

Chemical Bonding

The Big Idea

Atoms combine by forming ionic, covalent, and metallic bonds.

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About the PHOTO

What looks like a fantastic “sculpture” is really a model of deoxyribonucleic acid (DNA). DNA is one of the most complex molecules in living things. In DNA, atoms are bonded together in two very long spiral strands. These strands join to form a double spiral. The DNA in living cells has all the coding for passing on the traits of that cell and that organism.

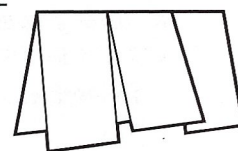
PRE-READING Activity



FOLDNOTES

Three-Panel Flip Chart

Before you read the chapter, create the FoldNote entitled “Three-Panel Flip Chart” described in the **Study Skills** section of the Appendix. Label the flaps of the three-panel flip chart with “Ionic bond,” “Covalent bond,” and “Metallic bond.” As you read the chapter, write information you learn about each category under the appropriate flap.



Electrons and Chemical Bonding

Have you ever stopped to consider that by using only the 26 letters of the alphabet, you make all of the words you use every day?

Although the number of letters is limited, combining the letters in different ways allows you to make a huge number of words. In the same way that words can be formed by combining letters, substances can be formed by combining atoms.

What You Will Learn

- Describe chemical bonding.
- Identify the number of valence electrons in an atom.
- Predict whether an atom is likely to form bonds.

Vocabulary

chemical bonding
chemical bond
valence electron

READING STRATEGY

Discussion Read this section silently. Write down questions that you have about this section. Discuss your questions in a small group.

Combining Atoms Through Chemical Bonding

Look at **Figure 1**. Now, look around the room. Everything you see—desks, pencils, paper, and even your friends—is made of atoms of elements. All substances are made of atoms of one or more of the approximately 100 elements. For example, the atoms of carbon, hydrogen, and oxygen combine in different patterns to form sugar, alcohol, and citric acid. **Chemical bonding** is the joining of atoms to form new substances. The properties of these new substances are different from the properties of the original elements. An interaction that holds two atoms together is called a **chemical bond**. When chemical bonds form, electrons are shared, gained, or lost.

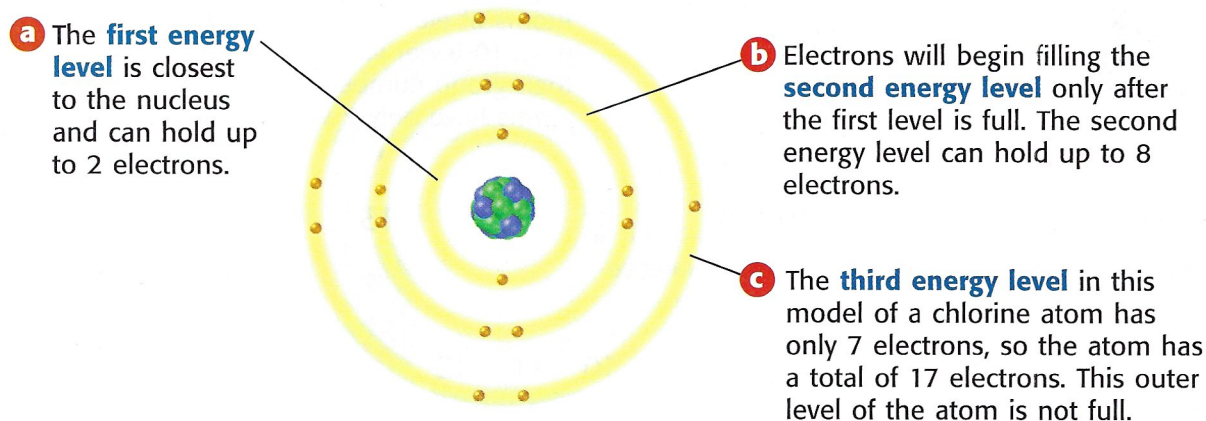
Discussing Bonding Using Theories and Models

We cannot see atoms and chemical bonds with the unaided eye. For more than 150 years, scientists have done many experiments that have led to a theory of chemical bonding. Remember that a theory is an explanation for some phenomenon that is based on observation, experimentation, and reasoning. The use of models helps people discuss the theory of how and why atoms form bonds.



Figure 1 Everything you see in this photo is formed by combining atoms.

Figure 2 Electron Arrangement in an Atom



Electron Number and Organization

To understand how atoms form chemical bonds, you need to know about the electrons in an atom. The number of electrons in an atom can be determined from the atomic number of the element. The *atomic number* is the number of protons in an atom. But atoms have no charge. So, the atomic number also represents the number of electrons in the atom.

Electrons in an atom are organized in energy levels. **Figure 2** shows a model of the arrangement of electrons in a chlorine atom. This model and models like it are useful for counting electrons in energy levels of atoms. But, these models do not show the true structure of atoms.

Outer-Level Electrons and Bonding

Not all of the electrons in an atom make chemical bonds. Most atoms form bonds using only the electrons in the outermost energy level. An electron in the outermost energy level of an atom is a **valence electron** (VAY luhns ee LEK TRAHN). The models in **Figure 3** show the valence electrons for two atoms.

✓ Reading Check Which electrons are used to form bonds?
(See the Appendix for answers to Reading Checks.)

chemical bonding the combining of atoms to form molecules or ionic compounds

chemical bond an interaction that holds atoms or ions together

valence electron an electron that is found in the outermost shell of an atom and that determines the atom's chemical properties

Figure 3 Counting Valence Electrons

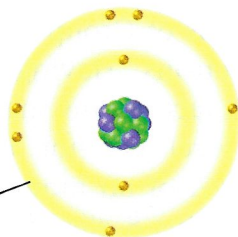
Oxygen

Electron total: 8

First level: 2 electrons

Second level: 6 electrons

An oxygen atom has 6 valence electrons.



