Section 2
Ionic Bonds

Key Concept Ionic bonds form when electrons are transferred from one atom to another atom.

What You Will Learn
- Ions of different elements can combine by forming ionic bonds.
- Positive ions and negative ions form when atoms lose or gain electrons.
- Ionic compounds form solids by building up a repeating pattern called a *crystal lattice.*

Why It Matters
Learning about ionic bonds can help you understand the properties of ionic compounds, such as table salt.

Have you ever tasted sea water? If so, you most likely didn't enjoy it. Sea water tastes different from tap water because salt is dissolved in sea water. One of the salts in sea water is the same as the table salt that you eat. The chemical bonds in salt are ionic bonds.

Forming Ionic Bonds
Figure 1 shows another substance that contains ionic bonds. An **ionic bond** forms when valence electrons are transferred from one atom to another atom. Like all chemical bonds, ionic bonds form so that the outermost energy levels of the atoms in the bonds are filled. In an ionic bond, one atom has lost electrons. And the other atom has gained electrons.

Figure 1 Calcium carbonate in this snail's shell contains ionic bonds.

Standards Check What happens during ionic bonding?

Charged Particles

An atom is neutral because the number of electrons in an atom equals the number of protons. So, the electric charges of the electrons and protons cancel each other. A transfer of electrons between atoms changes the number of electrons in each atom. But the number of protons stays the same in each atom. The negative charges and positive charges no longer cancel out, and the atoms become ions. **Ions** are charged particles that form when atoms gain or lose electrons. If an ion has more protons than electrons, it is a positive ion. If it has more electrons than protons, it is a negative ion.

Forming Positive Ions

During chemical changes, ionic bonds form when atoms pull electrons away from other atoms. The atoms that lose electrons form positive ions because these atoms have more protons than electrons. There are more positive charges than negative charges. So, the net charge on

these ions is positive.

Metal Atoms and the Loss of Electrons

Atoms of most metals have few electrons in their outermost energy level. When metal atoms bond with other atoms, the metal atoms tend to lose these valence electrons and form positive ions. The aluminum atom shown in **Figure 2** has three valence electrons. When it loses these electrons to another atom, the aluminum atom becomes an ion. So, an aluminum ion has three more protons than it has electrons. The ion has a 3+ charge. The chemical symbol for this ion is written as Al^{3+}. Notice that the charge is written to the upper right of the chemical symbol.

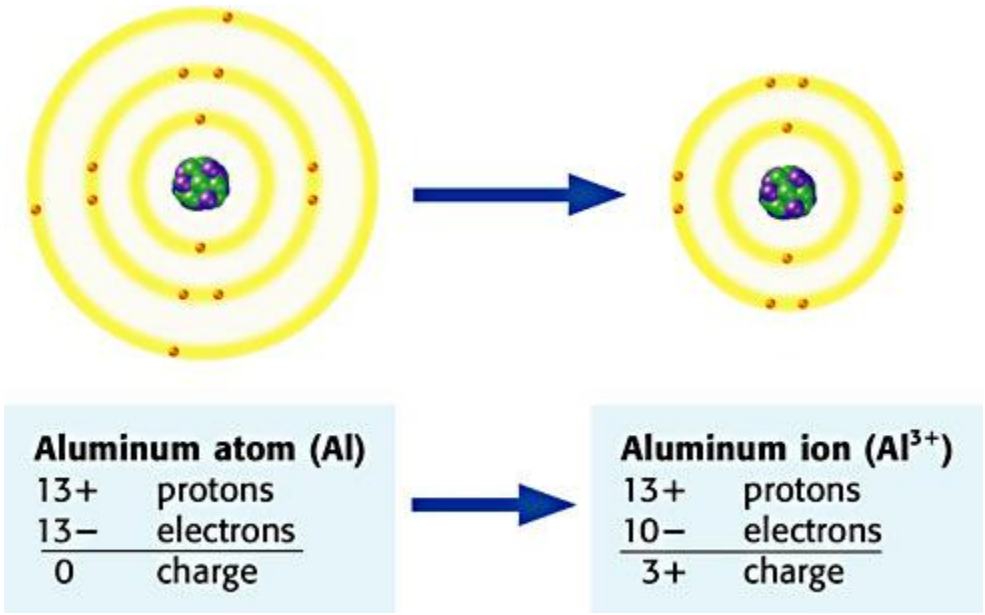


Figure 2 An aluminum atom can lose its three electrons in the third energy level to another atom. The filled second level then becomes the outermost energy level, so the aluminum ion has eight valence electrons.

The Energy Needed to Remove Electrons

When an atom loses electrons, energy is needed to overcome the attraction of the electrons to the protons in the nucleus. Much less energy is needed to take electrons from metal atoms than from nonmetal atoms. The elements in Groups 1 and 2 react very easily because the energy needed to remove electrons from their atoms is so small. So, only the ions, and not the atoms, of these elements are found in nature. In ionic bonding, the energy needed to remove electrons from metal atoms comes from the formation of negative ions.

Standards Check Explain why energy is needed to form positive ions.

