

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What is ionic bonding?
- What happens to atoms that gain or lose electrons?
- What kinds of solids are formed from ionic bonds?

How Do Ionic Bonds Form?

There are several types of chemical bonds. An ionic bond is one type. **Ionic bonds** form when valence electrons are transferred from one atom to another.

Like other bonds, ionic bonds form so that the outermost energy levels of the atoms that bond are filled. To understand why ionic bonds form, you need to learn what happens when atoms gain or lose electrons. ☑

What Happens When Atoms Gain or Lose Electrons?

An electron has a negative electrical charge. A proton has a positive electrical charge. An atom is *neutral*, or not charged, because the number of electrons in an atom equals the number of protons. The electrical charges cancel each other out.

Atoms that have gained or lost electrons are called **ions**. When an atom gains or loses electrons, the numbers of protons and electrons are no longer equal. Therefore, ions are not neutral like atoms. Atoms that lose electrons become positively charged ions because they have more protons than electrons. Atoms that gain electrons become negatively charged ions because they have more electrons than protons. ☑



A magnesium atom can lose its two valence electrons to another atom. The filled second level then becomes the outermost energy level. The magnesium ion has eight valence electrons.

How Do Positive Ions Form?

Electrons have a negative charge. Therefore, they are attracted to the positive charge of the protons in the nucleus. In order for an atom to lose an electron, the attraction between the electron and the protons has to be broken. Breaking the attraction takes energy. This energy is released when an ionic bond forms. ☐

Compared with other elements, only a small amount of energy is needed for metals to lose their valence electrons. Therefore, metals are much more likely to form positive ions than other elements are. Examples of metals are silver, sodium, copper, and aluminum.

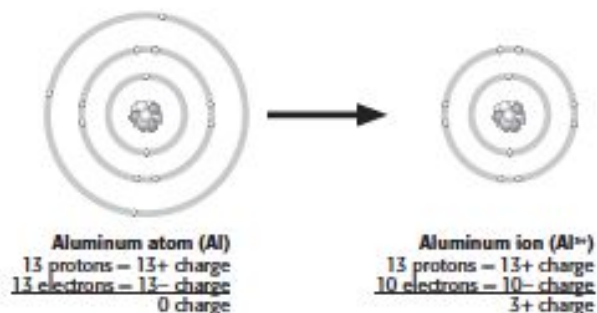
The elements in Groups 1 and 2 are all metals. They need little energy to lose their valence electrons. Therefore, the metals in Groups 1 and 2 form ions very easily. In the language of chemistry, that means they are very *reactive* metals.

DETERMINING THE CHARGE ON A POSITIVE ION

Ions can have different charges. The charge on a positive ion depends on the number of electrons the atom loses. The number of valence electrons in an atom tells you the charge on the ion that the atom will form. For example, Aluminum (Al) has three valence electrons. It is a metal, so it usually loses those electrons when it forms bonds. Two changes happen after it loses the electrons:

- The second energy level becomes the outermost level.
- The Al ion has three more protons than electrons.

The Al atom becomes an Al ion with a 3+ charge. The ion is written as Al^{3+} . The equations below show why the Al ion has a 3+ charge.



How Do Negative Ions Form?

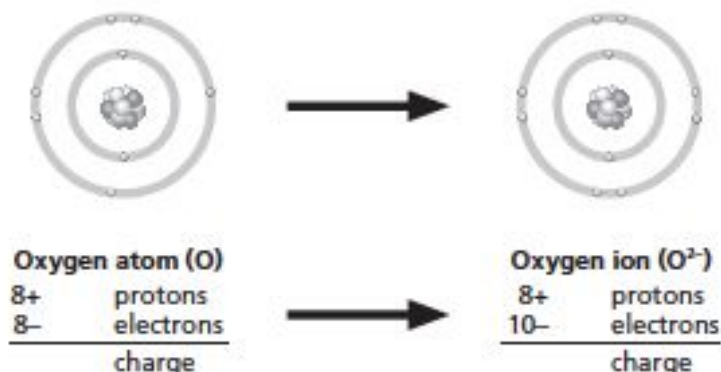
What happens to the electrons that metal atoms lose? They can move to nonmetal atoms, such as oxygen and nitrogen. The outermost energy level of a nonmetal is almost full. It is easier for it to fill its outer energy level by gaining electrons than by losing electrons. When atoms of most nonmetals gain electrons, they give off energy. ☐

The elements in Group 17 (the halogens) are all nonmetals. Their atoms give off a lot of energy when they gain electrons. In the language of chemistry, that means that the halogens are very reactive nonmetals. They can give off heat, light, and noise when they gain electrons. ☐

DETERMINING THE CHARGE ON A NEGATIVE ION

Like positive ions, negative ions can have different charges. The charge on a negative ion depends on the number of electrons the atom gains.

