Chapter 7

Ionic Compounds and Metals
Ionic Compounds and Metals

Section 7.1 Ion Formation

Section 7.2 Ionic Bonds and Ionic Compounds

Section 7.3 Names and Formulas for Ionic Compounds

Section 7.4 Metallic Bonds and the Properties of Metals

Click a hyperlink or folder tab to view the corresponding slides.
Section 7.1 Ion Formation

Objectives

• Define a chemical bond.

• Describe the formation of positive and negative ions.

• Relate ion formation to electron configuration.

Review Vocabulary

octet rule: atoms tend to gain, lose, or share electrons in order to acquire eight valence electrons

New Vocabulary

chemical bond
cation
anion

MAIN Idea

Ions are formed when atoms gain or lose valence electrons to achieve a stable octet electron configuration.
Valence Electrons and Chemical Bonds

• A chemical bond is the force that holds two atoms together.

• Chemical bonds form by the attraction between the positive nucleus of one atom and the negative electrons of another atom.
Valence Electrons and Chemical Bonds (cont.)

- Atom’s try to form the octet—the stable arrangement of eight valence electrons in the outer energy level—by gaining or losing valence electrons.

<table>
<thead>
<tr>
<th>Table 7.1</th>
<th>Electron-Dot Structures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
<td>1</td>
</tr>
<tr>
<td>Diagram</td>
<td>Li⁺</td>
</tr>
</tbody>
</table>
Positive Ion Formation

- A positively charged ion is called a **cation**.
- Sodium loses one valence electron to become a sodium cation, Na⁺.
• **Metals** are reactive because they **lose** valence electrons easily.

### Table 7.2 Group 1, 2, and 13 Ions

<table>
<thead>
<tr>
<th>Group</th>
<th>Configuration</th>
<th>Charge of Ion Formed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>[noble gas] $ns^1$</td>
<td>1+ when the $s^1$ electron is lost</td>
</tr>
<tr>
<td>2</td>
<td>[noble gas] $ns^2$</td>
<td>2+ when the $s^2$ electrons are lost</td>
</tr>
<tr>
<td>13</td>
<td>[noble gas] $ns^2np^1$</td>
<td>3+ when the $s^2p^1$ electrons are lost</td>
</tr>
</tbody>
</table>
Negative Ion Formation

- An **anion** is a negatively charged ion.
- Chlorine gains an electron to form a chlorine ion, Cl\(^{-}\).
Nonmetal ions gain the number of electrons required to fill an octet.

Table 7.3 Group 15–17 Ions

<table>
<thead>
<tr>
<th>Group</th>
<th>Configuration</th>
<th>Charge of Ion Formed</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>[noble gas] ns²np³</td>
<td>3− when three electrons are gained</td>
</tr>
<tr>
<td>16</td>
<td>[noble gas] ns²np⁴</td>
<td>2− when two electrons are gained</td>
</tr>
<tr>
<td>17</td>
<td>[noble gas] ns²np⁵</td>
<td>1− when one electron is gained</td>
</tr>
</tbody>
</table>
Section 7.1 Assessment

Oxygen gains two electrons to form what kind of ion?

A. 1– anion
B. 2– anion
C. 1+ cation
D. 2+ cation
Section 7.1 Assessment

Elements with a full octet have which configuration?

A. ionic configuration
B. halogen configuration
C. noble gas configuration
D. transition metal configuration
Click the mouse button to return to the Chapter Menu.
Section 7.2 Ionic Bonds and Ionic Compounds

Objectives

• **Describe** the formation of ionic bonds and the structure of ionic compounds.

• **Generalize** about the strength of ionic bonds based on the physical properties of ionic compounds.

• **Categorize** ionic bond formation as exothermic or endothermic.

Review Vocabulary

**compound**: a chemical combination of two or more different elements
Oppositely charged ions attract each other, forming electrically neutral ionic compounds.
The electrostatic force that holds oppositely charged ions together in an ionic compound is called an **ionic bond**.
Compounds that contain ionic bonds are called **ionic compounds**.

**Binary ionic compounds** contain only two different elements—a metallic cation and a nonmetallic anion.

Formation of an Ionic Bond

http://www.youtube.com/watch?v=Ftw7a5ccubs

Sodium Chloride
**Formation of an Ionic Bond (cont.)**

Table 7.4 Formation of Sodium Chloride

<table>
<thead>
<tr>
<th>Chemical Equation</th>
<th>Orbital Notation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na + Cl → Na⁺ + Cl⁻ + energy</td>
<td>Na⁺ + Cl⁻ + energy</td>
</tr>
</tbody>
</table>

### Electron Configurations

One electron is transferred.

\[
\begin{align*}
\text{Na: } & \quad [\text{Ne}]3s^1 \\
\text{Cl: } & \quad [\text{Ne}]3s^23p^5 \\
\text{Na⁺: } & \quad [\text{Ne}] \\
\text{Cl⁻: } & \quad [\text{Ar}] \\
\end{align*}
\]

### Electron-Dot Structures

One electron is transferred.

\[
\text{Na} + \text{Cl}^\text{-} \rightarrow \text{Na}^+ + \text{Cl}^- + \text{energy}
\]

### Atomic Models

- **Sodium atom**
  - 11 electrons (11⁻)
  - 11 protons (11⁺)
- **Chlorine atom**
  - 17 electrons (17⁻)
  - 17 protons (17⁺)
- **Sodium chloride**
  - 10 electrons (10⁻)
  - 18 electrons (18⁻)
  - + energy
Properties of Ionic Compounds

- The repeating pattern of particle packing in an ionic compound is called an ionic crystal.
- The strong attractions formed between the cations and anions form a crystal lattice.
Properties of Ionic Compounds (cont.)

