Chemistry 20

Unit A The Diversity of Matter and Chemical Bonding

Module 2—Chemical Compounds

In This Module

Lesson 1—Bonding Theory and Lewis Formulas

In this lesson you will learn to use electron dot diagrams to represent the arrangement of electrons within an atom and to illustrate how atoms bond together. This lesson will also use the periodic table and Lewis symbols to support and explain ionic bonding theory.

- What models are used to describe the bonding between atoms in molecular compounds?
- Can information contained within the periodic table be used to support and explain bonding theories?

Lesson 2—Molecular Shapes and VSEPR Theory

In this lesson you will study the Valence Shell Electron Pair Repulsion (VSEPR) model, recognized as the defining theory for predicting molecular shapes. The molecular shapes you will examine in this lesson are linear, bent, tetrahedral, trigonal pyramidal, and trigonal planar. An introduction to chemical representations of molecules that demonstrate three-dimensional shape will also be included.

- What is VSEPR theory, and how can it be used to predict molecular shapes?
- Can the structure of simple molecular substances be illustrated by drawing or building models?
- How are models and theories useful in helping to explain the structure and behaviour of matter?

Lesson 3—Molecular Polarity

In this lesson you will learn how to determine the polarity of a molecule by analyzing the structural shape and charge distribution within a molecule. Electronegativity, shape, and symmetry all affect the polarity of a molecule. The difference between polar and nonpolar bonds and polar and nonpolar molecules is important in many industrial processes.

- How can you determine the polarity of a molecule by using simple structural shapes and charge distribution?

Lesson 4—Intermolecular Forces

This lesson focuses on the different types of intermolecular bonding that occur within molecules. Intermolecular bonding includes London forces, dipole-dipole forces, and hydrogen bonding. Intermolecular bonding plays a large role in determining many characteristics of molecular substances, including melting and boiling points, solubility, surface tension, cohesion and adhesion, volatility, and density.

- What are intermolecular forces?
- Are the differences between the melting and boiling points of similar substances explained by differences in their intermolecular forces?
- How does scientific knowledge and theory develop through hypothesis, evidence collection, investigation, and explanation?

Module Assessment

The assessment in this module consists of four (4) assignments, one for each lesson.

- Module 2 Lesson 1 Assignment
- Module 2 Lesson 2 Assignment
- Module 2 Lesson 3 Assignment
- Module 2 Lesson 4 Assignment

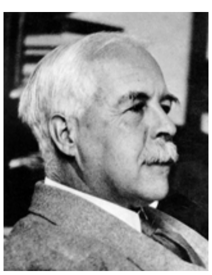
Lesson 1—Bonding Theory and Lewis Formulas

Get Focused


© Loneburro/iStockphoto


© Robert Churchill/iStockphoto

What a difference a century can make, especially when you consider the kind of equipment used to live outdoors. If you compare the two pictures, you can see the influence that chemical technologies have had. In the previous module you learned that many chemical compounds are used to make products. These chemical technologies are often related to the bonding of substances.


Courtesy of The Valley Library, Oregon State University

In the early 1900s, many scientists were asking questions regarding the bonding within chemical compounds. One of the key figures in this discussion was American chemist Gilbert Lewis. In this lesson you will learn about Lewis' theories and how to represent the arrangement of electrons when atoms bond.

Essential Questions

- What models are used to describe the bonding between atoms in molecular compounds?
- Can information contained within the periodic table be used to support and explain bonding theories?

Module 2: Lesson 1 Assignment

You will complete the Module 2 Lesson 1 Assignment at the end of the lesson.

Remember that the questions that are not marked by the teacher provide you with the practice and feedback that you need to successfully complete this course. You should respond to all the questions and place those answers in your course folder.

Explore

Read

Bonding theory is one of the most important concepts in chemistry. Although you studied bonding theory in Science 10, it is important to review these concepts. Understanding bonding may involve revising what you currently understand. Read the descriptions of different bonding theories in your textbook, on page 78 to the bottom of page 80. List terms that are new to you. You will use this list in the Try This exercise below.

Try This

Bonding Concept Map

Prepare a concept map or other graphic organizer that connects any new terms introduced on pages 78 to 80 of your textbook.

To create a concept map, follow these steps:

Step 1: Place terms that you currently use to explain the bonding of matter on a sheet of paper. The order of the terms is not important.

Step 2: Place new terms introduced in the textbook on the sheet of paper.

Step 3: Use lines to connect related terms that appear on the sheet of paper.

Step 4: For each line you draw, write a brief statement (maximum 5 words) that links the two concepts.

Save a copy of your bonding concept map in your course folder. Later in this module you may wish to review your concept map so that you can add terms, revise linking statements, or add additional lines and linking statements.

Self-Check

So far in your study of bonding you have seen different representations for electrons associated with atoms. Review the representation for valence electrons shown in “Figure 3” on page 80 of your textbook.

SC 1. Complete the table representing the arrangement of electrons in the following atoms.

a. fluorine

	e^-				
	e^-				
	p^+ (protons)				
	F atom				

b. magnesium

	e^-				
	e^-				
	e^-				
	p^+ (protons)				
Mg atom					

Check your work.

Self-Check Answers

SC 1.

a. Fluorine

7	e^-	**2 e^-**	**2 e^-**	**2 e^-**	**1 e^-**
2	e^-				
9	p^+ (protons)				

b. magnesium

2	e^-	**1 e^-**	**1 e^-**	**0 e^-**	**0 e^-**
8	e^-				
2	e^-				
12	p^+ (protons)				
Mg atom					

Read

Lewis Symbols

Earlier in this lesson you read about the theories of Gilbert Lewis. In order to support his theory, Lewis developed a model to represent the valence electrons, the electrons associated with bonding.

Read "Atomic Models: Lewis Symbols" on page 81 of your textbook.

Self-Check

SC 2. Draw a Lewis symbol for sulfur. Identify the lone pairs and the bonding electrons in your diagram.

SC 3. Explain how the location of elements on the periodic table provides information about the number of valence electrons they have.

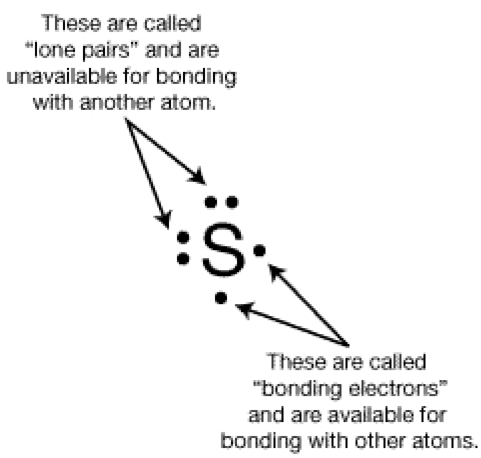
SC 4. Draw Lewis symbols for all of the group 1 elements. How are these elements similar?

