Chapter 7: Ionic and Metallic Bonding

7.1 Ions

Valence Electrons

- **Valence electrons** are the electrons in the highest occupied energy level of an element's atoms.
- The number of valence electrons largely determines the chemical properties of an element.

Valence Electrons

- To find the number of valence electrons in an atom of a representative element, simply look at its group number.

Valence Electrons

- **Electron dot structures** are diagrams that show valence electrons as dots.

Table 7.1

Electron Dot Structures of Some Group A Elements

Period	Group 1A	2A	3A	4A	5A	6A	7A	8A
1	H·							He:
2	Li·	·Be·	·B·	·C·	·N·	:O·	:F·	:Ne:
3	Na·	·Mg·	·Al·	·Si·	·P·	:S·	:Cl·	:Ar:
4	K·	·Ca·	·Ga·	·Ge·	·As·	:Se·	:Br·	:Kr:

The Octet Rule

- Noble gases, such as neon and argon, are unreactive in chemical reactions. In 1916, chemist Gilbert Lewis used this fact to explain why atoms form certain kinds of ions and molecules.
- He called his explanation the **octet rule:** In forming compounds, atoms tend to achieve the electron configuration of a noble gas.

The Octet Rule

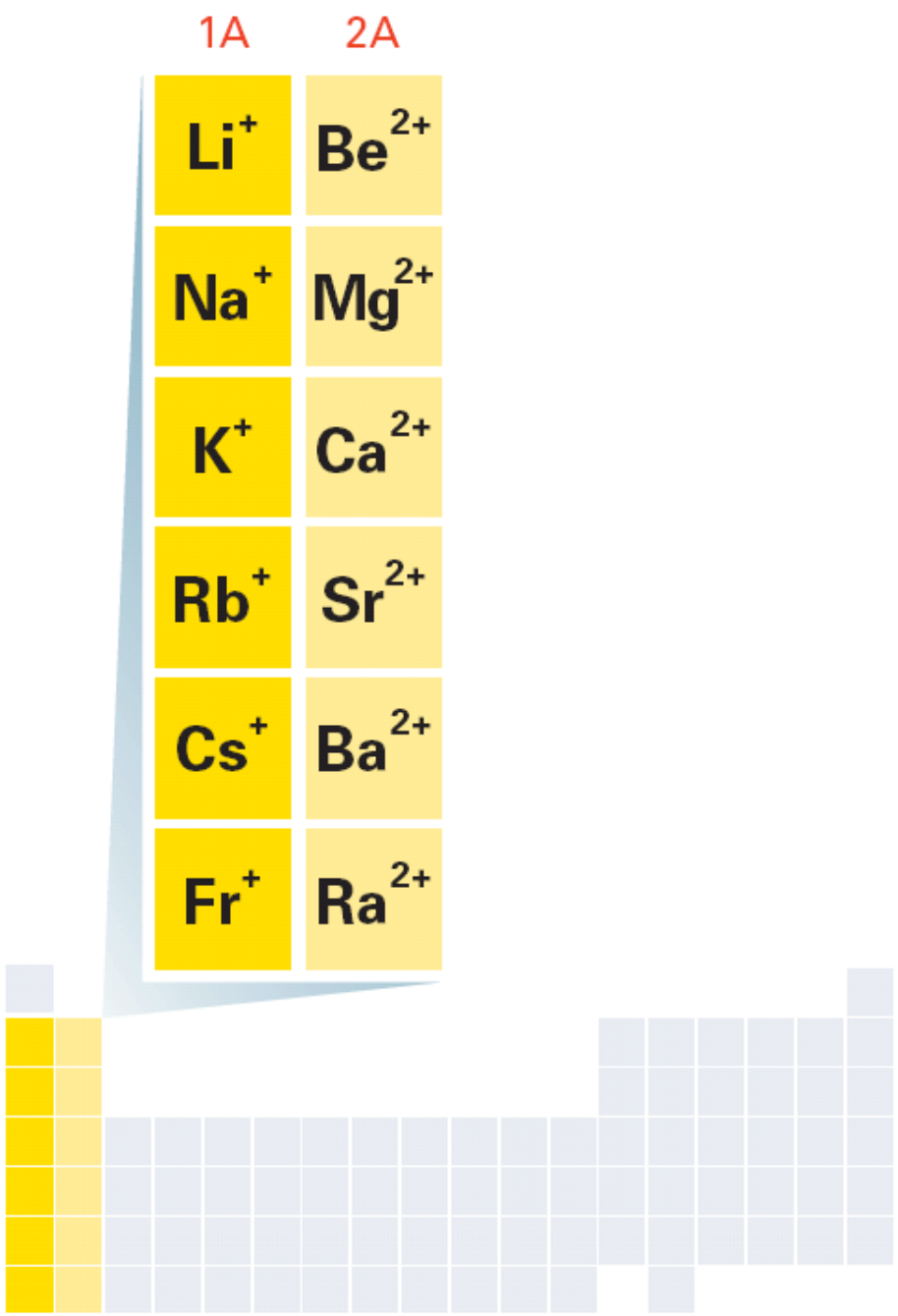
- Atoms of metals tend to lose their valence electrons, leaving a complete octet in the next-lowest energy level. Atoms of some non-metals tend to gain electrons or to share electrons with another nonmetal to achieve a complete octet.