- A **crystal lattice** is the 3-D arrangement of particles, and is responsible for the structure of many minerals.

Calcite - CaCO₃  
Galena - PbS  
Salesite - Cu(IO₃)OH
Properties of Ionic Compounds (cont.)

- An ion in aqueous solution that conducts electricity is an **electrolyte**.
## Properties of Ionic Compounds (cont.)

### Table 7.5

<table>
<thead>
<tr>
<th>Compound</th>
<th>Melting Point (°C)</th>
<th>Boiling Point (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NaI</td>
<td>660</td>
<td>1304</td>
</tr>
<tr>
<td>KBr</td>
<td>734</td>
<td>1435</td>
</tr>
<tr>
<td>NaBr</td>
<td>747</td>
<td>1390</td>
</tr>
<tr>
<td>CaCl$_2$</td>
<td>782</td>
<td>&gt;1600</td>
</tr>
<tr>
<td>NaCl</td>
<td>801</td>
<td>1413</td>
</tr>
<tr>
<td>MgO</td>
<td>2852</td>
<td>3600</td>
</tr>
</tbody>
</table>

![Diagram](undisturbed_ionic_crystal.png)

Undisturbed ionic crystal

![Diagram](applied_force_realignment.png)

Applied force realigns particles.

![Diagram](forces_of_repulsion_break_apart.png)

Forces of repulsion break crystal apart.
Properties of Ionic Compounds (cont.)

Summary of Ionic Compound Properties:

• High Melting and Boiling Points
• Are good electrolytes when in aqueous solution
• Solids can break down into smaller crystals
Energy and the Ionic Bond

• Reactions that absorb energy are **endothermic**.

Ammonium thiocyanate is mixed with barium hydroxide. A drop of water is placed on a block of wood. The bottom of the bottom becomes cold enough to freeze the water and stick to the wood.
Energy and the Ionic Bond

- Reactions that release energy are **exothermic**.

Hindenburgh Explosion, May 6, 1937

[YouTube Video](http://www.youtube.com/watch?v=lFptgQ8GA_U)
Why are solid ionic compounds poor conductors of electricity?

A. They are non-metals.
B. They are electrolytes.
C. They have electrons that cannot flow freely.
D. Solids do not conduct electricity.
Section 7.2 Assessment

What is the electrostatic charge holding two ions together?

A. covalent bond
B. pseudo-noble gas bond
C. crystal lattice bond
D. ionic bond
Click the mouse button to return to the Chapter Menu.
Section 7.3 Names and Formulas for Ionic Compounds

Objectives

• **Relate** a formula unit of an ionic compound to its composition.

• **Write** formulas for ionic compounds and oxyanions.

• **Apply** naming conventions to ionic compounds and oxyanions.

Review Vocabulary

**nonmetal**: an element that is generally a gas or a dull, brittle solid and is a poor conductor of heat and electricity
Section 7.3 Names and Formulas for Ionic Compounds (cont.)

New Vocabulary

- formula unit
- monatomic ion
- oxidation number
- polyatomic ion
- oxyanion

MAIN Idea In written names and formulas for ionic compounds, the cation appears first, followed by the anion.
Chemists around the world must communicate with one another, so a standardized system of naming compounds was developed.
Formulas for Ionic Compounds (cont.)

- A **formula unit** represents the simplest ratio of the ions involved.
- **Monatomic ions** are one-atom ions.

### Table 7.7: Common Monatomic Ions

<table>
<thead>
<tr>
<th>Group</th>
<th>Atoms that Commonly Form Ions</th>
<th>Charge of Ions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>H, Li, Na, K, Rb, Cs</td>
<td>1+</td>
</tr>
<tr>
<td>2</td>
<td>Be, Mg, Ca, Sr, Ba</td>
<td>2+</td>
</tr>
<tr>
<td>15</td>
<td>N, P, As</td>
<td>3—</td>
</tr>
<tr>
<td>16</td>
<td>O, S, Se, Te</td>
<td>2—</td>
</tr>
<tr>
<td>17</td>
<td>F, Cl, Br, I</td>
<td>1—</td>
</tr>
</tbody>
</table>
Formulas for Ionic Compounds (cont.)

- **Oxidation number**, or oxidation state, is the charge of a monatomic ion.

