TEACHER GUIDE

MOLECULES MATTER! STRUCTURE OF PHOTOSYNTHESIS

MATERIALS PER GROUP:

- Spice drops, Dots candy or colored mini marshmallows (different colors)
- Toothpicks

SAFETY PRECAUTIONS:

- Do not eat or drink in the laboratory.
- Please use caution when handling the toothpicks as their ends are sharp.

TOTAL DURATION:

5 min. pre-lab prep time;
40 min. class time

LESSON OBJECTIVES:

Students will be able to:

1. Use knowledge of atomic structure to build models of molecules.
2. Rearrange atoms of carbon dioxide and water to model the process and products of photosynthesis.

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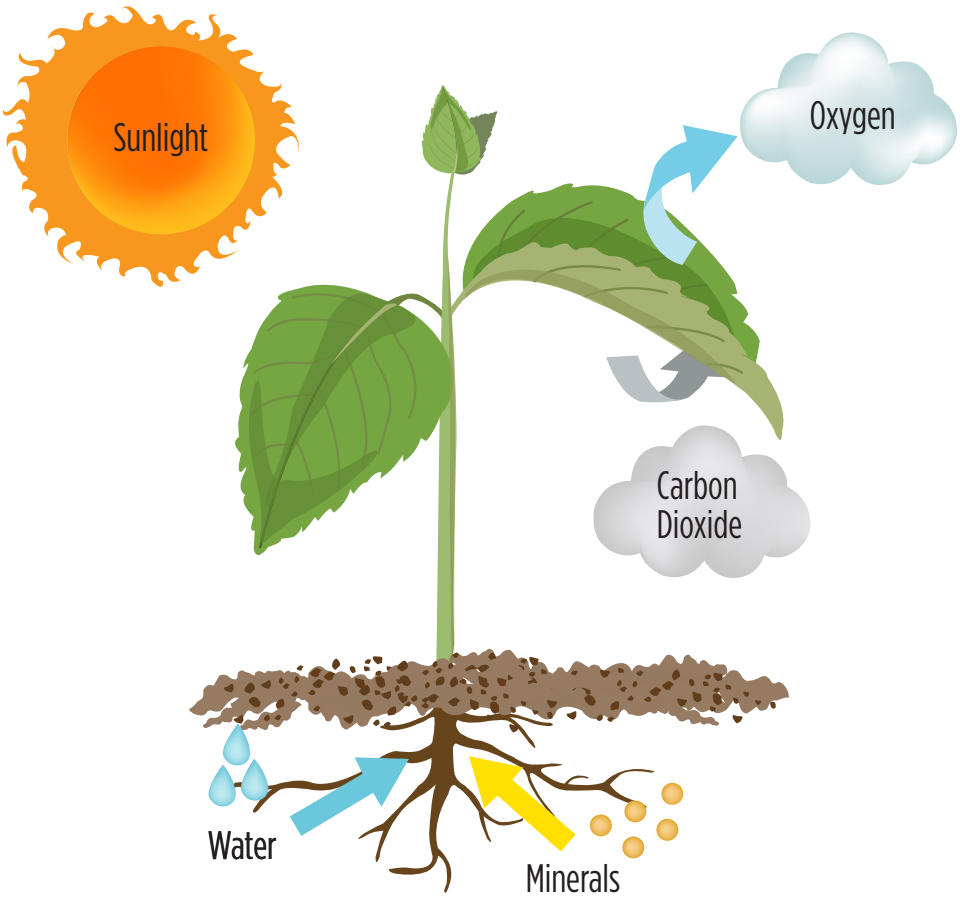

LESSON OVERVIEW:

Plants make the oxygen we breathe and the food we consume. They do this through a process known as **photosynthesis**. Photosynthesis is the single most important chemical process on the planet because all living creatures depend on it to survive. Without plants, photosynthesis would not occur and life on Earth would not exist.

ESSENTIAL QUESTION:

How do the structures of atoms relate to their ability to bond?

TOPICAL ESSENTIAL QUESTION:

How do the atoms in carbon dioxide and water recombine to form glucose during photosynthesis?

STANDARDS:

Middle School

MS-PS1-1
Students who demonstrate understanding will be able to: Develop models to describe the atomic composition of simple molecules and extended structures.

MS-PS1-5
Students who demonstrate understanding will be able to: Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved.

