Grade 10 NTI Day #5 Biology

Assignment: Please read the excerpt below as an independent reading assignment. Then read and answer the questions below the excerpt.

LESSON 2.1

The Nature of Matter

🔑 **KEY QUESTIONS**

- *What three subatomic particles make up atoms?*
- *How are all of the isotopes of an element similar?*
- *In what ways does a compound differ from its component elements?*
- *What are the main types of chemical bonds?*

VOCABULARY

atom
nucleus
electron
element
isotope
compound
ionic bond
ion
covalent bond
molecule
van der Waals forces

READING TOOL

As you read your textbook, outline the headings and sub-headings throughout this lesson. Fill in the table in your **Biology Foundations Workbook.**

What are you made of? Just as buildings are made from bricks, steel, and wood, all forms of life are made from chemical compounds. When you breathe, eat, or drink, your body uses the substances in air, food, and water to carry out chemical reactions that keep you alive.

Atoms

The study of chemistry begins with the basic unit of matter, the **atom**. The concept of the atom came first from the Greek philosopher Democritus, nearly 2500 years ago. Democritus called the smallest fragment of any substance an atom, from the Greek word *atomos*, which means "unable to be cut."

Atoms are incredibly small. Placed side by side, 100 million sulfur atoms would make a row only about 1 centimeter long—about the width of your little finger! Despite its extremely small size, an atom contains subatomic particles that are even smaller. **Figure 2-1** shows the subatomic particles in a carbon atom. 🔑 ***The subatomic particles that make up atoms are protons, neutrons, and electrons.***

Protons and Neutrons Protons and neutrons have about the same mass. However, protons are positively charged particles (+), and neutrons carry no charge at all. Strong forces bind protons and neutrons together to form the **nucleus**, at the center of the atom.

Electrons The **electron** is a negatively charged particle (–) with only 1/1840 the mass of a proton. Electrons are in constant motion in the space surrounding the nucleus. They are arranged in a series of shells or orbitals. The first shell can contain no more than two electrons, and the second shell, no more than eight. Atoms have equal numbers of electrons and protons, and are electrically neutral because the opposite charges cancel out.

Elements and Isotopes

A chemical **element** is a pure substance that consists entirely of one type of atom. Elements are represented by one- or two-letter symbols. C, for example, stands for carbon, H for hydrogen, Na for sodium, and I for iodine. The number of protons in the nucleus of an element is called its atomic number. Carbon's atomic number is 6, meaning that each atom of carbon has six protons and, consequently, six electrons.

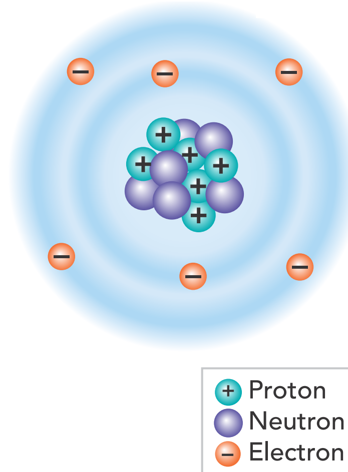
Although there are nearly a hundred naturally occurring chemical elements on Earth (see the Periodic Table in Appendix D), fewer than 20 of them are commonly found in living organisms. About 99 percent of the mass of living things is composed of just six elements: calcium, carbon, hydrogen, oxygen, nitrogen, and phosphorus. However, the remaining 1 percent, or trace elements, are also essential. In fact, a lack of trace elements can stunt plant growth or damage the developing organs in unborn animals.

If all atoms are made of the same three elementary particles, then why do different elements have such different properties? Part of the answer is found in their electron shells. When two atoms interact, their shells overlap and may even swap electrons with each other. This affects how they can interact with other atoms and even how they may participate in chemical reactions. You might say that the number of electrons in that outer shell is the "face" that a particular atom shows to its neighbors.

Figure 2-1

A Carbon Atom

All atoms have a nucleus of protons and neutrons. Electrons move around the nucleus.



INTERACTIVITY

Explore an interactive periodic table to discover the properties of the elements.

Isotopes

Isotopes Atoms of an element may have different numbers of neutrons. For example, look at **Figure 2-2**. Although all atoms of carbon have six protons, they may have different numbers of neutrons. Carbon-14, for example, has 8 neutrons. Atoms of the same element that differ in the number of neutrons they contain are known as **isotopes**.

The total number of protons and neutrons in the nucleus of an atom is called its mass number. Isotopes are identified by their mass numbers. The weighted average of the masses of an element's isotopes is called its atomic mass. "Weighted" means that the abundance of each isotope in nature is considered when the average mass is calculated.