<table>
<thead>
<tr>
<th>Group</th>
<th>Common Ions</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Sc$^{3+}$, Y$^{3+}$, La$^{3+}$</td>
</tr>
<tr>
<td>4</td>
<td>Ti$^{2+}$, Ti$^{3+}$</td>
</tr>
<tr>
<td>5</td>
<td>V$^{2+}$, V$^{3+}$</td>
</tr>
<tr>
<td>6</td>
<td>Cr$^{2+}$, Cr$^{3+}$</td>
</tr>
<tr>
<td>7</td>
<td>Mn$^{2+}$, Mn$^{3+}$, Tc$^{2+}$</td>
</tr>
<tr>
<td>8</td>
<td>Fe$^{2+}$, Fe$^{3+}$</td>
</tr>
<tr>
<td>9</td>
<td>Co$^{2+}$, Co$^{3+}$</td>
</tr>
<tr>
<td>10</td>
<td>Ni$^{2+}$, Pd$^{2+}$, Pt$^{2+}$, Pt$^{4+}$</td>
</tr>
<tr>
<td>11</td>
<td>Cu$^{+}$, Cu$^{2+}$, Ag$^{+}$, Au$^{+}$, Au$^{3+}$</td>
</tr>
<tr>
<td>12</td>
<td>Zn$^{2+}$, Cd$^{2+}$, Hg$^{2+}$, Hg$^{2+}$</td>
</tr>
<tr>
<td>13</td>
<td>Al$^{3+}$, Ga$^{2+}$, Ga$^{3+}$, In$^{+}$, In$^{2+}$, In$^{3+}$, Ti$^{3+}$, Ti$^{4+}$</td>
</tr>
<tr>
<td>14</td>
<td>Sn$^{2+}$, Sn$^{4+}$, Pb$^{2+}$, Pb$^{4+}$</td>
</tr>
</tbody>
</table>
Formulas for Ionic Compounds (cont.)

- The symbol for the cation is always written first, followed by the symbol of the anion.

- **Subscripts** represent the number of ions of each element in an ionic compound.

\[
\begin{align*}
\text{NaCl} & & \text{H}_2\text{O} \\
\text{LiNO}_3 & & \text{Al}_2(\text{CO}_3)_3
\end{align*}
\]
Formulas for Ionic Compounds (cont.)

- The total charge **must equal zero** in an ionic compound.

- If the charges do not add up to equal zero, use the **Criss-Cross Method**.
Polyatomic ions are ions made up of more than one atom.

- Never change subscripts of polyatomic ions!!
- If more than one polyatomic ion is needed, place in parentheses and write the appropriate subscript outside the parentheses.
### Table 7.9 Common Polyatomic Ions

<table>
<thead>
<tr>
<th>Ion</th>
<th>Name</th>
<th>Ion</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>NH$_4^+$</td>
<td>ammonium</td>
<td>IO$_4^-$</td>
<td>periodate</td>
</tr>
<tr>
<td>NO$_2^-$</td>
<td>nitrite</td>
<td>C$_2$H$_3$O$_2^-$</td>
<td>acetate</td>
</tr>
<tr>
<td>NO$_3^-$</td>
<td>nitrate</td>
<td>H$_2$PO$_4^-$</td>
<td>dihydrogen phosphate</td>
</tr>
<tr>
<td>OH$^-$</td>
<td>hydroxide</td>
<td>CO$_3^{2-}$</td>
<td>carbonate</td>
</tr>
<tr>
<td>CN$^-$</td>
<td>cyanide</td>
<td>SO$_3^{2-}$</td>
<td>sulfite</td>
</tr>
<tr>
<td>MnO$_4^-$</td>
<td>permanganate</td>
<td>SO$_4^{2-}$</td>
<td>sulfate</td>
</tr>
<tr>
<td>HCO$_3^-$</td>
<td>hydrogen carbonate</td>
<td>S$_2$O$_3^{2-}$</td>
<td>thiosulfate</td>
</tr>
<tr>
<td>ClO$^-$</td>
<td>hypochlorite</td>
<td>O$_2^{2-}$</td>
<td>peroxide</td>
</tr>
<tr>
<td>ClO$_2^-$</td>
<td>chlorite</td>
<td>CrO$_4^{2-}$</td>
<td>chromate</td>
</tr>
<tr>
<td>ClO$_3^-$</td>
<td>chlorate</td>
<td>Cr$_2$O$_7^{2-}$</td>
<td>dichromate</td>
</tr>
<tr>
<td>ClO$_4^-$</td>
<td>perchlorate</td>
<td>HPO$_4^{2-}$</td>
<td>hydrogen phosphate</td>
</tr>
<tr>
<td>BrO$_3^-$</td>
<td>bromate</td>
<td>PO$_4^{3-}$</td>
<td>phosphate</td>
</tr>
<tr>
<td>IO$_3^-$</td>
<td>iodate</td>
<td>AsO$_4^{3-}$</td>
<td>arsenate</td>
</tr>
</tbody>
</table>
Names for Ions and Ionic Compounds (cont.)

