Ionic Bonds

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CHAPTER 1

Ionic Bonds

Lesson Objectives

- Describe how ionic bonds form.
- List properties of ionic compounds.

Lesson Vocabulary

- ionic bond
- ionic compound

Introduction

All compounds form when atoms of different elements share or transfer electrons. In water, the atoms share electrons. In some other compounds, called **ionic compounds**, atoms transfer electrons. The electrons actually move from one atom to another. When atoms transfer electrons in this way, they become charged particles called ions. The ions are held together by ionic bonds.

Formation of Ionic Bonds

An **ionic bond** is the force of attraction that holds together positive and negative ions. It forms when atoms of a metallic element give up electrons to atoms of a nonmetallic element. **Figure** 1.1 shows how this happens.

In row 1 of **Figure** 1.1, an atom of sodium donates an electron to an atom of chlorine (Cl).

- By losing an electron, the sodium atom becomes a sodium ion. It now has one less electron than protons, giving it a charge of +1. Positive ions such as sodium are given the same name as the element. The chemical symbol has a plus sign to distinguish the ion from an atom of the element. The symbol for a sodium ion is Na^+.
- By gaining an electron, the chlorine atom becomes a chloride ion. It now has one more electron than protons, giving it a charge of -1. Negative ions are named by adding the suffix *–ide* to the first part of the element name. The symbol for chloride is Cl^-.

Sodium and chloride ions have equal but opposite charges. Opposites attract, so sodium and chloride ions attract each other. They cling together in a strong ionic bond. You can see this in row 2 of **Figure** 1.1. Brackets separate the ions in the diagram to show that the ions in the compound do not share electrons. You can see animations of sodium chloride forming at these URLs:

- http://web.jjay.cuny.edu/~acarpi/NSC/salt.htm
- http://www.visionlearning.com/library/module_viewer.php?mid=55

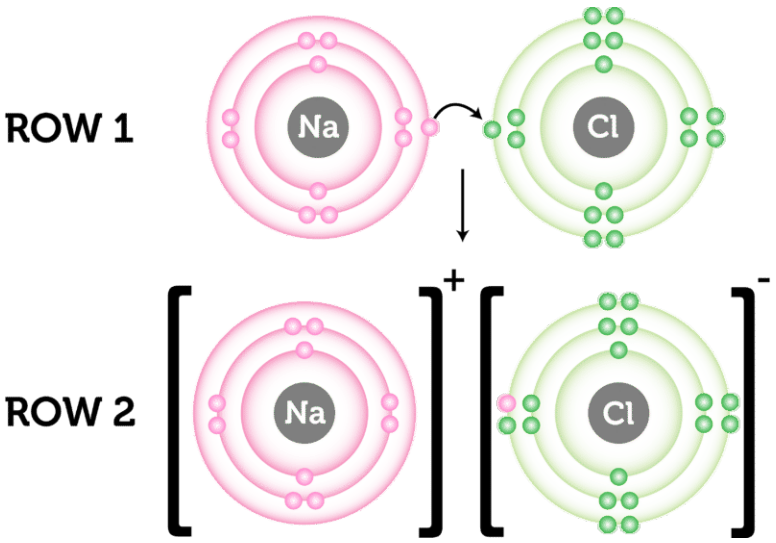


FIGURE 1.1

An ionic bond forms when the metal sodium gives up an electron to the non-metal chlorine.

Why Ionic Bonds Form

Ionic bonds form only between metals and nonmetals. Metals "want" to give up electrons, and nonmetals "want" to gain electrons. Find sodium (Na) in **Figure** 1.2. Sodium is an alkali metal in group 1. Like other group 1 elements, it has just one valence electron. If sodium loses that one electron, it will have a full outer energy level. Now find fluorine (F) in **Figure** 1.2. Fluorine is a halogen in group 17. It has seven valence electrons. If fluorine gains one electron, it will have a full outer energy level. After sodium gives up its valence electron to fluorine, both atoms have a more stable arrangement of electrons.

