CONCEPT 2

Ionic compounds are made of ions.

Activity

Salt or Sugar?

Your teacher has a sample of salt and a sample of sugar. Without tasting them, how can you tell which is which? As a class, based on prior knowledge of these two compounds, come up with a test or tests you could conduct to distinguish between the two. With the help of volunteers, your teacher will conduct the tests and record the results. Which properties of salt and sugar are you testing for? What do you think accounts for the differences between salt and sugar?

ionic compound a compound made of oppositely charged ions

ionic bond a strong attraction that forms between oppositely charged ions

Compounds made of ions are called **ionic compounds**. Ionic compounds consist of regular arrangements of negatively charged ions and positively charged ions. The ions are held together with **ionic bonds**, which is the name for the attraction between oppositely charged ions. Ionic bonds are very strong.

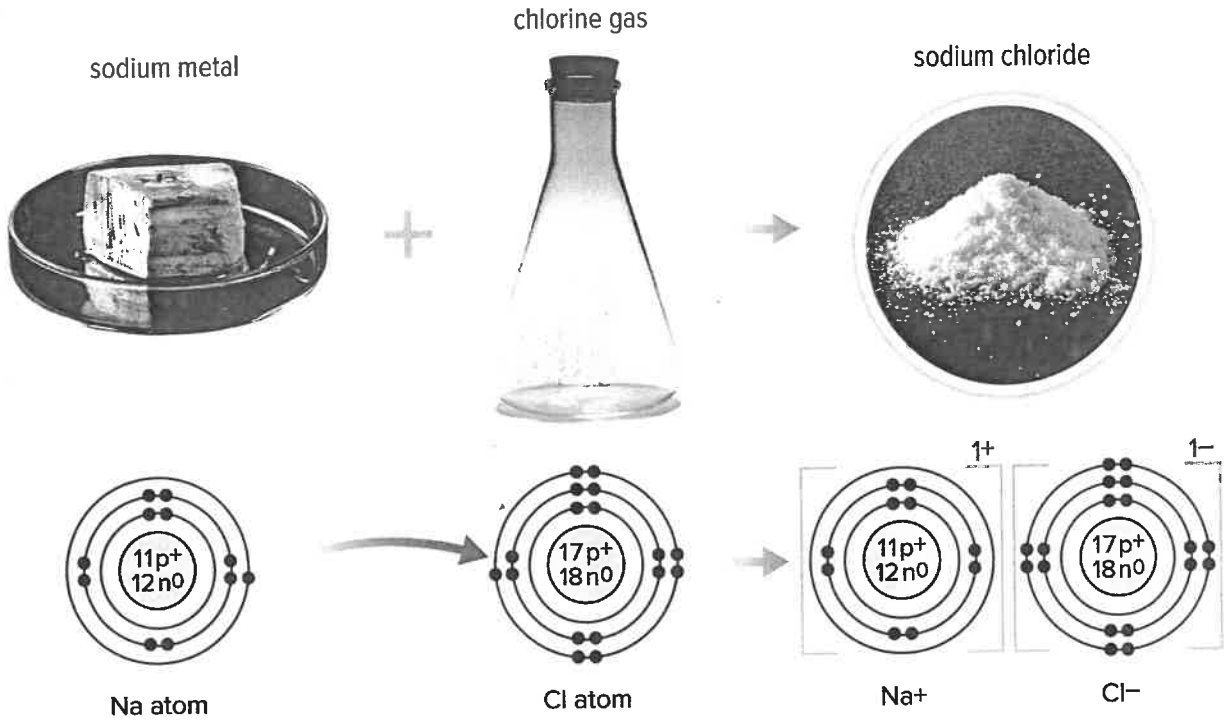
Formation of Ionic Compounds

The simplest types of ionic compounds are made up of two elements: a metal and a non-metal. Ionic compounds containing just two elements are called *binary ionic compounds*. These types of ionic compounds form when atoms of the metal element each lose one or more electrons to atoms of the non-metal element. For example, table salt—sodium chloride—forms when sodium atoms each transfer one electron to chlorine atoms. Each sodium atom becomes positively charged, a positive ion: Na^+. Each chlorine atom becomes negatively charged, a negative ion: Cl^-. This is what happens when sodium metal reacts with chlorine gas to form sodium chloride, as shown in **Figure 2.23**.