• Chemical nomenclature is a systematic way of naming compounds.
  – Name the cation followed by the anion.
  – For monatomic, cations use the element name.
  – For monatomic anions, use the root element name and the suffix –ide.
  – To distinguish between different oxidation states of the same element, the oxidation state is written in parentheses after the name of the cation.
  – When the compound contains a polyatomic ion, name the cation followed by the name of the polyatomic ion.
Names for Ions and Ionic Compounds (cont.)

Example

**Na₃PO₄**

<table>
<thead>
<tr>
<th>Cation</th>
<th>Anion</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Na⁺</strong></td>
<td><strong>PO₄³⁻</strong></td>
</tr>
</tbody>
</table>

Determine the cation and anion of the given formula.

Example

**Fe₂O₃**

<table>
<thead>
<tr>
<th>Anion</th>
<th>Cation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>O₂⁻</strong></td>
<td><strong>Fe⁺⁺</strong></td>
</tr>
</tbody>
</table>

Does the cation have only one oxidation number?

- Yes
  - Write the name of the cation, then write the name of the anion.
  - **Na₃PO₄** = sodium phosphate

- No
  - Write the name of the cation followed by a Roman numeral to represent the charge. Next, write the name of the anion.
  - **Fe₂O₃** = iron(III) oxide

Iron can have several oxidation numbers.
Section 7.3 Assessment

Which subscripts would you most likely use for an ionic compound containing an alkali metal and a halogen? (Remember, 1 = no written subscript)

A. 1 and 2
B. 2 and 1
C. 2 and 3
D. 1 and 1
What is the name of the compound Ca(OH)$_2$?  

A. calcium oxide  
B. calcium(I)oxide  
C. calcium hydroxide  
D. calcium peroxide
Click the mouse button to return to the Chapter Menu.
Section 7.4 Metallic Bonds and the Properties of Metals

Objectives

- **Describe** a metallic bond.
- **Relate** the electron sea model to the physical properties of metals.
- **Define** alloys, and categorize them into two basic types.

Review Vocabulary

**physical property**: a characteristic of matter that can be observed or measured without altering the sample’s composition
Section 7.4 Metallic Bonds and the Properties of Metals (cont.)

New Vocabulary

electron sea model
delocalized electron
metallic bond
alloy

MAIN Idea Metals form crystal lattices and can be modeled as cations surrounded by a “sea” of freely moving valence electrons.
Metallic Bonds and the Properties of Metals

• Metals are not ionic but share several properties with ionic compounds.

• Metals also form lattices in the solid state, where 8 to 12 other atoms closely surround each metal atom.
Metallic Bonds and the Properties of Metals (cont.)

• Within the crowded lattice, the outer energy levels of metal atoms overlap.

• The **electron sea model** proposes that all metal atoms in a metallic solid contribute their valence electrons to form a "sea" of electrons.

• The electrons are free to move around and are referred to as **delocalized electrons**, forming a metallic cation.
Metallic Bonds and the Properties of Metals (cont.)

- A **metallic bond** is the attraction of an metallic cation for delocalized electrons.
Metallic Bonds and the Properties of Metals (cont.)

- Boiling points are much more extreme than melting points because of the energy required to separate atoms from the groups of cations and electrons.

<table>
<thead>
<tr>
<th>Table 7.12</th>
<th>Melting and Boiling Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Element</td>
<td>Melting Point (°C)</td>
</tr>
<tr>
<td>Lithium</td>
<td>180</td>
</tr>
<tr>
<td>Tin</td>
<td>232</td>
</tr>
<tr>
<td>Aluminum</td>
<td>660</td>
</tr>
<tr>
<td>Barium</td>
<td>727</td>
</tr>
<tr>
<td>Silver</td>
<td>961</td>
</tr>
<tr>
<td>Copper</td>
<td>1083</td>
</tr>
</tbody>
</table>
Metallic Bonds and the Properties of Metals (cont.)

- Metals are malleable because they can be hammered into sheets.

- Metals are ductile because they can be drawn into wires.
Metallic Bonds and the Properties of Metals (cont.)

- Mobile electrons around cations make metals good conductors of electricity and heat.

- As the number of delocalized electrons increases, so does hardness and strength.
Metal Alloys

- An **alloy** is a mixture of elements that has metallic properties.

- The properties of alloys differ from the elements they contain.