MS-LS1-7
Students who demonstrate understanding will be able to: Develop a model to describe how food is rearranged through chemical reactions, forming new molecules that support growth and/or release energy as this matter moves through an organism.

High School

HS-PS1-1
Students who demonstrate understanding will be able to: Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.

HS-PS1-2
Students who demonstrate understanding will be able to: Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, knowledge of the patterns of chemical properties, and formation of compounds.

HS-PS1-7
Students who demonstrate understanding will be able to: Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.

HS-LS1-5
Students who demonstrate understanding will be able to: Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.

HS-LS1-6
Students who demonstrate understanding will be able to: Construct and revise an explanation based on evidence for how carbon, hydrogen and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules.

Science and Engineering Practices:

1. Asking questions
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations and designing solutions
7. Engaging in argument from evidence
8. Obtaining, evaluating and communicating evidence

Crosscutting Concepts:

1. Patterns
2. Cause and Effect: Mechanisms and explanations
3. Scale, Proportion and Quantity
4. Systems and System Models
5. Energy and Matter: Flows, cycles and conservation
6. Structure and Function
7. Stability and Change

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KEY VOCABULARY:

Atom
Valence electrons
Elements
Atomic number
Matter
Compounds
Protons
Chemical formula
Neutrons
Photosynthesis
Electrons

LAB BACKGROUND INFORMATION:

NOTE: This is background information for the teacher to assist in facilitating learning and will be explained to the students after the Explore section.

Plants make the oxygen we breathe and the food we consume. They do this through a process known as **photosynthesis**. Photosynthesis is the single most important chemical process on the planet because all living creatures depend on it to survive. Without plants, photosynthesis would not occur and life on Earth would not exist.

During photosynthesis, plants use light energy from the sun, carbon dioxide (CO_2) and water (H_2O) to produce energy in the form of glucose ($C_6H_{12}O_6$) and oxygen (O_2) as a byproduct. As we breathe, we inhale oxygen that is produced by the plants and exhale carbon dioxide that the plants use to make more oxygen.

Photosynthesis Equation:

$$6H_2O + 6CO_2 \xrightarrow{\text{Light}} C_6H_{12}O_6 + 6O_2$$

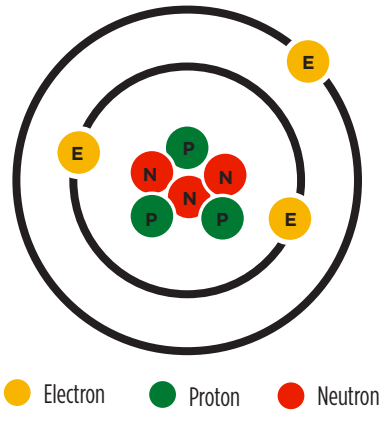
Plants convert the glucose that they produce into energy that they need to grow. When we eat plants or plant-derived food, we also use the glucose as energy. In fact, every living creature on the planet uses the glucose produced by plants.

Photosynthesis is a chemical process that involves compounds made up of elements found in the periodic table. With a little knowledge about chemistry and the elements, and how they interact, you will be able to build the compounds involved in photosynthesis.

Chemistry is the study of the composition, properties and behavior of matter. **Matter** is anything that has mass and takes up space. The smallest known unit of matter is the **atom**.

Atoms consist of three particles: protons, neutrons and electrons. **Protons** contain a positive electrical charge and are located in the nucleus of atoms. **Neutrons** are also located in the nucleus and are electrically neutral, meaning they have no electrical charge. **Electrons** have a negative electrical charge and move around the nucleus in what is called the atom's electron cloud, a spherical cloud of varying density surrounding the nucleus that is often depicted as shells or orbits around the nucleus (Figure 1).

Figure 1



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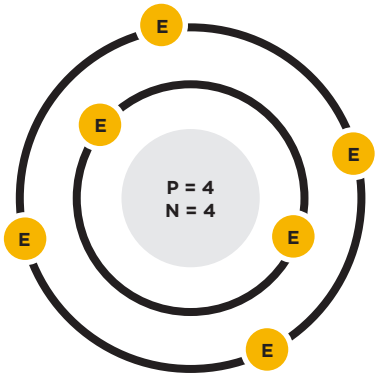
An **element** is matter made of only one kind of atom. Each element is different and has unique properties. So far, 118 elements have been identified; 98 of them occur naturally. These elements make up gases in the air, minerals in rocks and liquids such as water. Examples of naturally occurring elements include oxygen and nitrogen in the air you breathe, and metals such as iron, silver and gold. Of all these naturally occurring elements, 25 percent are important to living things. Four of these elements, carbon (C), hydrogen (H), oxygen (O) and nitrogen (N), make up 95 percent of the molecules in living things.



