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7 Ionic and Metallic Bonding

Big idea BONDING AND INTERACTIONS

7.1 Ions

For students using the Foundation edition, assign problems 1, 3–5, 7–12, 14, 15, 18–20.

Essential Understanding Ions form when atoms gain or lose valence electrons, becoming electrically charged.

Lesson Summary

Valence Electrons Valence electrons are the electrons in the outermost occupied energy level and are involved in ion formation.

- For a representative element, the group number equals the number of valence electrons the atom contains.
- An electron dot structure shows the symbol of the element and its valence electrons.
- Atoms tend to gain or lose the number of electrons that will provide the atom with a noble gas electron configuration.

Formation of Cations Cations are positively charged ions formed when an atom loses one or more valence electrons.

- Atoms and the cations formed from them have different properties.
- Elements in Group 1 form cations with a charge of 1+, and those in Group 2 form cations with a charge of 2+.
- Many transition metals form more than one cation and do not follow the octet rule.

Formation of Anions Anions are negatively charged ions formed when an atom gains one or more valence electrons.

- Commonly, the name of an anion ends in *-ide*.
- Anions form from nonmetallic elements.
- The anions formed from halogens are known as halides.

After reading Lesson 7.1, answer the following questions.

Valence Electrons

1. What are valence electrons?

Valence electrons are the electrons in the highest occupied energy level of an element's atoms.

2. The valence electrons largely determine the *chemical properties* of an element and are usually the only electrons used in *chemical bonds*.

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3. Is the following sentence true or false? The group number of a representative element in the periodic table is related to the number of valence electrons it has.
true

4. What is an electron dot structure?
It is a diagram that shows the symbol of an element and its valence electrons as dots.

5. Draw the electron dot structure for each of the following atoms.

a. argon 

b. calcium 

c. iodine 

6. What is the octet rule?
In forming compounds, atoms tend to achieve the electron configuration of a noble gas, which (except for helium) has eight electrons in its highest occupied energy level.

7. Metallic atoms tend to *lose* valence electrons to produce a positively charged ion. Most nonmetallic atoms achieve a complete octet by gaining or *sharing* electrons.

Formation of Cations

8. Write the electron configurations for these metals, and circle the electrons lost when each metal forms a cation.

a. Mg $1s^2 2s^2 2p^6 (2s^2)$

b. Al $1s^2 2s^2 2p^6 (3s^2 3p^1)$

c. K $1s^2 2s^2 2p^6 3s^2 3p^6 (4s^1)$

Match the noble gas with its electron configuration.

c	**9.** argon	**a.** $1s^2$
a	**10.** helium	**b.** $1s^2 2s^2 2p^6$
b	**11.** neon	**c.** $1s^2 2s^2 2p^6 3s^2 3p^6$
d	**12.** krypton	**d.** $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6$

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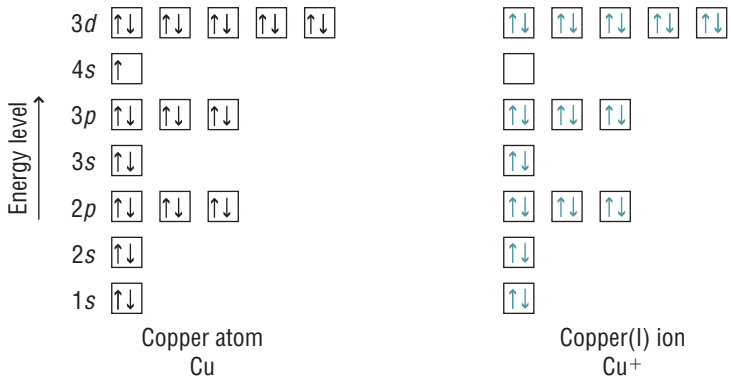
13. What is the electron configuration called that has 18 electrons in the outer energy level and all of the orbitals filled?

pseudo noble-gas configuration

14. Write the electron configuration for zinc.

$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2$

15. Fill in the electron configuration diagram for the copper(I) ion.



Formation of Anions

16. Atoms of most nonmetallic elements achieve noble-gas electron configurations by gaining electrons to become ***anions*** , or negatively charged ions.

17. What property of nonmetallic elements makes them more likely to gain electrons than lose electrons?

They have relatively full valence shells.

18. Is the following sentence true or false? Elements of the halogen family lose one electron to become halide ions. ***false***

19. How many electrons will each element gain in forming an ion?

a. nitrogen ***3***

b. oxygen ***2***

c. sulfur ***2***

d. bromine ***1***

20. Write the symbol and electron configuration for each ion from Question 19, and name the noble gas with the same configuration.

a. nitride ***N^{3-}; $1s^2 2s^2 2p^6$; neon***

b. oxide ***O^{2-}; $1s^2 2s^2 2p^6$; neon***

c. sulfide ***S^{2-}; $1s^2 2s^2 2p^6 3s^2 3p^6$; argon***

d. bromide ***Br^-; $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6$; krypton***

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7.2 Ionic Bonds and Ionic Compounds

For students using the Foundation edition, assign problems 1–3, 5–8, 10, 11, 13, 14.

