Atomic Theory and Bonding

Textbook pages 168-183

Before You Read

What do you already know about Bohr diagrams? Record your answer in the lines below.

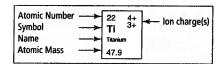
What are atoms?

An **atom** is the smallest particle of any element that retains the properties of the element.

The particles that make up an atom are called **subatomic particles**. Atoms are composed of three subatomic particles: protons, neutrons, and electrons.

| Name | Symbol | Electric Charge | Location in the Atom | Relative Mass |
|----------|--------|--------------------|----------------------------|---------------|
| Proton | р | 1+ | Nucleus | 1836 |
| Neutron | n | 0 | Nucleus | 1837 |
| Electron | е | 1- | Surrounding the nucleus | 1 |

Nuclear charge is the electric charge on the nucleus. This charge is always positive, since the protons have a positive charge and the neutrons are not charged. Atomic number is the number of protons. The nuclear charge or atomic number is given in the top left hand corner of the element box for each element in the periodic table.



How does the periodic table provide information about elements?

In the periodic table, each element is listed according to its atomic number. Each row is called a **period**. Each column



Mark the Text

Identify Definitions

Highlight the definition of each word that appears in bold type.



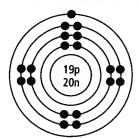
Reading Check

Which has a positive electric charge, a proton, a neutron, or an electron?

is called a **group** or **family**. Metals are on the left side and in the middle of the table. Non-metals are in the upper right corner. The metalloids form a staircase toward the right side. The block of elements from groups 3 through 12 are the transition metals. Elements in the same chemical group or family have similar chemical properties. For example, group 17 contains very reactive non-metals known as halogens (i.e., fluorine, chlorine, bromine, etc.) Group 18 contains the non-reactive noble gases.

How do Bohr diagrams represent atoms?

A Bohr diagram shows the arrangement of subatomic particles in atoms and ions. Electrons are organized in "shells". The first shell holds a maximum of two electrons; the second shell a maximum of eight. When this shell is filled, it is called a **stable octet**. The outermost shell containing electrons is called the **valence shell**. The electrons in this shell are called **valence electrons**. These electrons are involved in chemical bonding. When an atom forms a compound, it acquires a full valence shell of electrons and achieves a stable, low energy state. On the periodic table, elements in Group 1 have 1 electron in their valence shell, elements in Group 2 have 2 (a **lone pair**), elements in Group 3 have 3, and so on.



The Bohr diagram for a potassium atom

What are ionic and covalent compounds?

Section 4.1

There are two basic types of compounds: ionic and covalent.

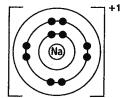
1. Ionic compounds: When atoms gain or lose electrons, they become electrically charged particles called **ions**. An ionic compound contains a positive ion (usually a metal) and a negative ion (usually a non-metal). In **ionic bonding**, one or more electrons transfer from each atom of the metal

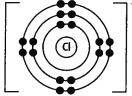
to each atom of the non-metal. The metal atoms lose electrons, forming **cations**. For example, aluminum forms a 3⁺ cation as a result of losing three electrons. Some metals are **multivalent** and can form ions in several ways, depending on the chemical reaction they undergo. For example, iron is multivalent because it can lose two or three electrons to become a Fe²⁺ or Fe³⁺ ion. The non-metal atoms gain electrons, forming **anions**. Chlorine gains one electron and forms a 1⁻ anion.

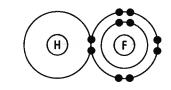
The common ions are sometimes shown in the upper righthand corner of the element's box in the periodic table. For a multivalent metal, the most common charge is listed first.



2. Covalent compounds: In **covalent bonding**, the atoms of a non-metal share electrons with other non-metal atoms. An unpaired electron from each atom will pair together, forming a **covalent bond**. These two electrons are sometimes called a **bonding pair**.







The ionic compound sodium chloride

The covalent compound hydrogen fluoride

What is a Lewis diagram?

A Lewis diagram illustrates chemical bonding by showing only an atom's valence electrons and its chemical symbol. Lewis diagrams can be used to represent elements, ions, and compounds.

| н• | [: ċi:] ⁻ | [Mg] ²⁺ [::::] ² |
|---------------|------------------------------|--|
| hydrogen atom | chlorine ion | magnesium oxide molecul |

| 4 | Reading Check |
|---|--------------------------|
| | What is a Lewis diagram? |
| | |
| | |
| | |
| | |

Names and Formulas of Compounds

Textbook pages 184-201

Before You Read

In this section, you will learn how to write the names and formulas of ionic and covalent compounds. Write what you already know about these compounds in the lines below.