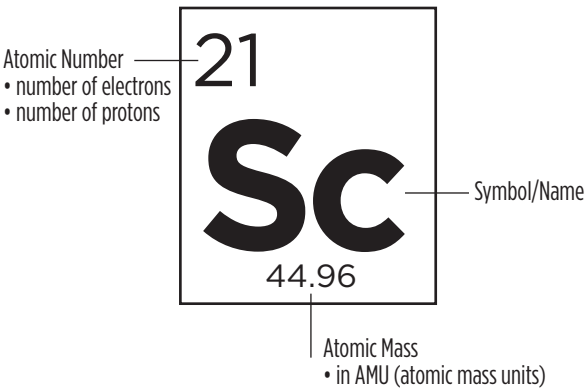
Elements fall into three categories: metals, metalloids and nonmetals. The elements in each category have similar properties. To help organize and display the elements, chemists have created a chart called the periodic table of elements.

The periodic table is neatly arranged in rows (left to right) and columns (top to bottom). The rows are called periods. Elements in a period have the same number of electron shells. The columns are called groups or families, and elements in each group have the same number of **valence electrons** or electrons in the outermost electron shell. A Bohr model shows the electrons in their shells.

The periodic table also contains letters and numbers that describe each element. Each element of the periodic table is abbreviated with one or two letters known as the element's symbol. For example, the symbol for oxygen is O and the symbol for sodium is Na.

Numbers for each element represent the element's atomic number and atomic mass. The number above the symbol is the **atomic number**, which describes how many protons are in the nucleus of each atom of that element. The number found below the element symbol is the atomic mass, the weighted average mass of an element (Figure 2). This number can vary because of isotopes or atoms of the same element that contain different numbers of neutrons.

Figure 2



Elements are capable of combining to form a **compound** because of the valence electrons in the outermost shell. A compound is a substance in which the smallest unit is made up of atoms of more than one element bonded together. Compounds are expressed as **chemical formulas**; the formula tells you which elements make up a compound as well as how many atoms (indicated by a subscript number written below and to the right of each element's symbol) of each element exist in one unit of that compound. For example, the chemical formula for water is H_2O, and it is made up of two atoms of hydrogen (H_2) and one atom of oxygen (O).

ENGAGE:

Prepare several transparent tubes labeled to represent the elements carbon, hydrogen and oxygen, and the compounds sugar and water. The carbon tube can be filled with crushed charcoal or burned wood, and the tubes representing the gases, hydrogen and oxygen, can be left empty. Pass the element tubes around to allow students to observe them and describe them. Ask the students about the possible compounds or molecules that can be made from combinations of carbon, hydrogen and oxygen. Show them the tubes of water and sugar, and discuss how individual properties of the elements have now changed. Discuss how this is done in nature, referencing plants, photosynthesis and cell respiration.

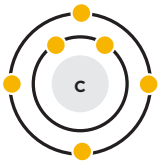
Introduction

In this activity, you will learn about the structure of atoms and use everyday materials to construct the life-sustaining molecules involved in photosynthesis and a variety of other molecules.

EXPLORE:

To assist you in building the molecules, please fill out the information below.

Table 1: Element Information Table

Element	Symbol	Color of Drop	Valence Electrons	Number of Bonds	Bohr Model
Hydrogen	H	White	1	1	
Carbon	C	Purple	4	4	
Oxygen	O	Red	6	2	

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PROCEDURE:

Using the information in the table above, draw the predicted structure for the molecules listed in Table 2 using lines to represent bonds connecting the atoms.

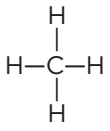
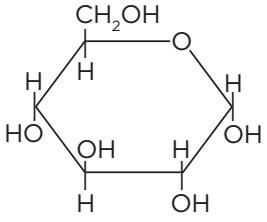
Construct the molecules, and then draw the actual structures in Table 2.

