7.2 Ionic Bonds and Ionic Compounds

Where does table salt come from?

In some countries, salt is obtained by the evaporation of seawater. In other countries, salt is mined from rock deposits deep underground.
Formation of Ionic Compounds

What is the electrical charge of an ionic compound?

Sodium chloride, or table salt, is an ionic compound consisting of sodium cations and chloride anions.

- An **ionic compound** is a compound composed of cations and anions.
Although they are composed of ions, ionic compounds are electrically neutral.

- The total positive charge of the cations equals the total negative charge of the anions.

Ionic Bonds

Anions and cations have opposite charges and attract one another by means of electrostatic forces.

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

\[
\begin{align*}
\text{Na}^+ & \quad \text{Cl}^- \\
1s^22s^22p^6 \quad 1s^22s^22p^63s^23p^5 & \quad 1s^22s^22p^6 \quad 1s^22s^22p^63s^23p^6
\end{align*}
\]

Formula Units

A **chemical formula** shows the numbers of atoms of each element in the smallest representative unit of a substance.

- \( \text{NaCl} \) is the chemical formula for sodium chloride.
Formula Units

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

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.
Formula Units

For sodium chloride, the lowest whole-number ratio of the ions is 1:1 (one Na\(^+\) ion to each Cl\(^-\) ion).

- The formula unit for sodium chloride is NaCl.
- Although ionic charges are used to derive the correct formula, they are not shown when you write the formula unit of the 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
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.

Solve

Apply the concepts to this problem.

a. Start with the atoms.

- K and O
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.

\[
\text{K}^+ \quad \text{O}^{2-} \quad \text{K}^+ \quad \text{O}^{2-}
\]

The formula of the compound formed is \( \text{K}_2\text{O} \) (potassium oxide).
2 Solve Apply the concepts to this problem.

b. Start with the atoms.

\[ \text{Mg} \quad \text{and} \quad \text{N} \]

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.
Sample Problem 7.1

b. Express the electron dot structure as a formula.

- The formula of the compound formed is $\text{Mg}_3\text{N}_2$ (magnesium nitride).

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Use electron dot structures to determine the formula of the ionic compound formed when calcium reacts with fluorine.
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\[
\text{Ca}^{2+} + 2\text{F}^{-} \rightarrow \text{CaF}_2
\]

Properties of Ionic Compounds

What are three properties of ionic compounds?
Most ionic compounds are crystalline solids at room temperature.

- The component ions in such crystals are arranged in repeating three-dimensional patterns.

Each ion is attracted strongly to each of its neighbors, and repulsions are minimized.

- The large attractive forces result in a very stable structure.
Ionic compounds generally have high melting points.

Would you expect to find sodium chloride in underground rock deposits as a solid, liquid, or gas? Explain.
Would you expect to find sodium chloride in underground rock deposits as a solid, liquid, or gas? Explain.

Sodium chloride is found in underground rock deposits as a solid. Like most ionic compounds, sodium chloride has a high melting point (about 800°C).

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.
  - The coordination number of Na\(^+\) is 6 because each Na\(^+\) ion is surrounded by six Cl\(^-\) ions.
  - The coordination number of Cl\(^-\) is also 6 because each Cl\(^-\) ion is surrounded by six Na\(^+\) ions.
In CsCl, each ion has a coordination number of 8.

- Each Cs\(^+\) ion is surrounded by eight Cl\(^-\) ions.
- Each Cl\(^-\) ion is surrounded by eight Cs\(^+\) ions.

Ionic compounds can conduct an electric current when melted or dissolved in water.
When sodium chloride is melted, the orderly crystal structure breaks down.

- If a voltage is applied across this molten mass, cations migrate freely to one electrode and anions migrate to the other.

Ionic compounds also conduct electric current if they are dissolved in water.

- When dissolved, the ions are free to move about in the solution.
When can ionic compounds 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
Although they are composed of ions, ionic compounds are electrically neutral.

Most ionic compounds are crystalline solids at room temperature.

Ionic compounds generally have high melting points.

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

- **ionic compound**: a compound composed of positive and negative ions
- **ionic bond**: the electrostatic attraction that binds oppositely charged ions together
- **chemical formula**: an expression that indicates the number and type of atoms present in the smallest representative unit of a substance
• **formula unit**: the lowest whole-number ratio of ions in an ionic compound; in magnesium chloride, the ratio of magnesium ions to chloride ions is 1:2 and the formula unit is MgCl$_2$

• **coordination number**: the number of ions of opposite charge that surround each ion in a crystal

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**Bonding and Interactions**

• The electrostatic forces between the oppositely charged ions hold the cations and anions together in an ionic compound.

• Ionic compounds generally have high melting points and can conduct an electric current in solution and in the molten state.
END OF 7.2