practices throughout the world?
2. Present and defend your position in a group debate.

8A Investigation

Classifying Solutions of Ionic Compounds

A compound is said to be ionic if it releases positive and negative ions when dissolved in water. A simple laboratory test is to measure the electrical conductivity of the solution formed because ionic solutions are relatively good conductors. Beyond the fact that ionic solutions conduct electricity, are there other interesting properties that separate these solutions into different groups? What further tests can be used?

Questions

What tests can be used to classify solutions of ionic compounds into groups? How can these groups be defined?

Experimental Design

In this investigation, you will be given some ionic solutions of compounds to test. In Part I, you will test several unknown solutions and note some of their properties. You will use the similarity of properties to classify these solutions into three groups. Then, the identities of the compounds in the solutions will be revealed and you will write definitions that explain why each compound belongs in its particular group.

In Part II of this investigation, you will test several known household compounds. From the results you obtain and information provided, you will use your definitions from Part I to classify these compounds.

Always wear eye protection when working with any of these solutions. Some of these chemicals can be corrosive to skin, eyes, and clothing. If any solution splashes on skin or in eyes, flush immediately with plenty of cold water, and inform your teacher. Wash away any spills on any other surface with plenty of water.

Bromothymol blue can stain clothing. Use with care.

INQUIRY SKILLS

- ○ Questioning
- ○ Hypothesizing
- ○ Predicting
- ○ Planning
- ● Conducting
- ● Recording
- ● Analyzing
- ● Evaluating
- ● Synthesizing
- ● Communicating

Materials

- safety goggles
- 6 small test tubes (10 mm × 75 mm)
- water soluble marker
- set of 6 unknown solutions (labelled A–F)
- 6 dropping pipettes
- test tube rack
- spot plate or glass square (10 cm × 10 cm)
- dropping bottles of phenolphthalein solution and bromothymol blue solution
- red litmus paper
- blue litmus paper
- magnesium ribbon
- set of 6 household solutions (vinegar, oven cleaner, table salt, colourless carbonated drink, lemon juice, milk of magnesia)

Procedure

Part I: Tests of the Unknown Solutions

1. Follow the safety instructions provided by your teacher and put on your safety goggles.
2. Label six small test tubes A to F with a water soluble marker. Obtain a sample of each of the six unknown solutions from your teacher and fill each test tube approximately half full. Place a dropping pipette in each test tube and organize these in a test tube rack.
3. Place two drops of each solution in separate labelled spots on a spot plate or a glass square. Next, add one drop of phenolphthalein solution to each spot and record your results in your copy of Table 1. If nothing happens, write "no change."

Table 1 Tests of the Unknown Solutions

Unknown solution	Phenolphthalein	Bromothymol blue	Red litmus	Blue litmus	Magnesium ribbon
A					
B					

4. Repeat Step 3 using bromothymol blue solution instead of phenolphthalein. Repeat Step 3 with a small piece of red litmus paper. Repeat Step 3 with a small piece of blue litmus paper.
5. Add a small strip of magnesium ribbon to the remaining solution in each test tube and record your results.
6. Place all solutions with solid waste such as litmus paper and magnesium ribbon in the designated waste container. Rinse all remaining chemicals from the glassware down the sink with lots of water.

Part II: Tests of Common Household Solutions

7. Repeat Part I for the household solutions. Record your results in your copy of Table 2.
8. Clean up your workstation and dispose of these materials as directed by your teacher. Wash your hands with soap and water.

Table 2 Tests of Common Household Solutions

Household solution	Phenolphthalein	Bromothymol blue	Red litmus	Blue litmus	Magnesium ribbon
vinegar					
oven cleaner					

Conclusion

Complete the following items to answer the questions posed at the beginning of the investigation.

Analysis

(a) Examine your results in Table 1. Classify ionic solutions A to F into one of three groups according to the following guidelines:

Group 1: all solutions that showed a change with the magnesium ribbon

Group 2: all solutions that showed changes with phenolphthalein, bromothymol blue, and litmus

Group 3: all solutions that fit in neither Group 1 nor Group 2

(b) Use your results from Table 2 to place the household solutions into your three groups.

(c) In chemistry terms, Group 1 chemicals are called acids, Group 2 chemicals are bases, and Group 3 chemicals are salts. Your teacher will provide you with the chemical formulas for the unknown solutions. Write these formulas under the headings of acids, bases, or salts.

(d) Examine the formulas for the acids and make up a definition of an acid. Do the same for bases and salts.

(e) Your teacher will provide you with the chemical formulas for the household solutions. Use your definitions to explain why each one is an acid, base, or salt.