Gases:
O_2 (Oxygen)
CO (Carbon monoxide)
CO_2 (Carbon dioxide)

Liquids:
H_2O (Water)
H_2O_2 (Hydrogen peroxide)
C_2H_6O (Ethanol)

Solids:
$C_6H_{12}O_6$ (Glucose)
$C_{12}H_{22}O_{11}$ (Table sugar)

Table 2: Molecule Construction Data

Molecule Name	Chemical Formula	Predicted Structure	Actual Structure
Methane	CH_4	H-H-C-H-H	
Oxygen	O_2	O=O	O=O
Carbon Dioxide	CO_2	O-C-O	O=C=O
Water	H_2O	O-H-O	
Glucose	$C_6H_{12}O_6$	H-C-O-H H-C-O-H H-C-O-H H-C-O-H H-C-O-H H-C-O-H	

EXPLAIN: (SEE LAB BACKGROUND)

The Lab Background information from the Teacher Guide is repeated in the Explain section of the Student Guide.

ELABORATE:

Optional Extension Activities

Using the information you have learned in this activity, try constructing more challenging molecules such as:

$C_{12}H_{22}O_{11}$ (Table sugar)

To learn more about the periodic table and its elements, watch some of these online resources at home:
http://www.periodicvideos.com/

http://www.ptable.com/

EVALUATE:

1. What is the smallest known unit of matter that retains the properties of a single element?
   Atom
2. Atoms are made up of what three particles?
   Protons, neutrons and electrons
3. What is the electrical charge for a proton, neutron and electron?
   Protons (+), neutrons (0), electrons (-)
4. A substance that is made up of only one specific type of atom is called a/an?
   Element
5. A group of two or more different elements bonded together is called a/an?
   Compound
6. What is an element?
   An element is a simple substance that cannot be broken down into simpler substances and still retains the properties of that substance.
7. What is the smallest unit of a single element?
   Atom
8. Do all molecules have the same shape?
   No
9. What three elements make up a glucose molecule?
   Carbon, hydrogen, oxygen
10. How many bonds can carbon form?
    4

The Noble Research Institute would like to thank the following people for their contributions to this lesson:

- Quentin Biddy
- Janie Herriott
- Susie Edens
- Fiona McAlister
- Kay Gamble
- Julie Smiley-Foster

STUDENT GUIDE

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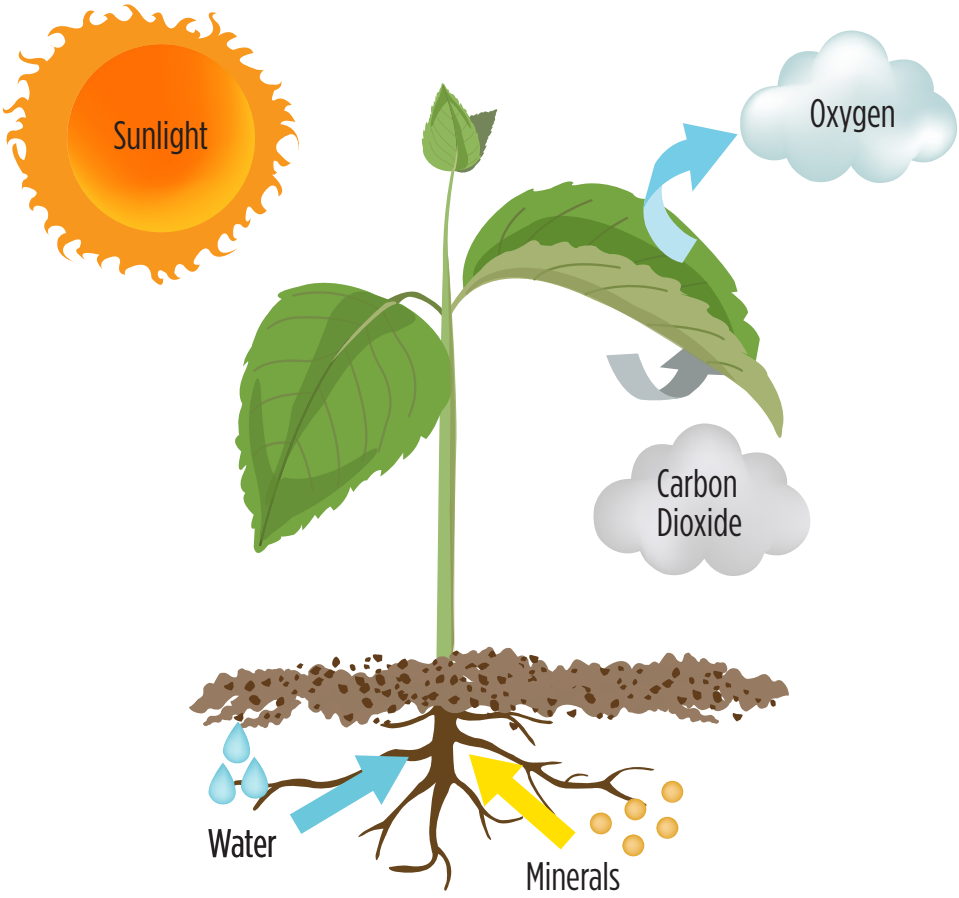

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ESSENTIAL QUESTION:

How do the structures of atoms relate to their ability to bond?