Formation of Cations

- An atom's loss of valence electrons produces a cation, or a positively charged ion.

7.1 Formation of Cations

- Cations of Group 1A elements always have a charge of 1+.
- Cations of group 2A elements always have a charge of 2+.

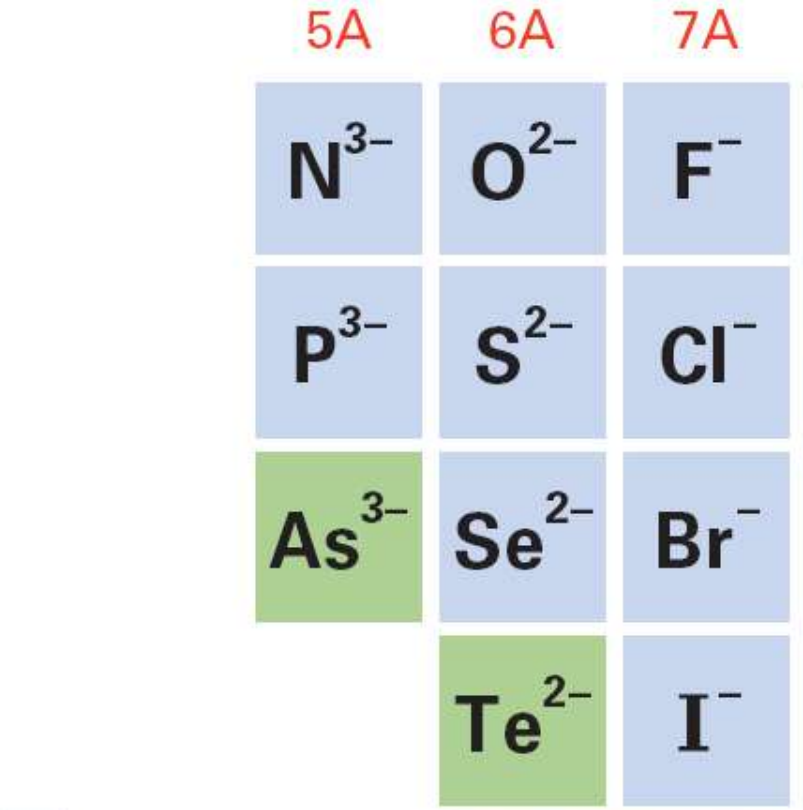


Formation of Anions

- **The gain of negatively charged electrons by a neutral atom produces an anion.**
  - An anion is an atom or a group of atoms with a negative charge.
  - The name of an anion typically ends in -*ide*.

Formation of Anions

- The figure shows the symbols of anions formed by some elements in Groups 5A, 6A, and 7A.



Formation of Anions

- The ions that are produced when atoms of chlorine and other halogens gain electrons are called **halide ions**.
  - All halogen atoms have seven valence electrons.
  - All halogen atoms need to gain only one electron to achieve the electron configuration of a noble gas.

Conceptual Problem 7.1

Writing the Symbols and Names of Ions

The beaker shown on the right contains iodine vapor. Write the symbol and name of the ion formed when

a. an iodine atom gains one electron.

b. a strontium atom loses two electrons.

Practice Problems For Conceptual Problem 7.1

1. Write the name and symbol of the ion formed when
   a. a sulfur atom gains two electrons.
   b. an aluminum atom loses three electrons.

7.1 Section Quiz.

- 1. How many valence electrons are there in an atom of oxygen?

  a) 2

  b) 4

  c) 6

  d) 8

7.1 Section Quiz.

- 2. Atoms that tend to gain a noble gas configuration by losing valence electrons are

  a) metals.

  b) nonmetals.

  c) noble gases.

  d) representative elements.

7.1 Section Quiz.

- 3. When a magnesium atom forms a cation, it does so by

  a) losing two electrons.

  b) gaining two electrons.

  c) losing one electron.

  d) gaining one electron.