You can use the number of valence electrons in an atom to learn the charge on the ion it can form. For example, an oxygen atom has six valence electrons. Oxygen tends to form ions by gaining two electrons. These two electrons fill the outermost energy level of the oxygen atom. The oxygen atom becomes a negative ion with a charge of 2-.

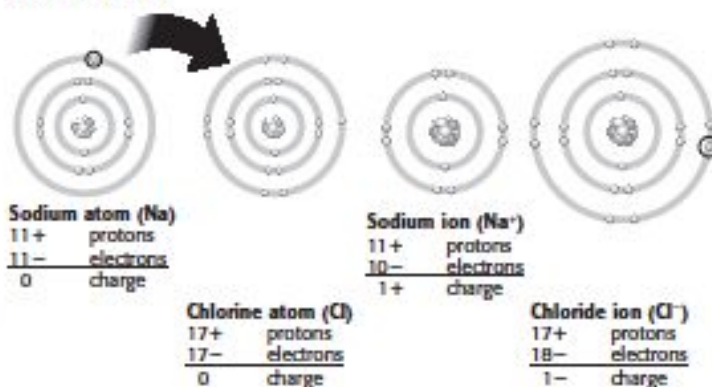


We change the names of atoms when they become negative ions by dropping the last few letters and adding *-ide*. For example, in the figure above, the oxygen atom becomes an oxide ion. Other examples of negative ions are chloride (Cl⁻) and fluoride (F⁻).

How Do Ionic Compounds Form?

Ionic bonds form because positive ions are attracted to negative ions. In order for electrons to move from one atom to another, the atoms must be very close together. When the electrons move, ions form. One ion has a positive charge. The other has a negative charge. The opposite charges on the ions cause the ions to stick together and form an ionic bond. The figure below shows an example of how an ionic bond forms. □

How It Works



The new compound shown in the figure is called sodium chloride. The chemical symbol for sodium is Na. The chemical symbol for chlorine is Cl. Sodium chloride is written NaCl. It is the salt that many people use to flavor their food.

The figure above shows how ionic bonds form. It also shows another important feature of chemical reactions. Compare the properties of the compound sodium chloride with the properties of sodium and chlorine. They are very different! You probably would not want to put sodium or chlorine on your food. However, sodium chloride is safe to eat. The properties of a compound are always different from the properties of the elements that form it.

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What is ionic bonding?
- What happens to atoms that gain or lose electrons?
- What kinds of solids are formed from ionic bonds?



California Science
Standards

8.3.a, 8.3.b, 8.3.c, 8.5.a

How Do Ionic Bonds Form?

There are several types of chemical bonds. An ionic bond is one type. **Ionic bonds** form when valence electrons are transferred from one atom to another.

Like other bonds, ionic bonds form so that the outermost energy levels of the atoms that bond are filled. To understand why ionic bonds form, you need to learn what happens when atoms gain or lose electrons. □

What Happens When Atoms Gain or Lose Electrons?

An electron has a negative electrical charge. A proton has a positive electrical charge. An atom is *neutral*, or not charged, because the number of electrons in an atom equals the number of protons. The electrical charges cancel each other out.

Atoms that have gained or lost electrons are called **ions**. When an atom gains or loses electrons, the numbers of protons and electrons are no longer equal. Therefore, ions are not neutral like atoms. Atoms that lose electrons become positively charged ions because they have more protons than electrons. Atoms that gain electrons become negatively charged ions because they have more electrons than protons. □



A magnesium atom can lose its two valence electrons to another atom. The filled second level then becomes the outermost energy level. The magnesium ion has eight valence electrons.