![Images of Bronze, Brass, and Pewter](URLs)

Bronze  
Brass  
Pewter
# Table 7.13: Commercial Alloys

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Composition</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alnico</td>
<td>Fe 50%, Al 20%, Ni 20%, Co 10%</td>
<td>magnets</td>
</tr>
<tr>
<td>Brass</td>
<td>Cu 67–90%, Zn 10–33%</td>
<td>plumbing, hardware, lighting</td>
</tr>
<tr>
<td>Bronze</td>
<td>Cu 70–95%, Zn 1–25%, Sn 1–18%</td>
<td>bearings, bells, medals</td>
</tr>
<tr>
<td>Cast iron</td>
<td>Fe 96–97%, C 3–4%</td>
<td>casting</td>
</tr>
<tr>
<td>Gold, 10-carat</td>
<td>Au 42%, Ag 12–20%, Cu 37.46%</td>
<td>jewelry</td>
</tr>
<tr>
<td>Lead shot</td>
<td>Pb 99.8%, As 0.2%</td>
<td>shotgun shells</td>
</tr>
<tr>
<td>Pewter</td>
<td>Sn 70–95%, Sb 5–15%, Pb 0–15%</td>
<td>tableware</td>
</tr>
<tr>
<td>Stainless steel</td>
<td>Fe 73–79%, Cr 14–18%, Ni 7–9%</td>
<td>instruments, sinks</td>
</tr>
<tr>
<td>Sterling silver</td>
<td>Ag 92.5%, Cu 7.5%</td>
<td>tableware, jewelry</td>
</tr>
</tbody>
</table>
• Substitutional alloys are formed when some atoms in the original metallic solid are replaced by other metals of similar atomic structure. Ex: sterling silver - some Ag atoms are replaced by Cu atoms.
Metal Alloys (cont.)

- Interstitial alloys are formed when small holes in a metallic crystal are filled with smaller atoms. Ex: Steel – Fe has small holes that get filled with C atoms. This makes the steel much harder and stronger.
The attraction of a metallic cation and delocalized electrons forms what kind of bond?

A. ionic  
B. covalent  
C. diatomic  
D. metallic
Which property of metals allows them to be easily drawn into wires?

A. malleability
B. ductility
C. conductivity
D. durability
Click the mouse button to return to the Chapter Menu.
Chemistry Online
Study Guide
Chapter Assessment
Standardized Test Practice
Image Bank
Concepts in Motion
A chemical bond is the force that holds two atoms together.

Some atoms form ions to gain stability. This stable configuration involves a complete outer energy level, usually consisting of eight valence electrons.

Ions are formed by the loss or gain of valence electrons.

The number of protons remains unchanged during ion formation.
**Key Concepts**

- Ionic compounds contain ionic bonds formed by the attraction of oppositely charged ions.

- Ions in an ionic compound are arranged in a repeating pattern known as a crystal lattice.

- Ionic compound properties are related to ionic bond strength.

- Ionic compounds are electrolytes; they conduct an electric current in the liquid phase and in aqueous solution.
Key Concepts

• Lattice energy is the energy needed to remove 1 mol of ions from its crystal lattice.
Key Concepts

- A formula unit gives the ratio of cations to anions in the ionic compound.

- A monatomic ion is formed from one atom. The charge of a monatomic ion is its oxidation number.

- Roman numerals indicate the oxidation number of cations having multiple possible oxidation states.

- Polyatomic ions consist of more than one atom and act as a single unit.
Key Concepts

- To indicate more than one polyatomic ion in a chemical formula, place parentheses around the polyatomic ion and use a subscript.
Key Concepts

• A metallic bond forms when metal cations attract freely moving, delocalized valence electrons.

• In the electron sea model, electrons move through the metallic crystal and are not held by any particular atom.

• The electron sea model explains the physical properties of metallic solids.

• Metal alloys are formed when a metal is mixed with one or more other elements.
Cations form when atoms _______ electrons.

A. gain
B. lose
C. charge
D. delocalize
What is the repeating pattern of atoms in an ionic solid called?

A. crystal lattice
B. ionic lattice
C. energy lattice
D. ionic bonding
Give the name of the following: $\text{NaClO}_4$

A. sodium hypochlorite
B. sodium chlorite
C. sodium chlorate
D. sodium perchlorate
As the distance between ions in an ionic bond is shortened,

A. the energy to break the bond decreases.

B. the electrostatic attraction decreases.

C. the electrostatic attraction increases.

D. the ionic bond changes to a metallic bond.
An alloy is what type of substance?

A. heterogeneous mixture
B. compound
C. mixture of elements
D. element
Which is NOT true about metallic solids?

A. Metals are shiny.
B. Metals are good conductors of heat and electricity.
C. Metals are ductile.
D. Metals have relatively low boiling points.
Electrons in an atom’s outer most energy level are referred to as what?

A. ions

B. cations

C. valence electrons

D. noble-gas electrons
What is the oxidation state of copper in Cu(II)Cl₂?

A. 1+
B. 2+
C. 2–
D. unable to determine
Which elements naturally occur with a full octet of valence electrons?

A. alkali metals
B. alkali earth metals
C. halogens
D. noble gases
How many electrons are in a full octet?

A. 10
B. 8
C. 6
D. 4
Click on an image to enlarge.
<table>
<thead>
<tr>
<th>Group</th>
<th>1</th>
<th>2</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diagram</td>
<td>Li·</td>
<td>Be·</td>
<td>B·</td>
<td>C·</td>
<td>N·</td>
<td>O·</td>
<td>F·</td>
<td>Ne·</td>
</tr>
</tbody>
</table>
Neutral sodium atom

11 electrons (11→)

498 kJ/mol

11 protons (11+)

↓

10 electrons (10→)

