Ionic and Metallic Bonding

Chapter 7

Ions

Sec 7.1

Connecting to Your World

Pyrite (FeS_2), a common mineral that emits sparks when struck against steel, is often mistaken for gold—hence its nickname, "fool's gold." Although certainly not worth its weight in gold, pyrite can be used as a source of sulfur in the production of sulfuric acid, a common industrial chemical. Pyrite is an example of a crystalline solid. In crystalline solids, the component particles of the substance are arranged in an orderly, repeating fashion. In this chapter, you will learn about crystalline solids composed of ions that are bonded together. But first you need to understand how ions form from neutral atoms.

What are some characteristics you have observed in "fool's gold?"

What are crystals?

Valence Electrons

- e- in the highest occupied (outermost) E level.
- Largely determines the chemical properties of elements.
- For representative (Group A) elements this is the same as the group number.
- Usually the only e- used in chemical bonding.
- Can be represented with e- dot (Lewis) structures.

The Octet Rule

- In forming compounds, atoms tend to achieve the e- configuration of a noble gas by gaining or losing electrons.
- Metals tend to lose their valence e-, leaving a complete octet in the next lowest energy level.
- Nonmetals tend to gain e- from metals, or share e- with another nonmetal to achieve a complete octet.

Formation of Ions

- Cations (positive ions)
  - Generally metals
  - Loss of e-
  - Achieve octet of next lowest noble gas
  - Name of ion same as atom
  - Transition metals can form ions of different charges
- Anions (negative ions)
  - Generally nonmetals
  - Gain of electrons
  - Achieve octet of next highest noble gas
  - Name of ion ends in “-ide”

Ionic Bonds and Ionic Compounds

Sec 7.2

Connecting to Your World

You have heard of harvesting crops such as wheat or rice—but salt? In many coastal countries that have warm, relatively dry climates, salt is produced by the evaporation of seawater. The salty water is channeled into a series of shallow ponds, where it becomes more concentrated as the water evaporates by exposure to the sun. When the saltwater is concentrated enough, it is diverted into a pan, on which the sodium chloride crystals deposit. Salt farmers then drain the pans and collect the salt into piles to dry. In this section, you will learn how cations and anions combine to form stable compounds such as sodium chloride.

What are some properties of sodium? Of chlorine? Of sodium chloride?

What characteristics of sodium and chlorine allow them to form the stable compound sodium chloride?

Formation of Ionic Compounds

- Ionic compounds are formed from the electrostatic attraction of oppositely charged ions.
- Exist in a crystal lattice.
- Cation + Anion = Ionic Compound
- Ionic compounds are NEUTRAL.
  – Total Positive charge of cation = total negative charge of anions
- Ions must combine in a ratio that produces an electrically neutral compound.

Formation of Ionic Compounds (cont)

- Chemical formulas are used to represent compounds. Ionic compounds represent:

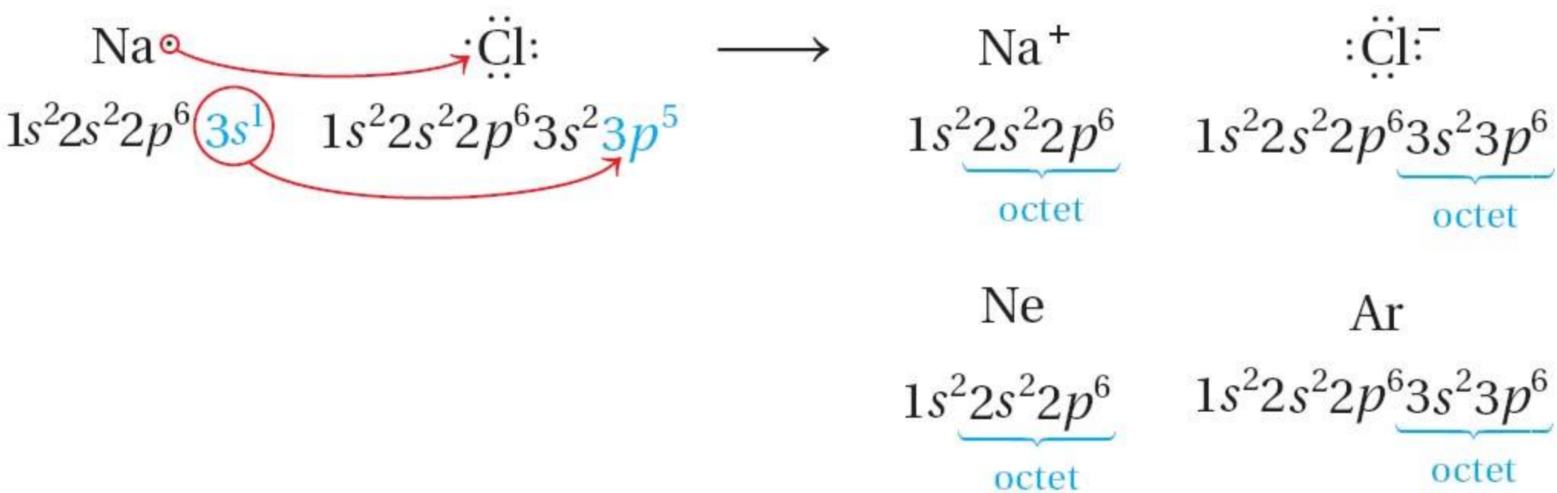
  -smallest, whole # ratio of cations to anions

