Ionic Compounds & Metals

Chemistry Chapter 7

Objectives

- **Define** a chemical bond
- **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.
- **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
- **Describe** a metallic bond

Review

- **octet rule:** atoms tend to gain, lose, or share electrons in order to acquire eight valence electrons
- **compound:** a chemical combination of two or more different elements
- **nonmetal:** an element that is generally a gas or a dull, brittle solid and is a poor conductor of heat and electricity
- **physical property:** a characteristic of matter that can be observed or measured without altering the sample's composition

Chemical Bonding

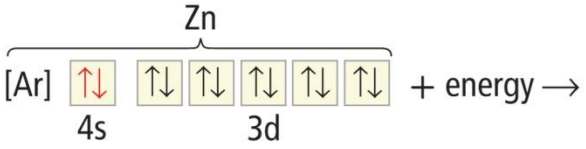
- A **chemical bond** is the force that holds two atoms together
- Chemical bonds form by the attraction between the positive nucleus of one atom and the negative electrons of another atom

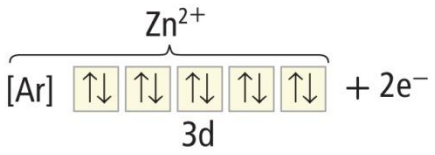
- **2 Types of chemical bonds**
  - **Ionic bond** – transfer of electron
  - **Covalent bond** – sharing of electrons

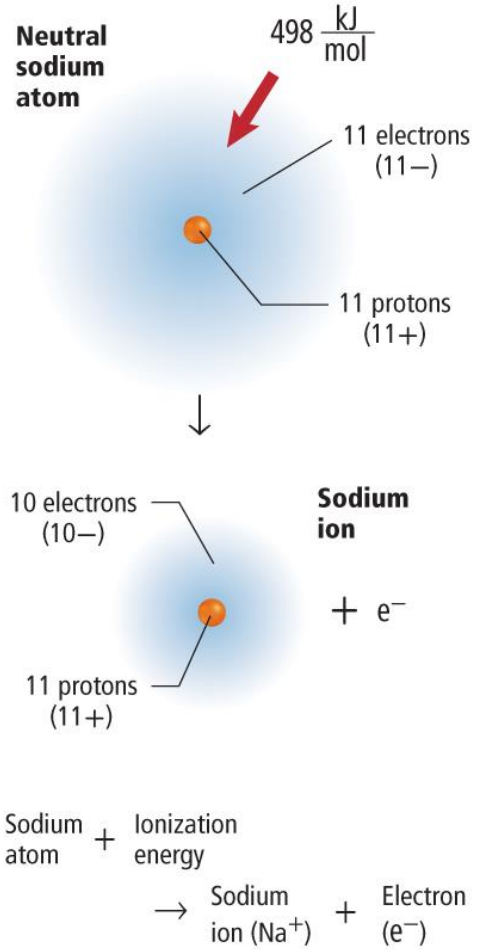
- **Octet rule** - Bonded atoms attain the stable electron configuration of a noble gas. 8 electrons in outer shell!!

Positive Ion Formation

- A positively charged ion is called a **Cation**
- Metals are reactive because they lose valence electrons easily
- Transition metals commonly form 2^+ or 3^+ ions, but can form greater than 3^+ ions
- Stable electron arrangements are referred to as **pseudo-noble gas configurations**.







Formation of an Ionic Bond

- An **anion** is a negatively charged ion.
  - **Nonmetal** ions **gain** the number of electrons

- The electrostatic force that holds oppositely charged particles 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**
    - Example: NaCl – yes NaOH – not binary

Different examples of ionic compound formation

Table 7.4 Formation of Sodium Chloride

Chemical Equation

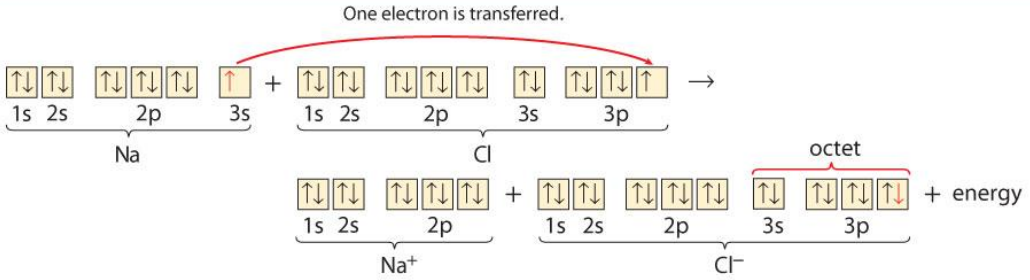
$$Na + Cl \rightarrow Na^+ + Cl^- + \text{energy}$$

Electron Configurations

One electron is transferred.

$$\underbrace{[Ne]3s^1}_{Na} + \underbrace{[Ne]3s^23p^5}_{Cl} \rightarrow \underbrace{[Ne]}_{Na^+} + \underbrace{[Ar]}_{Cl^-} + \text{energy}$$