7.1 Section Quiz.

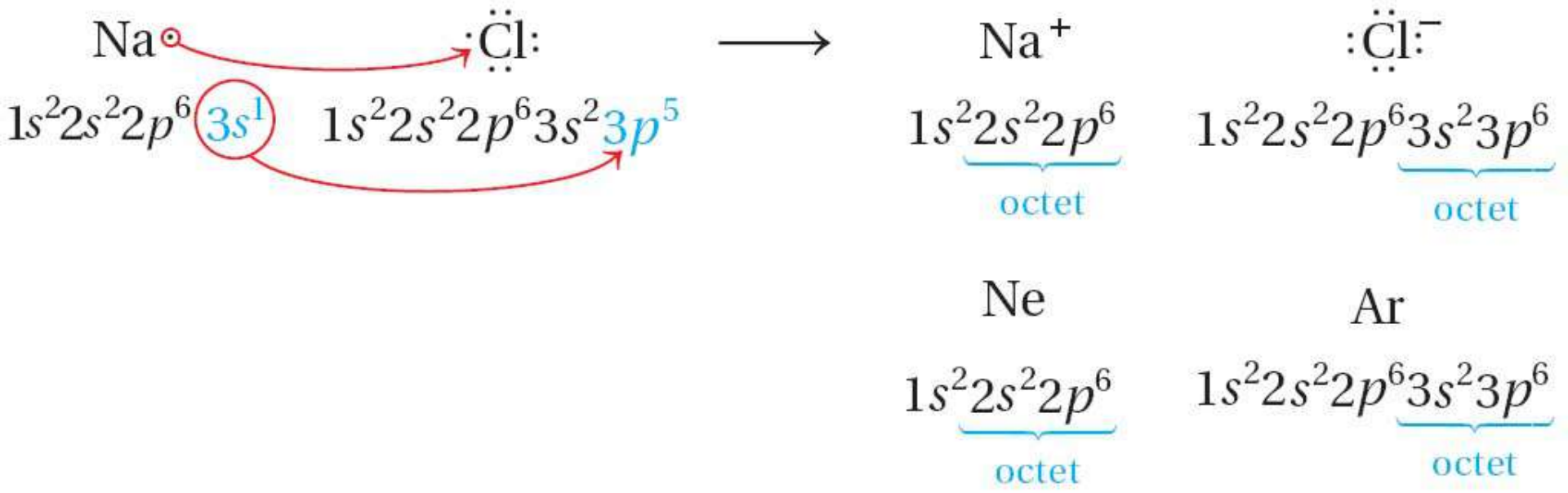
- 4. When a bromine atom forms an anion, it does so by
  - a) losing two electrons.
  - b) gaining two electrons.
  - c) losing one electron.
  - d) gaining one electron

7.2 Ionic Bonds and Ionic Compounds

Formation of Ionic Compounds

- Compounds composed of cations and anions are called **ionic compounds.**
  - Although they are composed of ions, ionic compounds are electrically neutral.

- Ionic Bonds
  - The electrostatic forces that hold ions together in ionic compounds are called **ionic bonds.**



Formation of Ionic Compounds

- Formula Units
  - A **chemical formula** shows the kinds and numbers of atoms in the smallest representative unit of a substance.
  - A **formula unit** is the lowest whole-number ratio of ions in an ionic compound.

Conceptual Problem 7.2

Predicting Formulas of Ionic Compounds

The ionic compound formed from potassium and oxygen is used in ceramic glazes. Use electron dot structures to predict the formulas of the ionic compounds formed from the following elements.

a. potassium and oxygen

b. magnesium and nitrogen

for Conceptual Problem 7.2

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

a. potassium reacts with iodine.

b. aluminum reacts with oxygen.

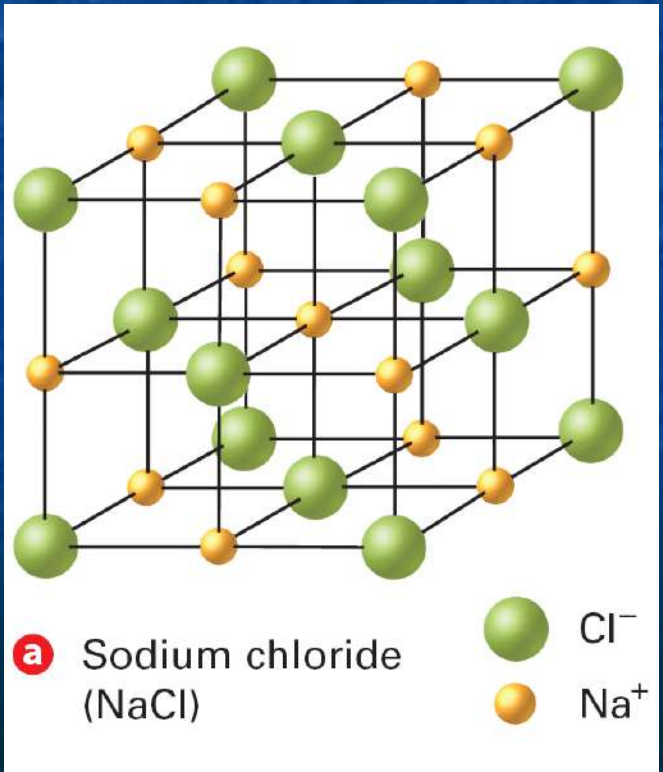
Properties of Ionic Compounds

- Most ionic compounds are crystalline solids at room temperature.