How do you represent an ionic compound?

Ionic compounds are composed of positive and negative ions. They can be represented with both a name and a chemical formula.

- 1. Name: In an **ionic compound**, the first part of the name indicates the positive ion (a metal) and the second part indicates the negative ion (a non-metal). The non-metal's name always ends with the suffix "-ide." For example, lead sulphide.
- 2. Chemical formula: Follow the steps in the table below to write the chemical formula for an ionic compound.

| Steps | Example Ionic Compound: Lead Sulphide |
|--|--|
| Identify the chemical symbol for each ion and its charge. | lead: Pb ⁴⁺ sulphide: S ²⁻ |
| Determine the total charges needed to balance the positive and negative charges of each ion. | Pb ⁴⁺ : +4 = +4 S ²⁻ : -2 -2 = -4 |
| Note the ratio of positive to negative ions. | 1 Pb ⁴⁺ : 2 S ²⁻ |
| Use these subscripts to write the chemical formula. Make sure the subscripts represent the smallest whole number formula. A "1" is not shown as a subscript. | PbS ₂ |

There are also two special cases you must consider when naming and writing the chemical formulas of ionic compounds. These are compounds containing multivalent metals and polyatomic ions.



Mark the Text

Check for Understanding

As you read this section, be sure to reread any parts you do not understand. Highlight any sentences that help make concepts clearer for you.

| Reading Check | |
|------------------------------|--|
| What is a multivalent metal? | |
| | |
| | |

- 1. Multivalent metals: Multivalent metals can form two or more positive ions with different ionic charges. To distinguish between two ions formed from multivalent metals, the name must contain the ion's charge. The Roman numerals I, II, III, IV, V, VI, and VII, corresponding to ion charges 1+ to 7+, are used for this purpose. The Roman numerals are included in the name of the compound. For example, nickel (II) chloride has the formula NiCl₂. Thus, nickel (II) has an ion charge of 2+. Nickel (III) has the formula NiCl₃. The ion charge of nickel (III) is 3+. ▶
- 2. Polyatomic ions: A **polyatomic ion** is an ion composed of more than one type of atom joined by covalent bonds. For example, carbonate (CO₃²⁻) is a polyatomic atom. All polyatomic atoms have special names assigned to them. You will need to look these up in the following table when naming a compound that includes a polyatomic ion.

| Table 4.11 Names, Formulas, and Charges of Some Polyatomic Ions Positive Ions Negative Ions | | | |
|---|---|--|---------------------------------------|
| NH ₄ + ammonium | CH ₃ COO ⁻ acetate | HCO ₃ hydrogen carbonate, bicarbonate NO ₂ nitrite | |
| | CO ₃ ²⁻ carbonate | HSO ₄ - hydrogen sulfate, bisulfate | CIO, - perchlorate |
| | ClO ₃ - chlorate | HS ⁻ hydrogen sulfide, bisulfide | MnO ₄ − permanganate |
| | CIO ₂ - chlorite | HSO ₃ ⁻ hydrogen sulfite, bisulfite | PO ₄ 3- phosphate |
| | CrO ₄ 2- chromate | OH ⁻ hydroxide | PO ₃ 3- phosphite |
| | CN ⁻ cyanide | CIO- hypochlorite | SO ₂ 2- sulfate |
| | Cr ₂ O ₇ ²⁻ dichromate | NO ₃ nitrate | SO ₂ ²⁻ sulfite |

How do you represent a binary covalent compound?

A binary covalent compound contains two non-metal elements joined together by one or more covalent bonds. Like ionic compounds, binary covalent compounds can be represented with both a name and a chemical formula.

1. Name: When naming a binary covalent compound, prefixes are used to indicate how many atoms of each element are present. The second element's name ends with the suffix "-ide." For example, dinitrogen trioxide has two atoms of nitrogen and three atoms of oxygen. No prefix is used if there is just one atom of the first element. For example, carbon dioxide. The table below provides the first ten prefixes used to name binary covalent compounds.

| Prefix | Number of atoms |
|--------|-----------------|
| mono- | 1 |
| di- | 2 |
| tri- | 3 |
| tetra- | 4 |
| penta- | 5 |
| hexa- | 6 |
| hepta- | 7 |
| octa- | 8 |
| nona- | 9 |
| deca- | 10 |

2. Chemical formula: When writing the chemical formula, subscripts are used to indicate the number of atoms present. For example, dinitrogen trioxide has the chemical formula N₂O₃. The exact number of atoms is always shown in the formula. For example, hydrogen peroxide is written as H₂O₂, not HO. Unlike the formula for an ionic compound, the subscripts do not always represent the smallest whole number formula.