(f) Summarize your test results in your copy of Table 3.

Table 3 Summary of Tests on Ionic Solutions

	Phenolphthalein	Bromothymol blue	Red litmus	Blue litmus	Magnesium ribbon
acids					
bases					
salts					

Evaluation

(g) Did your evidence enable you to confidently classify all of the solutions? Explain.

Synthesis

(h) Use your copy of Table 4 to predict the results for the given solutions.

Table 4 Summary of Tests on Ionic Solutions

Solution	Phenolphthalein	Bromothymol blue	Red litmus	Blue litmus	Magnesium ribbon
KBr					
$Sr(OH)_2$					
HNO_3					

CHAPTER 8

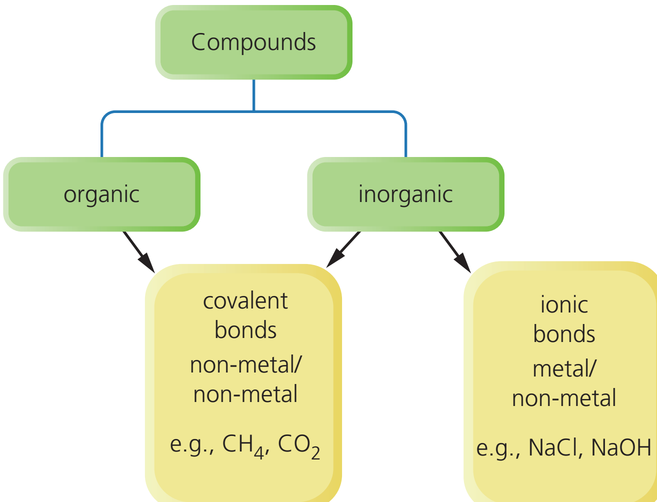
Review

Classifying Chemical Compounds

Key Ideas

All chemical compounds are either organic or inorganic.

- Organic compounds have a high percentage (by mass) of the element carbon; inorganic compounds do not.



Inorganic compounds can be molecular or ionic (acids, bases, or salts).

- Inorganic compounds can be molecular or ionic based on the type of bonds that hold the components (elements) together.
- Inorganic molecular compounds are common but few in number.
- Inorganic ionic compounds can be classified as acids, bases, or salts depending on their properties.
- Acids can be defined as substances that release H^+ ions in solution; bases as substances that release OH^- ions in solution; and salts as substances that release positive ions and negative ions *other than* H^+ and OH^- in solution.
- Acidity is the measure of the relative amounts of H^+ and OH^- in a solution and is often measured on a pH scale.
- Most acids can be named using a conventional system.

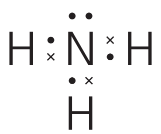
Solution classification	Relative ion count	Examples
acidic	$H^+ > OH^-$	HCl (aq) provides extra H^+
neutral	$H^+ = OH^-$	H_2O, NaCl (aq)
basic	$H^+ < OH^-$	NaOH (aq) provides extra OH^-

Vocabulary

organic compound, p. 201
inorganic compound, p. 201
acids, p. 203
bases, p. 203
salts, p. 203
aqueous, p. 203
acidity, p. 205
pH scale, p. 205
Lewis diagram, p. 210
bonding pair, p. 210
electron dot diagram, p. 210
octet rule, p. 212
covalent chemical bonds, p. 212
lone electron pairs, p. 212
organic chemistry, p. 215
structural formulas, p. 216
hydrocarbons, p. 218

Lewis diagrams (electron dot) can explain how molecular compounds form as a result of bonding pairs of electrons.

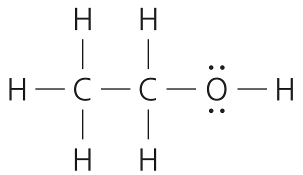
- A Lewis diagram is helpful for understanding covalent bonding in molecular compounds.
- Lewis diagrams only show valence electrons, which are typically represented by dots around an element's symbol.
- An element prepares for bonding by arranging valence electrons as single electrons whenever possible.
- Single electrons from one element pair with single electrons from other elements to form bonding pairs of electrons.
- Atoms of elements attempt to achieve complete valence shells similar to their nearest noble gas. This is known as the octet rule.

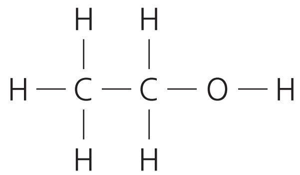


Organic compounds are molecular and contain carbon and hydrogen.