Orbital Notation

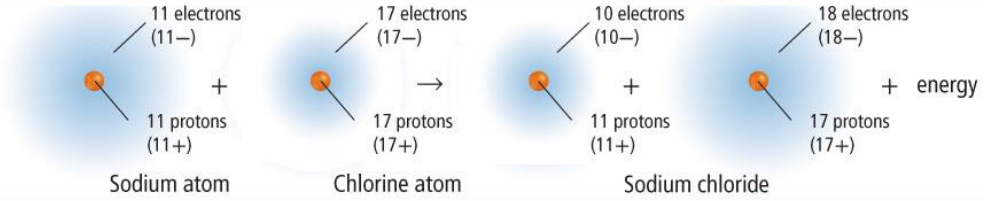


Electron-Dot Structures

One electron is transferred.

$$Na\odot + \cdot\ddot{Cl}: \rightarrow [Na]^+ + [:\ddot{Cl}:]^- + \text{energy}$$

Atomic Models

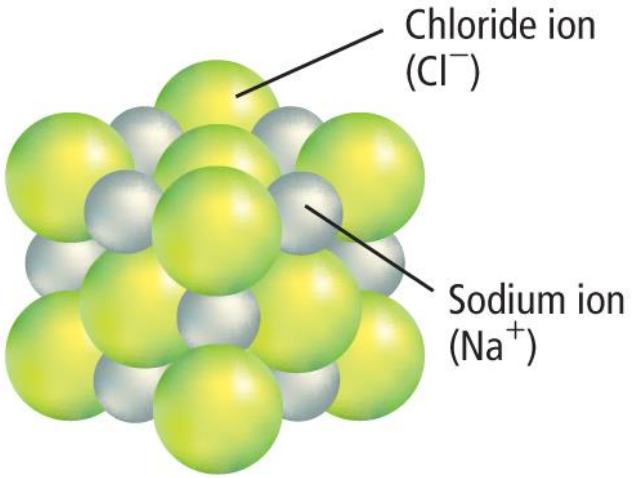


Properties of Ionic Compounds

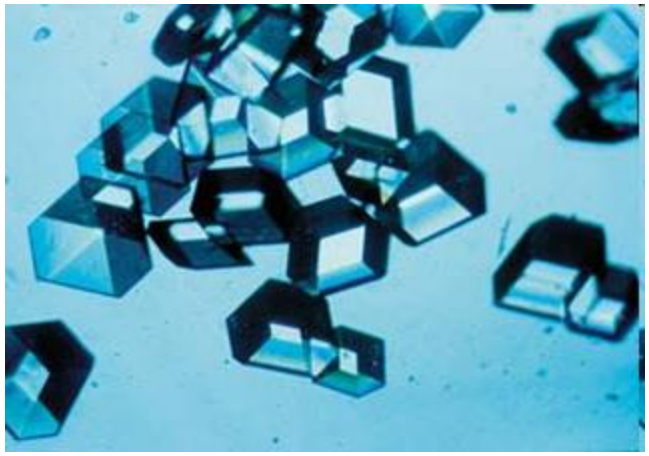
- The repeating pattern of particle packing in an ionic compound is called an **ionic crystal**

- The strong attractions among the positive and negative ions result in the formation of the **crystal lattice**

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



Sodium chloride crystal



Common Ionic compound properties

1. Solid Crystals at Room Temperature
2. High melting & Boling points
3. Brittle
4. Conduct electricity (liquid or dissolved)

Properties of Ionic Compounds

- Melting point, boiling point, and hardness depends on the strength of the attraction
  - Read more in Section 7.2 about these properties

- In a solid, ions are locked into position and electrons cannot flow freely—solid ions are poor conductors of electricity

- Liquid ions or ions in **aqueous solution** have electrons that are free to move, so they conduct electricity easily

- An ion in aqueous solution that conducts electricity is an **electrolyte**

Ionic Compounds

- **Chemical Formulas** - Tells 2 things
  1. Elements make up a Compound
  2. Ratios of the atoms in Compound

Na_2O

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

- A **Formula unit** represents the simplest ratio of the ions involved

- **Monatomic ions** are one-atom ions

Na^{+1} O^{-2}

- **Oxidation numbers:** + or – number assigned to elements to show combining ability (charge) of a monatomic ion

Calcium Chloride

Rules for writing Ionic Compounds

Rule 1 Write the chemical symbols
Rule 2 Write the metallic (cation) element 1st followed by anion

Ca Cl

Rule 3 Find and write the ion charge above the symbols

Ca^{+2} Cl^{-1}

Rule 4 The sum of the charges must equal zero!!

