Chapter 6

Chapter Organizer

The Shape of Things Chapter 6

ENGAGE—Water Bending?
Key Idea: It seems odd that water bends toward both positive and negative objects

Linking Question: How can students begin to figure out trends in molecular shapes?

EXPLORE — Trends in Molecular Shape
Key Idea: Molecular shape is predictable based on bonding and non-bonding electrons.

Linking Question: How does shape and charge for molecules affect properties?

EXPLAIN—Polar Molecules
Key Ideas: Electronegativity and symmetry play a role in molecular behavior.

Linking Question: Can students use shape and charge to predict which gases are greenhouse gases?

ELABORATE— Shape, Charge, and Greenhouse Gases
Key Idea: IR activity (greenhouse gases) depends of atom-to-atom dipoles.

Linking Question: Can students demonstrate knowledge by evaluating a tutorial video?

EVALUATE— Video Feedback
Key Idea: It is possible to demonstrate knowledge by evaluating someone else's work.

Learning Goals for Chapter 6

Use 2-dimensional (Lewis dot) and 3-dimensional (VSEPR) models to predict molecular shape.

Use periodic table and electronegativity to determine dipole (between atoms and overall molecule).

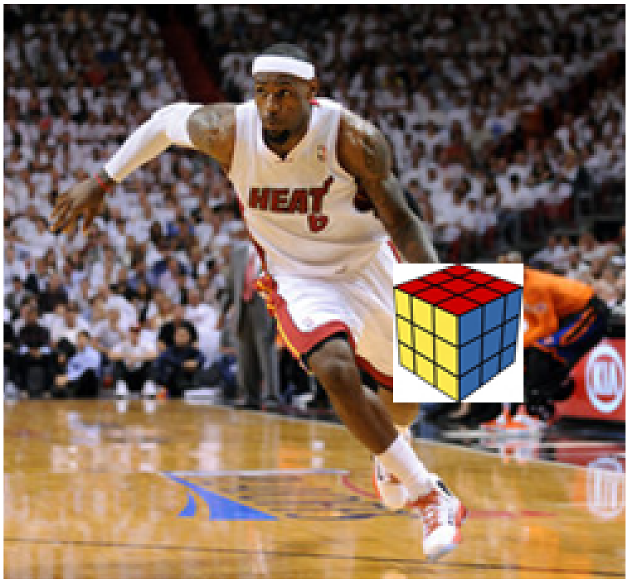
Apply knowledge of shape and dipole to determine is a gas is a greenhouse gas.

Engage

Water Bending?

Introduction

You really know a lot about atoms and molecules. You know they are held together by forces of attraction called chemical bonds. These various types of bonds result in properties like conductivity, solubility, hardness, and melting point. But there's more! It turns out that molecules are not just spheres like atoms are. They have interesting shapes. And those shapes, along with the type of bond, result in even more fascinating and useful properties. That is, shape matters!



In this Engage lesson, Water Bending? you will observe water behaving strangely. After you see what happens, you may want to ask yourself, "Why does water behave this way. Why does water behave this way? What charge do water molecules have? Does the shape of a water molecule have anything to do with its behavior? You will try to answer these questions in the next several lessons.

Caption: Imagine trying to dribble a cube. It sounds silly. But the idea is important at the molecular level, too. The shape of molecules matters.

But first, let's bend water!

Process and Procedure

Your teacher will perform a demonstration, using everyday materials like glass, balloons, cloth, and paper. The demonstration device your teacher will use is called an electroscope. It can test the type of charge on an object—either positive or negative. Place all observations in your science notebook under the heading, "Engage: Water Bends?"

Chapter 6

Materials	Cautions
for teacher ● Electroscope ● Flat-bottomed glass flask ● Balloon ● Paper towel or silk ● Head of hair	

Part A: Two-charges Demonstration

1. After the electroscope demonstration, record evidence that helps you answer this question: Are the charges on a balloon and a glass flask the *same* or *different*? The sentences below can help you get started. Answers for Part A will go in your textbook.

- I think the charges on a balloon and a glass flask are (different or same). Circle your answer.
- I say this because of what the electroscope does. When the teacher charges the electroscope with a balloon, the electroscope has a balloon charge on it. The glass flask makes the electroscope… (describe or sketch what electroscope does).

- This means that the balloon and glass flask have (opposite or the same) charges. Circle your answer.
- If balloon and glass have the same charge, then the electroscope would (describe or sketch what the electroscope would do).

Part B: Two-charges and a Trickle of Water

Materials	Safety
for each team of four students • 50 mL burette • Ring stand • Burette clamp • Water • 250 mL beaker • Balloon • Paper towel • 250 mL Erlenmeyer flask	

Safety

Every investigation begins with safety. Your wellbeing is important. That's why determining and preparing for any safety issues is up front in all laboratory investigations. Read and perform the safety steps below.