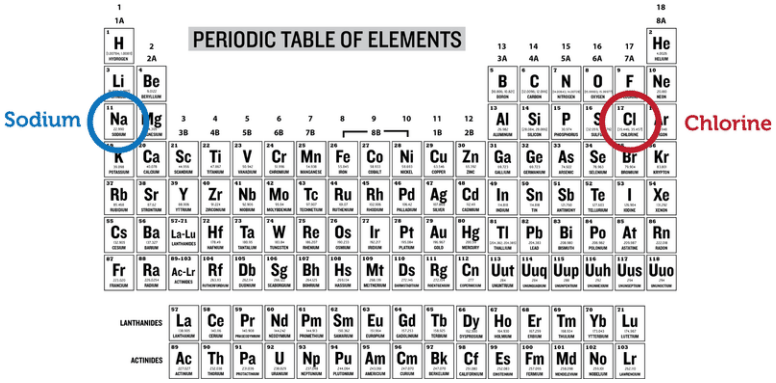


FIGURE 1.2

Sodium and chlorine are on opposite sides of the periodic table. How is this related to their numbers of valence electrons?

Energy and Ionic Bonds

It takes energy to remove valence electrons from an atom. The force of attraction between the negative electrons and positive nucleus must be overcome. The amount of energy needed depends on the element. Less energy is needed to remove just one or a few electrons than many. This explains why sodium and other alkali metals form positive ions so easily. Less energy is also needed to remove electrons from larger atoms in the same group. For example, in group 1, it takes less energy to remove an electron from francium (Fr) at the bottom of the group than from lithium (Li) at the top of the group (see **Figure** 1.2). In bigger atoms, valence electrons are farther from the nucleus. As a result, the force of attraction between the electrons and nucleus is weaker.

What happens when an atom gains an electron and becomes a negative ion? Energy is released. Halogens release the most energy when they form ions. As a result, they are very reactive.

Ionic Compounds

Ionic compounds contain ions of metals and nonmetals held together by ionic bonds. Ionic compounds do not form molecules. Instead, many positive and negative ions bond together to form a structure called a crystal. You can see an example of a crystal in **Figure** 1.3. It shows the ionic compound sodium chloride. Positive sodium ions (Na^+) alternate with negative chloride ions (Cl^-). The oppositely charged ions are strongly attracted to each other.

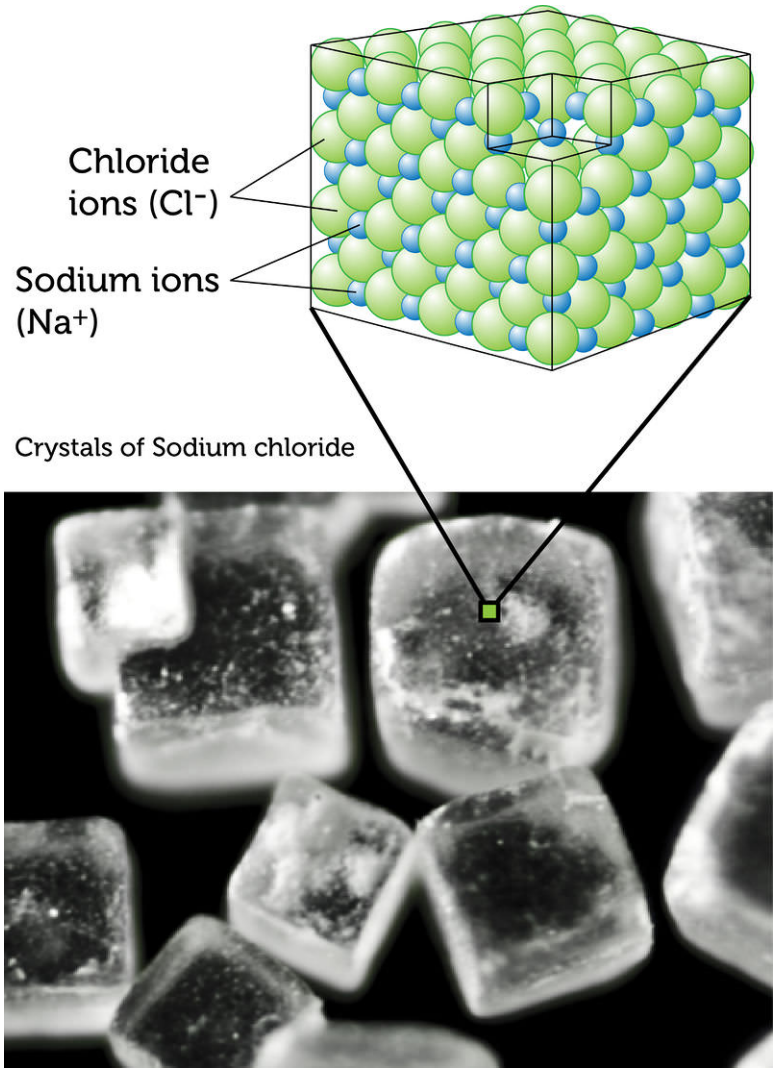


FIGURE 1.3

Sodium chloride crystals are cubic in shape. Other ionic compounds may have crystals with different shapes.

