

# Classes of Elements

---

**Say Thanks to the Authors**

Click <http://www.ck12.org/saythanks>

*(No sign in required)*



To access a customizable version of this book, as well as other interactive content, visit [www.ck12.org](http://www.ck12.org)

CK-12 Foundation is a non-profit organization with a mission to reduce the cost of textbook materials for the K-12 market both in the U.S. and worldwide. Using an open-source, collaborative, and web-based compilation model, CK-12 pioneers and promotes the creation and distribution of high-quality, adaptive online textbooks that can be mixed, modified and printed (i.e., the FlexBook® textbooks).

Copyright © 2016 CK-12 Foundation, [www.ck12.org](http://www.ck12.org)

The names “CK-12” and “CK12” and associated logos and the terms “**FlexBook®**” and “**FlexBook Platform®**” (collectively “CK-12 Marks”) are trademarks and service marks of CK-12 Foundation and are protected by federal, state, and international laws.

Any form of reproduction of this book in any format or medium, in whole or in sections must include the referral attribution link <http://www.ck12.org/saythanks> (placed in a visible location) in addition to the following terms.

Except as otherwise noted, all CK-12 Content (including CK-12 Curriculum Material) is made available to Users in accordance with the Creative Commons Attribution-Non-Commercial 3.0 Unported (CC BY-NC 3.0) License (<http://creativecommons.org/licenses/by-nc/3.0/>), as amended and updated by Creative Commons from time to time (the “CC License”), which is incorporated herein by this reference.

Complete terms can be found at <http://www.ck12.org/about/terms-of-use>.

Printed: December 12, 2016

**flexbook**  
next generation textbooks



## CHAPTER

## 1

# Classes of Elements

## Lesson Objectives

- Identify properties of metals.
- List properties of nonmetals.
- Describe metalloids.
- Relate valence electrons to reactivity of elements by class.

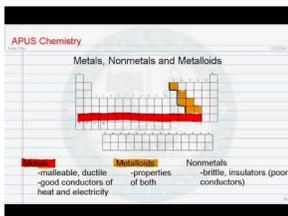
## Vocabulary

- metal
- metalloid
- nonmetal
- valence electron

## Introduction

Elements in different groups are lumped together in one of three classes, depending on their properties. The classes are metals, nonmetals, and metalloids. Knowing the class of an element lets you predict many of its properties. The video at the URL below is a good introduction to the classes.

<http://www.youtube.com/watch?v=ZuQmionhkGU> (2:04)



### MEDIA

Click image to the left or use the URL below.

URL: <https://www.ck12.org/flx/render/embeddedobject/5077>

## Metals

**Metals** are elements that are good conductors of electricity. They are the largest of the three classes of elements. In fact, most elements are metals. Look back at the modern periodic table (**Figure** above) in this chapter's lesson "How Elements Are Organized." Find the metals in the table. They are all the elements that are color-coded blue. Examples include sodium (Na), silver (Ag), and zinc (Zn).

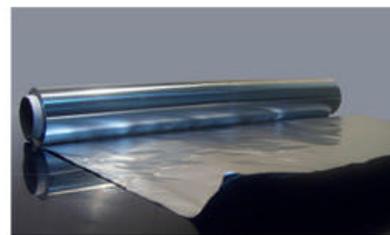
Metals have relatively high melting points, so almost all are solids at room temperature. The only exception is mercury (Hg), which is a liquid. Most metals are also good conductors of heat. That's why they are used for cooking



Most metals are shiny. That's because they reflect a lot of light. This tray is made mainly of the metal silver (Ag).



Most metals are ductile. This means they can be pulled into long thin shapes, like these wires made of the metal copper (Cu).



Most metals are malleable. This means they can be formed into thin sheets without breaking, like this foil made of the metal aluminum (Al).

**FIGURE 1.1**

The three properties described here characterize most metals.

pots and stovetops. Metals have other characteristic properties as well. Most are shiny, ductile, and malleable. These properties are illustrated in **Figure 1.1**. You can dig deeper into the properties of metals at this URL: [http://www.bc.co.uk/schools/gcsebitesize/science/add\\_gateway/periodictable/metalsrev1.shtml](http://www.bc.co.uk/schools/gcsebitesize/science/add_gateway/periodictable/metalsrev1.shtml) .

## Nonmetals

**Nonmetals** are elements that do not conduct electricity. They are the second largest class of elements. Find the nonmetals in **Figure** above. They are all the elements on the right side of the table that are color-coded green. Examples of nonmetals include helium (He), carbon (C), and oxygen (O).