- Organic chemistry is the chemistry of carbon compounds.
- Besides carbon, organic compounds contain hydrogen, and sometimes oxygen or other non-metals.
- Organic compounds can be natural or synthetic.
- Simplified Lewis diagrams or structural formulas can be drawn to help visualize organic molecules.
- Organic compounds are so numerous that an elaborate classification scheme into families is necessary. Families include hydrocarbons, alcohols, and ethers.

C_2H_5OH





Many of these questions are in the style of the Science 10 Provincial Exam. The following icons indicate an exam-style question and its cognitive level.
K Knowledge U Understanding and Application HMP Higher Mental Processes

Review Key Ideas and Vocabulary

K **1.** Which of the following did early chemists think applied to organic compounds?
A. They were healthy to eat.
B. They were free of pesticides.
C. They were composed of organic matter.
D. They were derived from living organisms.

K **2.** Which of the following is found in all organic compounds?
A. water
B. carbon
C. oxygen
D. nitrogen

K **3.** Which of the following is *not* a type of ionic compound?
A. salt
B. acid
C. base
D. water

K **4.** Which of the following is correct in a Lewis diagram?

I	The electrons are represented by dots.
II	Only valence electrons are represented.
III	The electrons are shown in different shells.

A. I and II only
B. I and III only
C. II and III only
D. I, II, and III

K **5.** The octet rule generally refers to the tendency for a bonding atom to acquire
A. 8 valence electrons.
B. a total of 8 electrons.
C. 2 plus 8 for a total of 10 electrons.
D. an equal number of electrons and protons.

K **6.** Which of the following statements applies to acids, bases, and salts?
A. Their solutions conduct electricity.
B. They react with chemical indicators.
C. They cause litmus paper to change colour.
D. They react with metals to produce hydrogen gas.

7. (a) What types of elements are commonly found in ionic compounds?
(b) What types of elements are commonly found in molecular compounds?

8. (a) Use relative amounts of H^+ and OH^- to describe how a solution is classified as acidic, basic, or neutral.
(b) Explain why water is neutral.

9. (a) What is the normal range of the pH scale?
(b) What do the following pH values represent?
(i) 3
(ii) 9
(iii) 7

10. What difference exists between the acidity of a solution with a pH of 3 and one with a pH of 2?

11. Why does carbon form such a large number of organic compounds?

K **12.** Which of the following describes the number and location of the electrons in a Bohr diagram of an atom?

	Number of electrons	Location of electrons
A.	equal to the number of protons	arranged in shells around the nucleus
B.	equal to the number of protons	arranged in a single shell around the nucleus
C.	equal to the number of neutrons	arranged in shells around the nucleus
D.	equal to the number of neutrons	arranged in a single shell around the nucleus

Use What You've Learned

13. What test is commonly used to determine if a compound is ionic or covalent and what would be its results?

U 14. What is the name of the acid H_2CrO_4?
   A. chromic acid
   B. chromous acid
   C. hydrochromic acid
   D. hydrochromous acid

15. Copy Table 1, and then complete.

Table 1

Formula	Name	Litmus test result	Classification (acid, base, or salt)
KOH			
	chloric acid		
	potassium chromate		
H_2SO_3			
	lead(II) iodide		
HBr			
	calcium hydroxide		

U 16. What is the number of valence electrons for a phosphorus atom?
   A. 5
   B. 8
   C. 15
   D. 31

17. Draw Lewis diagrams for atoms of the following elements:
   (a) Ca
   (b) H
   (c) C
   (d) O
   (e) N

18. Draw Lewis diagrams for the following molecules. Then, draw structural formulas for the molecules.
   (a) PH_3
   (b) H_2O
   (c) CCl_4

19. Draw structural formulas for the following organic molecules:
   (a) C_2H_6
   (b) C_3H_8

Think Critically

HMP 20. If some acid is added to a solution with a pH of 10.0, what will always happen to the pH of the solution?
   A. The pH will increase.
   B. The pH will decrease.
   C. The pH will become 7.0.
   D. The pH will stay the same.

21. Conduct an Internet search to make a list of some common situations where pH is important.

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22. Carbon dioxide is a common gas with the well-known formula, CO_2. Attempt to draw a Lewis diagram for a molecule of CO_2 to discover why more advanced Lewis theories are necessary.

23. Do an Internet search to learn the chemical formula for an organic chemical of your choice. For ideas of an organic chemical, consider the name of a medicine, drug, household plastic, fabric, or others. Examine labels for ideas. How will you know when you discover an organic chemical formula?

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Reflect on Your Learning

24. Write a short paragraph to explain how your ideas about acids, bases, and salts have changed since studying this chapter. What did you think about these chemicals before?

Visit the Quiz Centre at
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