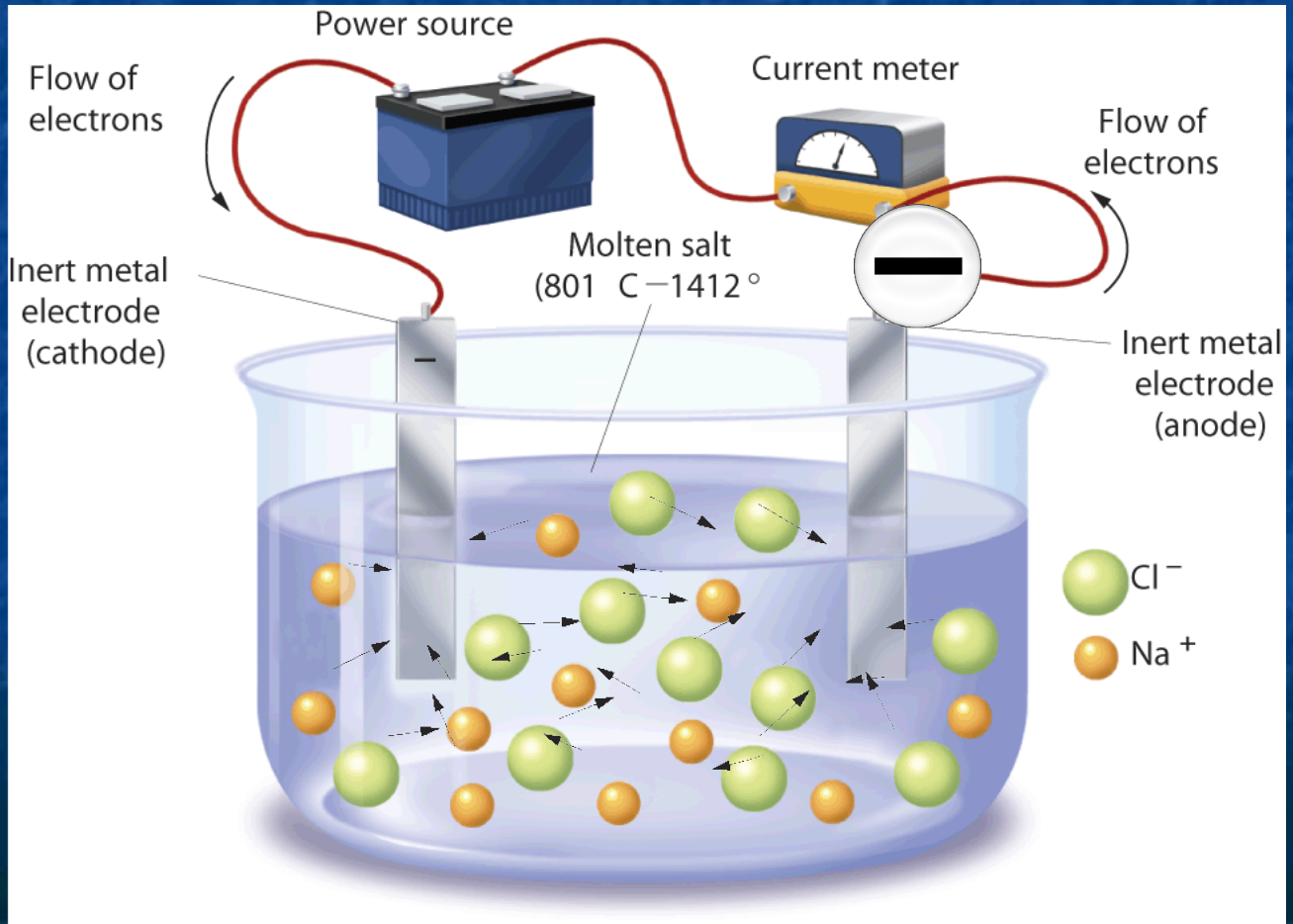
- Ionic compounds generally have high melting points.

Properties of Ionic Compounds

- The **coordination number** of an ion is the number of ions of opposite charge that surround the ion in a crystal.
- In NaCl, each ion has a coordination number of 6.