Nonmetals generally have properties that are the opposite of those of metals. They also tend to vary more in their properties than metals do. For example, nonmetals have relatively low boiling points, so many of them are gases at room temperature. But several nonmetals are solids, including carbon and phosphorus (P). One nonmetal, bromine (Br), is a liquid at room temperature.

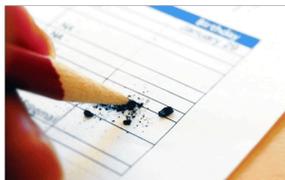
Generally, nonmetals are also poor conductors of heat. In fact, they may be used for insulation. For example, the down filling in a down jacket is mostly air, which consists mainly of nitrogen (N) and oxygen (O). These nonmetal gases are poor conductors of heat, so they keep body heat in and cold air out. Solid nonmetals are dull rather than shiny. They are also brittle rather than ductile or malleable. You can see examples of solid nonmetals in **Figure 1.2**. You can learn more about specific nonmetals with the interactive table at this URL: <http://library.thinkquest.org/3659/pertable/nonmetal.html> .

## Metalloids

Metalloids are elements that fall between metals and nonmetals in the periodic table. Just seven elements are metalloids, so they are the smallest class of elements. In **Figure** above, they are color-coded orange. Examples



These yellow piles of powder are sulfur (S), a nonmetal. Sulfur in rocks has been ground up to produce a powder. The powder has been heaped on a dock for shipment.



The "lead" in this pencil is actually graphite, a form of the nonmetal carbon (C). Graphite is brittle. It breaks easily if you put too much pressure on it.



These match heads are coated with the nonmetal phosphorus (P). Phosphorus is not malleable. If you tried to pound it flat, it would crumble into a powder.

### FIGURE 1.2

Unlike metals, solid nonmetals are dull and brittle.

of metalloids include boron (B), silicon (Si), and germanium (Ge).

**Metalloids** have some properties of metals and some properties of nonmetals. For example, many metalloids can conduct electricity but only at certain temperatures. These metalloids are called semiconductors. Silicon is an example. It is used in computer chips. It is also the most common metalloid on Earth. It is shiny like a metal but brittle like a nonmetal. You see a sample of silicon in **Figure 1.3**. The figure also shows other examples of metalloids. You can learn more about the properties of metalloids at this URL: <http://library.thinkquest.org/3659/pertable/metalloid.html> .

## Classes of Elements and Electrons

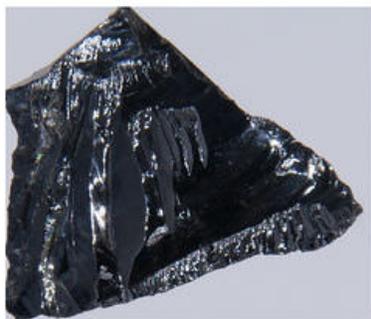
From left to right across the periodic table, each element has one more proton than the element to its left. Because atoms are always electrically neutral, for each added proton, one electron is also added. Electrons are added first to the lowest energy level possible until that level is full. Only then are electrons added to the next higher energy level.

### Electrons by Class

The increase in electrons across the periodic table explains why elements go from metals to metalloids and then to nonmetals from left to right across the table. Look at period 2 in **Figure 1.4** as an example. Lithium (Li) is a metal, boron (B) a metalloid, and fluorine (F) and neon (Ne) are nonmetals. The inner energy level is full for all four elements. This level has just one orbital and can hold a maximum of two electrons. The outer energy level is a different story. This level has four orbitals and can hold a maximum of eight electrons. Lithium has just one electron in this level, boron has three, fluorine has seven, and neon has eight.

### Valence Electrons and Reactivity

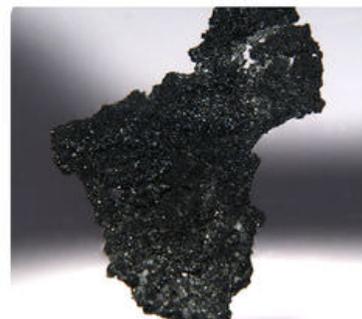
The electrons in the outer energy level of an atom are called **valence electrons**. It is valence electrons that are potentially involved in chemical reactions. The number of valence electrons determines an element's reactivity, or



Silicon (Si) is a metal that can conduct electricity but not as well as a metal. It is shiny but brittle. It chips easily, like glass.



Antimony (Sb) is a metalloid that is shiny like a metal but brittle like a nonmetal.



Boron (B) is a metalloid that is somewhat shiny. It also conducts electricity like a metal. However, it is brittle like a nonmetal.