SC 5. Draw Lewis models for all of the group 16 non-metals. How are these elements similar?

Check your work.

Self-Check Answers

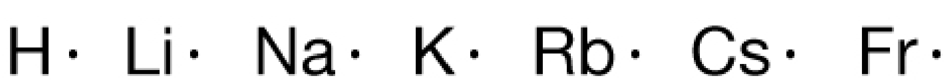
SC 2.



SC 3. The column or group number provides information about the number of valence electrons. Elements in group 1(1A) (first column) all have one valence electron. Information for other columns is listed below.

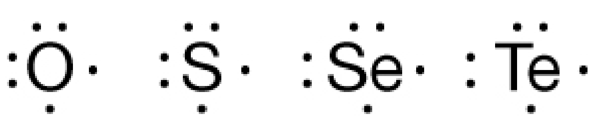
Group #		Valence
1	IA	1
2	IIA	2
13	IIIA	3
14	IVA	4
15	VA	5
16	VIA	6
17	VIIA	7
18	VIIIA	8

SC 4.



They all have 1 bonding electron.

SC 5.



They all have 6 valence electrons, 2 bonding electrons, and 2 lone pairs.

Try This

TR 1.

Lewis symbols, sometimes called electron dot diagrams, are static, two-dimensional representations of an atom. Lewis symbols are a convenient way to show valence electrons. In reality the electrons are in constant motion in three-dimensional space.
The organization of orbitals within an energy level can have important considerations.

Use materials available to you at home or school to build three-dimensional representations of Lewis symbols. Use a digital camera or other means to keep a record of your 3-D models in your course folder. Identify what principle is involved in a three-dimensional model to represent the position of valence electrons in orbitals around the atoms.

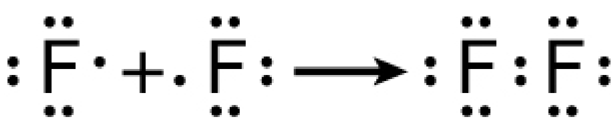
Explaining Molecular Formulas Using Lewis Symbols

Since valence electrons are involved in chemical bonding, Lewis symbols should be useful in explaining the changes that occur to atoms when they bond.

Molecular Elements

Seven elements are diatomic, including F_2. How could Lewis symbols be used to represent a hydrogen molecule? Explain why this is a diatomic element.

Fluorine has seven valence electrons, requiring one more electron to complete its octet. You recall that atoms tend toward stability, meaning filled orbitals. Can you think of ways that a fluorine atom could complete its one unfilled orbital?
You may recall from your study in the previous module that metals often transfer electrons to non-metals, resulting in the formation of ions that have filled orbitals. Another possible association between atoms with unfilled orbitals is to share electrons. Two fluorine atoms could each obtain a stable octet of electrons if they shared a pair of electrons, forming a covalent bond.



This diagram explains why fluorine is diatomic.

What about oxygen?

An oxygen atom has six valence electrons. Sharing a pair of bonding electrons like fluorine would leave both oxygen atoms with seven valence electrons, which is less than a stable octet. The solution lies in having a **double bond**—the two oxygen atoms share two pairs of electrons at once like this:

double bond: an attraction between atoms in a molecule due to the sharing of two pairs of electrons in a covalent bond

Covalent bonds are represented by the pairs of electrons shown between the Lewis symbols. Covalent bonds can also be represented using a line to represent each shared pair of electrons. The result is a **structural diagram**. The structural diagram for fluorine (F_2) would be written as F–F and for oxygen (O_2) as O=O.

structural diagram: a visual representation of a chemical compound that shows the relative placement of every atom within the compound, in addition to all intramolecular bonds

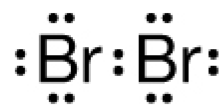
Self-Check

SC 6. Draw the molecular elements chlorine and bromine using Lewis symbols and structural diagrams.

Check your work.

Self-Check Answers

SC 6.

Chlorine	Bromine
	
Cl – Cl	Br – Br

Read

Molecular Compounds

You have seen how molecular elements are formed through the sharing of electrons. The same principles can be used to explain the bonding of different non-metallic atoms. Read "Molecular Compounds" on pages 86 and 87 of your textbook.

From your reading you should be able to explain how the bonding capacity of an atom can be determined from its Lewis diagram. Can you explain how bonding capacity of the atoms involved in a compound will determine the chemical formula for the compound?

Try This

TR 2. Copy into your notebook "Table 1: Bonding Capacities of Some Common Atoms" on page 87 of your textbook. Add rows to your table to provide information for these elements: phosphorous, sulfur, and silicon.

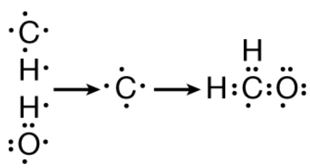
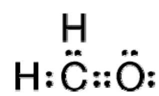
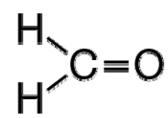
TR 3. Use the information that you just read in the textbook to help you to write steps that describe how to draw Lewis formulas for molecular compounds. Provide an example in your description for a molecular compound. Use examples other than water (H_2O) or carbon dioxide (CO_2).

Watch and Listen

Watch the animation of the preparation of a Lewis formula for carbon dioxide. Use the animation to check the accuracy of the instructions you wrote. To watch the animation, click on Module 2 Page 4 in your Flash Drive.

Example

Draw the Lewis diagram and structural diagram for CH_2O, commonly called formaldehyde.

Steps 1 and 2	Steps 3 and 4	Step 5
		

In Chemistry 20 the discussion of molecular bonding is limited to valence electrons and the assumption that all electrons must be paired. In reality, there are compounds that violate these assumptions, but you are not required to study these exceptions in Chemistry 20.

Self-Check

SC 7. Draw the Lewis formulas and structural diagrams for the following compounds:

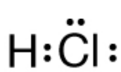
hydrogen chloride (HCl)
methane (CH_4)
hydrogen peroxide (H_2O_2)
methanal (CH_2O)

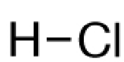
Check your work.