Essential Understanding Ionic compounds are the result of ionic bonds forming between oppositely charged ions.

Lesson Summary

Formation of Ionic Compounds An ionic compound is made up of anions and cations and has an overall charge of 0.

- The electrostatic attraction between an anion and a cation is an ionic bond.
- The representative unit of an ionic compound is its formula unit.
- A formula unit of an ionic compound shows the ions in the compound in their lowest, whole-number ratio.

Properties of Ionic Compounds Ionic compounds have characteristic properties that distinguish them from other substances.

- Most ionic compounds are crystalline solids at room temperature.
- In general, ionic compounds have high melting points because the ions have a strong attraction for one another.
- Ionic compounds conduct an electric current when melted or in an aqueous solution because the ions are then free to move.

After reading Lesson 7.2, answer the following questions.

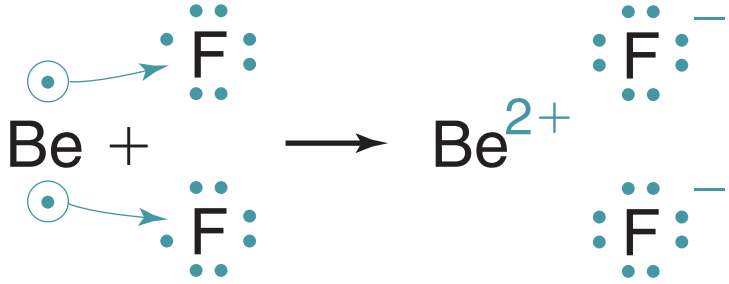
Formation of Ionic Compounds

1. What is an ionic bond?

It is the electrostatic force of attraction that binds oppositely charged ions.

2. In an ionic compound, the charges of the *cations* and *anions* must balance to produce an electrically *neutral* substance.

3. Complete the electron dot structures below to show how beryllium fluoride (BeF_2) is formed. Use the diagram on page 203 as a model.



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4. Why do beryllium and fluorine combine in a 1:2 ratio?

Each beryllium atom gives up two electrons, but each fluorine atom accepts only one electron. Therefore, two fluorine atoms are needed to react with each beryllium atom.

5. A chemical formula shows the types and *numbers* of atoms in the smallest representative unit of a substance.

6. List the numbers and types of atoms represented by these chemical formulas.

   a. Fe_2O_3 *2 atoms of iron, 3 atoms of oxygen*

   b. $KMnO_4$ *1 atom of potassium, 1 atom of manganese, 4 atoms of oxygen*

   c. CH_3 *1 atom of carbon, 3 atoms of hydrogen*

   d. NH_4NO_3 *2 atoms of nitrogen, 4 atoms of hydrogen, 3 atoms of oxygen*

7. What is a formula unit?

A formula unit is the lowest whole-number ratio of ions in an ionic compound.

8. Explain why the ratio of magnesium ions to chloride ions in $MgCl_2$ is 1:2.

There must be twice as many chloride ions (Cl^-) to balance the magnesium ions (Mg^{2+}) to form an electrically neutral compound.

9. Describe the structure of ionic compounds.

Ionic compounds exist as collections of positively and negatively charged ions arranged in repeating three-dimensional patterns.

Properties of Ionic Compounds

10. Most ionic compounds are *crystalline solids* at room temperature.

11. Is the following sentence true or false? Ionic compounds generally have low melting points. *false*

12. What does a coordination number tell you?

It is the number of ions of opposite charge that surround an ion in a crystal.

13. What is the coordination number of the ions in a crystal of NaCl? *6*

14. Circle the letter of each statement that is true about ionic compounds.

   (a.) When dissolved in water, ionic compounds can conduct electricity.

   b. When melted, ionic compounds do not conduct electricity.

   c. Ionic compounds have very unstable structures.

   (d.) Ionic compounds are electrically neutral.

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7.3 Bonding in Metals

For students using the Foundation edition, assign problems 1–3, 5–16.

Essential Understanding The characteristic properties of metals depend on the mobility of valence electrons among metal atoms.

Reading Strategy

Cause and Effect A cause and effect chart is a useful tool when you want to describe how, when, or why one event causes another. A cause is the reason something happens. The effect is what happens.

As you read Lesson 7.3, use the cause and effect chart below. Complete the chart to show how the mobility of electrons in a metal causes the properties of metals.

Cause

The sea of electrons in metals causes the characteristic properties of metals.

