CHAPTER OUTLINE

Section 1 Compounds and Molecules

Key Idea questions
> What holds a compound together?
> How can the structure of chemical compounds be shown?
> What determines the properties of a compound?

Chemical Bonds

> What holds a compound together?

> The forces that hold atoms or ions together in a compound are called chemical bonds.

  • chemical bond: the attractive force that holds atoms or ions together

Chemical Structure

> How can the structure of chemical compounds be shown?

> The structure of chemical compounds can be shown by various models. Different models show different aspects of compounds.

  • chemical structure: the arrangement of atoms in a substance

  • Some models represent bond lengths and angles.

    – bond length: the average distance between the nuclei of two bonded atoms

    – bond angle: the angle formed by two bonds to the same atom

  • In a ball-and-stick model, atoms are represented by balls. The bonds that hold the atoms together are represented by sticks.

  • In structural formulas, chemical symbols are used to represent the atoms.

  • Space-filling models show the space occupied by atoms.
Chapter 6 The Structure of Matter

• Bonds can bend, stretch, and rotate without breaking.
  – Bonds can be represented by flexible springs.
  – Most reported bond lengths are average distances.
  – Bonds hold atoms together tightly.

How Does Structure Affect Properties?

> What determines the properties of a compound?

> The chemical structure of a compound determines the properties of that compound.

• Compounds with network structures are strong solids.
  – Example: Quartz, SiO$_2$ is made of silicon and oxygen atoms.
  – The atoms are bonded in a strong, rigid structure.

• Some networks are made of bonded ions.
  – The strong attractions between the oppositely charged ions give ionic compounds high melting points and high boiling points.
  – Example: Table salt—sodium chloride—is made of a tightly packed repeating network of positive sodium ion and negative chlorine ions.

• Some compounds are made of molecules.
  – Some compounds made of molecules are solids, others are liquids, others are gases.
  – The strength of attractions between molecules varies.
  – Attractions between water molecules are called hydrogen bonds.
    • Hydrogen bonds are not as strong as the bonds holding oxygen and hydrogen atoms together within a molecule.
Section 2 Ionic and Covalent Bonding

Key Idea questions
> Why do atoms form bonds?
> How do ionic bonds form?
> What do atoms joined by covalent bonds share?
> What gives metals their distinctive properties?
> How are polyatomic ions similar to other ions?

Why Do Chemical Bonds Form?

> Why do atoms form bonds?

> Generally, atoms join to form bonds so that each atom has a stable electron configuration.

• There are two basic kinds of chemical bonding:
  – ionic bonding
  – covalent bonding

Ionic Bonds

> How do ionic bonds form?

> Ionic bonds form from the attractions between such oppositely charged ions.

• ionic bonds: the attractive force between oppositely charged ions, which form when electrons are transferred from one atom to another

• Ionic bonds are formed by the transfer of electrons.

  – Two atoms tend to form an ionic bond when one atom has more attraction for electrons than the other.

• Ionic compounds are in the form of networks, not molecules.

  – A formula unit is the smallest ratio of ions in ionic compounds.

• When melted or dissolved in water, ionic compounds conduct electricity.
Covalent Bonds

> What do atoms joined by covalent bonds share?

> Atoms joined by covalent bonds share electrons.

- **covalent bond**: a bond formed when atoms share one or more pairs of electrons.
  - Compounds that are networks of bonded atoms, such as silicon dioxide, are also covalently bonded.
  - Covalent bonds usually form between nonmetal atoms.
- **Covalent compounds can be solids, liquids, or gases.**
  - In a chlorine molecule, Cl₂, the atoms share two electrons.
  - They are joined by one covalent bond.
- **Atoms may share more than one pair of electrons.**
  - Two pairs of shared electrons (4 electrons) form a double covalent bond.
  - Three pairs of shared electrons (6 electrons) form a triple covalent bond.
  - Double bonds are stronger than single bonds.
  - Triple bonds are stronger than double bonds.
- **Atoms do not always share electrons equally.**
  - *nonpolar covalent bonds*: bonds in which electrons are shared equally
  - When two atoms of different elements share electrons, the electrons are not shared equally.
  - *polar covalent bond*: a bond in which there is an unequal sharing of electrons
- **Electrons tend to be more attracted to atoms of elements that are located farther to the right and closer to the top of the periodic table.**
Chapter 6 The Structure of Matter

Metallic Bonds

> What gives metals their distinctive properties?

> Metals are flexible and conduct electric current well because their atoms and electrons can move freely throughout a metal's packed structure.

• metallic bond: a bond formed by the attraction between positively charged metal ions and the electrons around them

Polyatomic Ions

> How are polyatomic ions similar to other ions?

> A polyatomic ion acts as a single unit in a compound, just as ions that consist of a single atom do.

• polyatomic ion: an ion made of two or more atoms

• There are many common polyatomic ions.

• A polyatomic ion acts as a single unit in a compound.

• Parentheses group the atoms of a polyatomic ion.
  – Example: the formula for ammonium sulfate is written as (NH₄)₂SO₄, not N₂H₈SO₄.

• Some names of polyatomic anion relate to their oxygen content.
  – An -ate ending is used to name an ion with more oxygen atoms.
    • Examples: sulfate (SO₄²⁻), nitrate (NO₃⁻), chlorate (ClO₃⁻)
  – An -ite ending is used to name an ion with fewer oxygen atoms.
    • Examples: sulfite (SO₃²⁻), nitrite (NO₂⁻), chlorite (ClO₂⁻)
Section 3 Compound Names and Formulas

Key Idea questions
> How are ionic compounds named?
> What do the numerical prefixes used in naming covalent compounds tell you?
> What does a compound’s empirical formula indicate?