Self-Check Answers

SC 7.

hydrogen chloride





methane

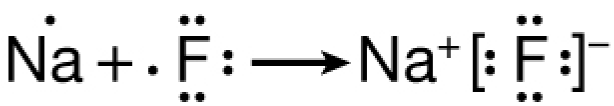
hydrogen peroxide

Methanal

Watch and Listen

Ionic Compounds

Recall from your work in Module 1 that the formation of an ionic compound is a result of the collision between a metal atom and a non-metal atom. This collision results in a transfer of electrons, forming positive and negative ions that have filled energy levels. This transfer is due largely to the difference in electronegativity between the metal and non-metal atoms. The formation of ionic compounds can be represented using Lewis symbols as well. For example, the formation of sodium fluoride can be written as follows:



The formation of an ionic compound, like sodium fluoride, involves a loss of electrons by a metal and a gain of electrons by a non-metal.

The following animation will allow you to see the formation of sodium chloride and magnesium sulfide using Lewis symbols. Notice that magnesium sulfide is MgS rather than Mg_2S_2. Remember that ionic compounds are referred to by their simplest number ratio. To watch the animation, click on Module 2 Page 4 in your Flash Drive.

Reflect and Connect

In this lesson you used Lewis structures and formulas to explain the formation of chemical compounds. Different models of the atom have been used throughout this unit.

Prepare a summary table of the different models of the atom that you have seen so far in this course. For each model, identify what aspects or features of the atom they attempt to represent. Place a copy of your summary in your course folder.

Reflect on the Big Picture

At the beginning of this lesson you considered how the equipment used for outdoor activities, like camping, has changed over the past century. How have other practices or activities changed as a result of chemical technologies that have been developed?

Talk to an elderly relative or visit a museum in your local area to observe medicines, clothing, tools, foods, or another aspect of human activity. Compare the materials used at that time with those used now. You will likely be amazed at the number of chemicals you encounter.

To keep track of your research, prepare a list that includes the name of the chemical involved, the substance it is found in, the purpose of the product, and the function of the chemical in the product. You may also choose to indicate whether a similar product was used by previous generations, and, if so, what substance (or chemical) was used for that purpose.

Save a copy of your list to your course folder. Later in the module you will be come back to this file and continue to work on it.

Module 2: Lesson 1 Assignment

Complete the Module 2 Lesson 1 Assignment according to the pathway you choose.

Lesson Summary

In your study in this lesson you considered the following questions:

- What models are used to describe the bonding between atoms in molecular compounds?
- Can information contained within the periodic table be used to support and explain bonding theories?

In this lesson you learned about Lewis structures and formulas. Lewis formulas are commonly used to represent the bonding between atoms in molecular compounds. In the next lesson you will continue to draw Lewis formulas for compounds and further analyze important aspects of the bonding that exists within molecules.

You may wish to prepare answers to the questions listed above as a way to record what you have learned in this lesson. If you do this, place a copy of your answers in your course folder.

Lesson Glossary

double bond: an attraction between atoms in a molecule due to the sharing of two pairs of electrons in a covalent bond

structural diagram: a visual representation of a chemical compound that shows the relative placement of every atom within the compound, in addition to all intramolecular bonds

Lesson 2—Molecular Shapes and VSEPR Theory

Get Focused

© wojciech wojcik/shutterstock

Summer activities are often disturbed by swarms of bloodthirsty mosquitoes. You may include insect repellent on your equipment list when you go camping or enjoy other outdoor activities. In some parts of the world, mosquitoes spread infectious diseases, such as malaria or the West Nile virus. Recently it was discovered that the West Nile virus has reached Alberta, causing the government to launch a public health campaign to minimize exposure to mosquito bites. One prevention method is to use insect repellent, the most common of which contains DEET.

DEET is used now, but what repellent was used by First Nations people and the early settlers in Alberta? You may have heard about alternative insect repellents, including citronella and carbon dioxide. Are these alternatives, or traditional methods, effective? It might surprise you to find that the effectiveness of insect repellent is partially determined by the shape of molecules like DEET.

Essential Questions

- What is VSEPR theory, and how can it be used to predict molecular shapes?
- Can the structure of simple molecular substances be illustrated by drawing or building models?
- How are models and theories useful in helping to explain the structure and behaviour of matter?

Module 2: Lesson 2 Assignment

You will complete the Module 2 Lesson 2 Assignment at the end of the lesson.

Remember that the questions that are not marked by the teacher provide you with the practice and feedback that you need to successfully complete this course. You should respond to all the questions and place those answers in your course folder.

Explore Read

Read page 91 in your textbook. Copy the five statements on VSEPR theory listed at the bottom of the page. Save a copy of these statements in your course folder. You may wish to refer back to this list as you complete the next activity or later when you are reviewing the material from this lesson.

Try This

Using VSEPR Theory to Predict Molecular Shape

In this activity you will draw Lewis formulas for chemical compounds and then use the information to consider the three-dimensional shape of these molecules.

Step 1: In Chemistry 20 molecule shape focuses on the arrangement of atoms around central atoms. As you will learn in this activity, the presence of bond pairs as well as lone pairs of electrons influences a molecule's shape.

To complete this activity you will need to be familiar with the following electron pair arrangements and the shapes that result.

Linear	Angular	Tetrahedral	Trigonal Pyramidal	Trigonal Planar

Complete the following table as you work through the activity.

Molecule	Lewis Formula	Bond Pairs	Lone Pairs	Total Pairs	Electron Pair Arrangement (shape)	Stereochemical Formula (3-D representation)
beryllium dihydride, BeH_2						
boron trihydride, BH_3						
methane, CH_4						
ammonia, NH_3						
water, H_2O						
hydrogen chloride, HCl						
oxygen, O_2						
nitrogen, N_2						
carbon dioxide, CO_2						

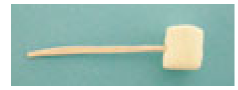
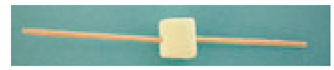
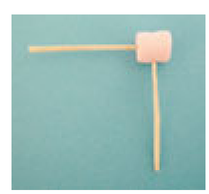
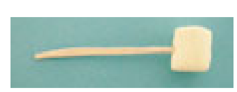
Step 2: In the second column on the table, write the Lewis formula for beryllium dihydride, BeH_2.

Step 3: Use the Lewis formula drawn in step 2 to complete columns 3 through 5.

Step 4: Use the information from the Lewis formula to determine the distribution of electron pairs in three dimensions around the surface of the central atom, Be. A **central atom** is the atom in a molecule that has the most bonding electrons and, therefore, is likely to form the most bonds.

central atom: the atom in a molecule that has the most bonding electrons and, therefore, is likely to form the most bonds

Record your answer in column 6 using a term that describes the shape of the molecule around its central atom. You may wish to use a molecular model kit or other materials to represent the atoms involved. If you are using other materials and need assistance, refer to the following information as needed.