$Ca^{+2}\ Cl^{(-1)2} = 0$

Rule 5 Write the chemical formula using the ratio used to equal zero

$CaCl_2$

Notes:

- Don't write numbers if the ratio is one to one
- Don't write ones

Ionic Formula Examples

- Potassium Sulfide
  - K_2S
- Iron III Oxide
  - Fe_20_3
- Copper I Chloride
  - CuCl

Naming Ionic Compounds

CaO

- Write name of 1st element
  - check and see if a roman Numeral is necessary
  - Some elements have more than one oxidation number.
  - Use roman numerals
    - Iron III, Fe^{+3}
    - Iron II, Fe^{+2}

Calcium Oxygen

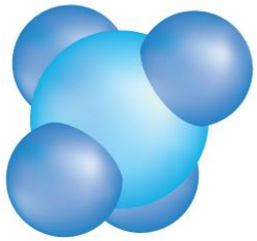
- Write root of 2nd element
  - Add "ide" to root

Calcium Oxide

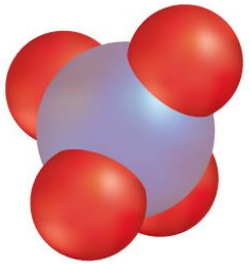
Naming Ionic Compounds Examples

- $BaCl_2$
  - Barium Chloride
- FeO
  - Iron II Oxide
- Cu_2O
  - Copper I Oxide
- SnO_2
  - Tin IV Oxide

Naming Ionic Compounds



Ammonium ion (NH_4^+)



Phosphate ion (PO_4^{3-})

- **Polyatomic ions** are ions made up of more than one atom
  - Listed on Pink sheet
  - Memorize, quiz!!
- Never change the subscripts of polyatomic ions
  - Don't change names – no "ide" ending
  - Write ( ) around polyatomic ions when using a subscript

Calcium Chlorate

Ca^{+2} ClO_3^-

$Ca(ClO_3)_2$ ~~$CaClO_{32}$~~

Polyatomic Ions

- An **oxyanion** is a polyatomic ion composed of an element (usually a non-metal), bonded to one or more oxygen atoms
  - Learn table 7.10 & 7.11 in book

Table 7.10 Oxyanion Naming Conventions for Sulfur and Nitrogen

- 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*.

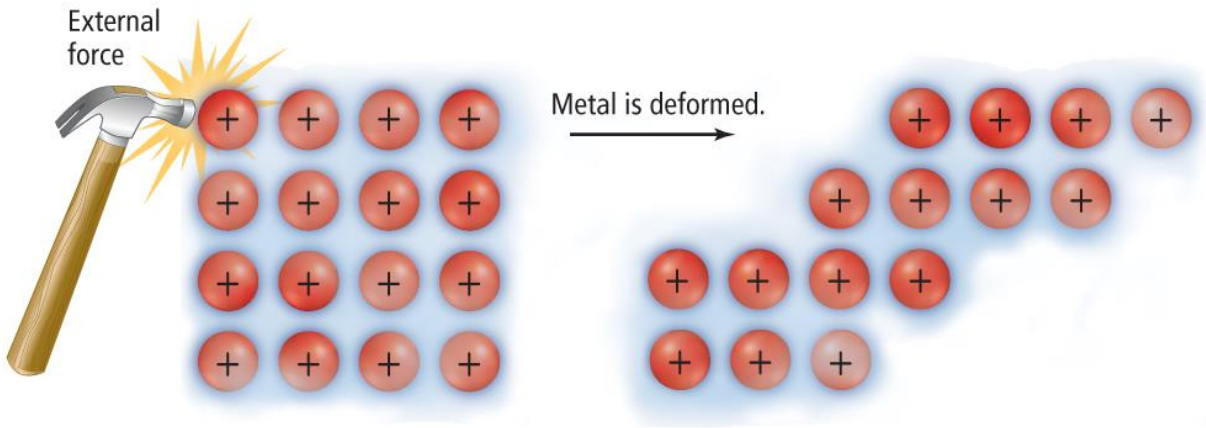
Examples:	NO_3^-	NO_2^-	SO_4^{2-}	SO_3^{2-}
	nitr*ate*	nitr*ite*	sulf*ate*	sulf*ite*

Metallic Properties

- Boiling points are much more extreme than melting points because of the energy required to separate atoms from the groups of cations and electrons.
- Metals are **malleable** because they can be hammered into sheets.
- Metals are **ductile** because they can be drawn into wires.

Table 7.12 Melting and Boiling Points

Element	Melting Point (°C)	Boiling Point (°C)
Lithium	180	1347
Tin	232	2623
Aluminum	660	2467
Barium	727	1850
Silver	961	2155
Copper	1083	2570



Metal Alloys

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

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

Table 7.13 Commercial Alloys

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

Main Ideas

- Ions are formed when atoms gain or lose valence electrons to achieve a stable octet electron configuration
- Oppositely charged ions attract each other, forming electrically neutral ionic compounds
- Metals form crystal lattices and can be modeled **as cations surrounded by a "sea" of freely moving valence electrons**
- 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.

Main Ideas

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

Main Ideas

- 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.