Sodium

Electron total: 11

First level: 2 electrons

Second level: 8 electrons

Third level: 1 electron

A sodium atom has 1 valence electron.

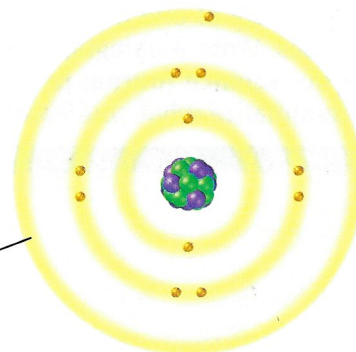


Figure 4 Determining the Number of Valence Electrons

Atoms of elements in **Groups 1 and 2** have the same number of valence electrons as their group number.

Atoms of elements in **Groups 13–18** have 10 fewer valence electrons than their group number. However, helium atoms have only 2 valence electrons.

H																	18
1	2	Atoms of elements in Groups 3–12 do not have a rule relating their valence electrons to their group number.										13	14	15	16	17	He
Li	Be											B	C	N	O	F	Ne
Na	Mg	3	4	5	6	7	8	9	10	11	12	Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds	Uuu	Uub	Uut	Uuq	Uup			

Valence Electrons and the Periodic Table

You can use a model to determine the number of valence electrons of an atom. But what would you do if you didn't have a model? You can use the periodic table to determine the number of valence electrons for atoms of some elements.

Elements are grouped based on similar properties. Within a group, or family, the atoms of each element have the same number of valence electrons. So, the group numbers can help you determine the number of valence electrons for some atoms, as shown in **Figure 4**.

CONNECTION TO Social Studies

WRITING SKILL

History of a Noble Gas

When Dmitri Mendeleev organized the first periodic table, he did not include the noble gases. The noble gases had not been discovered at that time. Research the history of the discovery of one of the noble gases. Write a paragraph in your **science journal** to summarize what you learned.

To Bond or Not to Bond

Not all atoms bond in the same manner. In fact, some atoms rarely bond at all! The number of electrons in the outermost energy level of an atom determines whether an atom will form bonds.

Atoms of the noble gases (Group 18) do not usually form chemical bonds. Atoms of Group 18 elements (except helium) have 8 valence electrons. Having 8 valence electrons is a special condition. In fact, atoms that have 8 electrons in their outermost energy level do not usually form bonds. The outermost energy level of an atom is considered to be full if the energy level contains 8 electrons.



Reading Check The atoms of which group in the periodic table rarely form chemical bonds?

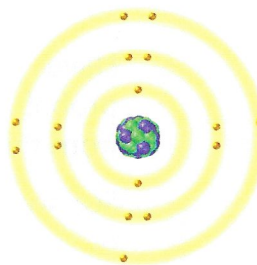
Filling The Outermost Level

An atom that has fewer than 8 valence electrons is much more likely to form bonds than an atom that has 8 valence electrons is. Atoms bond by gaining, losing, or sharing electrons to have a filled outermost energy level. A filled outermost level contains 8 valence electrons. **Figure 5** describes how atoms can achieve a filled outermost energy level.

Is Two Electrons a Full Set?

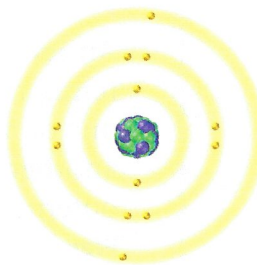
Not all atoms need 8 valence electrons to have a filled outermost energy level. Helium atoms need only 2 valence electrons. The outermost energy level in a helium atom is the first energy level. The first energy level of any atom can hold only 2 electrons. So, the outermost energy level of a helium atom is full if the energy level has only 2 electrons. Atoms of hydrogen and lithium also form bonds by gaining, losing, or sharing electrons to achieve 2 electrons in the first energy level.

Figure 5 Filling Outermost Energy Levels



Sulfur

An atom of sulfur has 6 valence electrons. It can have 8 valence electrons by sharing 2 electrons with or gaining 2 electrons from other atoms.



Magnesium

An atom of magnesium has 2 valence electrons. It can have a full outer level by losing 2 electrons. The second energy level becomes the outermost energy level and contains 8 electrons.

SECTION Review

Summary

- Chemical bonding is the joining of atoms to form new substances. A chemical bond is an interaction that holds two atoms together.
- A valence electron is an electron in the outermost energy level of an atom.
- Most atoms form bonds by gaining, losing, or sharing electrons until they have 8 valence electrons. Atoms of some elements need only 2 electrons to fill their outermost level.

Using Key Terms

1. Use the following terms in the same sentence: *chemical bond* and *valence electron*.

Understanding Key Ideas

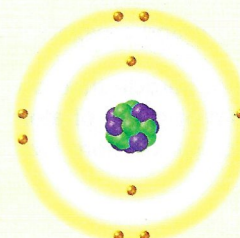
2. Which of the following atoms do not usually form bonds?
a. calcium c. hydrogen
b. neon d. oxygen
3. Describe chemical bonding.
4. Explain how to use the valence electrons in an atom to predict if the atom will form bonds.

Critical Thinking

5. **Making Inferences** How can an atom that has 5 valence electrons achieve a full set of valence electrons?
6. **Applying Concepts** Identify the number of valence electrons in a barium atom.

Interpreting Graphics

7. Look at the model below. How many valence electrons are in a fluorine atom? Will fluorine atoms form bonds? Explain.



Fluorine

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Topic: The Electron; Periodic Table
SciLinks code: HSM0489; HSM1125