**FIGURE 1.3**

Metalloids share properties with both metals and nonmetals.

how likely the element is to react with other elements. The number of valence electrons also determines whether the element can conduct electric current. That's because electric current is the flow of electrons. **Table 1.1** shows how these properties vary in elements from each class.

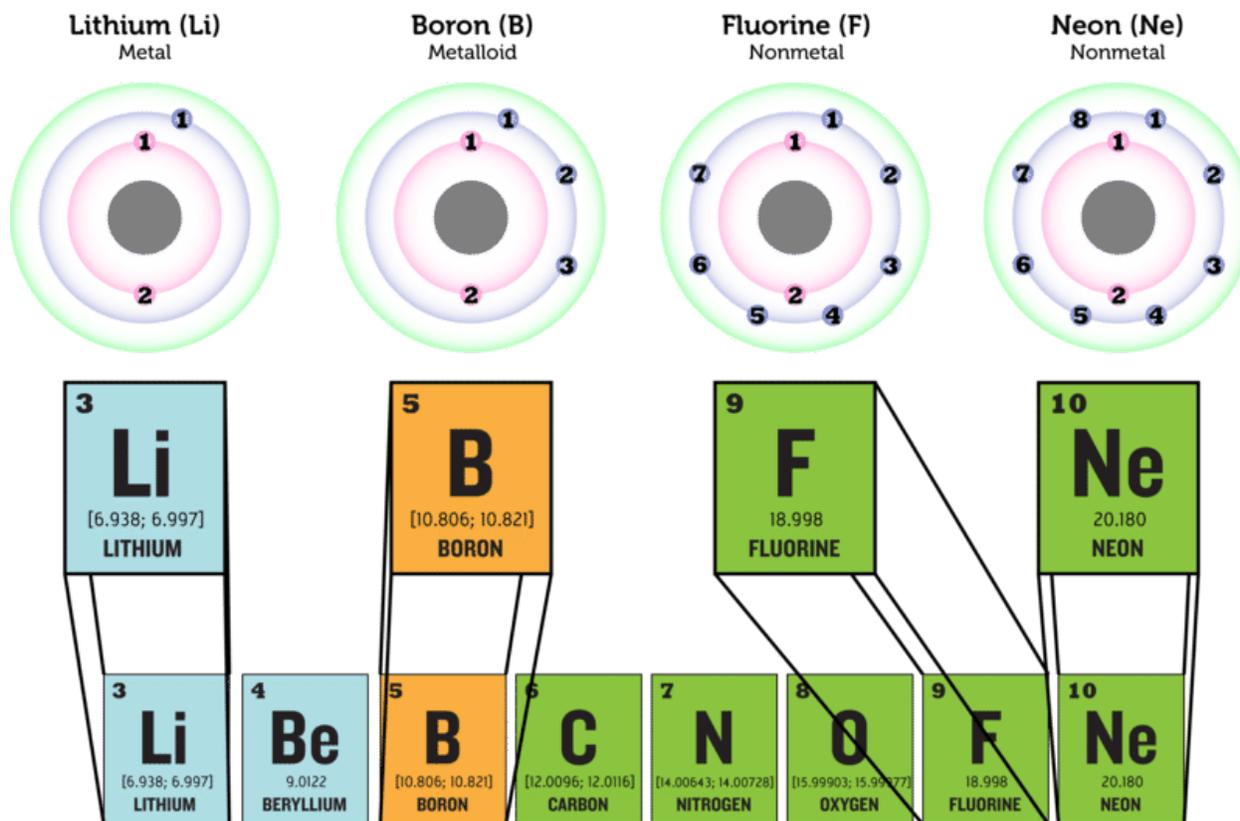
- Metals such as lithium have an outer energy level that is almost empty. They "want" to give up their few valence electrons so they will have a full outer energy level. As a result, metals are very reactive and good conductors of electricity.
- Metalloids such as boron have an outer energy level that is about half full. These elements need to gain or lose too many electrons for a full outer energy level to come about easily. As a result, these elements are not very reactive. They may be able to conduct electricity but not very well.
- Some nonmetals, such as bromine, have an outer energy level that is almost full. They "want" to gain electrons so they will have a full outer energy level. As a result, these nonmetals are very reactive. Because they only accept electrons and do not give them up, they do not conduct electricity.
- Other nonmetals, such as neon, have a completely full outer energy level. Their electrons are already in the most stable arrangement possible. They are unreactive and do not conduct electricity.

**TABLE 1.1:** These examples show the relative reactivity of elements in the three classes.

Element	Description
Lithium 	Lithium (Li) is a highly reactive metal. It has just one electron in its outer energy level. Lithium reacts explosively with water (see picture). It can react with moisture on skin and cause serious burns.