Element	Lewis Formula	Lone Pairs	Bonding Electrons	Attachment Points	Location of Attachment Points
Hydrogen	H·	0	1	1	H– 
Beryllium	·Be·	0	2	2	–Be– 
Boron	·B̈·	0	3	3	–B– 
Carbon	·C̈·	0	4	4	–C– 
Nitrogen	·N̈·	1	3	3	–N– 
Oxygen	·Ö:	2	2	2	–O– 
Halogen (fluorine, chlorine, iodine, bromine)	·F̈:	0	1	1	–F 

Step 5: To view the video BeH_2 to confirm the shape and representation you have determined, click on Module 2 Lesson 2 Page 2 on the Flash Drive. (There is no audio in the video)

Step 6: Draw the stereochemical formula for BeH_2.

Step 7: Repeat steps 2 through 6 for boron trihydride, methane, and ammonia, which are listed in the first column on your table.

To view the video Boron trihydride, BH_3, click on Module 2 Lesson 2 Page 2 on the Flash Drive. (There is no audio in the video)

To view the video Methane, CH_4, click on Module 2 Lesson 2 Page 2 on the Flash Drive. (There is no audio in the video)

To view the video Ammonia, NH_3, click on Module 2 Lesson 2 Page 2 on the Flash Drive. (There is no audio in the video)

Step 8: Read pages 92 and 93 in your textbook. Use the information in the textbook to check the accuracy of your table.

Step 9: Repeat steps 2 through 6 for the remaining substances listed in your table. Use your knowledge of the VSEPR theory to predict the effect that a multiple bond would have on a central atom. To check your work use the information on pages 92 to 95 in your textbook and use the videos listed below for the molecules.

To view the video Water, H_2O, click on Module 2 Lesson 2 Page 2 on the Flash Drive. (There is no audio in the video)

To view the video Hydrogen chloride, HCl, click on Module 2 Lesson 2 Page 2 on the Flash Drive.

To view the video Oxygen, O_2, click on Module 2 Lesson 2 Page 2 on the Flash Drive. (There is no audio in the video)

To view the video Nitrogen, N_2, click on Module 2 Lesson 2 Page 2 on the Flash Drive. (There is no audio in the video)

To view the video Carbon dioxide, CO_2, click on Module 2 Lesson 2 Page 2 on the Flash Drive. (There is no audio in the video)

Self-Check

For each compound, draw the Lewis formula and stereochemical formula. Identify its molecular shape as predicted by the VSEPR theory.

SC 1. SF_2

SC 2. CCl_4

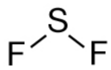
SC 3. PCl_3

SC 4. H_2S

SC 5. BF_3

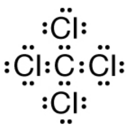
Self-Check Answers

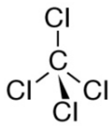
SC 1.



angular

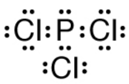
SC 2.

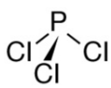




tetrahedral

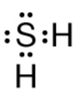
SC 3.

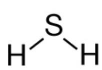




trigonal pyramidal

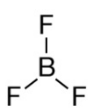
SC 4.





angular

SC 5.



trigonal planar

Reflect and Connect

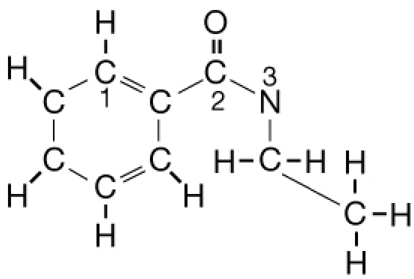
Discuss

Answer one of the following questions. Your answer to the second question will consider the influence that shape has on the function of a molecule.

1. VSEPR is an abbreviation for valence shell electron pair repulsion. Which word, or words, from the title do you feel are most significant in identifying how this theory can be used to predict molecular shapes? Justify your answer.

Before you complete this question, you may wish to take the opportunity to revise your answer by adding detail to the justification you wrote. Place a copy of your completed work in your course folder.

2. Many strategies are used to confuse mosquitoes and prevent their feeding during summer outdoor activities. DEET is a common component of insect repellents. The chemical structure of DEET is shown below.



© Lai Leng Yiap/iStockphoto

   a. Determine the stereochemical shape of the molecule at each of central atoms labelled 1, 2, 3, and 4 in the diagram. If you wish to build a model of the DEET molecule, follow the instructions on the handout "Representing Atoms Using Models" that you printed earlier in the lesson.

   b. DEET is believed to act by confusing a mosquito's sense of smell. Evidence shows that DEET blocks the mosquito's sense receptors that detect the molecule 1-octen-3-ol, which is present in human sweat. If sense receptors rely on molecular shape to be stimulated, comment on the shape of the DEET molecule as compared to 1-octen-3-ol. Suggest how this information could be used to develop other insect repellents.

   Share your answers with your classmates or some other people.

Module 2: Lesson 2 Assignment

Complete the Module 2 Lesson 2 Assignment according to the pathway you choose.

Lesson 3—Molecular Polarity

Get Focused

Mmmm, pancakes. Although pancakes are great to eat, sometimes cooking them can be tricky. Many people like to use non-stick cookware to prevent pancakes and other foods from sticking to the metal surface of their cookware. What is special about the coating that prevents food from sticking? Does this property relate to an aspect of the bonding of the molecules used to make the coating?

Essential Question

- How can you determine the polarity of a molecule by using the shape of its structure and its distribution of charge?

Module 2: Lesson 3 Assignment

You will complete the Module 2 Lesson 3 Assignment at the end of the lesson.

Remember that the questions that are not marked by the teacher provide you with the practice and feedback that you need to successfully complete this course. You should respond to all the questions and place those answers in your course folder.

Explore

In previous science courses you learned about the unique properties of water, including its high surface tension and high boiling point. You may recall hearing that these properties were due to the polarity of the water molecule. How can you test to see if a molecule is polar? Complete the next investigation to find out.

Try This: Bending a Stream of Water

Can you cause a thin stream of water from a tap to bend without actually touching the water?

Materials

- a plastic object (e.g., a bendable plastic ruler, plastic ballpoint stick pen, or comb) or a balloon. The balloon works best, especially when you rub it on your hair.
- a piece of cotton (e.g., a tea towel or cotton shirt) or a piece of fur

Procedure

Step 1: Rub the plastic object with the cotton or fur or rub the balloon in your hair. Make sure you rub vigorously to build up a good static charge on the object.