Why do ionic compounds form? In binary ionic compounds, neutral atoms of metals transfer the electrons in their valence shells to neutral atoms of non-metals. This transfer results in full valence shells for the oppositely charged ions that are formed. The stability of a full valence shell is what drives the formation of compounds.

To analyze what happens when ionic compounds form, recall what you have learned about the electron arrangements of elements in the different groups of the periodic table. How can atoms of alkali metals or halogens achieve full valence shells? Explore these questions in the Activity on the next page.

Figure 2.23 A sodium atom loses one electron to a chlorine atom, forming a sodium ion, Na^+, and a chloride ion, Cl^-. These ions are strongly attracted to each other. **What do you notice about the valence shells of the sodium ion and the chloride ion?**



Activity

Patterns in Ion Formation

Examine the periodic table to learn how elements in various groups form ions.

11	1+
Na	
sodium	
23.0	

1. Take a look at the periodic table. Notice that many of the element cells have one or more charges listed in the upper right-hand corner. What are these charges?
2. Look at the groups (vertical columns) of the periodic table. What patterns in ion charges do you notice?
3. What ions are formed by the atoms of elements from Groups 1, 2, 16, 17, and 18? Make generalizations for each group.
4. Think about what you know about the electron arrangement for atoms of each element. How would you explain the patterns in ion formation that you have noticed?
5. Many elements of the periodic table have ion charges listed. What do these charges mean? Do these elements always exist as ions? Explain your answer.

The Structure of Ionic Compounds

Ionic compounds consist of positive and negative ions arranged in regular repeating patterns called *lattices*. The cube-shaped, or *cubic*, structure of sodium chloride is an example of a lattice. Notice the cubic shape of the sodium chloride crystals in the magnified image in **Figure 2.24**. This shape reflects the underlying lattice structure of the ionic compound.

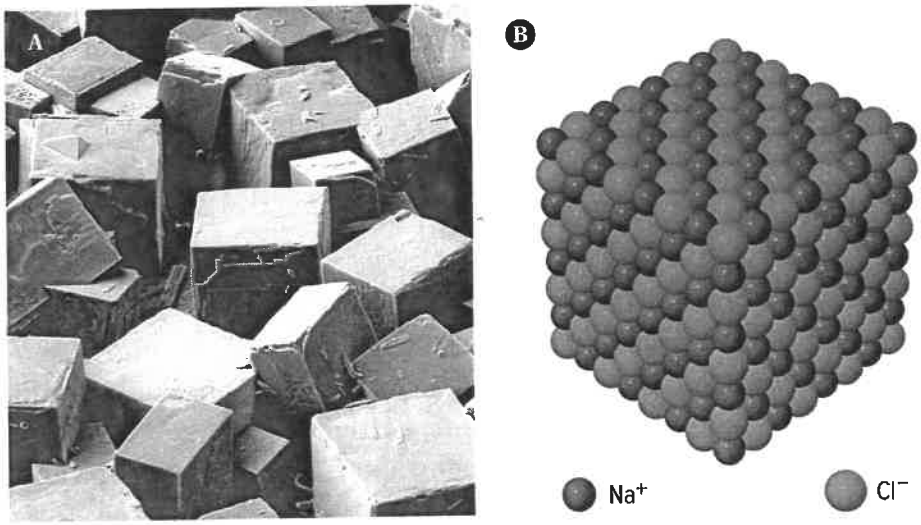


Figure 2.24 Ⓐ This image shows the cubic structure of sodium chloride crystals. Each crystal contains millions and millions of sodium ions and chloride ions. Ⓑ Sodium chloride crystals consist of sodium and chloride ions arranged in a repeating pattern. **Sodium chloride is made of charged particles, but the compound overall has no charge. Why?**

Properties of Ionic Compounds

Although ionic compounds have a wide variety of properties, they all have high melting points. They tend to be hard and brittle, breaking along sharp lines. In addition, they are good conductors of electric current when melted or dissolved. These characteristics can all be explained by the structure of ionic compounds.

What are some typical properties of ionic compounds? Ionic compounds ...

- *Have high melting points:* To melt an ionic compound requires overcoming the strong electrostatic forces holding the ions together in the lattice structure of the solid—the ionic bonds. Because these bonds are so strong, a great deal of energy is required to break them. As a result, ionic compounds tend to melt only at very, very high temperatures. For example, the melting point of sodium chloride is 801°C.