Sodium ion

+ e⁻

11 protons (11+)

Sodium atom + Ionization energy

→ Sodium ion (Na⁺) + Electron (e⁻)
<table>
<thead>
<tr>
<th>Group</th>
<th>Configuration</th>
<th>Charge of Ion Formed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>[noble gas] ns(^1)</td>
<td>1(^+) when the s(^1) electron is lost</td>
</tr>
<tr>
<td>2</td>
<td>[noble gas] ns(^2)</td>
<td>2(^+) when the s(^2) electrons are lost</td>
</tr>
<tr>
<td>13</td>
<td>[noble gas] ns(^2)np(^1)</td>
<td>3(^+) when the s(^2)p(^1) electrons are lost</td>
</tr>
</tbody>
</table>
\[
\text{Zn} \quad \text{[Ar]} \quad \uparrow \downarrow \quad \uparrow \downarrow \quad \uparrow \downarrow \quad \uparrow \downarrow \quad \uparrow \downarrow \quad \uparrow \downarrow \quad + \text{ energy} \quad \rightarrow
\]

\[
\text{Zn}^{2+} \quad \text{[Ar]} \quad \uparrow \downarrow \quad \uparrow \downarrow \quad \uparrow \downarrow \quad \uparrow \downarrow \quad \uparrow \downarrow \quad \uparrow \downarrow \quad + \ 2e^{-}
\]
Neutral chlorine atom

17 electrons (17\textsuperscript{−})

17 protons (17\textsuperscript{+})

+ e\textsuperscript{−}

18 electrons (18\textsuperscript{−})

\downarrow

Chloride ion

17 protons (17\textsuperscript{+})

\rightarrow 349 \frac{\text{kJ}}{\text{mol}}

Chlorine atom + electron (e\textsuperscript{−})

\rightarrow Chloride ion (\text{Cl}^\text{−}) + energy
<table>
<thead>
<tr>
<th>Group</th>
<th>Configuration</th>
<th>Charge of Ion Formed</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>[noble gas] (ns^2np^3)</td>
<td>3— when three electrons are gained</td>
</tr>
<tr>
<td>16</td>
<td>[noble gas] (ns^2np^4)</td>
<td>2— when two electrons are gained</td>
</tr>
<tr>
<td>17</td>
<td>[noble gas] (ns^2np^5)</td>
<td>1— when one electron is gained</td>
</tr>
</tbody>
</table>
### Table 7.4 Formation of Sodium Chloride

<table>
<thead>
<tr>
<th>Chemical Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Na + Cl \rightarrow Na^+ + Cl^- + energy$</td>
</tr>
</tbody>
</table>

#### Electron Configurations

One electron is transferred.

$$\text{[Ne]}^{3s^1} + \text{[Ne]}^{3s^33p^5} \rightarrow \text{[Ne]} + \text{[Ar]} + energy$$

#### Orbital Notation

One electron is transferred.

$$\begin{align*}
\text{1s} & \quad \text{2s} \\
\text{Na} & \quad \text{3s} \\
\text{1s} & \quad \text{2s} \\
\text{Cl} & \quad \text{3p} \\
\text{Na}^+ & \quad \text{Cl}^- \\
\text{1s} & \quad \text{2s} \\
\text{2p} & \quad \text{3p} \\
\text{1s} & \quad \text{2s} \\
\text{2p} & \quad \text{3p} \\
\text{Na}^+ & \quad \text{Cl}^- \\
\text{1s} & \quad \text{2s} \\
\text{2p} & \quad \text{3p} \\
\text{1s} & \quad \text{2s} \\
\text{2p} & \quad \text{3p} \\
\end{align*}$$

#### Electron-Dot Structures

One electron is transferred.

$$Na^{\cdot} + Cl^{-} \rightarrow Na^{+} + Cl^{-}\cdot^{-} + energy$$

#### Atomic Models

- Sodium atom
- Chlorine atom
- Sodium chloride
Sodium chloride crystal
<table>
<thead>
<tr>
<th>Compound</th>
<th>Melting Point (°C)</th>
<th>Boiling Point (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NaI</td>
<td>660</td>
<td>1304</td>
</tr>
<tr>
<td>KBr</td>
<td>734</td>
<td>1435</td>
</tr>
<tr>
<td>NaBr</td>
<td>747</td>
<td>1390</td>
</tr>
<tr>
<td>CaCl₂</td>
<td>782</td>
<td>&gt;1600</td>
</tr>
<tr>
<td>NaCl</td>
<td>801</td>
<td>1413</td>
</tr>
<tr>
<td>MgO</td>
<td>2852</td>
<td>3600</td>
</tr>
</tbody>
</table>
Image Bank

Undisturbed ionic crystal

Applied force realigns particles.