  -the composition of the formula unit.

Ionic Bonds

When sodium and chlorine react to form a compound, the sodium atom transfers its one valence electron to the chlorine atom.

- Sodium and chlorine atoms combine in a one-to-one ratio, and both ions have stable octets.



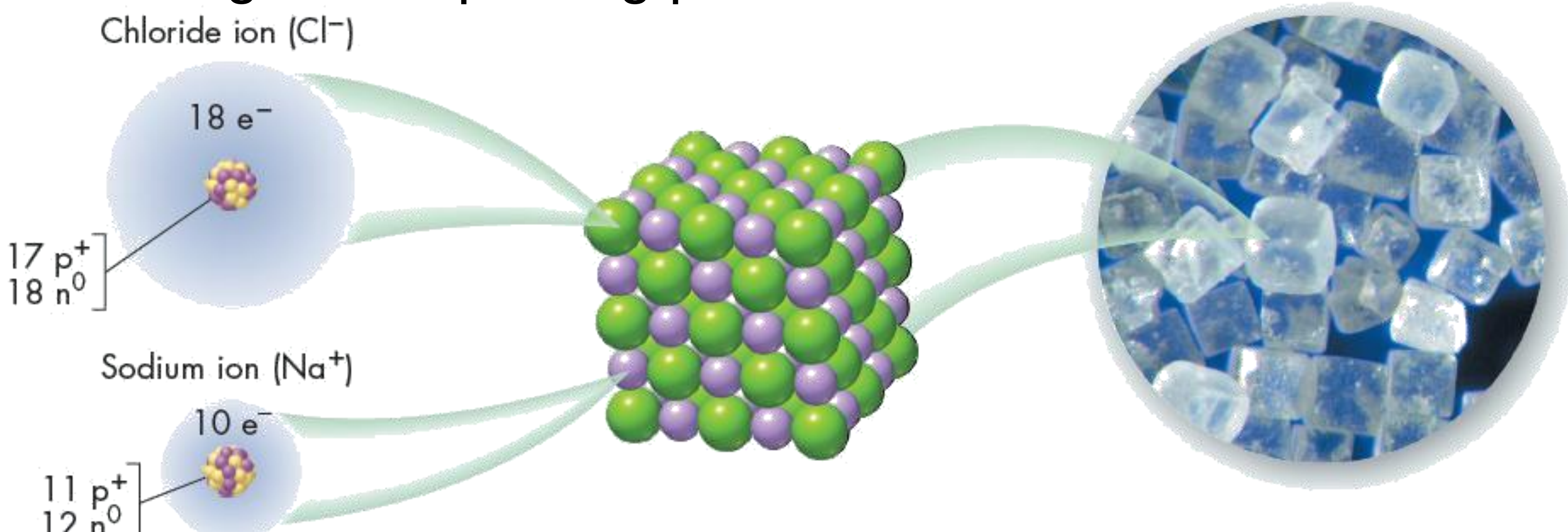
Ionic Bonds

Aluminum metal (Al) and the nonmetal bromine (Br_2) react violently to form the ionic solid aluminum bromide ($AlBr_3$).