Step 2: Turn on the tap to allow a thin stream of water to pour out. Kitchen taps work well. The thinner the stream, the more observable the change will be.

Step 3: Bring the plastic object close to, but do not touch, the stream of water. What do you notice? Record your observations.

Step 4: Record your observations when you approach the stream of water with the plastic object from the opposite side.

Step 5: If you have a piece of wool handy, try rubbing it on the plastic object. This will place an opposite charge on the object. Repeat Steps 3 and 4. Record your observations.

Save a copy of your data to your course folder. You may wish to refer to your investigation and your data later in this lesson.

Read

In Lesson 3 of Module 1 you were introduced to electronegativity, the attraction that an atom has for a shared pair of electrons. In that lesson you calculated differences in electronegativity between atoms; and when the difference was large, you classified these bonds as being polar.

You may wish to reread the section titled "Electronegativity and Bond Polarity" on pages 99 and 100 in your textbook.

Your observation of the bending of the stream of water when exposed to a charged object, demonstrates the polarity of the water molecule. Polarity means having two different regions of charge.

As you have seen, it is possible to have a **bond dipole**. A bond dipole is the charge separation that occurs when the electronegativity difference of two bonded atoms shifts the shared electrons, making one end of the bond partially positive and the other partially negative.

bond dipole: the charge separation that occurs when the electronegativity difference of two bonded atoms shifts the shared electrons, making one end of the bond partially positive and the other partially negative

What happens when a molecule is composed of many atoms?

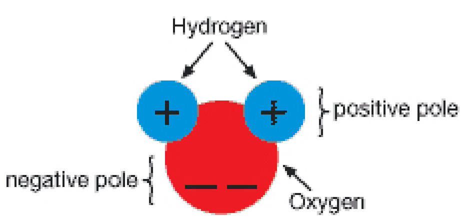
Read the section, "Bond Polarity and Molecular Polarity" on pages 101 and 102 in your textbook. Work through "SAMPLE problem 3.5" on page 102 in your textbook.

Try This:

TR 1. Explain why the stereochemistry (shape) of a molecule needs to be considered when determining if a substance is polar. To support your answer, use one example other than the ones discussed in your textbook. Save a copy of your answer to this question to your course folder. Send a second copy to your teacher.

Water is a **polar molecule**. This means that although water molecules are neutral, the electron charge within the molecule is not symmetrically distributed. The oxygen portion of the water molecule is slightly negative, while the hydrogen portions are slightly positive. Because there is a difference of charge within the molecule, there is a negative pole and a positive pole.

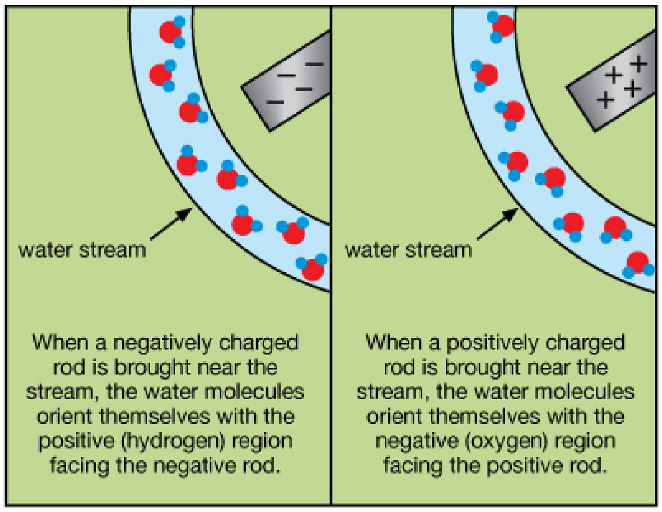
polar molecule: a molecule in which the negative charge is not distributed symmetrically among the atoms, resulting in partial positive and negative charges on opposite ends of the molecule



Notice that the overall charge of the molecule is zero, although the side with the hydrogen atoms is slightly positive and the side with the oxygen atom is slightly negative.

The molecules in liquid form are loosely packed together and are able to rotate. If a negatively charged object is brought close to the water stream, the molecules within the water will orient themselves so that the slightly positive hydrogen atoms will be attracted to the negatively charged object.

Conversely, if a positively charged object is brought close to the stream of water molecules, the molecules will orient themselves so that the slightly negative oxygen atoms are attracted to the positively charged object.



When a negatively charged rod is brought near the stream, the water molecules orient themselves with the positive (hydrogen) region facing the negative rod.

When a positively charged rod is brought near the stream, the water molecules orient themselves with the negative (oxygen) region facing the positive rod.

This action leads to the water being attracted to both types of charges; therefore, the water always bends toward the object. A bond dipole is the charge separation that occurs when the electronegativity difference of two bonded atoms shifts the shared electrons, making one end of the bond partially positive and the other partially negative.

A **nonpolar molecule** has a symmetrical electron distribution—there is no positive pole or negative pole. Diatomic elements, such as fluorine, are nonpolar.

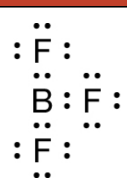
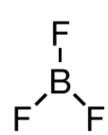
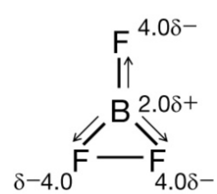
nonpolar molecule: a molecule in which the negative (electron) charge is distributed symmetrically among the atoms making up the molecule

Self-Check

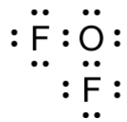
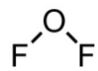
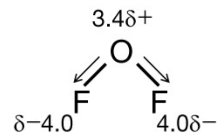
SC 1. Complete question 14 at the top of page 103 in your textbook.

Self-Check Answers

SC 1. 14. a.

Molecule	Lewis Formula	Stereochemical Formula	Stereochemical Formula with Dipoles	Polarity?
BF_3				Nonpolar (bond dipole symmetrical)

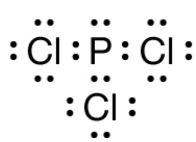
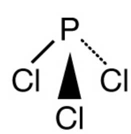
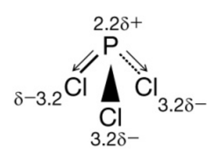
14. b.

Molecule	Lewis Formula	Stereochemical Formula	Stereochemical Formula with Dipoles	Polarity?
O F_2				polar

14. c.

Molecule	Lewis Formula	Stereochemical Formula	Stereochemical Formula with Dipoles	Polarity?
CS_2	:S̈::C::S̈:	S=C=S	2.6 2.6 2.6 S=C=S	nonpolar (no bond dipoles)

14. d.