- Ionic compounds can conduct an electric current when melted or dissolved in water.



Lattice Energy

- Lattice Energy – energy released when one mole of an ionic crystalline compound is formed from gaseous ions
  - Used to compare bond strengths in ionic compounds
  - Directly related to the size of the ions bonded
  - Ions with larger positive or negative charges have greater lattice energy

Lattice Energy

- The melting points for the compounds Li_2S, Rb_2S, and K_2S are 900°C, 530°C, and 840°C, respectively. List these three compounds in order of increasing lattice energy.

7.2 Section Quiz.

- 1. Which chemical formula is incorrect?

  a)KF_2

  b)CaS

  c)MgO

  d)NaBr

7.2 Section Quiz.

- 2. Ionic compounds can conduct an electric current

  a)only when melted.

  b)when melted or dissolved in water.

  c)only when dissolved in water.

  d)when solid or melted.

7.2 Section Quiz.

- 3. At room temperature, most ionic compounds are
  - a)crystalline solids.
  - b)liquids.
  - c)gases.
  - d)soft, low melting-point solids.

9.1 Naming Ions

Monatomic Ions

- **Monatomic ions** consist of a single atom with a positive or negative charge resulting from the loss or gain of one or more valence electrons, respectively.

Monatomic Ions

- Cations

  - When the metals in Groups 1A, 2A, and 3A lose electrons, they form cations with positive charges equal to their group number.

Monatomic Ions

- The names of the cations of the Group 1A, Group 2A, and Group 3A metals are the same as the name of the metal, followed by the word *ion* or *cation*.

Monatomic Ions

- Anions

  - The charge of any ion of a Group A nonmetal is determined by subtracting 8 from the group number.
  - **Anion names start with the stem of the element name and end in *-ide*.**

Monatomic Ions

- The charges of the cations of many transition metal ions must be determined from the number of electrons lost.

Monatomic Ions

- In the Stock system, a Roman numeral in parentheses is placed after the name of the element to indicate the numerical value of the charge.

Conceptual Problem 9.1

Classifying and Naming Cations and Anions

Write the symbol for the ion formed by each element. Classify the ions as cations or anions and name the ion. Potassium and iodine combine to form potassium iodide, an additive to table salt that protects the thyroid gland.

a. potassium **b.** iodine **c.** sulfur **d.** lead, 4 electrons lost

Practice Problems For Conceptual Problem 9.1

1. Name the ions formed by these elements and classify them as anions or cations.

a. selenium **b.** barium **c.** phosphorus

Polyatomic Ions

- Some ions, called **polyatomic ions**, are composed of more than one atom.
  - The names of most polyatomic anions end in -*ite* or -*ate*.

Polyatomic Ions

- Names and Formulas of Some Common Polyatomic Ions

Table 9.3

Common Polyatomic Ions

Formula	Name
Charge = 1–	
$H_2PO_4^-$	Dihydrogen phosphate
$C_2H_3O_2^-$	Acetate
HSO_3^-	Hydrogen sulfite
HSO_4^-	Hydrogen sulfate
HCO_3^-	Hydrogen carbonate
NO_2^-	Nitrite
NO_3^-	Nitrate
CN^-	Cyanide
OH^-	Hydroxide
MnO_4^-	Permanganate
ClO^-	Hypochlorite
ClO_2^-	Chlorite
ClO_3^-	Chlorate
ClO_4^-	Perchlorate
Charge = 2–	
HPO_4^{2-}	Hydrogen phosphate
$C_2O_4^{2-}$	Oxalate
SO_3^{2-}	Sulfite
SO_4^{2-}	Sulfate
CO_3^{2-}	Carbonate
CrO_4^{2-}	Chromate
$Cr_2O_7^{2-}$	Dichromate
SiO_3^{2-}	Silicate
Charge = 3–	
PO_3^{3-}	Phosphite
PO_4^{3-}	Phosphate
Charge = 1+	
NH_4^+	Ammonium

9.1 Section Quiz.

- 1.When metals from groups 1A, 2A, and 3A form cations, the charge on the ion is equal to

  a)8 minus the group number.

  b)the group number minus 8.

  c)the period number.

  d)the group number.

- 2.Which of the following are positively charged polyatomic ions?
  - (I) ammonium ion
  - (II) perchlorate ion
  - (III) ferric ion

a)I only

b)II only

c)III only

d)I and III

9.1 Section Quiz

- 3.If the name of an ion ends in *-ite* or *-ate*, the ion is a
  - a)polyatomic cation.
  - b)polyatomic anion.
  - c)transition metal cation.
  - d)monatomic anion.