- *Are hard and brittle:* Because of the strength of ionic bonds, ionic solids are very hard. But when enough force is applied, the ions will shift out of alignment. This causes ions with the same charge to be close together. The resulting repulsive force pushes the solid apart, as shown in **Figure 2.25**.
- *Conduct electric current when liquid or dissolved:* Ionic compounds are not electrical conductors in the solid state, as shown in **Figure 2.26**. Even though they are made of ions, those ions are held rigidly in place, and charged particles that can move are required to conduct an electric current. Ionic compounds dissolved in water or melted ionic compounds do, however, conduct electric current. In those forms, the ions in an ionic compound are free to move and can therefore conduct electric current.

Figure 2.26 Electric current is the flow of charged particles. In solid form, ionic compounds do not conduct electric current because the ions are held tightly in place. But when dissolved in water, ionic compounds are good conductors because the ions are free to move around.

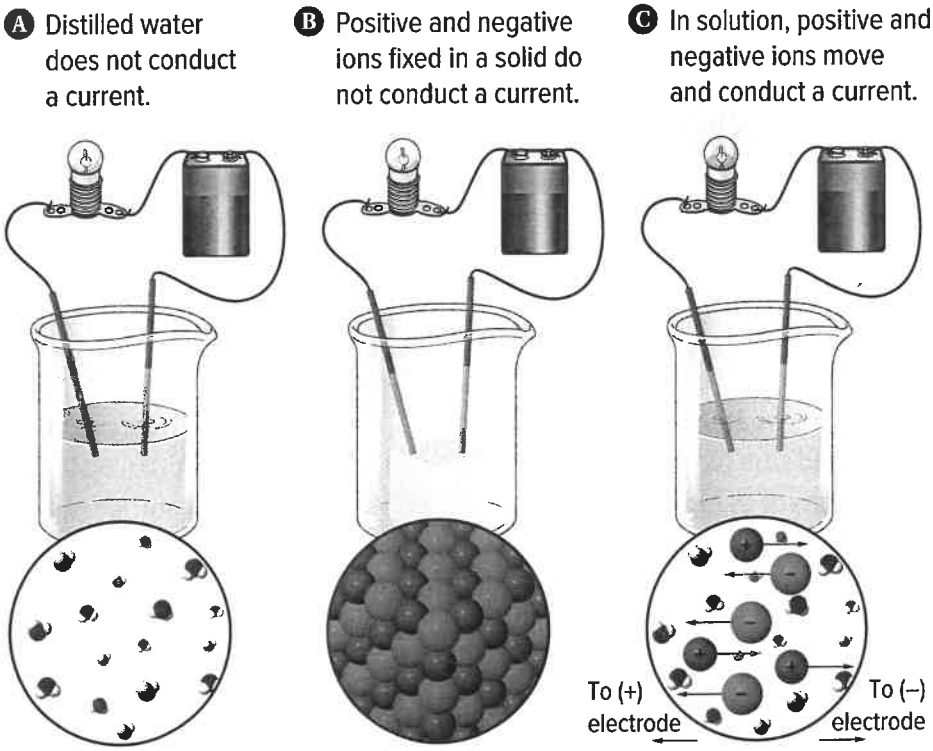
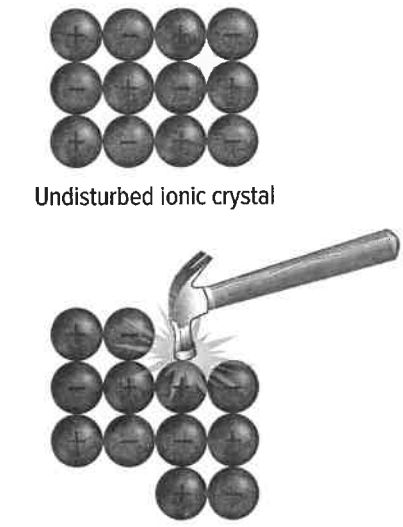


Figure 2.25 When a force strong enough to overcome the strong forces of attraction between oppositely charged ions is applied, ions with like charges come close together. They repel one another and the solid cracks.



Before you leave this page . . .

1. What is an ionic bond?
2. Describe the formation of sodium chloride from sodium and chlorine.
3. Binary ionic compounds form when which two types of elements react?
4. When do ionic compounds conduct electric current? Explain.