- Each bromine atom has seven valence electrons and readily gains one additional electron.
- Three bromine atoms combine with each aluminum atom.

Formula Units

Ionic compounds do not exist as discrete units, but as collections of positively and negatively charged ions arranged in repeating patterns.



Structures of sodium ion and chloride ion

Arrangement of Na^+ ions and Cl^- ions in a crystal of sodium chloride

Crystals of sodium chloride

Formula Units

The chemical formula of an ionic compound refers to a ratio known as a formula unit.

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

Predicting Formulas of Ionic Compounds

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

1 Analyze Identify the relevant concepts.

- Atoms of metals lose valence electrons when forming an ionic compound.
- Atoms of nonmetals gain electrons.
- Enough atoms of each element must be used in the formula so that electrons lost equal electrons gained.

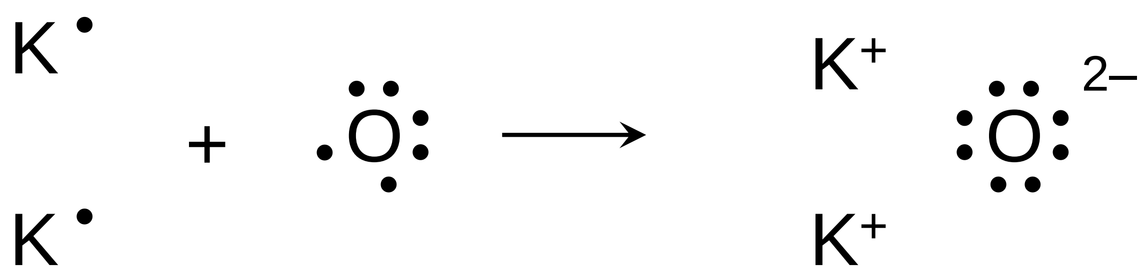
2 Solve **Apply the concepts to this problem.**

a. Start with the atoms.

K• and •Ö:

2 Solve Apply the concepts to this problem.

a. In order to have a completely filled valence shell, the oxygen atom must gain two electrons. These electrons come from two potassium atoms, each of which loses one electron.



2 Solve Apply the concepts to this problem.

a. Express the electron dot structure as a formula.

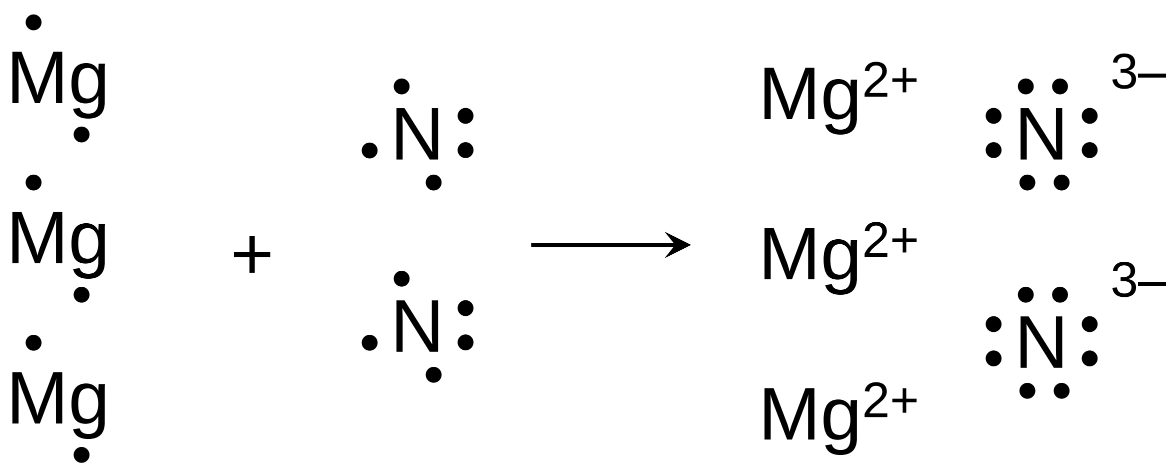
- The formula of the compound formed is K_2O (potassium oxide).

2 Solve **Apply the concepts to this problem.**

b. Start with the atoms.

2 Solve **Apply the concepts to this problem.**

b. Each nitrogen atom needs three electrons to have an octet, but each magnesium atom can lose only two electrons. Three magnesium atoms are needed for every two nitrogen atoms.