Although neutrons affect the atomic mass of an isotope, they do not affect its chemical properties. ***Isotopes have different masses, but their chemical properties are the same.***

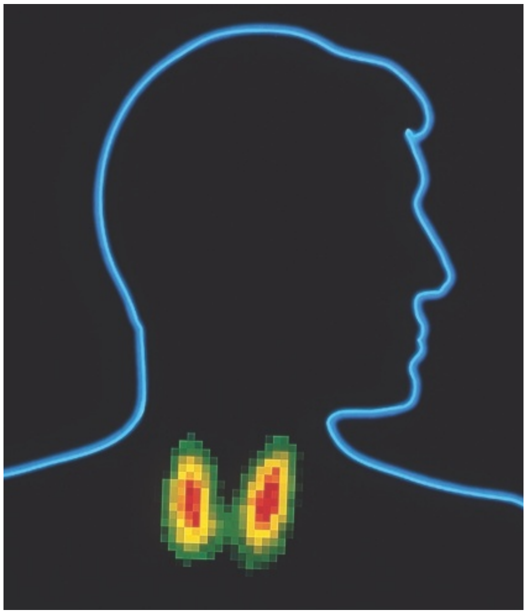
Isotopes of Carbon

Isotope	Number of Protons	Number of Electrons	Number of Neutrons
Carbon–12 (nonradioactive)	6	6	6
Carbon–13 (nonradioactive)	6	6	7
Carbon–14 (radioactive)	6	6	8

Figure 2-2

Carbon Isotopes

Isotopes of carbon all have 6 protons but different numbers of neutrons—6, 7, or 8. Isotopes are identified by the total number of protons and neutrons in the nucleus: carbon-12, carbon-13, and carbon-14. **Interpret Tables** Which isotope of carbon is radioactive?



CASE STUDY

Figure 2-3

Radioactive Imaging of the Thyroid

A radioactive scan reveals the location of the thyroid gland at the base of the neck. Iodine, including the radioactive isotope ^{131}I, is concentrated in the thyroid.

Radioactive Isotopes Some isotopes are radioactive, meaning that their nuclei are unstable and break down at a constant rate over time. The radiation these isotopes give off can be dangerous, but radioactive isotopes have a number of important scientific and practical uses. Geologists can determine the ages of rocks and fossils by analyzing the isotopes found in them. Radiation from certain isotopes can be used to detect cancer and to kill bacteria that cause food to spoil. Radioactive isotopes can also be used as labels or "tracers" to follow the movements of substances within organisms. For example, if the radioactive isotope of iodine, ^{131}I, is injected into the body, in just a few minutes nearly all of the radioactivity is found in just one place—a gland in the front of the neck called the thyroid (See **Figure 2-3**).

READING CHECK **Define** What is an isotope?

Chemical Compounds

In nature, most elements are found combined with other elements in compounds. A chemical **compound** is a substance formed by the chemical combination of two or more elements in definite proportions. Scientists show the composition of compounds by a kind of shorthand known as a chemical formula. Water, which contains two atoms of hydrogen for each atom of oxygen, has the chemical formula H_2O. The formula for table salt, NaCl, indicates that the elements that make up table salt—sodium and chlorine—combine in a 1:1 ratio.

The physical and chemical properties of a compound are usually very different from those of the elements from which it is formed. For example, hydrogen and oxygen, which are gases at room temperature, can combine explosively and form liquid water. Sodium is a silver-colored metal that is soft enough to cut with a knife. It reacts explosively with water. Chlorine is very reactive, too. It is a poisonous, yellow-green gas that was used as a weapon in World War I. But the compound sodium chloride, more commonly known as table salt, shown in **Figure 2-4**, is a white solid that dissolves easily in water. As you know, sodium chloride is not poisonous. In fact, it is essential for the survival of most living things.

Figure 2-4

Sodium Chloride

Sodium (left) is a silvery metal. Chlorine (middle) is a poisonous yellow-green gas. Yet, the compound made from sodium and chlorine is sodium chloride—common table salt (right).

Chemical Bonds

The atoms in compounds are held together by chemical bonds. Much of chemistry is devoted to understanding how and when chemical bonds form. Bond formation involves the electrons that surround each atomic nucleus. The electrons in an atom's outer shell that are available to form bonds are called valence electrons. ***The main types of chemical bonds are ionic bonds and covalent bonds.***

Ionic Bonds An **ionic bond** is formed when one or more electrons are transferred from one atom to another. Recall that atoms are electrically neutral when they have equal numbers of protons and electrons. A neutral atom that loses electrons becomes positively charged. A neutral atom that gains electrons has a negative charge. These positively and negatively charged atoms are known as **ions**.

INTERACTIVITY

Discover how electrons are involved in chemical bonds.

INTERACTIVITY

Figure 2-5

Ionic Bonding

The compound sodium chloride forms when sodium loses its valence electron to chlorine.

