What Are Covalent Bonds?

Another type of bond is a covalent bond. A covalent bond forms when atoms share electrons. Covalent bonds most often form between atoms of nonmetals. Remember that most nonmetals can fill the outermost energy level by gaining an electron. When a covalent bond forms, both atoms are able to fill their outermost energy level. They do this by sharing electrons between the two atoms.

Hydrogen is one example of an atom that bonds covalently. A hydrogen atom has one electron in its outermost level. Two hydrogen atoms can come together and share their electrons. This fills the first energy level of both atoms. The electrons move around both hydrogen nuclei. The protons and the shared electrons attract one another. This attraction holds the atoms together.

By sharing electrons in a covalent bond, each hydrogen atom (the smallest atom) has a full outermost energy level containing two electrons.

What Are Molecules?

Atoms that join with each other by covalent bonds form particles called molecules. Most molecules are made of atoms of two or more elements. The atoms share electrons. In the figure above, two hydrogen atoms have formed a covalent bond. The result is a hydrogen molecule.
PROPERTIES OF MOLECULES
Remember that an atom is the smallest piece of an element that still has the properties of that element. In the same way, a molecule is the smallest piece of a covalent compound that has the properties of that compound. This means that if a molecule is broken down, it will no longer have the properties of that compound.

Most covalently bonded substances have low melting and boiling points (water is an exception to this). Many are gases at room temperature. When a substance with covalent bonds forms a solid, the solid tends to be soft.

How Can You Model a Covalent Bond?
An electron-dot diagram is a model that shows only the valence electrons of an atom. The figure below shows the electron-dot diagrams for the elements in the second row of the periodic table.

<table>
<thead>
<tr>
<th>Electron-Dot Diagrams</th>
<th>Li·</th>
<th>Be·</th>
<th>B·</th>
<th>C·</th>
<th>N·</th>
<th>O=</th>
<th>F·</th>
<th>Ne:</th>
</tr>
</thead>
</table>

Electron-dot diagrams are used to show how atoms bond in molecules. In the diagram below, you can see the pairs of electrons that form the covalent bonds in a water molecule.

Critical Thinking
4. Apply Concepts Draw the electron-dot diagram that shows how two hydrogen atoms bond with a covalent bond.
What Kinds of Molecules Can Form?

Molecules contain at least two atoms bonded by covalent bonds. The simplest molecules are made up of only two bonded atoms. They are called diatomic molecules. If the two atoms are of the same element, the substance is known as a diatomic element. The oxygen and nitrogen in the air that we breathe are both diatomic elements.

In any diatomic molecule, each of the shared electrons is counted as a valence electron for both atoms. As a result, both atoms of the molecule have filled outermost energy levels.

Electron-Dot Diagrams for Chlorine, Oxygen, and Nitrogen Gas

\[ \text{Cl} \cdot \text{Cl} \quad \text{O} :: \text{O} \quad \text{N} :: \text{N} \]

Chlorine  Oxygen  Nitrogen

COUNTING COVALENT BONDS

We have seen how atoms can share one or more pairs of electrons. The oxygen atom in water shares two pairs of electrons, one pair with each hydrogen atom. This means that the oxygen atom in a water molecule forms two covalent bonds.

The number of shared pairs of electrons tells you the number of covalent bonds in a molecule. In the figure above, you counted the number of electron pairs shared in molecules of chlorine, oxygen, and nitrogen. In a chlorine molecule, there is one covalent bond. There are two covalent bonds in an oxygen molecule and three in a nitrogen molecule.

Many molecules are more complex than the molecules in the figure. As you may suspect, some molecules have many covalent bonds.

READING CHECK

5. Identify What type of molecule is made of only two bonded atoms?

TAKE A LOOK

6. Count How many electrons are around each chlorine atom, each oxygen atom, and each nitrogen atom? (Remember, the electrons that are shared count for each atom.)

Chlorine: _____________
Oxygen: ______________
Nitrogen: ______________

7. Count How many pairs of electrons are shared in each molecule?

Chlorine: ______________
Oxygen: ______________
Nitrogen: ______________

Critical Thinking

8. Apply Concepts How many covalent bonds does phosphorus (P) form in the molecule shown below:

\[ \text{H}::\text{P}::\text{H} \]
MORE COMPLEX MOLECULES

Many molecules are much larger and more complex than diatomic molecules or water. Complex molecules have many atoms joined by covalent bonds. Complex molecules make up many important and familiar substances, such as gasoline, soap, plastics, proteins, and sugars. In fact, most of the substances that make up your body are complex molecules!