Reading Check

A certain element has 5 atoms in a binary covalent compound. Which prefix is used to name this element?

Chemical Equations

Textbook pages 202-215

Before You Read

What do you already know about chemical equations? Write your ideas in the lines below.



Create a Table

Create a table that outlines the steps you need to take when writing and balancing chemical equations



| List the four states of matter. | |
|---------------------------------|---|
| | _ |



| servation of mass state? |
|--------------------------|
| |
| |

How are chemical changes and chemical reactions linked?

A chemical change is a change in the arrangements and connections between ions and atoms. Chemical change always involves the conversion of pure substances (elements and compounds) called **reactants** into other pure substances called **products**, which have different properties than the reactants. One or more chemical changes that occur at the same time are called a **chemical reaction**.

How is a chemical reaction represented?

A chemical reaction can be represented using a **chemical equation**. A chemical equation may be written in words (a **word equation**) or in chemical symbols (a **symbolic equation**). In a chemical equation, the reactants are written to the left of an arrow and the products are written to the right. The symbols for **states of matter** may be used to show whether each reactant or product is solid (s), liquid (l), gas (g), or aqueous (aq).

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$$

$$+ \qquad \qquad \qquad \rightarrow$$

Chemical reactions obey the law of **conservation of mass**. Atoms are neither destroyed nor produced in a chemical reaction. The total mass of the products is always equal to the total mass of the reactants.

How are chemical equations written and balanced?

Chemical equations are written and balanced through a series of steps, as shown below.

1. Write a word equation: The simplest form of a chemical equation is a word equation. A word equation provides the names of the reactants and products in a chemical reaction. It provides the starting point for writing and balancing chemical equations.

word equation: methane + oxygen → water + carbon dioxide

2. Write a skeleton equation: A skeleton equation replaces the names of the reactants and products in a word equation with formulas. However, it does not show the correct proportions in which the reactants will actually combine and the products will be produced.

A skeleton equation is not balanced.

skeleton equation: $CH_4 + O_2 \rightarrow H_2O + CO_2$

3. Write a balanced equation: A balanced chemical equation shows the identities of each pure substance involved in the reaction, as well as the number of atoms of each element on both sides of a chemical equation. Chemical equations are balanced using the lowest whole number coefficients. These are integers placed in front of the formula or chemical symbol for each product and reactant. The number of atoms after a chemical reaction is the same as it was before a chemical reaction. You can use this information to determine the coefficients that balance the equation.

balanced chemical equation: $CH_4 + 2O_2 \rightarrow 2H_2O + CO_2$

The following strategies can help you translate a word equation into a skeleton equation.

- ◆ A chemical symbol is used for nearly all elements when they are not in a compound.
- ◆ Three common compounds containing hydrogen that you should memorize are methane (CH₄), ammonia (NH₃), and water (H₂O).

There are seven common diatomic elements, all of which are non-metals. These are hydrogen, nitrogen, oxygen, fluorine, chlorine, bromine, and iodine. When they occur alone (not in a compound), they are written as H_2 , O_2 , F_2 , Br_2 , I_2 , N_2 , and Cl_2 . You can use the word "HOFBrINCI" to remember them. If an element occurs alone and is not diatomic, no subscript is used. For example, in a chemical equation, oxygen is written as O_2 when it occurs alone, while lead is written as Pb.

The following strategies can help you balance a skeleton equation.

- ♦ Balance compounds first and single elements last.
- ◆ If you place a coefficient in front of a formula, be sure to balance all the atoms of that formula before moving on.
- ◆ Add coefficients only in front of formulas. Do not change subscripts.
- ♦ When oxygen or hydrogen appears in more than one formula on the reactant side or the product side of the chemical equation, balance oxygen and hydrogen last.
- ◆ You can often treat polyatomic ions, such as SO₄²-, as a unit.
- ◆ If an equation is balanced by using half a molecule (i.e., ½ O₂), you must double all coefficients so that they are all integers.
- ♦ When you are finished, perform a final check to be sure that all elements are balanced.