9.2 Naming and Writing Formulas for Ionic Compounds

Binary Ionic Compounds

- Naming Binary Ionic Compounds
  - A **binary compound** is composed of two elements and can be either ionic or molecular.
    - To name any binary ionic compound, place the cation name first, followed by the anion name.

Naming Binary Ionic

1) CsF
2) $AlCl_3$
3) MgI_2
4) Rb_2O
5) SrI_2
6) K_2S
7) KCl
8) ZnS
9) $CaBr_2$
10) Al_2S_3

Naming Binary Ionic with Transition Metals

1) $CuCl$
2) HgO
3) Fe_2O_3
4) MnO_2
5) $PbCl_4$
6) $CoCl_3$
7) CuI
8) $SnBr_4$
9) $HgCl_2$
10) PbS

Mixed Naming Binary Ionic

1) $CoBr_2$
2) $CaCl_2$
3) Al_2O_3
4) $CrCl_3$
5) SnI_4
6) K_3N
7) RbF
8) NaH
9) CrF_2
10) $MgBr_2$

Binary Ionic Compounds

- Writing Formulas for Binary Ionic Compounds
  - Write the symbol of the cation and then the anion. Add whatever subscripts are needed to balance the charges.

Writing Formulas for Binary Ionic Compounds

9.2

Write formulas for these binary ionic compounds.

a. copper(II) sulfide, shown in the photo

b. potassium nitride

Sample Problems For Conceptual Problem 9.2

11. Write formulas for these compounds.

a. sodium iodide

b. stannous chloride

c. potassium sulfide

d. calcium iodide

Write Formulas for:

- 1) calcium chloride
- 2) lead (IV) oxide
- 3) aluminum oxide
- 4) magnesium bromide
- 5) cesium fluoride

Write formulas for

- Iron (II) oxide
- Iron (III) oxide
- Potassium bromide
- Aluminum sulfide
- Lithium oxide

Compounds With Polyatomic Ions

- Write the symbol for the cation followed by the formula for the polyatomic ion and balance the charges.

Conceptual Problem 9.3

Writing Formulas for Compounds with Polyatomic Ions

What are the formulas for these ionic compounds?

a. magnesium hydroxide, shown in the photo as milk of magnesia

b. potassium sulfate

Practice Problems For Conceptual Problem 9.3

12. Write formulas for compounds formed from these pairs of ions.

a. NH_4^+, SO_3^{2-}

b. calcium ion, phosphate ion

Write formulas for:

- 1) lithium perchlorate
- 2) potassium acetate
- 3) cesium sulfite
- 4) cobalt (III) hydroxide
- 5) sodium hypochlorite

Write formulas for:

- 1) ammonium nitrite
- 2) sodium perchlorate
- 3) barium acetate
- 4) aluminum hydroxide
- 5) calcium nitrate

Compounds With Polyatomic Ions

- Naming Compounds with Polyatomic Ions

  - To name a compound containing a polyatomic ion, state the cation first and then the anion, just as you did in naming binary ionic compounds.

Naming Polyatomics

- 1) Na_2SO_4
- 2) KH_2PO_4
- 3) $Fe(NO_3)_3$
- 4) $Mn(OH)_2$
- 5) Na_2SO_3
- 6) $Ca(OH)_2$
- 7) Na_3PO_4
- 8) $KMnO_4$
- 9) $(NH_4)_2Cr_2O_7$
- 10) $Co(ClO_4)_2$

Naming Polyatomics

- 1) $KClO_3$
- 2) $Cu(NO_2)_2$
- 3) $Cu(NO_3)_2$
- 4) $PbCO_3$
- 5) $KHSO_4$
- 6) NH_4I
- 7) $NaCN$
- 8) Na_2CO_3
- 9) $CuSO_4$
- 10) $CsClO_4$

9.2 Section Quiz

- 1.The correct name for $CrCl_3$ is
  a) chromium chlorine.
  b) chromium(III) chloride.
  c) monochromium trichloride.
  d) chromium(III) trichloride.

9.2 Section Quiz

- 2.What is the correct formula for strontium nitride?
  - a) Sr_3N_2
  - b) SrN_2
  - c) Sr_2N_3
  - d) Sr_3N

9.2 Section Quiz

- 3.Which one of the following compounds is named correctly?