Molecule	Lewis Formula	Stereochemical Formula	Stereochemical Formula with Dipoles	Polarity?
PCl_3				polar

Self-Check Lab: Evidence for Polar Molecules

In this lesson you learned how to predict if a substance is polar, but are your predictions verified by experiment?

Problem

Which of the liquids have polar molecules?

Part 1: Pre-Lab

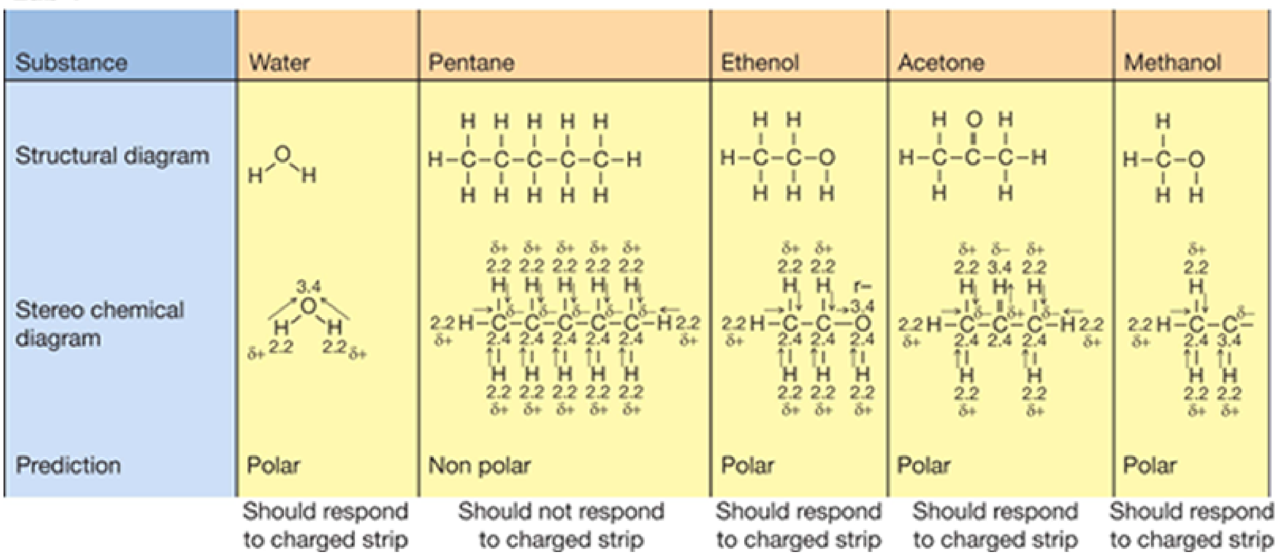
1. Draw structural and stereochemical formulas for each of the molecules in the following table.

Substance	Water	Pentane	Ethanol	Acetone	Methanol
Chemical Formula	H_2O	C_5H_{12}	C_2H_5OH	CH_3CHOCH_3	CH_3OH
Structural Formula					
Stereochemical Formula					

2. Complete an analysis to predict which substances are polar.

Self-Check Answers

Lab 1



Substance	Water	Pentane	Ethenol	Acetone	Methanol
Structural diagram					
Stereo chemical diagram					
Prediction	Polar	Non polar	Polar	Polar	Polar
	Should respond to charged strip	Should not respond to charged strip	Should respond to charged strip	Should respond to charged strip	Should respond to charged strip

Part 2: Virtual Lab
To complete the virtual investigation of the procedure described on page 131 of your textbook, click on Module 2 Lesson 3 Page 4 on your Flash Drive.
Use a table to record your data.

Self-Check Answers

Substance	Water	Pentane	Ethanol	Acetone	Methanol
Response to Acetate Strip	bends	no change	bends	bends	bends
Response to Vinyl Strip	bends	no change	bends	bends	bends

Part 3: Analysis of Data

Answer the following questions. In developing your answers make specific references to your predictions, observations, and other data.

1. Were the predictions you made in Part 1: Pre-Lab above supported by the data collected during your experiment?

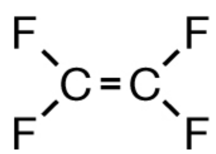
2. Suggest an explanation for any of the discrepancies that were observed.

Your answers may vary, depending on predictions made. If the method for predicting polarity was properly followed, then the investigation had the potential of verifying the predictions made. You should have an explanation for any observed discrepancies.

Save a copy of your work to your course folder.

Reflect and Connect

The molecule used to make the non-stick coating in many types of cookware is shown below. Determine the polarity of this molecule. How does its polarity compare with water?



You may recall that oil and water do not mix. Oils are nonpolar substances, and as you will learn, polarity is an important consideration if you want substances to mix or to go into solution. In the case of cookware, a nonpolar surface provided by the non-stick coating repels water and most of the food particles, preventing their sticking.

Can you predict what might happen to the performance of non-stick cookware if the coating on the surface is scratched?

Reflect on the Big Picture

Knowledge of polar and nonpolar substances is essential in many industries. In the cleaning business, the removal of grease, oil, dirt, and other stains can be facilitated by using a compound with the “correct” polarity.

You may have seen stainfree and wrinkle-free fabrics. Take a look at the clothes that you wear—how many are made from special materials that prevent stains, are wrinkle resistant, are designed to stay dry (remove perspiration), and repel water?

Make a list of the fabrics that are used. Consider whether similar types of materials existed 100 years ago and, if so, what was used?

Briefly explain how polarity is involved in the function of current and past fabrics that were intended to have a function. Place a copy of your answers in your course folder.

Module 2: Lesson 3 Assignment

Complete the Module 2 Lesson 3 Assignment according to the pathway you choose.

Lesson Summary

In this lesson you investigated the following essential question:

- How can you determine the polarity of a molecule by using simple structural shapes and charge distribution?

As part of your study you learned to use electronegativities to determine both bond dipoles, and then to consider the shape of molecules to determine their polarity. You predicted the polarity of different substances and performed an experiment to test your predictions.

Lesson Glossary

bond dipole: the charge separation that occurs when the electronegativity difference of two bonded atoms shifts the shared electrons, making one end of the bond partially positive and the other partially negative

nonpolar molecule: a molecule in which the negative (electron) charge is distributed symmetrically among the atoms making up the molecule

polar molecule: a molecule in which the negative charge is not distributed symmetrically among the atoms, resulting in partial positive and negative charges on opposite ends of the molecule

Lesson 4—Intermolecular Forces

Get Focused

© robcocquyt/shutterstock

Although we cannot see intermolecular forces, they do influence the behaviour of matter. In the previous lesson you observed how the polarity of a molecule can be examined, and you learned that the polarity of compounds is important to their function in a technology like non-stick cookware. It might not seem immediately apparent when your car overheats on a deserted stretch of road, but boiling point is another property of matter that is influenced by intermolecular bonds. You may recall from your driver training course that antifreeze is an important substance that helps to maintain a car's performance. How does antifreeze work?