STUDY TIP

Ask Questions As you read, make a list of questions that you have. Talk about your questions in a small group.

READING CHECK

1. **Explain** How does an ionic bond form?

READING CHECK

2. **Explain** How are ions different from atoms?

READING CHECK

3. Explain What has to happen in order for an atom to lose an electron?

Critical Thinking

4. Apply Concepts What is the charge of a nickel atom that has lost two electrons?

How Do Positive Ions Form?

Electrons have a negative charge. Therefore, they are attracted to the positive charge of the protons in the nucleus. In order for an atom to lose an electron, the attraction between the electron and the protons has to be broken. Breaking the attraction takes energy. This energy is released when an ionic bond forms. □

Compared with other elements, only a small amount of energy is needed for metals to lose their valence electrons. Therefore, metals are much more likely to form positive ions than other elements are. Examples of metals are silver, sodium, copper, and aluminum.

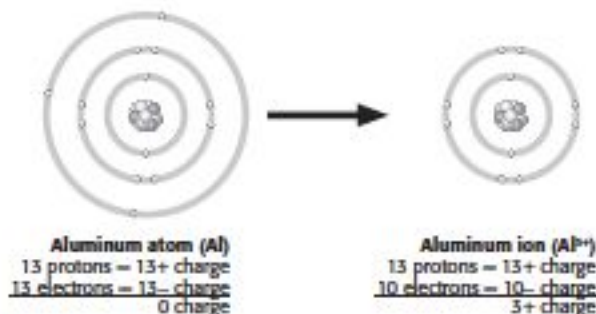
The elements in Groups 1 and 2 are all metals. They need little energy to lose their valence electrons. Therefore, the metals in Groups 1 and 2 form ions very easily. In the language of chemistry, that means they are very *reactive* metals.

DETERMINING THE CHARGE ON A POSITIVE ION

Ions can have different charges. The charge on a positive ion depends on the number of electrons the atom loses. The number of valence electrons in an atom tells you the charge on the ion that the atom will form. For example, Aluminum (Al) has three valence electrons. It is a metal, so it usually loses those electrons when it forms bonds. Two changes happen after it loses the electrons:

- The second energy level becomes the outermost level.
- The Al ion has three more protons than electrons.

The Al atom becomes an Al ion with a 3+ charge. The ion is written as Al^{3+} . The equations below show why the Al ion has a 3+ charge.



How Do Negative Ions Form?

What happens to the electrons that metal atoms lose? They can move to nonmetal atoms, such as oxygen and nitrogen. The outermost energy level of a nonmetal is almost full. It is easier for it to fill its outer energy level by gaining electrons than by losing electrons. When atoms of most nonmetals gain electrons, they give off energy. ☑

The elements in Group 17 (the halogens) are all nonmetals. Their atoms give off a lot of energy when they gain electrons. In the language of chemistry, that means that the halogens are very reactive nonmetals. They can give off heat, light, and noise when they gain electrons. ☑

DETERMINING THE CHARGE ON A NEGATIVE ION

Like positive ions, negative ions can have different charges. The charge on a negative ion depends on the number of electrons the atom gains.

You can use the number of valence electrons in an atom to learn the charge on the ion it can form. For example, an oxygen atom has six valence electrons. Oxygen tends to form ions by gaining two electrons. These two electrons fill the outermost energy level of the oxygen atom. The oxygen atom becomes a negative ion with a charge of 2^- .



| | |
|-----------------|-----------|
| Oxygen atom (O) | |
| 8+ | protons |
| 8- | electrons |
| <hr/> | |
| | charge |



| | |
|-------------------------------|-----------|
| Oxygen ion (O ²⁻) | |
| 8+ | protons |
| 10- | electrons |
| <hr/> | |
| | charge |

We change the names of atoms when they become negative ions by dropping the last few letters and adding *-ide*. For example, in the figure above, the oxygen atom becomes an oxide ion. Other examples of negative ions are chloride (Cl⁻) and fluoride (F⁻).

READING CHECK

5. **Identify** What kinds of atoms tend to gain electrons?

READING CHECK

6. **Describe** What does a halogen atom give off when it gains an electron?

Math Focus

7. **Analyze Data** In the figure to the left, write the charge of the oxygen atom and the oxygen ion. Write the charge to the left of the word "charge."