  a) sodium chlorite, NaClO

  b) potassium nitrate, KNO_2

  c) sodium acetate, $NaC_2H_3O_2$

  d) lithium sulfate, Li_2SO_3

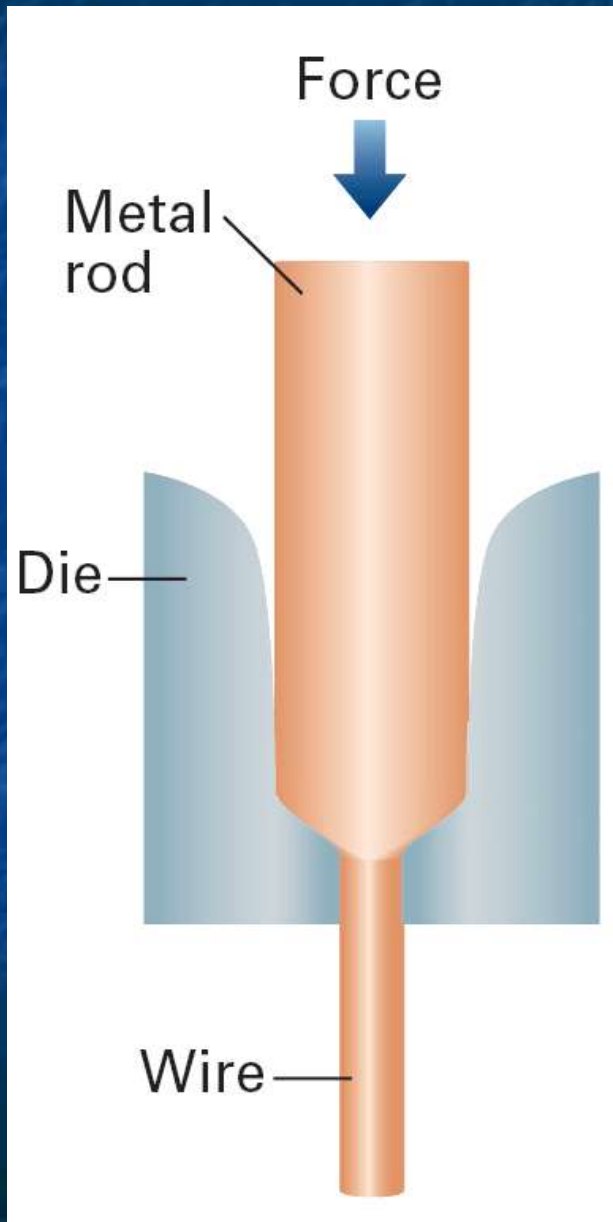
7.3 Bonding in Metals

7.3 Metallic Bonds and Metallic Properties

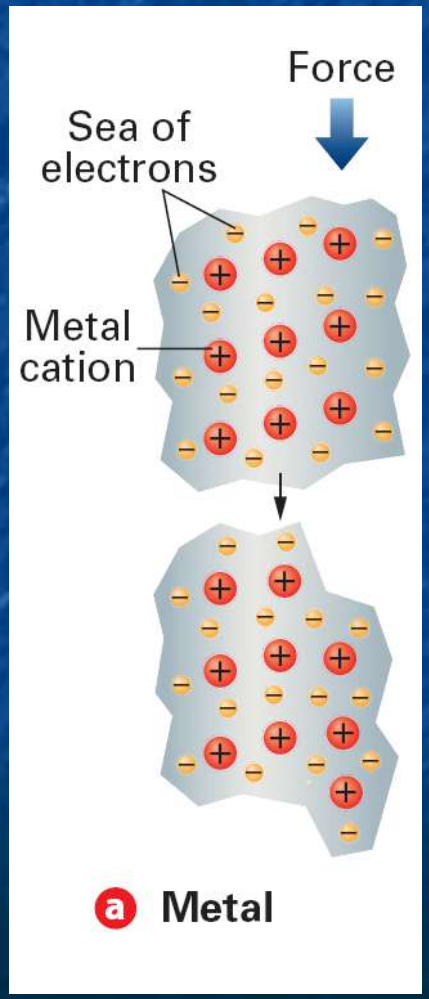
- The valence electrons of metal atoms can be modeled as a sea of electrons.
- The valence electrons are mobile and can drift freely from one part of the metal to another.
- Metallic bonds consist of the attraction of the free-floating valence electrons for the positively charged metal ions.