Carbon (C) atoms are the basis of many complex molecules. Carbon has four valence electrons. To fill its outer energy level, a carbon atom needs to gain four electrons. Therefore, carbon atoms can form four covalent bonds. Carbon atoms can form bonds with other carbon atoms. They also can bond to atoms of other elements, such as oxygen, hydrogen, and nitrogen. Most of the molecules that carbon forms are very complex.

Model of an Octane Molecule Found in Gasoline

What Are Metallic Bonds?

The bonding in metals is different from the bonding we have discussed. Metals are substances like copper, iron, silver, and nickel. A metallic bond is formed by the attraction between positively charged metal ions and the electrons around the ions.

Model Showing Metallic Bonding

The bonding in metals is a result of the closeness of many metal atoms. Their outermost energy levels overlap. Because of the overlapping, metallic bonds form and extend throughout the metal in all directions. The valence electrons can move throughout the metal. The electrons keep the ions together and cancel the positive charge of the ions.
What Are the Properties of Metals?

You probably know if something is metal as soon as you look at it. Most metals are very shiny, like gold, silver, copper, nickel, and platinum. Metals have other properties that identify a substance as a metal.

CONDUCTING ELECTRIC CURRENT

Metallic bonding allows metals to conduct electricity. Metals are used to make wires. When the wire is attached to an electrical source, the valence electrons are free to move throughout the wire. They can light a bulb or power a radio. ✓

RESHAPING METALS

The atoms in metals can be rearranged easily because the electrons move around freely. The valence electrons of metals are constantly moving around the metal ions. This movement maintains the metallic bonds. As a result, no matter how the shape of the metal is altered, it won’t break. This is why metals can so easily change their shape. Two properties describe a metal’s ability to be reshaped:

• **Ductility** is the ability to be shaped into long, thin wires.
• **Malleability** is the ability to be hammered into thin sheets. ✓

Ductility and malleability are the properties that make many metals useful for people. Copper can be stretched to make electrical wires. Aluminum can be pounded to form sheets of foil. Silver and gold can be mixed with other metals and bent to form jewelry or fill cavities in teeth.

✓ READING CHECK

12. Explain Why can a wire conduct an electric current when it is connected to an electrical source?

13. Define What does ductility mean? What does malleability mean?
Section 3 Review

SECTION VOCABULARY

<table>
<thead>
<tr>
<th>covalent bond</th>
<th>a bond formed when atoms share one or more pairs of electrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>metallic bond</td>
<td>a bond formed by the attraction between positively charged metal ions and the electrons around them</td>
</tr>
<tr>
<td>molecule</td>
<td>a group of atoms that are held together by chemical forces; a molecule is the smallest unit of matter that can exist by itself and retain all of a substance’s chemical properties</td>
</tr>
</tbody>
</table>

1. Apply Ideas  The following is a list of elements: gold, carbon, oxygen, aluminum, copper, and fluorine. In the table below, list each under the correct heading.

<table>
<thead>
<tr>
<th>Forms covalent bonds</th>
<th>Forms metallic bonds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gold</td>
<td></td>
</tr>
<tr>
<td>Carbon</td>
<td></td>
</tr>
<tr>
<td>Oxygen</td>
<td></td>
</tr>
<tr>
<td>Aluminum</td>
<td></td>
</tr>
<tr>
<td>Copper</td>
<td></td>
</tr>
<tr>
<td>Fluorine</td>
<td></td>
</tr>
</tbody>
</table>

2. Apply Concepts  Nitrogen has five valence electrons, and hydrogen has one. An ammonia molecule has one nitrogen atom and three hydrogen atoms. Draw an electron-dot diagram for a molecule of ammonia.

3. Apply Concepts  In addition to conducting electricity, metals conduct heat quickly. Substances with covalent bonds are not good conductors of heat or electricity. Which type of substance would you use as insulating material for a hot mitt? Which type of substance would you use as a heating coil in an electric toaster?

4. Make Inferences  What happens to the properties of oxygen when oxygen bonds with hydrogen to form water?

5. Identify  List three properties of metals that are caused by metallic bonding.
Chapter 1 Chemical Bonding

SECTION 1 ELECTRONS AND CHEMICAL BONDING

1. Atoms gain, lose, or share electrons.
2. in energy levels outside the nucleus
3. in the outermost energy level
4. six protons, six electrons
5. two
6. six
7. to get a full outermost energy level
8. lose

Review

1. Atoms bond by losing electrons to other atoms, gaining electrons from other atoms, or sharing electrons with other atoms.
2. two dots on inner circle, seven red dots on outer circle
3. The easiest way for an atom with seven valence electrons to complete its outermost level is to gain one electron from another atom (but it may share electrons).
4. The Mg atom can give its two valence electrons to the O atom.
5. 16, 16