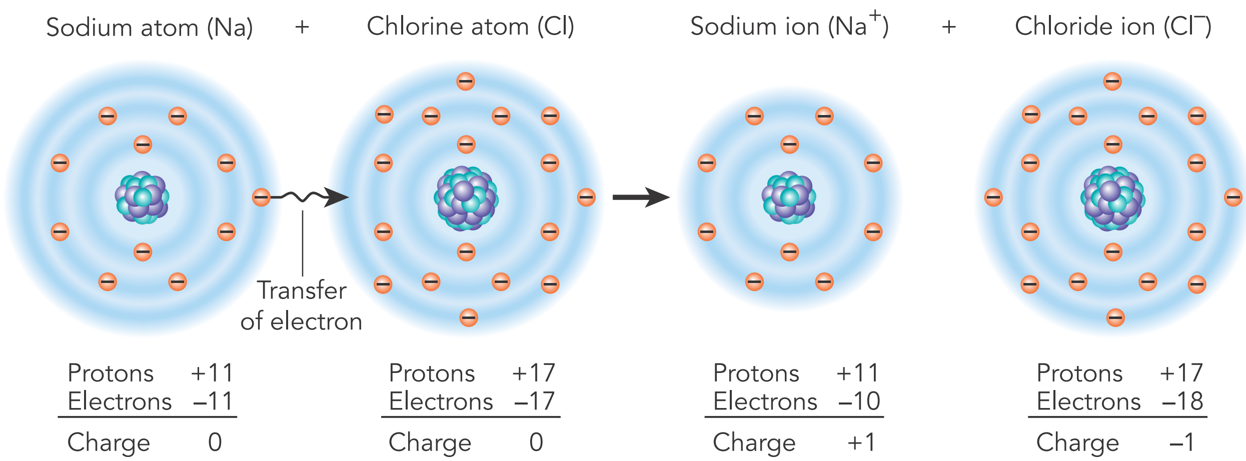


Figure 2-5 shows how ionic bonds form between sodium and chlorine in table salt. A sodium atom loses its one electron from its outer shell to become a sodium ion (Na^+). A chlorine atom gains an electron and becomes a chloride ion (Cl^-). In a salt crystal, there are trillions of sodium and chloride ions. These oppositely charged ions have a strong attraction for each other, forming an ionic bond.

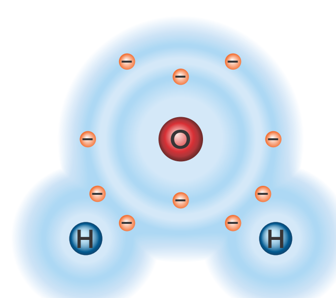
Covalent Bonds Sometimes electrons are shared by atoms instead of being transferred. What does it mean to share electrons? It means that the moving electrons actually travel about the nuclei of both atoms, forming a **covalent bond**. When the atoms share one electron from each atom, a single covalent bond is formed. Sometimes the atoms share four electrons to form a double bond. In other cases, atoms can share six electrons, forming a triple bond. The structure that results when atoms are joined together by covalent bonds is called a **molecule**, as shown by the diagram of a water molecule in **Figure 2-6**. The molecule is the smallest unit of most compounds.

READING CHECK **Compare** How are ionic and covalent bonds alike? How are they different?