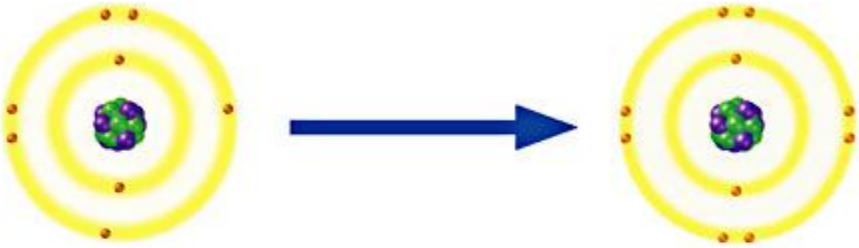
Forming Negative Ions

During chemical changes, some atoms gain electrons from other atoms. The ions that form have more electrons than protons. These ions have an overall negative charge because there are more negative charges than positive charges.

How Nonmetal Atoms Become Negative Ions

The outermost energy level of nonmetal atoms is almost full. Only a few electrons are needed to fill it. So, atoms of nonmetals tend to gain electrons from other atoms.

Figure 3 shows how an atom can become a negative ion. An atom of oxygen has six valence electrons. So, an oxygen atom needs only two electrons to have a full set of valence electrons. When an oxygen atom gains two electrons, it becomes an oxide ion that has a 2− charge. The symbol for the oxide ion is O^{2-}.



Oxygen atom (O)	
8+	protons
8−	electrons
0	charge

Oxide ion (O^{2-})	
8+	protons
10−	electrons
2−	charge

Figure 3 An oxygen atom can gain two electrons in the second energy level from another atom. An oxide ion that has eight valence electrons is formed. Thus, its outermost energy level is filled.

Notice that the name of the negative ion formed from oxygen ends with *-ide.* This ending is used for the names of the negative ions formed when atoms gain electrons.

The Energy of Gaining Electrons

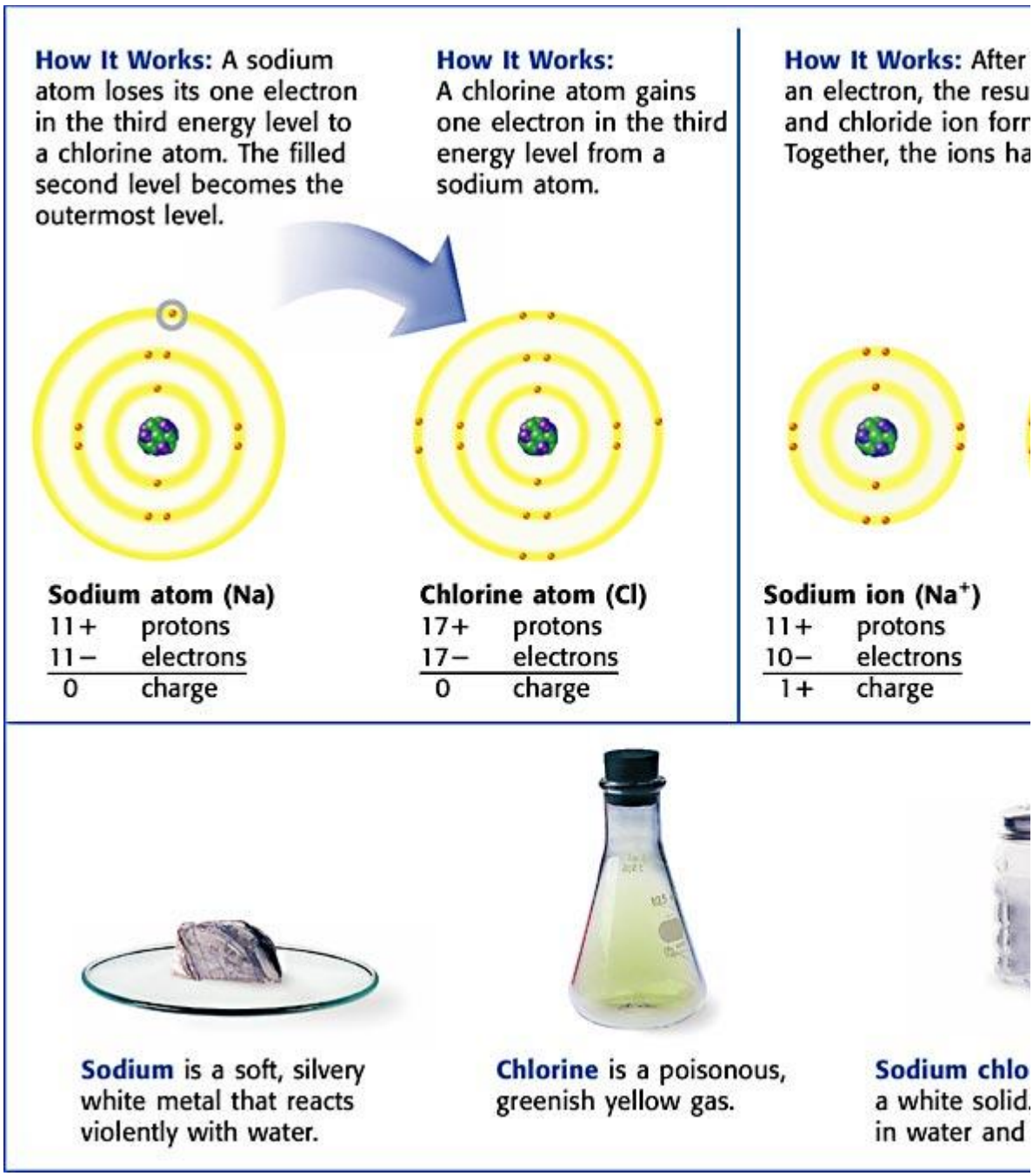
Atoms of most nonmetals fill their outermost energy level by gaining electrons. Energy is given off by most nonmetal atoms when they gain electrons. The more easily an atom gains an electron, the more energy the atom releases. Atoms of Group 17 elements (the halogens) give off the most energy when they gain an electron. The halogens, such as fluorine and chlorine, are very reactive because they release a large amount of energy. An ionic bond forms because of the strong forces of attraction between the positive metal ions and the negative nonmetal ions.