How Do Ionic Compounds Form?

Ionic bonds form because positive ions are attracted to negative ions. In order for electrons to move from one atom to another, the atoms must be very close together. When the electrons move, ions form. One ion has a positive charge. The other has a negative charge. The opposite charges on the ions cause the ions to stick together and form an ionic bond. The figure below shows an example of how an ionic bond forms. □

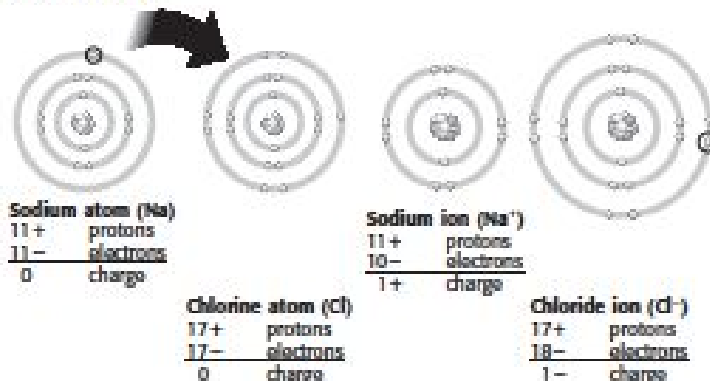
READING CHECK

8. Explain Why do ionic bonds form?

TAKE A LOOK

9. Apply Concepts If an atom of sodium combines with an atom of fluorine, what is the name of the new compound?

How It Works



The new compound shown in the figure is called sodium chloride. The chemical symbol for sodium is Na. The chemical symbol for chlorine is Cl. Sodium chloride is written NaCl. It is the salt that many people use to flavor their food.

The figure above shows how ionic bonds form. It also shows another important feature of chemical reactions. Compare the properties of the compound sodium chloride with the properties of sodium and chlorine. They are very different! You probably would not want to put sodium or chlorine on your food. However, sodium chloride is safe to eat. The properties of a compound are always different from the properties of the elements that form it.

CALIFORNIA STANDARDS CHECK

8.3.b Students know that compounds are formed by combining two or more different elements and that compounds have properties that are different from their constituent elements.

Word Help: constituent
 necessary part of a whole

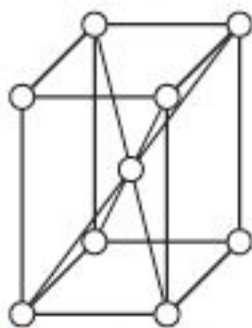
10. Compare How do the properties of salt compare with the properties of sodium and chlorine?

What Are the Characteristics of Ionic Compounds?

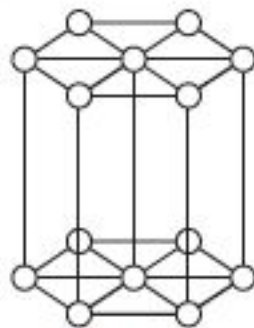
Ionic bonds are very strong. It takes a very large amount of energy to separate the ions in an ionic bond. Compounds formed from ionic bonds have several important features.

CRYSTALS

Ionic compounds form hard solids with flat faces and straight edges. These solids are called *crystals*. In a crystal, the positive and negative ions are found in a repeating three-dimensional pattern. This arrangement of ions is called a **crystal lattice**. □



Body-centered lattice



Hexagonal lattice

These two models are examples of crystal lattices.

Different ionic compounds form crystals with different properties. Some crystals are shaped like cubes. Others have more complex shapes, as shown in the figure above. Some of the crystals are clear. Other crystals, such as rubies and emeralds, are colored.

OTHER PROPERTIES

Ionic compounds form brittle solids. Something that is *brittle* breaks apart when it is hit with another object. They also have high melting points. This means they have to be heated to very high temperatures before they become liquids. Many ionic compounds also dissolve easily in water. For example, seawater tastes salty because sodium chloride and other ionic compounds are dissolved in it.

READING CHECK

11. **Identify** What is the name given to the arrangement of ions in a crystal?



Say It

Share Observations Spread several grains of salt on a sheet of dark construction paper. Use a magnifying lens to examine the salt grains. Try to crush the grains with your fingers. Talk to your class about your observations.