2 Solve Apply the concepts to this problem.

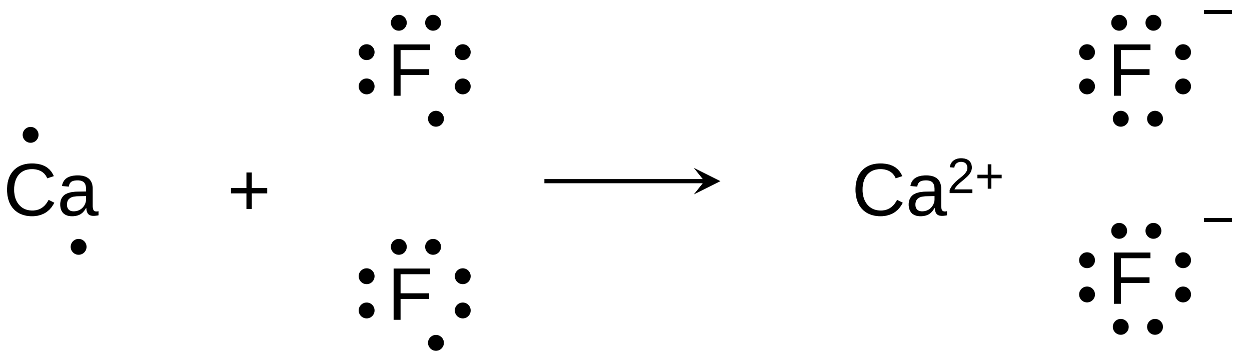
b. Express the electron dot structure as a formula.

- The formula of the compound formed is Mg_3N_2 (magnesium nitride).

Use electron dot structures to determine the formula of the ionic compound formed when calcium reacts with fluorine.

Checkpoint

Use electron dot structures to determine the formula of the ionic compound formed when calcium reacts with fluorine.



CaF_2

Group #	# of Valence Electrons	Gains/Loses to achieve octet	Charge that typically forms
1	1	Loses 1	+1
2	2	Loses 2	+2
13	3	Loses 3	+3
14	4	Loses 4/gains 4	+4 or -4
15	5	Gains 3	-3
16	6	Gains 2	-2
17	7	Gains 1	-1
18	8	N/A	0

Properties of Ionic Compounds

- Crystalline solids at room temp.
  - Ions arrange themselves in repeating 3-D pattern (crystal lattice)
- Generally have high melting points.
- Can conduct an electric current when they are melted or dissolved in water (electrolyte).
- Are hard but brittle due to arrangement in crystal lattice

Ionic vs. Molecular Compounds

Ionic	**Molecular**
• Ionic Bonds	• Covalent Bonds
• Solids	• Gases/Liquids
• Hard/Brittle	
• High Melting points	• Low Melting points
• Good conductors	• Bad conductors
• Dissolve in water	

Bonding in Metals

Sec 7.3

Connecting to Your World

You have probably seen decorative fences, railings, or weathervanes made of a metal called wrought iron. Wrought iron is a very pure form of iron that contains trace amounts of carbon. It is a tough, malleable, ductile, and corrosion-resistant material that melts at a very high temperature. As you already know, metals often have distinctive, useful properties. In this section, you will learn how metallic properties derive from the way that metal ions form bonds with one another.