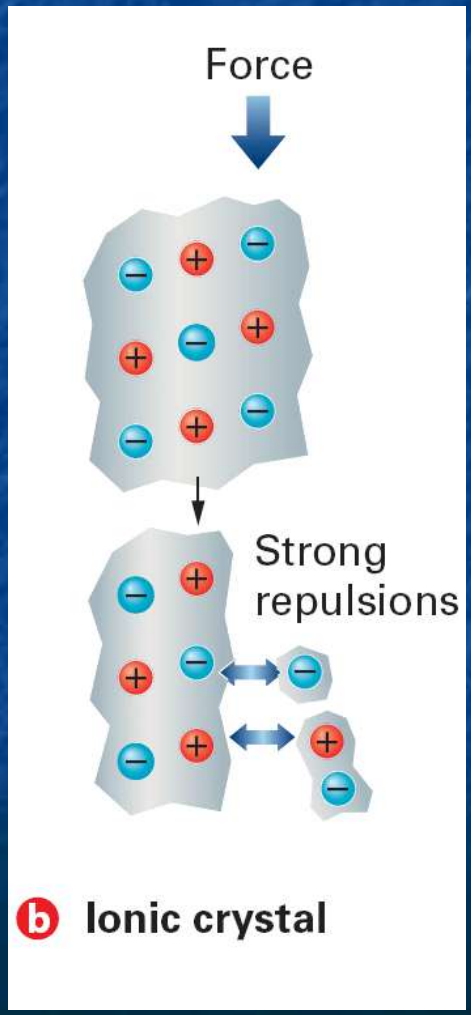
Metallic Bonds and Metallic Properties

- Metals are ductile—that is, they can be drawn into wires.



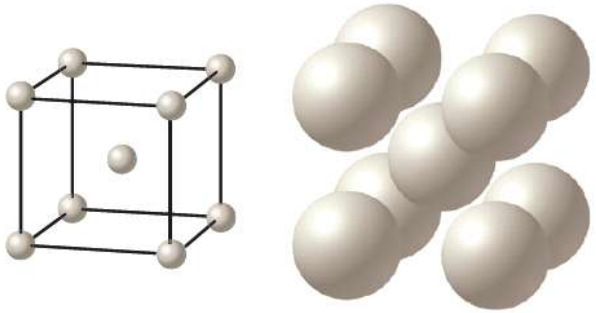
- A force can change the shape of a metal. A force can shatter an ionic crystal.





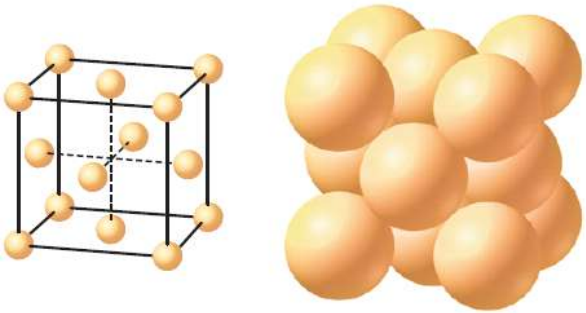
- **Metal atoms are arranged in very compact and orderly patterns.**

Chromium



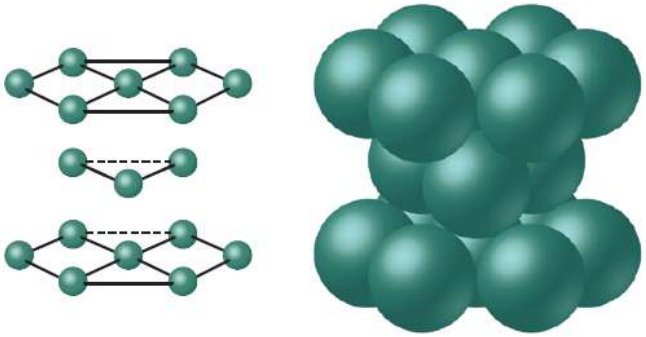
Body-centered cubic

Gold



Face-centered cubic

Zinc



Hexagonal close-packed

Alloys

- **Alloys** are mixtures composed of two or more elements, at least one of which is a metal.
  - Alloys are important because their properties are often superior to those of their component elements.

Alloys

- The most important alloys today are steels. Steels have a wide range of useful properties, such as corrosion resistance, ductility, hardness, and toughness.

Table 7.3
Composition of Some Common Alloys

Name	Composition (by mass)
Sterling silver	Ag 92.5% Cu 7.5%
Cast iron	Fe 96% C 4%
Stainless steel	Fe 80.6% Cr 18.0% C 0.4% Ni 1.0%
Spring steel	Fe 98.6% Cr 1.0% C 0.4%
Surgical steel	Fe 67% Cr 18% Ni 12% Mo 3%

7.3 Section Quiz.

- 1.The valence electrons of metals can be modeled as
  - a)a body-centered cube.
  - b)octets of electrons.
  - c)a rigid array of electrons.
  - d)a sea of electrons.

7.3 Section Quiz.

- 2. In most metals, the atoms are

  a) free to move from one part of the metal to another.

  b) arranged in a compact and orderly pattern.

  c) placed at irregular locations.

  d) randomly distributed.

7.3 Section Quiz.

- 3. Alloys are important because they

  a) are pure substances.

  b) are the ores from which metals can be refined.

  c) can have properties superior to those of their components.

  d) are produced by the combustion of metals.