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KEY VOCABULARY:

Atom
Valence electrons
Elements
Atomic number
Matter
Compounds
Protons
Chemical formula
Neutrons
Photosynthesis
Electrons

ENGAGE:

Observe the materials provided by your teacher and describe them. What possible compounds or molecules could be made by combining carbon, hydrogen and oxygen?

INTRODUCTION:

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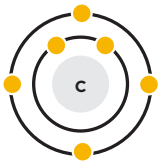
Carbon		Purple	4		
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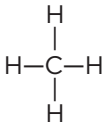
Methane	CH_4	H-H-C-H-H	
Oxygen	O_2		
Carbon Dioxide	CO_2		
Water	H_2O		
Glucose	$C_6H_{12}O_6$		

EXPLAIN:

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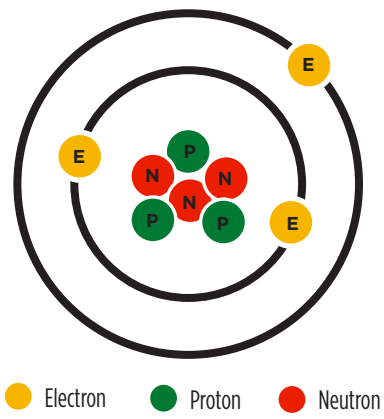

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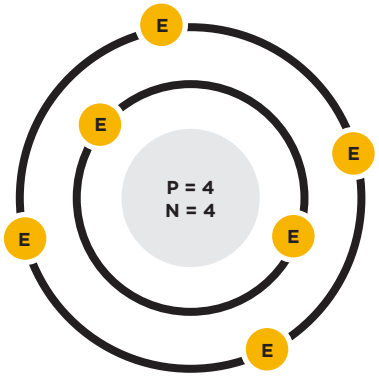

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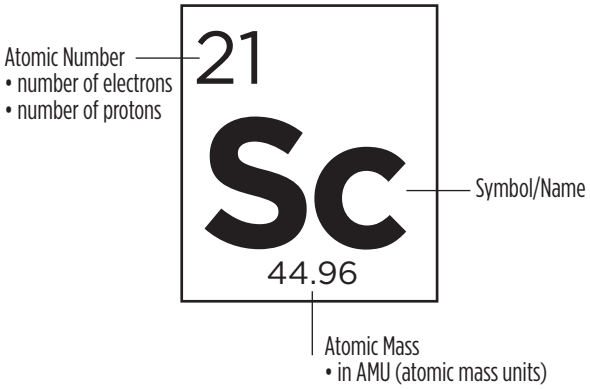
The periodic table also contains letters and numbers that describe each element. Each element of the periodic table is abbreviated with one or two letters known as the element's symbol. For example, the symbol for oxygen is O and the symbol for sodium is Na.

Figure 2



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Elements are capable of combining to form a **compound** because of the valence electrons in the outermost shell. A compound is a substance in which the smallest unit is made up of atoms of more than one element bonded together. Compounds are expressed as **chemical formulas**; the formula tells you which elements make up a compound as well as how many atoms (indicated by a subscript number written below and to the right of each element's symbol) of each element exist in one unit of that compound. For example, the chemical formula for water is H_2O, and it is made up of two atoms of hydrogen (H_2) and one atom of oxygen (O).

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EVALUATE:

Name: _____

Use knowledge gained from this lesson to complete the questions.

1. What is the smallest known unit of matter that retains the properties of a single element?

2. Atoms are made up of what three particles?

3. What is the electrical charge for a proton, neutron and electron?

4. A substance that is made up of only one specific type of atom is called a/an?

5. A group of two or more different elements bonded together is called a/an?

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7. What is the smallest unit of a single element?

8. Do all molecules have the same shape?

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10. How many bonds can carbon form?