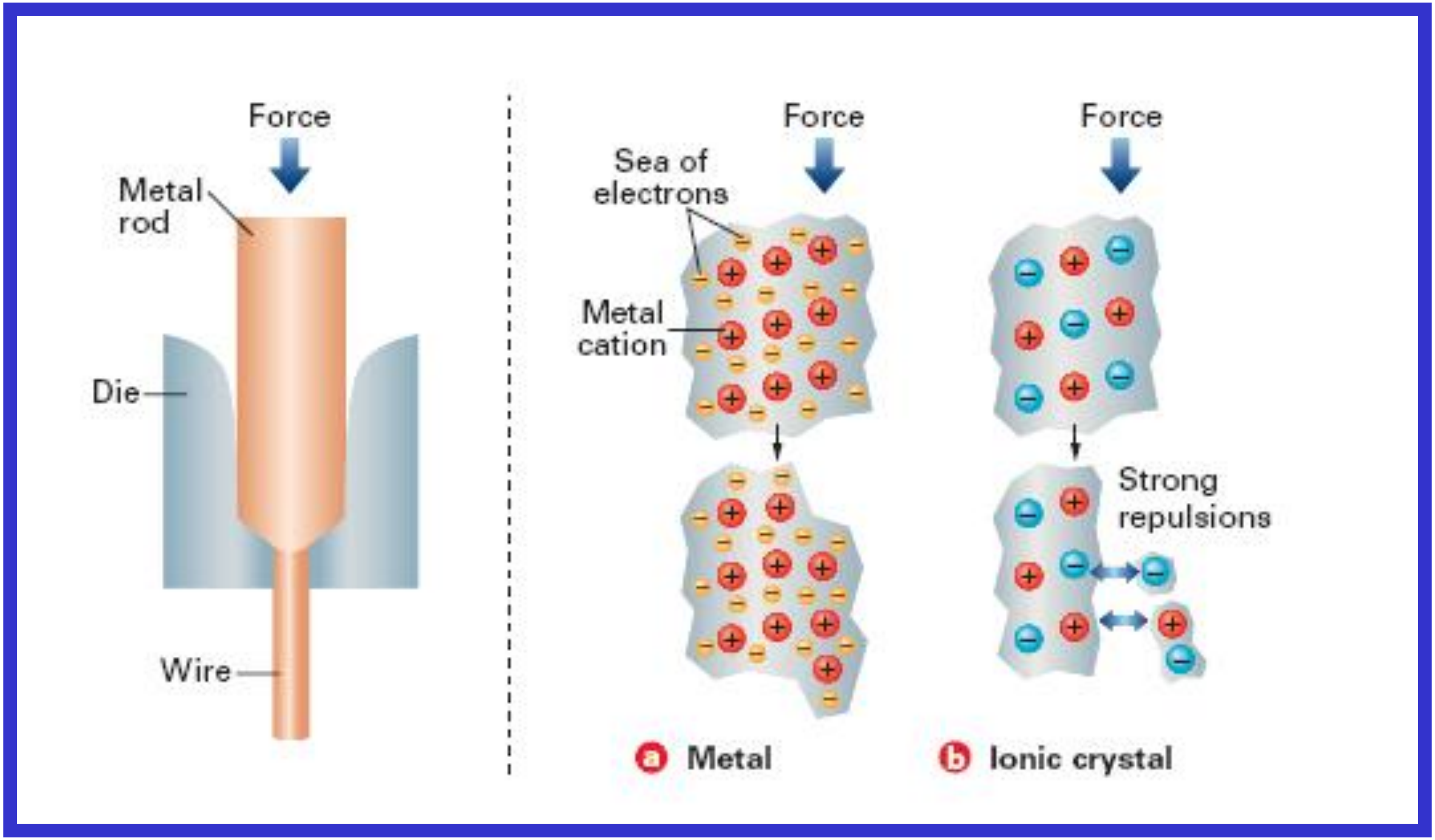
What property makes metals good electrical conductors?

Metallic Bonds

- NOT ionic but do form “lattice” – every metal atom surrounded by 8 to 12 other atoms
- The 1 or 2 valence e- of each atom are loosely held and move freely throughout the metal
- “Electron Sea Model” – valence e- are mobile and drift freely from one part of the metal to another
- A metallic bond is the attraction between the free-floating valence electrons and positively charged metal ions

Properties of Metals

- Physical properties related to strength of bond
- Moderately high melting points; very high boiling points
- Malleable & ductile
- Durable; cations not easily removed
- Good conductors; freely moving e-
- Luster; moving e- reflect light
- Hardness & strength increase with # of drifting valence e-



Why are metals malleable and ductile? Why do ionic compounds shatter when a force is applied to the crystal lattice?

Alloys

- A mixture of two or more elements, at least one of which is a metal.
- Alloys are primarily metallic.
- Alloys generally have properties superior to that of the pure metal (harder, more durable).
- Iron alloys are most important industrial alloy:
  - Resist rusting (corrosion)
  - Ductile
  - Hard
  - Durable
- Non-iron alloys used primarily for making coins.
- Examples of alloys:
- Brass- Cu + Zn
- Bronze- Sn + Cu
- Cast iron- Fe + C
- Sterling silver- Ag + Cu