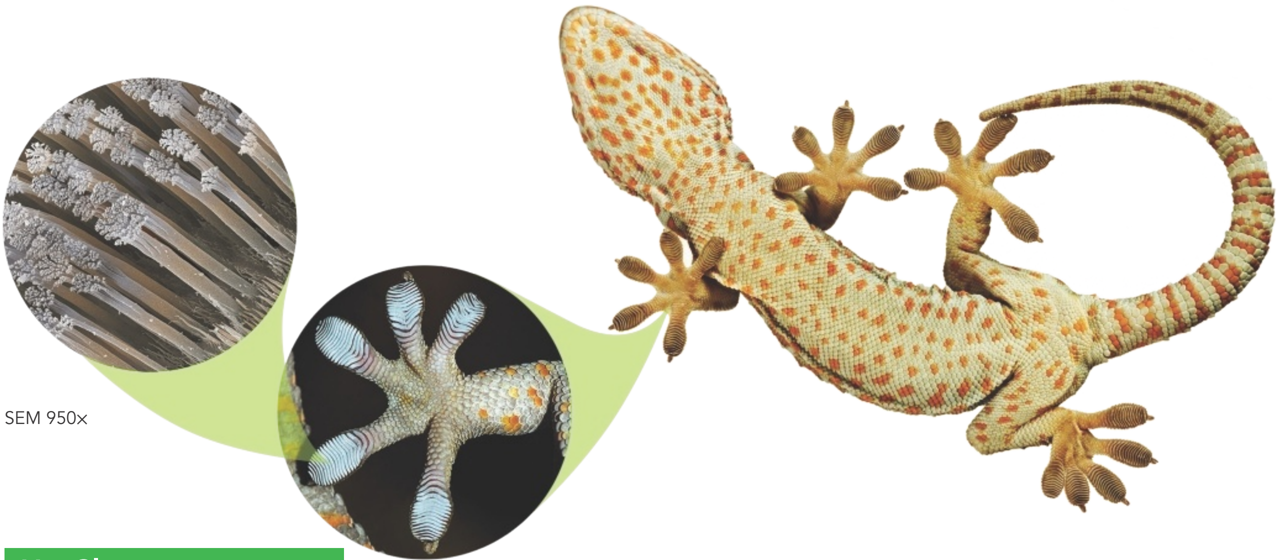
Figure 2-6

Covalent Bonding

In a water molecule, each hydrogen atom shares two electrons with the oxygen atom.



Water molecule (H_2O)



Up Close

Figure 2-7

Van der Waals Forces

The underside of each foot of this gecko is covered by millions of tiny hairlike projections. The projections themselves are made of even finer fibers, creating more surface area for "sticking" to surfaces at the molecular level. This allows geckos to scurry up walls and across ceilings.

BUILD VOCABULARY

Academic Words The noun interaction means "a shared action or influence." The interactions between molecules due to van der Waals forces can hold them together.

Weak Interactions While the strongest chemical bonds are ionic or covalent, one of the most interesting things about the chemistry of living things is the importance of weak interactions between atoms and molecules. Within a living cell, many molecules interact only briefly to send signals, carry out chemical reactions, or copy information from one molecule to another. One example of these weak interactions is the attraction between molecules known as **van der Waals forces**. These forces produce a slight attraction between the molecules when they are very close together. If two molecules have shapes that match so they can fit against each other with very little space between them, these forces may be strong enough to hold the molecules together. The combined van der Waals forces along the feet of a gecko are strong enough to hold the gecko to a wall, as shown in **Figure 2-7**.

Hydrogen bonds are another form of weak interaction. These bonds form between a hydrogen atom of one molecule and an oxygen or nitrogen atom of a neighboring molecule. Because hydrogen bonds are essential to understanding the special properties of water, they will be considered in detail in the next lesson.

Name ______________________________ Class ____________ Date __________

Lesson Quiz

2.1 The Nature of Matter

Directions

For multiple choice questions, write the letter that best answers the question or completes the statement on the line provided. For other question types, follow the directions provided.

_______ **1.** How are electric charges distributed within the atom?

a. Positive and negative charges are distributed evenly.
b. Positive charges are concentrated in the nucleus; negative charges surround the nucleus.
c. Negative charges are concentrated in the nucleus; positive charges surround the nucleus.
d. Both positive and negative charges are concentrated in the nucleus.

2. For each missing word or phrase, circle the choice that correctly completes the sentence.

When electrons transfer from one atom to another, both atoms become **(ions / isotopes / molecules / electrons)** and they are held together by a(n) **(polar / covalent / molecular / ionic)** bond. When electrons are shared between atoms, a(n) **(ionic / covalent / hydrogen / point)** bond forms between the atoms, and the joined atoms become a(n) **(element / ionic compound / molecule / isotope)**.

_______ **3.** Deuterium is an isotope of hydrogen. It has a mass number of two. Which describes a deuterium atom?

a. a nucleus of one proton and one neutron, which is orbited by one electron
b. a nucleus of one proton, which is orbited by one neutron and one electron
c. nucleus of one neutron, which is orbited by one electron
d. a nucleus of two neutrons which is orbited by two electrons

Name ______________________ Class __________ Date __________

_______ **4.** A carbon atom has 6 protons and 6 electrons. Carbon has three naturally occurring isotopes, carbon-12, carbon-13, and carbon-14. Which of these statements is true about carbon and its isotopes?

a. All carbon atoms have six neutrons.

b. All carbon atoms have six protons and six electrons.

c. Atoms of all carbon isotopes have either more than 6 electrons or fewer than 6 electrons.

d. Atoms of some naturally-occurring carbon isotopes may have twelve neutrons.

_______ **5.** How does a molecular compound compare to the elements that make up the compound?

a. The properties of a compound depend on the identity of the component elements, and not the chemical bonds they form.

b. The properties of a compound depend on the size of the molecule, and not the component elements.

c. The properties of a compound are generally similar to the properties of the elements that make it up.

d. The properties of a compound are usually very different from the properties of the elements that make it up.

_______ **6.** Molecules are attracted to one another by Van der Waals forces. How do Van der Waals forces compare with ionic and covalent bonds?

a. Van der Waals forces are stronger than ionic and covalent bonds.

b. Van der Waals forces are weaker than ionic and covalent bonds.

c. Van der Waals forces are stronger than ionic bonds, but weaker than covalent bonds.

d. Van der Waals forces are stronger than covalent bonds, but weaker than ionic bonds.