Naming Ionic Compounds

> How are ionic compounds named?

> The names of ionic compounds consist of the names of the ions that make up the compounds.

• Names of cations include the elements of which they are composed.
  – Example: a sodium atom loses an electron to form a sodium ion, Na⁺.

• Names of anions are altered names of elements.
  – Example: a fluorine atom gains an electron to form a fluoride ion, F⁻.

• An ionic compound must have a total charge of zero.
  – If an ionic compound is made up of ions that have different charges, the ratio of ions will not be 1:1.

• Some cation names must show their charge.
  – Transition metals may form several cations—each with a different charge.

  • Fe₂O₃ is made of Fe³⁺ ions, so it is named iron(III)oxide.
  • FeO is made of Fe²⁺ ions, so it is named iron(II) oxide.
Chapter 6 The Structure of Matter

• To determine the charge of a transition metal cation, look at the total charge of the compound.
  
  – Fe$_2$O$_3$
    • The total charge of the compound is zero
    • The iron ion in has a charge of 3+
    • An oxide ion, O$^{2-}$, has a a charge of 2–.
    • Fe$_2$O$_3$: (2 × 3+) + (3 × 2–) = 0

Naming Covalent Compounds

> What do the numerical prefixes used in naming covalent compounds tell you?

> For covalent compounds of two elements, numerical prefixes tell how many atoms of each element are in the molecule.

• Numerical prefixes are used to name covalent compounds of two elements.

• Examples:
  
  – Boron trifluoride, contains one boron atom and three fluorine atoms in BF$_3$.

  – Dinitrogen tetroxide, N$_2$O$_4$, is made of two nitrogen atoms and four oxygen atoms.

Empirical Formulas

> What does a compound’s empirical formula indicate?

> An empirical formula tells us the smallest whole-number ratio of atoms that are in a compound.

• empirical formula: the composition of a compound in terms of the relative numbers and kinds of atoms in the simplest ratio

• Different compounds can have the same empirical formula.
• Molecular formulas are determined from empirical formulas.
  – molecular formula: a chemical formula that shows the number and kinds of atoms in a molecule, but not the arrangement of atoms

• Masses can be used to determine empirical formulas.
Section 4 Organic and Biochemical Compounds

Key Idea questions
- What is an organic compound?
- What is a polymer?
- What organic compounds are essential to life?

Organic Compounds

> What is an organic compound?

> An organic compound is a covalently bonded compound that contains carbon.

- organic compound: a covalently bonded compound that contains carbon, excluding carbonates and oxides.

- Many ingredients of familiar substances contain carbon.

- Carbon atoms form four covalent bonds in organic compounds.

- hydrocarbon: a compound made of only carbon and hydrogen atoms

- Alkanes are hydrocarbons that have only single covalent bonds.

- Arrangements of carbon atoms in alkanes may vary.
  - The carbon atoms in any alkane with more than three carbon atoms can have more than one possible arrangement.
  - Carbon atom chains may have many branches, and they can even form rings.

- Alkane chemical formulas usually follow a pattern.
  - The number of hydrogen atoms is always two more than twice the number of carbon atoms, except for cyclic alkenes.
  
  \[ C_nH_{2n+2} \]

- Alkenes are hydrocarbons that have double carbon-carbon bonds.
  - The simplest alkene is ethane.
Chapter 6 The Structure of Matter

- Alcohols have hydroxyl, or –OH, groups.
  - Example: methanol, CH₃OH
  - Alcohols have the suffix -ol in their names.

- Alcohol and water molecules behave similarly.
  - Neighboring alcohol molecules are attracted to one another.

Polymers

What is a polymer?

> A polymer is a molecule that is a long chain made of smaller molecules.

- Polymers have repeating subunits.
  - Polyethene, or polyethylene is made from many molecules of ethene.
  
  - monomer: the smaller molecule that makes up the polymer
  
  • Ethene is the monomer in polyethene.

- Some polymers are natural, and others are artificial.
  - natural polymers: rubber, starch, protein, and DNA
  - human-made polymers: plastics and synthetic fibers

- A polymer’s structure determines its elasticity.
  
  - Polyethene is made of long chains.
  
  • It is flexible, but not elastic.
  
  • milk jugs

  - Polymers with connected chains are elastic.
      
  • They can stretch.
  
  • rubber bands
Biochemical Compounds

> What organic compounds are essential to life?

> Biochemicals, which are essential to life, include carbohydrates, proteins, and DNA.

• Many carbohydrates are made of glucose.

• 

  carbohydrate: any organic compound that is made of carbon, hydrogen, and oxygen and that provides nutrients to the cells of living things

• Proteins are complex polymers of amino acids.

  – protein: an organic compound that is made of one or more chains of amino acids and that is a principal component of all cells

  – amino acid: any one of 20 different organic molecules that contain a carboxyl and an amino group and that combine to form proteins

• Each protein is made of a specific combination of a certain number of amino acids.

• DNA is a polymer that stores genetic information.

• DNA is a very long molecule made of carbon, hydrogen, oxygen, nitrogen, and phosphorus.

  – It is in the form of paired strands.

  – It has the shape of a twisted ladder known as a double helix.

• Most cells in your body have a copy of your genetic material in the form of chromosomes made of DNA.

• DNA is the information that the cell uses to make proteins.