Name _____ Class _____ Date _____

2 The Chemistry of Life

Big idea Matter and Energy

Q: What are the basic chemical principles that affect living things?

	WHAT I KNOW	WHAT I LEARNED
2.1 What is the matter in organisms made of?	SAMPLE ANSWER: *Matter is made up of atoms.*	SAMPLE ANSWER: *Atoms have three subatomic particles: protons, neutrons, and electrons.*
2.2 Why are the properties of water important to organisms?	SAMPLE ANSWER: *Many parts of an organism's body contain water.*	SAMPLE ANSWER: *Some of the most important biological fluids contain water. Also, water's high heat capacity protects living things both internally and externally from drastic temperature changes.*
2.3 How do organisms use different types of carbon compounds?	SAMPLE ANSWER: *Carbon is the primary element found in living things.*	SAMPLE ANSWER: *Organisms use carbon compounds to form four types of molecules: lipids, carbohydrates, nucleic acids, and proteins.*
2.4 How do chemicals combine and break apart inside living things?	SAMPLE ANSWER: *A lot of what that happens in an organism is based on chemical reactions.*	SAMPLE ANSWER: *Enzymes are proteins that speed up chemical reactions that take place in cells.*

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2.1 The Nature of Matter

Lesson Objectives

- Identify the three subatomic particles found in atoms.
- Explain how all of the isotopes of an element are similar and how they are different.
- Explain how compounds are different from their component elements.
- Describe the two main types of chemical bonds.

Lesson Summary

Atoms The **atom** is the basic unit of matter, made up of three subatomic particles.

- Protons have a positive charge and neutrons carry no charge. Strong forces bind protons and neutrons together in the **nucleus**.
- An **electron** is a negatively charged particle that has only about 1/1840 the mass of a proton. Electrons constantly move around the space surrounding the atom's nucleus.
- Because an atom has the same number of protons and electrons, if it is electrically neutral.

Elements and Isotopes A chemical **element** is a pure substance that consists entirely of one type of atom.

- Atoms of the same element that differ in the number of neutrons are called **isotopes**. Isotopes are identified by their mass number, the total number of protons and neutrons in the nucleus. Because they have the same number of electrons in each atom, all isotopes of an element have the same chemical properties.
- Radioactive isotopes have unstable nuclei and break down at a constant rate.

Chemical Compounds A chemical **compound** is a substance formed by the chemical combination of two or more elements in definite proportions. The physical and chemical properties of a compound are usually very different from those of the elements from which it is formed. Scientists use formulas to show the ratio of elements that make up a compound.

Chemical Bonds The atoms in compounds are held together by chemical bonds. Electrons that are available to form bonds are called valence electrons.

- An **ionic bond** forms when one or more electrons are transferred from one atom to another, forming **ions**. An atom that loses electrons becomes positively charged. An atom that gains electrons becomes negatively charged.
- A **covalent bond** forms when electrons are shared rather than transferred. The structure formed by atoms joined by covalent bonds is called a **molecule**. The molecule is the smallest unit of most compounds.
- When molecules are close together, a slight attraction can form between the oppositely charged portions of nearby molecules. These intermolecular forces of attraction are called **van der Waals forces**.

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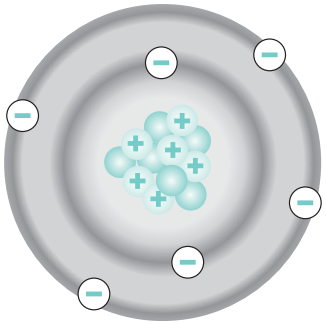
Atoms

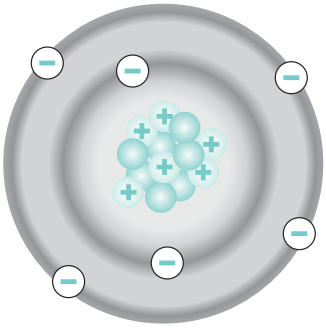
1. THINK VISUALLY The diagram shows a model of a carbon atom, with an atomic number of 6. Complete the diagram by drawing in the rest of the atomic particles, including their charges. Label all particles and the nucleus.



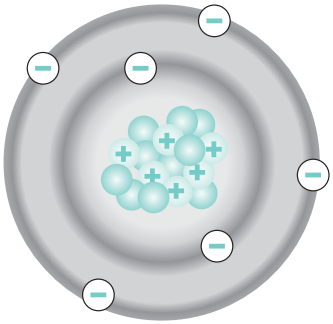
Diagrams should contain six protons, six electrons, and six neutrons. Check that students have correctly labeled each type of subatomic particle.

Elements and Isotopes

2. THINK VISUALLY The diagrams show models of carbon isotopes. Complete the diagrams by drawing in the rest of the atomic particles, including their charges.



Nonradioactive carbon-13



Radioactive carbon-14

Use your completed diagrams to answer Questions 3–4.