Standards Check Atoms of which group in the periodic table give off the most energy when forming negative ions?

Forming Ionic Compounds

When ionic bonds form, the number of electrons lost by the metal atoms equals the number gained by the nonmetal atoms, as shown in **Figure 4.** The ions that bond are charged. But the compound formed is neutral because the charges cancel each other. An ionic bond forms because the opposite charges of the ions cause the ions to stick together.

Figure 4 Forming Sodium Chloride



When a metal and a nonmetal combine by ionic bonding, the resulting compound has different properties than the metal and nonmetal did. In **Figure 4,** you can see how the properties of sodium and chlorine differ from the properties of the ionic compound sodium chloride.

Standards Check Compare the properties of sodium chloride with the properties of the elements sodium and chlorine.

Ionic Compounds

The ions that make up an ionic compound are bonded in a repeating three-dimensional pattern called a **crystal lattice.** In ionic compounds such as table salt, the crystal lattice is built up so that the positive ions are nearest to the negative ions, forming a solid. The model in **Figure 5** shows a small part of a crystal lattice. The shape of the crystals of an ionic compound depends on the pattern of ions in its crystal lattice.

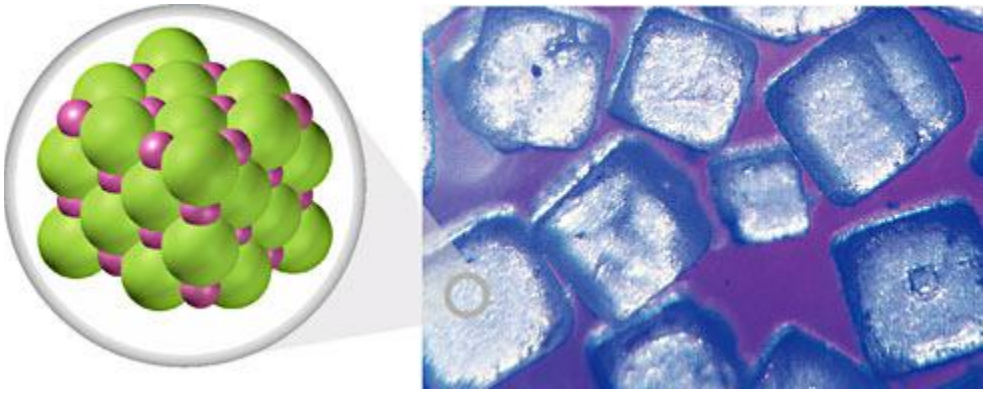


Figure 5 This model of the crystal lattice of sodium chloride, or table salt, shows a three-dimensional view of the bonded ions. In the model, the sodium ions are pink and the chloride ions are green. **What pattern do you see in the order of the ions?**

Standards Check What is a crystal lattice?

Properties of Ionic Compounds

The strong attraction between ions in a crystal lattice gives ionic compounds certain physical properties. Ionic compounds tend to be brittle solids at room temperature. So, these solids will break apart when they are hit with a hammer. Ionic compounds have high melting points. For example, magnesium oxide has to be heated to 2,800°C before it will melt. Because most substances have to melt before they boil, ionic compounds also have very high boiling points.

Another property of many ionic compounds is high solubility in water. High solubility means that compounds dissolve easily in water. Sea water tastes salty because it has sodium chloride and many other ionic compounds dissolved in it.

Section Summary

- An ionic bond forms when electrons are transferred from one atom to another. During ionic bonding, the atoms become oppositely charged ions.
- Ionic bonding usually occurs between atoms of metals and atoms of nonmetals.
- Energy is needed to remove electrons from metal atoms. Energy is released when most nonmetal atoms gain electrons.
- Ionic compounds form solids by building up a three-dimensional repeating pattern called a crystal lattice.
- Ionic compounds are brittle and highly soluble, with high melting and boiling points.