Effects

Property: ***conductivity***

Because: ***Electrons can flow freely in the metal.***

Property: ***ductility***

Because: ***The sea of electrons enables the cations to move past each other when pressure is applied.***

Property: ***malleability***

Because: ***The sea of electrons enables the cations to be pushed closer together when hit.***

EXTENSION **Draw a diagram that illustrates each effect in the chart.**
The conductivity diagram should show electrons moving one direction among stationary cations. The ductility and malleability diagrams should be similar to the metal diagram in Figure 7.12.

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Lesson Summary

Metallic Bonds and Metallic Properties The properties of metals are based on the attraction between stationary metal cations and the valence electrons that surround them.

- The valence electrons in metals surround metallic cations in what is called a sea of electrons.
- Properties of metals, such as conductivity, ductility, and malleability, are the result of these electrons being free to move from one part of the metal to another.
- Metal atoms are packed together tightly in crystalline structures.

Alloys Alloys are mixtures of elements, at least one of which is a metal.

- The composition of alloys can be varied to result in an alloy with desired properties.
- A widely used alloy is steel, which contains iron, carbon, and other metals.
- Alloys are either substitutional or interstitial, depending on how they form.

After reading Lesson 7.3, answer the following questions.

Metallic Bonds and Metallic Properties

1. Is the following sentence true or false? Metals are made up of cations and valence electrons, not neutral atoms. ***true***

2. What are metallic bonds?

   Metallic bonds are the forces of attraction between free-floating valence electrons and positively charged metal ions.

3. Name three properties of metals that can be explained by metallic bonding.

   a. ***electrical conductivity***

   b. ***ductility***

   c. ***malleability***

4. What happens to an ionic crystal when a force is applied to it?

   The force tends to push ions of like charge into contact. They repel each other, and the crystal shatters.

5. Metal atoms in crystals are arranged into very ***compact*** and orderly patterns.

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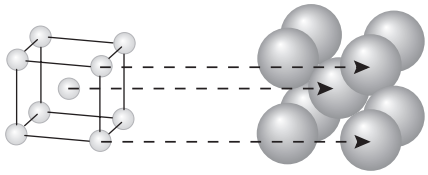
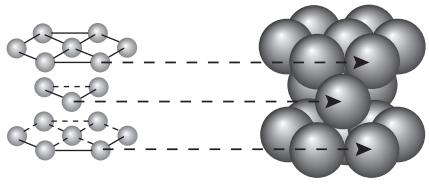
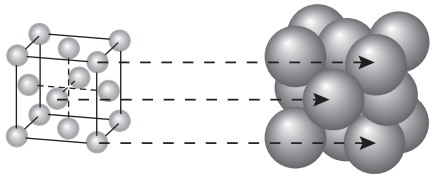
6. Label each of the following arrangements of atoms with the correct name.



body-centered cubic



hexagonal close-packed



face-centered cubic

7. Circle the letter of each metal whose atoms form a face-centered cubic pattern.

a. magnesium
c. sodium
b. copper
d. aluminum

Match the arrangement with the number of neighbors belonging to each atom in the arrangement.

b **8.** body-centered cubic — **a.** 12

a **9.** face-centered cubic — **b.** 8

a **10.** hexagonal close-packed

Alloys

11. A mixture of two or more elements, at least one of which is a metal, is called a(n) *alloy*.

12. Is the following sentence true or false? Pure metals are usually harder and more durable than alloys. *false*

13. The most common use of nonferrous alloys is in *coins*.

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14. What four properties make steel an important alloy?

a. *corrosion resistance*

b. *ductility*

c. *hardness*

d. *toughness*

15. What are the component elements for the following alloys?

a. sterling silver *silver and copper*

b. brass *copper and zinc*

c. stainless steel *iron, chromium, nickel, and carbon*

d. cast iron *iron and carbon*

16. *Interstitial* alloys have smaller atoms that fit into the spaces between larger atoms. *Substitutional* alloys have component atoms that are roughly equal in size.

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Guided Practice Problems

Answer the following questions about Practice Problem 10.

Use electron dot structures to determine formulas of the ionic compounds formed when

a. potassium reacts with iodine.

b. aluminum reacts with oxygen.

Potassium Reacts with Iodine

Analyze

Step 1. Is one of the elements a metal? If so, which one? ***potassium***

Step 2. Metal atoms ***lose*** their valence electrons when forming ionic compounds. Nonmetal atoms ***gain*** electrons when forming ionic compounds.

Solve

Step 3. Draw the electron dot structures for potassium and iodine.

potassium  iodine 

Step 4. The metal atom, ***potassium***, must lose ***1*** electron(s) in order to achieve an octet in the next-lowest energy level. The nonmetal atom, ***iodine***, must gain ***1*** electron(s) in order to achieve a complete octet.