Forces of repulsion break crystal apart.
# Table 7.6: Lattice Energies of Some Ionic Compounds

<table>
<thead>
<tr>
<th>Compound</th>
<th>Lattice Energy (kJ/mol)</th>
<th>Compound</th>
<th>Lattice Energy (kJ/mol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KI</td>
<td>632</td>
<td>KF</td>
<td>808</td>
</tr>
<tr>
<td>KBr</td>
<td>671</td>
<td>AgCl</td>
<td>910</td>
</tr>
<tr>
<td>RbF</td>
<td>774</td>
<td>NaF</td>
<td>910</td>
</tr>
<tr>
<td>NaI</td>
<td>682</td>
<td>LiF</td>
<td>1030</td>
</tr>
<tr>
<td>NaBr</td>
<td>732</td>
<td>SrCl₂</td>
<td>2142</td>
</tr>
<tr>
<td>NaCl</td>
<td>769</td>
<td>MgO</td>
<td>3795</td>
</tr>
</tbody>
</table>
## Table 7.7  Common Monatomic Ions

<table>
<thead>
<tr>
<th>Group</th>
<th>Atoms that Commonly Form Ions</th>
<th>Charge of Ions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>H, Li, Na, K, Rb, Cs</td>
<td>1+</td>
</tr>
<tr>
<td>2</td>
<td>Be, Mg, Ca, Sr, Ba</td>
<td>2+</td>
</tr>
<tr>
<td>15</td>
<td>N, P, As</td>
<td>3−</td>
</tr>
<tr>
<td>16</td>
<td>O, S, Se, Te</td>
<td>2−</td>
</tr>
<tr>
<td>17</td>
<td>F, Cl, Br, I</td>
<td>1−</td>
</tr>
<tr>
<td>Group</td>
<td>Common Ions</td>
<td></td>
</tr>
<tr>
<td>-------</td>
<td>-----------------------------</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Sc$^{3+}$, Y$^{3+}$, La$^{3+}$</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Ti$^{2+}$, Ti$^{3+}$</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>V$^{2+}$, V$^{3+}$</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Cr$^{2+}$, Cr$^{3+}$</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Mn$^{2+}$, Mn$^{3+}$, Tc$^{2+}$</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Fe$^{2+}$, Fe$^{3+}$</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Co$^{2+}$, Co$^{3+}$</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Ni$^{2+}$, Pd$^{2+}$, Pt$^{2+}$, Pt$^{4+}$</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Cu$^+$, Cu$^{2+}$, Ag$^+$, Au$^+$, Au$^{3+}$</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Zn$^{2+}$, Cd$^{2+}$, Hg$^{2+}$, Hg$^{2+}$</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Al$^{3+}$, Ga$^{2+}$, Ga$^{3+}$, In$^+$, In$^{2+}$, In$^{3+}$, Tl$^+$, Tl$^{3+}$</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Sn$^{2+}$, Sn$^{4+}$, Pb$^{2+}$, Pb$^{4+}$</td>
<td></td>
</tr>
</tbody>
</table>
Ammonium ion
(NH$_4^+$)

Phosphate ion
(PO$_4^{3-}$)
### Table 7.9  Common Polyatomic Ions

<table>
<thead>
<tr>
<th>Ion</th>
<th>Name</th>
<th>Ion</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>NH₄⁺</td>
<td>ammonium</td>
<td>IO₄⁻</td>
<td>periodate</td>
</tr>
<tr>
<td>NO₂⁻</td>
<td>nitrite</td>
<td>C₂H₃O₂⁻</td>
<td>acetate</td>
</tr>
<tr>
<td>NO₃⁻</td>
<td>nitrate</td>
<td>H₂PO₄⁻</td>
<td>dihydrogen phosphate</td>
</tr>
<tr>
<td>OH⁻</td>
<td>hydroxide</td>
<td>CO₃²⁻</td>
<td>carbonate</td>
</tr>
<tr>
<td>CN⁻</td>
<td>cyanide</td>
<td>SO₃²⁻</td>
<td>sulfite</td>
</tr>
<tr>
<td>MnO₄⁻</td>
<td>permanganate</td>
<td>SO₄²⁻</td>
<td>sulfate</td>
</tr>
<tr>
<td>HCO₃⁻</td>
<td>hydrogen carbonate</td>
<td>S₂O₃²⁻</td>
<td>thiosulfate</td>
</tr>
<tr>
<td>ClO⁻</td>
<td>hypochlorite</td>
<td>O₂²⁻</td>
<td>peroxide</td>
</tr>
<tr>
<td>ClO₂⁻</td>
<td>chlorite</td>
<td>CrO₄²⁻</td>
<td>chromate</td>
</tr>
<tr>
<td>ClO₃⁻</td>
<td>chlorate</td>
<td>Cr₂O₇²⁻</td>
<td>dichromate</td>
</tr>
<tr>
<td>ClO₄⁻</td>
<td>perchlorate</td>
<td>HPO₄²⁻</td>
<td>hydrogen phosphate</td>
</tr>
<tr>
<td>BrO₃⁻</td>
<td>bromate</td>
<td>PO₄³⁻</td>
<td>phosphate</td>
</tr>
<tr>
<td>IO₃⁻</td>
<td>iodate</td>
<td>AsO₄³⁻</td>
<td>arsenate</td>
</tr>
<tr>
<td>Table 7.10</td>
<td>Oxyanion Naming Conventions for Sulfur and Nitrogen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------</td>
<td>--------------------------------------------------</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Identify the ion with the greatest number of oxygen atoms. This ion is named using the root of the nonmetal and the suffix -ate.