SECTION 2 IONIC BONDS

1. when valence electrons are transferred from one atom to another
2. Ions are atoms that have gained or lost electrons. Atoms are neutral; ions have a charge.
3. 2+
4. The attraction between the electron and the protons has to be broken.
5. from forming negative ions
6. nonmetals
7. a lot of energy
8. because positive ions are attracted to negative ions

Review

1. Magnesium loses its two electrons to a nonmetal atom. It becomes a positive ion with a charge of 2+.
2. Two arrows should be drawn from the outermost electrons in magnesium to the outermost electron levels in sulfur.

3. Potassium will become a positive ion because it will lose an electron. Fluorine will become a negative ion because it will gain an electron.
4. crystal lattice

SECTION 3 COVALENT AND METALLIC BONDS

1. Electrons are shared in covalent bonds; they are not gained or lost.
2. covalent
3. H
4. H:H
5. diatomic molecule
6. Chlorine: eight
   Oxygen: eight
   Nitrogen: eight
7. Chlorine: one pair
   Oxygen: two pairs
   Nitrogen: three pairs
8. three covalent bonds
9. four
10. It is formed by the attraction between positively charged metal ions and the electrons around the ions.
11. The electrons can move throughout the metal.
12. Valence electrons are free to move throughout the wire.
13. Ductility means being able to be shaped into long, thin wires. Malleability means being able to be hammered into sheets.

Review

1. | Forms covalent bonds | Forms metallic bonds |
   | oxygen | gold |
   | carbon | aluminum |
   | fluorine | copper |

2. \[
\begin{array}{c}
H \quad \vdots \\
\vdots \\
H : N : H \\
\vdots \\
\end{array}
\]

3. First question: You would use substances with covalent bonds as insulation.
   Second question: You would use a metal to conduct heat.
4. The properties of oxygen change; water does not have the same properties as oxygen.

5. Metals can conduct electricity, can be stretched into wires, and can be hammered into thin sheets.

Chapter 2 Chemical Reactions

SECTION 1 FORMING NEW SUBSTANCES

1. One or more substances break apart or combine to form one or more new substances.

2. A solid forms in a solution.

3. No, some physical changes, like boiling, may produce a gas.

4. The chemical properties of the new substances are different from those of the original substances.

5. Some bonds are broken and new bonds form.

6. The bonds in the hydrogen and chlorine molecules are broken. The bonds in the hydrogen chloride molecule form.

Review

1. New substances are formed during a chemical reaction. Formation of a precipitate is one sign that a new substance has been formed.

2. Observed during a chemical reaction | Sign of a chemical reaction
--- | ---
precipitate in a solution | solid formation
heat given off | energy change
green gas | gas formation
colorless solution turned blue | color change

3. chemical bond

4. When water boils, a new substance is not formed. The water vapor that forms during boiling can condense into liquid water.

5. The chemical properties of the material in the beaker are different from those of the original substances. This shows that a chemical reaction must have occurred.

SECTION 2 CHEMICAL FORMULAS AND EQUATIONS

1. the elements found in a substance and how many atoms of each element are in a molecule

2. three

3. PCl₃

4. 3+

5. a short way to show what happens in a chemical reaction using symbols and formulas

6. Reactants: C, O₂
   Products: CO₂

7. If you use the wrong chemical formula, a chemical equation will not describe the reaction you are trying to describe.

8. A chemical equation shows that no atoms are lost or gained during a chemical reaction.

9. a number that is placed in front of a chemical formula

10. subscripts

11. 2Na + Cl₂ → 2NaCl

Review

1. A chemical formula represents a substance. A chemical equation represents a chemical reaction.

2. | Chemical equation | Number of atoms in the reactants | Number of atoms in the products | Is the equation balanced?
--- | --- | --- | ---
Na + Cl₂ → NaCl | Na = 1 Cl = 2 | Na = 1 Cl = 1 | no
HCl + NaOH → NaCl + H₂O | H = 2 Cl = 1 Na = 1 O = 1 | H = 2 Cl = 1 Na = 1 O = 1 | yes
2Sb + 3I₂ → 2SbI₃ | Sb = 2 I = 6 | Sb = 2 I = 6 | yes

3. SiO₂: silicon dioxide
   SbF₃: antimony trifluoride

4. Changing the subscripts changes the substance in the chemical reaction. Therefore, if you change subscripts, you change the chemical reaction that you are describing.

5. 3Mg + N₂ → Mg₃N₂