Step 5. Using electron dot structures, write an equation that shows the formation of the ionic compound from the two elements. Make sure that the electrons lost equals the electrons gained.

Step 6. The chemical formula for the ionic compound formed is ***KI***.

Aluminum Reacts with Oxygen

Analyze

Step 1. Is one of the elements a metal? If so, which one? ***aluminum***

Step 2. Metal atoms ***lose*** valence electrons when forming ionic compounds. Nonmetal atoms ***gain*** electrons when forming ionic compounds.

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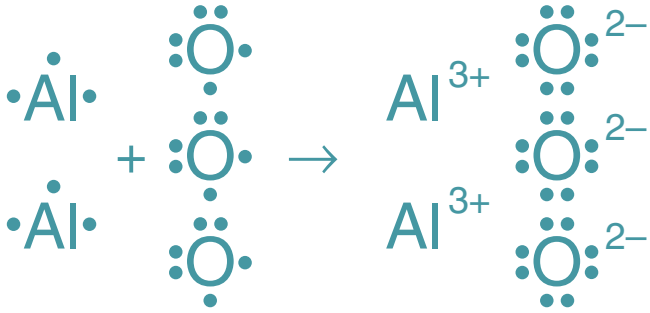
Solve

Step 3. Draw the electron dot structures for aluminum and oxygen.

aluminum  oxygen 

Step 4. The metal atom, ***aluminum***, must lose ***3*** electron(s) in order to achieve an octet in the next-lowest energy level. The nonmetal atom, ***oxygen***, must gain ***2*** electron(s) in order to achieve a complete octet.

Step 5. Using electron dot structures, write an equation that shows the formation of the ionic compound from the two elements. Make sure that the electrons lost equals the electrons gained.



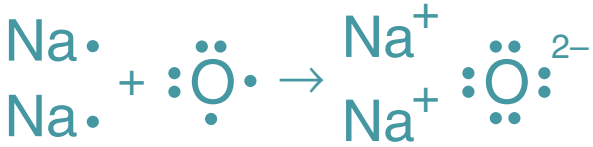
Step 6. The chemical formula for the ionic compound formed is ***Al_2O_3***.

Apply the Big idea

Sodium is a very reactive element. It can make compounds with elements from Groups 5, 6, and 7. Draw electron dot diagrams of compounds made with sodium as the cation and elements from Groups 5, 6, and 7 as the anions. How do they differ?

They differ in the number of sodium cations needed to balance the charge on the anion.

Sample answers:



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7 Self-Check Activity

For Questions 1–9, complete each statement by writing the correct word or words. If you need help, you can go online.

7.1 Ions

1. The ***group number*** of a representative element is also the number of valence electrons it has.

2. When an atom loses one or more valence electrons, it becomes a ***positively*** charged ion, also known as a(n) ***cation***.

3. When an atom gains one or more valence electrons, it becomes a ***negatively*** charged ion, also known as a(n) ***anion***.

7.2 Ionic Bonds and Ionic Compounds

4. Ionic compounds are composed of positive and negative ions, but the compounds themselves are electrically ***neutral***.

5. At room temperature, most ionic compounds are ***crystalline solids***.

6. In general, ionic compounds have ***high*** melting points.

7. Ionic compounds exhibit the property of electrical ***conductivity*** when they are melted or in an aqueous solution.

7.3 Bonding in Metals

8. In a pure metal, the ***valence electrons*** can be modeled as a sea of electrons.

9. The properties of alloys are often ***superior*** to the properties of the elements they contain.

If You Have Trouble With…									
Question	1	2	3	4	5	6	7	8	9
See Page	194	195	198	201	204	204	206	209	211

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Review Vocabulary

Write the meaning of each vocabulary term below. Then invent a method that will help you remember the meaning of the terms. One has been done for you.

Vocabulary	Meaning	How I'm going to remember the meaning
formula unit	shows what anions and cations are in an ionic compound and the simplest ratio of these ions	formula unit - "for" showing ions and ratio simply, e.g., NaCl
ionic bond	*the force of attraction between an anion and a cation*	*Answers will vary.*
ionic compound	*what forms when anions and cations are joined by ionic bonds*	
metallic bond	*the attraction between a metal cation and the electrons that surround it*	
valence electron	*an electron located in the outer energy level of an electron cloud*	
chemical formula	*a combination of element symbols and subscripts that shows the composition of a representative unit of a compound*	
electron dot formula	*uses an element's symbol and dots to represent valence electrons and model an atom*	
halide ion	*an anion formed when a halogen atom gains an electron*	
coordination number	*the number of oppositely charged ions that surround an ion in an ionic crystal*	
alloy	*a mixture of a metal and at least one other element*	
octet rule	*explains how elements in a compound try to achieve the configuration of a noble gas*	