- Identify the ion with fewer oxygen atoms. This ion is named using the root of the nonmetal and the suffix -ite.

Examples:

<table>
<thead>
<tr>
<th>Ion</th>
<th>Root</th>
<th>Suffix</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO₃⁻</td>
<td>nitrate</td>
<td></td>
</tr>
<tr>
<td>NO₂⁻</td>
<td>nitrite</td>
<td></td>
</tr>
<tr>
<td>SO₄²⁻</td>
<td>sulfate</td>
<td></td>
</tr>
<tr>
<td>SO₃²⁻</td>
<td>sulfite</td>
<td></td>
</tr>
</tbody>
</table>
### Table 7.11 Oxyanion Naming Conventions for Chlorine

- The oxyanion with the greatest number of oxygen atoms is named using the prefix *per-* , the root of the nonmetal, and the suffix -ate.
  
- The oxyanion with one fewer oxygen atom is named using the root of the nonmetal and the suffix -ate.

- The oxyanion with two fewer oxygen atoms is named using the root of the nonmetal and the suffix -ite.

- The oxyanion with three fewer oxygen atoms is named using the prefix hypoor-, the root of the nonmetal, and the suffix -ite.

  **Examples:**
  
  \[
  \begin{array}{ll}
  \text{ClO}_4^- & \text{ClO}_3^- \\
  \text{perchlorate} & \text{chlorate} \\
  \text{ClO}_2^- & \text{ClO}^- \\
  \text{chlorite} & \text{hypochlorite}
  \end{array}
  \]
Example
\( \text{Na}_3\text{PO}_4 \)

Cation
Anion

Example
\( \text{Fe}_2\text{O}_3 \)

Anion
Cation

Determine the cation and anion of the given formula.

Does the cation have only one oxidation number?

Yes

Write the name of the cation, then write the name of the anion.

\( \text{Na}_3\text{PO}_4 = \text{sodium phosphate} \)

No

Write the name of the cation followed by a Roman numeral to represent the charge. Next, write the name of the anion.

\( \text{Fe}_2\text{O}_3 = \text{iron(III) oxide} \)

Iron can have several oxidation numbers.

Sodium has only one oxidation number.
### Table 7.12: Melting and Boiling Points

<table>
<thead>
<tr>
<th>Element</th>
<th>Melting Point (°C)</th>
<th>Boiling Point (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lithium</td>
<td>180</td>
<td>1347</td>
</tr>
<tr>
<td>Tin</td>
<td>232</td>
<td>2623</td>
</tr>
<tr>
<td>Aluminum</td>
<td>660</td>
<td>2467</td>
</tr>
<tr>
<td>Barium</td>
<td>727</td>
<td>1850</td>
</tr>
<tr>
<td>Silver</td>
<td>961</td>
<td>2155</td>
</tr>
<tr>
<td>Copper</td>
<td>1083</td>
<td>2570</td>
</tr>
</tbody>
</table>
External force

Metal is deformed.
### Table 7.13 Commercial Alloys

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Composition</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alnico</td>
<td>Fe 50%, Al 20%, Ni 20%, Co 10%</td>
<td>magnets</td>
</tr>
<tr>
<td>Brass</td>
<td>Cu 67–90%, Zn 10–33%</td>
<td>plumbing, hardware, lighting</td>
</tr>
<tr>
<td>Bronze</td>
<td>Cu 70–95%, Zn 1–25%, Sn 1–18%</td>
<td>bearings, bells, medals</td>
</tr>
<tr>
<td>Cast iron</td>
<td>Fe 96–97%, C 3–4%</td>
<td>casting</td>
</tr>
<tr>
<td>Gold, 10-carat</td>
<td>Au 42%, Ag 12–20%, Cu 37.46%</td>
<td>jewelry</td>
</tr>
<tr>
<td>Lead shot</td>
<td>Pb 99.8%, As 0.2%</td>
<td>shotgun shells</td>
</tr>
<tr>
<td>Pewter</td>
<td>Sn 70–95%, Sb 5–15%, Pb 0–15%</td>
<td>tableware</td>
</tr>
<tr>
<td>Stainless steel</td>
<td>Fe 73–79%, Cr 14–18%, Ni 7–9%</td>
<td>instruments, sinks</td>
</tr>
<tr>
<td>Sterling silver</td>
<td>Ag 92.5%, Cu 7.5%</td>
<td>tableware, jewelry</td>
</tr>
</tbody>
</table>
Table 7.1  Electron-Dot Structure

Table 7.4  Formation of Sodium Chloride
Click any of the background top tabs to display the respective folder.

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Simple navigation buttons will allow you to progress to the next slide or the previous slide.

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The “Return” button will allow you to return to the slide that you were viewing when you clicked either the Resources or Help tab.

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