3. Identify two differences between carbon-12 and carbon-14.

Carbon-14 is radioactive, carbon-12 is not. Carbon-14 has two more neutrons than carbon-12.

4. Identify two ways in which carbon-12, carbon-13, and carbon-14 are alike.

They have the same number of protons and electrons and they are chemically similar.

For Questions 5–7, complete each statement by writing the correct word or words.

5. A chemical element is a pure substance that consists entirely of one type of *atom*.

6. Atoms of the same element that differ in the number of neutrons they contain are called *isotopes*.

7. An atom is made up of protons, neutrons, and *electrons*.

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Chemical Compounds

8. What is a chemical compound?

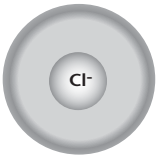
A chemical compound is a substance formed by the chemical combination of two or more elements in definite proportions.

9. What do the formulas for table salt, NaCl, and water, H_2O, indicate about these compounds?

In table salt, sodium and chlorine combine in a 1:1 ratio; in water, hydrogen and oxygen combine in a 2:1 ratio.

Chemical Bonds

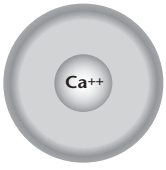
10. Sea salt contains calcium chloride ($CaCl_2$), an ionic compound similar to table salt. One atom of calcium (atomic number 20) bonds to two atoms of chlorine (atomic number 17). Fill in the number of protons and electrons in each ion.



Chloride ion

Protons *+17*

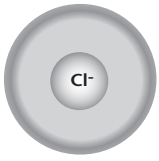
Electrons *−18*



Calcium ion

Protons *+20*

Electrons *−18*



Chloride ion

Protons *+17*

Electrons *−18*

11. What is the difference between an ionic bond and a covalent bond?

In an ionic bond, electrons are transferred from one atom to another. In a covalent bond, electrons are shared between atoms.

Apply the Big Idea

12. How are chemical bonds important in metabolism?

Metabolism includes all of the processes in the body that break down or build substances. These substances break down because chemical bonds are broken and form because chemical bonds are made.

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2.2 Properties of Water

Lesson Objectives

- Discuss the unique properties of water.
- Differentiate between solutions and suspensions.
- Explain what acidic solutions and basic solutions are.

Lesson Summary

The Water Molecule Water molecules (H_2O) are polar because of an uneven distribution of electrons, creating a slight negative (–) charge in the oxygen atom and a slight positive (+) charge in each hydrogen atom. The attraction between a hydrogen atom of one water molecule and the oxygen atom of another water molecule is called a **hydrogen bond**.

- **Cohesion** is an attraction between molecules of the same substance. It causes water molecules to be drawn together, producing surface tension.
- **Adhesion** is an attraction between molecules of different substances. It causes capillary action, an effect that causes water to rise in a narrow tube against the force of gravity.

Solutions and Suspensions A **mixture** is a material composed of two or more elements or compounds that are physically mixed together but not chemically combined. A **solution** is a mixture in which all the components are evenly spread out: the substance dissolved is the **solute**; the substance that causes the dissolving is the **solvent**. Mixtures of water and undissolved materials are **suspensions**.

Acids, Bases, and pH A water molecule (H_2O) can split apart to form a hydrogen ion (H^+) and a hydroxide ion (OH^-).

- The **pH scale** measures the concentration of hydrogen ions in a solution. The scale ranges from 0 to 14. Pure water has a pH of 7.
- An **acid** is any compound that forms H^+ ions in solution. Acidic solutions have pH values below 7. A **base** is a compound that forms OH^- ions in solution. Basic, or alkaline, solutions have pH values above 7.
- **Buffers** are weak acids or bases that can react with strong acids or bases to prevent sudden changes in pH.

The Water Molecule

For Questions 1–4, write True or False on the line provided.

True **1.** Water is a polar molecule.

False **2.** Hydrogen bonds are an example of adhesion.

False **3.** Covalent bonds give water a low heat capacity.

False **4.** A hydrogen bond is stronger than a covalent bond.

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Solutions and Suspensions

5. Complete the table.

Substance	Definition	Example(s)
Mixture	Physical combination of two or more substances	Cinnamon sugar
Solute	*Substance that is dissolved*	Salt in saltwater
Solvent	*Substance in which solute dissolves*	*Water in saltwater*
Suspension	Mixture of water and nondissolved substance	Blood
Solution	*Mixture in which all substances are evenly distributed*	*Saltwater*

Acids, Bases, and pH

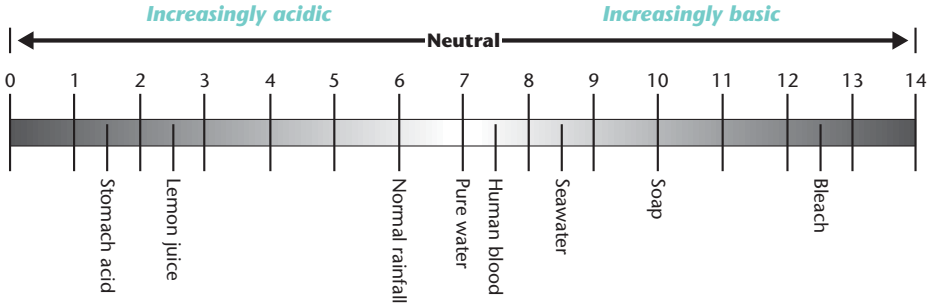
6. What makes pure water neutral?