Helpful Hints

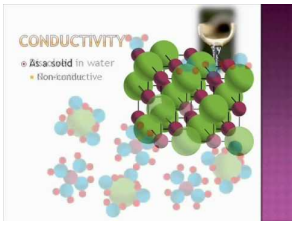
Naming Ionic Compounds Ionic compounds are named for their positive and negative ions. The name of the positive ion always comes first. For example, sodium and chloride ions form the compound named sodium chloride.

You Try It!

Problem: What is the name of the ionic compound composed of positive barium ions and negative iodide ions?

Properties of Ionic Compounds

The crystal structure of ionic compounds is strong and rigid. It takes a lot of energy to break all those strong ionic bonds. As a result, ionic compounds are solids with high melting and boiling points (see **Table** 1.1). The rigid crystals are brittle and more likely to break than bend when struck. As a result, ionic crystals tend to shatter. You can learn more about the properties of ionic compounds by watching the video at this URL: http://www.youtube.com/watch?v=buWrSgs_ZHk (3:34).



MEDIA

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URL: https://www.ck12.org/flx/render/embeddedobject/5081

Compare the melting and boiling points of these ionic compounds with those of water (0°C and 100°C), which is *not* an ionic compound.

TABLE 1.1: Melting and Boiling Points of Select Ionic Compounds

Ionic Compound	**Melting Point** (°C)	**Boiling Point** (°C)
Sodium chloride (NaCl)	801	1413
Calcium chloride ($CaCl_2$)	772	1935
Barium oxide (BaO)	1923	2000
Iron bromide ($FeBr_3$)	684	934

Solid ionic compounds are poor conductors of electricity. The strong bonds between ions lock them into place in the crystal. However, in the liquid state, ionic compounds are good conductors of electricity. Most ionic compounds dissolve easily in water. When they dissolve, they separate into individual ions. The ions can move freely, so they are good conductors of electricity. Dissolved ionic compounds are called electrolytes.

Uses of Ionic Compounds

Ionic compounds have many uses. Some are shown in **Figure** 1.4. Many ionic compounds are used in industry. The human body also needs several ions for good health. Having low levels of the ions can endanger important functions such as heartbeat. Solutions of ionic compounds can be used to restore the ions.

FIGURE 1.4

Have you ever used any of these ionic compounds?

Lesson Summary

- An ionic bond is the force of attraction that holds together oppositely charged ions. It forms when atoms of a metal transfer electrons to atoms of a nonmetal. When this happens, the atoms become oppositely charged ions.
- Ionic compounds form crystals instead of molecules. Ionic bonds are strong and the crystals are rigid. As a result, ionic compounds are brittle solids with high melting and boiling points. In the liquid state or dissolved in water, ionic compounds are good conductors of electricity.

Lesson Review Questions

Recall

1. What is an ionic bond?
2. Outline the role of energy in the formation of an ionic bond.
3. List properties of ionic compounds.

Apply Concepts

4. Create a model to represent the ionic bonds in a crystal of the salt lithium iodide (LiI).
5. A mystery compound is a liquid with a boiling point of 50°C. Is it likely to be an ionic compound? Why or why not?

Think Critically

6. Explain why ionic bonds form only between atoms of metals and nonmetals.

Points to Consider

Bonds form not only between atoms of metals and nonmetals. Nonmetals may also bond with nonmetals.

- How do you think bonds form between atoms of nonmetals?
- Can you think of examples of compounds that consist only of nonmetals?

References

1. Christopher Auyeung. CK-12 Foundation . CC BY-NC 3.0
2. Christopher Auyeung. CK-12 Foundation . CC BY-NC 3.0
3. Salt: Tony L Wong; Illustration: Christopher Auyeung (CK-12 Foudnation). http://www.flickr.com/photos/tonylwong/3954263897/ . CC BY 2.0
4. Fireworks:Epic Fireworks; Battery: Lukas A, CZE; Others: Christopher Auyeung (CK-12 Foundation). Fireworks: http://www.flickr.com/photos/epicfireworks/8838128619/; Battery: http://commons.wikimedia.org/wiki/File:Energizer_lithium.jpg . Fireworks: CC BY 2.0; Battery: Public Domain; Others: CC BY-NC 3.0