TABLE 1.1: (continued)

Element	Description
<p data-bbox="159 237 232 260">Boron</p> 	<p data-bbox="824 237 1461 373">Boron (B) is a metalloid. It has three valence electrons and is less reactive than lithium. Boron compounds dissolved in water form boric acid. Dilute boric acid is weak enough to use as eye wash.</p>
<p data-bbox="159 653 261 676">Bromine</p>	<p data-bbox="824 653 1461 747">Bromine (Br) is an extremely reactive nonmetal. In fact, reactions with fluorine are often explosive, as you can see in the URL below.</p> <p data-bbox="824 751 1409 785"><a href="http://www.youtube.com/watch?v=vtWp45Eewtw">http://www.youtube.com/watch?v=vtWp45Eewtw</a></p>
<p data-bbox="159 795 224 819">Neon</p> 	<p data-bbox="824 795 1461 1001">Neon (Ne) is a nonmetal gas with a completely filled outer energy level. This makes it unreactive, so it doesn't combine with other elements. Neon is used for lighted signs like this one. You can learn why neon gives off light at this link: <a href="http://www.scientificamerican.com/article.cfm?id=how-do-neon-lights-work">http://www.scientificamerican.com/article.cfm?id=how-do-neon-lights-work</a></p>



**FIGURE 1.4**

The number of electrons increases from left to right across each period in the periodic table. In period 2, lithium (Li) has the fewest electrons and neon (Ne) has the most. How do the numbers of electrons in their outer energy levels compare?

## Lesson Summary

- Metals are elements that are good conductors of electricity. They are the largest class of elements. Many metals are shiny, ductile, and malleable. They are also good conductors of heat. Almost all metals are solids at room temperature.
- Nonmetals are elements that do not conduct electricity. They are the second largest class of elements. Nonmetals are also poor conductors of heat. The majority of nonmetals are gases. Solid nonmetals are dull and brittle.
- Metalloids are elements that have properties of both metals and nonmetals. Some can conduct electricity but only at certain temperatures. They may be shiny but brittle. All metalloids are solids at room temperature.
- Atoms of elements in different classes vary in their number of valence electrons. This explains their differences in reactivity and conductivity.

---

## Lesson Review Questions

### Recall

1. What are metals? Name one example.
2. Define nonmetal, and give an example.
3. State one way that metalloids may be like metals and one way they may be like nonmetals.
4. What are valence electrons?

### Apply Concepts

5. A mystery element is a dull, gray solid. It is very reactive with other elements. Classify the mystery element as a metal, nonmetal, or metalloid. Explain your answer.

### Think Critically

6. Create a Venn diagram for metals, metalloids, and nonmetals. The diagram should show which properties are different and which, if any, are shared among the three groups of elements.
7. Relate number of valence electrons to reactivity of classes of elements.

---

## Points to Consider

The number of valence electrons increases from left to right across each period of the periodic table. By the end of the period, the outer energy level is full. Moving on to the next period of the table, electrons are added to the next higher energy level. This happens in each row of the periodic table.

- How do you think the number of valence electrons compares in elements within the same column (group) of the periodic table?
- How might this be reflected in the properties of elements within a group?

---

## References

1. Silver tray: The Living Room; Copper wire: Flickr:Flavio~; Aluminum foil: User:MdeVicente/Wikimedia Commons. Silver tray: <http://www.flickr.com/photos/thelivingroominkenmore/4546677601/>; Copper wire: <http://www.flickr.com/photos/37873897@N06/6154424083/>; Aluminum foil: <http://commons.wikimedia.org/wiki/File:Aluminio.jpg> . Silver tray: CC BY 2.0; Copper wire: CC BY 2.0; Aluminum foil: Public Domain
2. Sulfur: Ed Uthman; Pencil: Robert Lopez; Matches: Charles Knowles. Sulfur: <http://www.flickr.com/photos/euthman/9183618186/>; Pencil: CK-12 Foundation; Matches: <http://www.flickr.com/photos/theknowledgallery/4536616288/> . Sulfur: CC BY 2.0; Pencil: CC BY-NC 3.0; Matches: CC BY 2.0
3. User: Jurii/Wikimedia Commons. Silicon: <http://commons.wikimedia.org/wiki/File:Silicon.jpg>; Antimony: <http://commons.wikimedia.org/wiki/File:Antimony-piece.jpg>; Boron: <http://commons.wikimedia.org/wiki/File:Bron.jpg> . CC BY 3.0
4. Christopher Auyeung. CK-12 Foundation . CC BY-NC 3.0