It has an equal number of positive hydrogen ions and negative hydroxide ions.

7. What does the pH scale measure?

concentration of hydrogen ions (H^+) in solution

8. On the pH scale, indicate which direction is increasingly acidic and which is increasingly basic.



9. Identify two solutions that have more H^+ ions than OH^- ions.

SAMPLE ANSWER: *rainfall, lemon juice*

10. Identify two solutions that have more OH^- ions than H^+ ions.

SAMPLE ANSWER: *human blood, seawater*

11. How would you buffer a solution that has a pH of 12?

add a weak acid to decrease the pH

Apply the Big Idea

12. Why are buffers important to living things?

Buffers react with strong acids or bases to prevent sharp, sudden changes in pH. In living things, controlling pH is important for maintaining homeostasis.

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2.3 Carbon Compounds

Lesson Objectives

- Describe the unique qualities of carbon.
- Describe the structures and functions of each of the four groups of macromolecules.

Lesson Summary

The Chemistry of Carbon Organic chemistry is the study of compounds with bonds between carbon atoms. Carbon atoms have four valence electrons, allowing them to form strong covalent bonds with many other elements, including hydrogen, oxygen, phosphorus, sulfur, and nitrogen. Living organisms are made up of molecules made of carbon and these other elements.

- One carbon atom can bond to another to form chains and rings.
- Carbon can form millions of different large and complex structures.

Macromolecules Many of the carbon molecules in living things are so large they are called macromolecules. Macromolecules form by polymerization, in which smaller units called **monomers** join together to form **polymers**. Biochemists sort the macromolecules in living things into groups based on their chemical composition.

- **Carbohydrates** (starches and sugars) are composed of carbon, hydrogen, and oxygen. Carbohydrates are the main energy source for living things. Plants and some animals also use carbohydrates for structural purposes. Molecules with one sugar monomer are **monosaccharides**. A disaccharide is made of two monosaccharides.
- **Lipids** (fats, oils, and waxes) are made mostly of carbon and hydrogen atoms. Lipids can be used to store energy and form parts of biological membranes and waterproof coverings. Steroids manufactured by the body are lipids as well.
- **Nucleic acids** contain hydrogen, oxygen, nitrogen, carbon, and phosphorus. They are polymers of **nucleotides**. A nucleotide has three parts: a 5-carbon sugar, a phosphate ($-PO_4$) group, and a nitrogenous base. Nucleic acids store and transmit hereditary (genetic) information. There are two kinds of nucleic acids: DNA (deoxyribonucleic acid) and RNA (ribonucleic acid).
- **Proteins** are made up of nitrogen, carbon, hydrogen, and oxygen. Proteins are polymers of **amino acids**. An amino acid molecule has an amino group ($-NH_2$) on one end and a carboxyl group (–COOH) on the other end. Proteins control the rate of reactions, regulate cell processes, form cellular structures, carry substances into or out of cells, and help fight disease.
  - More than 20 different amino acids are found in nature. Any amino acid can bond with any other.
  - Covalent bonds called peptide bonds link amino acids together to form a polypeptide.
  - Amino acids are assembled into polypeptide chains according to instructions coded in DNA.

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The Chemistry of Carbon

1. How many valence electrons does each carbon atom have?

Each carbon atom has four valence electrons.

2. What gives carbon the ability to form chains that are almost unlimited in length?

A carbon atom can bond to other carbon atoms.

Macromolecules

For Questions 3–5, complete each statement by writing the correct word or words.

3. Many of the molecules in living cells are so large they are called *macromolecules*.

4. *Polymerization* is the process that forms large organic molecules.

5. When two or more *monomers* join together, a polymer forms.

6. Create a table in which you compare the components and functions of the following macromolecules: carbohydrates, lipids, nucleic acids, and proteins.

Macromolecule	Components	Functions
Carbohydrate	*carbon, hydrogen, and oxygen*	*main source of energy; structural purposes*
Lipid	*mostly carbon and hydrogen*	*stores energy; forms parts of biological membranes and waterproof coverings*
Nucleic acid	*hydrogen, oxygen, nitrogen, carbon, and phosphorus*	*stores and transmits genetic information*
Protein	*nitrogen, hydrogen, carbon, and oxygen*	*controls rate of reactions, regulates cell processes, forms cellular structures, carries substances into or out of cell, fights disease*

Apply the Big idea

7. How did organic compounds get their name? How is the word related to its meaning?

Organic means "living." The four major groups of organic compounds are molecules that are produced by organisms using energy and the raw material of nonliving matter.