In this lesson you will learn about different types of intermolecular bonding forces and how they are believed to influence the properties of matter.

Essential Questions

- What are intermolecular forces?
- Are the differences between the melting and boiling points of similar substances explained by differences in their intermolecular forces?
- How does scientific knowledge and theory develop through hypothesis, evidence collection, investigation, and explanation?

Module 2: Lesson 4 Assignment

You will complete the Module 2 Lesson 4 Assignment at the end of the lesson.

Remember that the questions that are not marked by the teacher provide you with the practice and feedback that you need to successfully complete this course. You should respond to all the questions and place those answers in your course folder.

Explore Read

Your study in Module 1 focused on reviewing **intramolecular forces**. In this module you have been learning about **intermolecular forces**.

Read about intermolecular forces on pages 105 and 106 in your textbook.

intermolecular force: attraction and repulsion between molecules

intramolecular force: attraction and repulsion within a molecule; typically covalent bonds

momentary dipole: an uneven distribution of electrons around a molecule, resulting in a temporary charge difference between its ends

Watch and Listen

To view the animation that illustrates the formation of a **momentary dipole** between carbon atoms, click on Module 2 Lesson 4 Page 2 on the Flash Drive. A momentary dipole is an uneven distribution of electrons around a molecule, resulting in a temporary charge difference between its ends.

The predicted existence of momentary dipoles is an important part of the hypothesis supporting the London force. How is it possible for atoms to have momentary dipoles?

To view the animation that illustrates the attractions between polar molecules, click on Module 2 Lesson 4 Page 2 on the Flash Drive. Can you recall what causes molecules to be polar?

Is there a similarity between London forces and dipole-dipole forces?
Make sure you answer these questions as you complete the next activity.

Try This

Construct a table to summarize the differences between intramolecular and intermolecular bonding forces.

In your table provide examples of each type of bonding and a brief description. For each example, indicate factors that will influence the strength of the respective type of bond.

Save your table to your course folder.

Lab: Boiling Points of Hydrocarbons

Background Information

When a substance boils, molecules leave the liquid phase and enter the gaseous phase. In order to make this transition to a higher energy phase, they must have sufficient energy to overcome attractive forces between neighbouring molecules in the liquid phase. It is hypothesized that molecules with greater intermolecular forces have higher boiling temperatures.

Purpose

The purpose of this investigation is to test the hypothesis relating boiling temperature to strength of intermolecular forces.

Problem

Do molecules with larger intermolecular forces have higher boiling temperatures?

Procedure

Step 1: Open the learning object, Boiling Points of Hydrocarbons, by clicking on Module 2 Lesson 4 Page 3.

Step 2: Follow the instructions shown in the learning object.

Record your observations in question 1 in the Module 2 Lesson 4 Assignment according to the pathway you choose.

Module 2: Lesson 4 Assignment

Complete questions 2 and 3 in the Module 2 Lesson 4 Assignment according to the pathway you choose.

Read

Read “Using Dipole-Dipole and London Forces to Predict Boiling Points” on pages 107 and 108 in your textbook.

Self-Check

After reading this section, answer the following questions.

1. Does the data shown in "Table 1" on page 107 support the hypothesis relating number of electrons and boiling point? Explain your reasoning.

2. State the name of the type of intermolecular bonding force that is influenced by number of electrons.

3. Was the comparison between hydrocarbons in the lab, Boiling Points of Hydrocarbons, a valid set of compounds to examine to study this type of relationship? Support your answer by making specific reference to the structure and polarity of the compounds involved.

Check your work.

Self-Check Answers

1. Yes, as the number of electrons increases, the respective compounds have higher boiling points.

2. London forces

3. Yes, all of the hydrocarbons studied in the boiling point lab were nonpolar and have the same stereochemical shape around each central atom. The only difference between the molecules studies was their length. (number of atoms, and in turn, the number of electrons)

Self-Check

SC 1. Complete "Practice" problem 1 on page 109 of your textbook.

SC 2. Complete "Practice" problem 2 on page 109 of your textbook.

SC 3. Complete "Practice" problem 3 on page 109 of your textbook.

SC 4. Complete "Practice" problem 4 on page 109 of your textbook.

Check your work.

Self-Check Answers

SC 1.

a) London, dipole-dipole (Water is a polar substance.)
b) London
c) London
d) London, dipole-dipole (Ethanol is a polar substance.)
e) London, dipole-dipole (Ammonia is a polar substance.)
f) London

SC 2.

a. hydrogen fluoride. The difference in electronegativity between H and F is greater than the difference between H and Cl, resulting in stronger bond dipoles.

b. CH_3Cl. The bond dipole between C and Cl is greater than C and I.

c. Ammonia, NH_3. The bond dipole between N and H is greater than N and Br.

d. Water. The bond dipole between H and O is greater than H and S.

SC 3.

a.

Compound	Number of Electrons
methane	10
ethane	18

Ethane will have stronger London forces since it has the greater number of electrons.

b.

Compound	Number of Electrons
oxygen	16
nitrogen	14

Oxygen will have stronger London forces since it has the greater number of electrons.

c.

Compound	Number of Electrons
sulfur dioxide	32
nitrogen dioxide	23

Sulfur dioxide will have stronger London forces since it has the greater number of electrons.

d.

Compound	Number of Electrons
methane	10
ammonia	10

The two compounds being compared are isoelectronic; therefore, if the London force is the only intermolecular bonding force, then they should have the same boiling point.
SC 4.

a.

Compound	Number of Electrons	Stereochemical Shape	Polar
boron trifluoride	32	trigonal planar	no
nitrogen trifluoride	34	trigonal pyramidal	yes

Nitrogen trifluoride would have the higher boiling point since it has the larger number of electrons; therefore, has stronger London forces, is polar, and will have additional dipole-dipole forces.

Boron trifluoride is nonpolar, has only London forces, and has fewer electrons; therefore, it has relatively weaker attractive forces.

b.

Compound	Number of Electrons	Stereochemical Shape	Polar
chloromethane, CH_3Cl	26	tetrahedral	yes
ethane, C_2H_6	18	tetrahedral	nonpolar

Chloromethane would have the higher boiling point of the two compounds but stronger London forces and dipole-dipole forces due to its polarity.

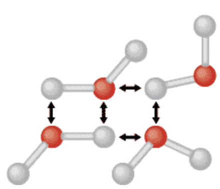
Module 2: Lesson 4 Assignment

Continue working on Module 2 Assignment 4 by completing questions 4 and 5.

Read

Can you think of a reason why the boiling points of some compounds cannot be explained using the hypothesis for London and dipole-dipole forces? Maybe another type of intermolecular bonding force exists.

Read "Hydrogen Bonding" on pages 111 and 112 in your textbook.



Watch and Listen

To view the animation of the hydrogen bonding in ammonia, click on Module 2 Lesson 4 Page 5 on your Flash Drive.

Use a diagram of your choice to explain why hydrogen atoms become attracted to neighbouring nitrogen atoms in ammonia.

The boiling points of water, ammonia, and hydrogen fluoride demonstrate that the hydrogen bonding is stronger than other dipole-dipole forces.

Self-Check

SC 5. Complete the following table. The first row has been done for you.

Molecule	Structural Formula	Shape	Polarity	Types of Intermolecular Forces
HBr	H–Br	linear	polar	dipole-dipole
HF				
AsH_3				
BF_3				
HI				

Self-Check Answers

SC 5.

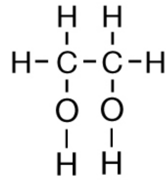
Molecule	Structural Formula	Shape	Polarity	Types of Intermolecular Forces
HBr	H–Br	linear	polar	dipole-dipole
HF	**H–F**	**linear**	**polar**	**hydrogen bonding**
AsH_3	**H – As – H | H**	**trigonal pyramidal**	**polar**	**dipole-dipole**
BF_3	**F – B – F | F**	**trigonal planar**	**nonpolar**	**London**
HI	**H–I**	**linear**	**polar**	**dipole-dipole**

Read

Read “Physical Properties of Liquids” on page 113 of your textbook.

Reflect and Connect

At the beginning of this lesson, you considered the function of antifreeze in an automobile engine. Engine coolants often contain alcohol compounds like ethane-1,2-diol, pictured here.



An antifreeze, or engine coolant, is responsible for transferring heat from the engine by circulating it through the radiator. Antifreeze is a solution containing mainly water and the coolant molecule. The boiling point of antifreeze is much higher than pure water. Knowing what you do about chemical structures and intermolecular bonds, can you suggest a reason?

Going Beyond

You may be interested in cloud seeding—a process that takes place in Alberta, particularly in the corridor between Red Deer and Calgary. For more information read "Web Quest—Cloud Seeding" on page 112 of your textbook.

You may also be interested in the case study "Current Research on Intermolecular Forces" on pages 114 and 115 of your textbook. This case study examines the work of Canadian scientist Dr. Robert J. Le Roy.

Module 2: Lesson 4 Assignment

Continue working on Module 2 Assignment 4 by completing the rest of the questions.

Lesson Summary

In this lesson you focused on the following essential questions:

- What are intermolecular forces?
- Are the differences between the melting and boiling points of similar substances explained by differences in their intermolecular forces?
- How does scientific knowledge and theory develop through hypothesis, evidence collection, investigation, and explanation?

Throughout your work in this lesson, you focused on boiling points and empirical data, and you developed a conceptual understanding of how intermolecular bonding forces could be responsible for the phenomena observed.

The melting and boiling points of a substance are related to the strength of intermolecular forces between the molecules of that substance. Higher melting and boiling points indicate stronger intermolecular forces. With an increase in the overall size of the molecule, there is an associated increase in the number of electrons. This increase, too, will increase the strength of intermolecular bonds and lead to higher melting points and boiling points.

You also examined some of the physical properties of liquids, focusing on solubility, surface tension, cohesion and adhesion, volatility, and density and how these could be explained by the intermolecular forces you learned about in this lesson.

Lesson Glossary

intermolecular force: the relatively weak forces of attraction and repulsion between molecules

intramolecular force: the relatively strong bonds or forces of attraction and repulsion within a molecule; typically covalent bonds

momentary dipole: an uneven distribution of electrons around a molecule, resulting in a temporary charge difference between its ends

Module Summary

As you worked through this module, you kept the following questions in mind. Did your studies help you answer these questions?

- What are the roles of modelling, evidence, and theory in explaining and understanding the structure, bonding, and properties of molecular compounds?
- Why do substances have different melting and boiling points?
- How can principles of bonding in matter be used to develop unique materials?

Throughout your study in this module you learned about many technologies involving molecular compounds and about how the bonding of these compounds can be used to make materials useful to you. Chemical principles you studied include electronegativity, bond polarity, VSEPR theory, stereochemistry, molecular polarity, and different types of intermolecular bonding forces including London, dipole-dipole, and hydrogen bonds.

Module Assessment

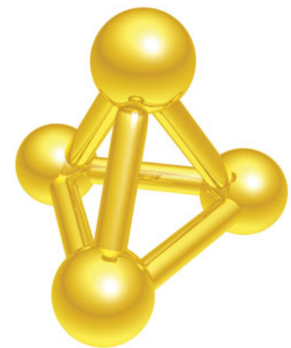
The assessment in this module consisted of four (4) assignments.

- Module 2 Lesson 1 Assignment **16 marks**
- Module 2 Lesson 2 Assignment **26 marks**
- Module 2 Lesson 3 Assignment **8 marks**
- Module 1 Lesson 4 Assignment **19 marks**

As you completed the assignments, you have also considered some of the larger questions regarding the application of principles of bonding to technologies used throughout history.

Unit Conclusion

In this unit you have studied many theories relating to the structure and organization of matter. You have learned that electrostatic attraction between oppositely charges particles is an important force used in the organization of subatomic particles that make up atoms. Electrostatics is also involved when atoms are together in a system.
You also studied chemical technologies and how the principles of atomic structure and bonding apply to their performance and development.



©AlexandrShebanov/shutterstock

Throughout your study in this unit, you have seen how these theories have been used to explain observable properties of matter. You have considered the differences in boiling points, as one property, as well as others.

You have learned that the study of chemical bonding is not complete, and that new areas, including nanotechnology, require constant collection and interpretation of data to understand how matter will behave at the atomic level and in larger samples.

Unit Assessment

The last assessment of this unit is a unit test. Your work on the assignments has prepared you to complete the Unit A Test. When you have finished reviewing all of the marked assignments for this unit, phone or email your lead teacher to get the password to the unit test. If you have not had all of your assignments in this unit marked, you will not be given the password.