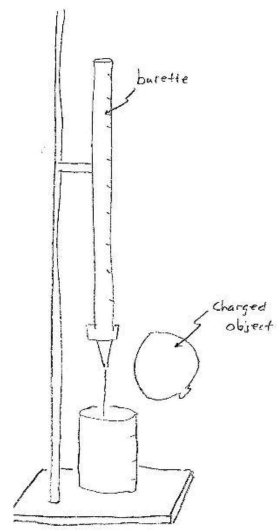
a. Read procedural steps 1 through 4 below. Think about safety issues as you read.
b. Complete the following table in your textbook.

Hazard	Precaution	Emergency Procedure
What could go wrong in this experience? What is the worst thing that could happen?	*What can you do to prepare and to prevent the hazards? What protective equipment could you use?*	*What emergency procedure(s) will you utilize to minimize harm if a problem happens?*

Chapter 6

1. *2.* *3.*	*1.* *2.* *3.*	*1.* *2.* *3.*

1. Set up a burette filled with water, so a trickle of water from the burette drains slowly into a beaker. A sketch is shown on the right.



2. Create a table similar to the one below in your notebook. You will complete the right side *after* Step 3. Sketch what you see when you slowly bring a charged balloon close to a trickle of water. Here's a reminder of what your teacher did to charge the balloon.

- Balloon: rub the balloon on your hair or clothing.

Water trickle and "balloon" charge	Water trickle and "glass" charge
Place your sketch here. Be certain that your sketch shows: • *charged object* • *direction of bend*	*Complete this side of the table **AFTER** you predict what will happen with charged glass.*

3. Predict as a team what will happen when charged glass is brought close to a trickle of water. Be certain to use the idea of electrical charge in your prediction.
4. Test your prediction. Bring a charged glass close to a trickle of water. Sketch your results in your observation table from Step 2. Here's a reminder of how to charge glass.

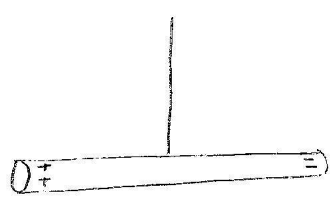
- Glass: rub the glass on a dry paper towel or on silk.

5. Discuss the results with your team. Talk about any surprises you observed. Complete ***one*** of the following statements in your notebook:
    a. I was surprised when the trickle of water bent (toward or away from) the charged glass. I expected the trickle of water to ________________________________.
    b. I was not surprised when the trickle of water bent (toward or away from) the charged glass. I expected water to do this because ________________________________.

Reflect and Connect

Your teacher will let you know how to record your answers to the following questions.

1. Think of things in your everyday life that have electrical charge. Write as many of these things down as you can. By each one, tell how you know it is charged.
2. Draw two sketches. One sketch should show a plastic rod with negative charges and the other sketch should show a square of wool cloth with positive charges. Draw how a trickle of water would behave as it flows past these two types of charges.
3. The sketch below shows a rod hanging from a string. The rod can hold a charge for several minutes. It rotates easily. Notice that the rod has a positive end and a negative end. Sketch what happens when you slowly bring the following objects near the rod:
    a. Charged glass
    b. Charged balloon



4. Write down the questions you still have about water and how it behaves when it flows past oppositely charged objects. Some starter questions are below:
    a. Why does water bend toward both _______________?
    b. What is it about a water molecule that makes it _____?
    c. *Add more of your questions here.*
5. Thinking back over the activities and learning from this section, what activities from the "How Science Works" chart did you engage in?

End of Engage lesson.

Explore

Trends in Molecular Shapes

Introduction

What makes water bend toward *both* negative and positive charges? Is it only because water has a particular charge? That can't be the only reason. If so, water would bend toward one charge or the other, but not both. It turns out that the shape of water molecules influences the way water behaves—the way it functions. But this idea of form or shape having a lot to do with its function is not new to you. You see it every day!

Caption: Dandelion seeds have a shape. That is a big part of how they function. Park benches have a shape. That shape makes them function as a place for us to sit. Gears in a car transmission are shaped for a specific purpose—to make the car move in a certain way. Yes, you already know that form and function have a lot to do with each other.

In this Explore lesson, *Trends in Molecular Shapes*, you will investigate the shapes of several compounds. You'll use a variety of ways to represent the shape of these microscopic particles. Along the way, you will use prior knowledge of the periodic table. Your goal is to predict molecular shapes with models. Then you will come up with general rules for predicting shapes.

Materials

For each team of 4 students:

- Molecular model kits
- Periodic table

Process and Procedure

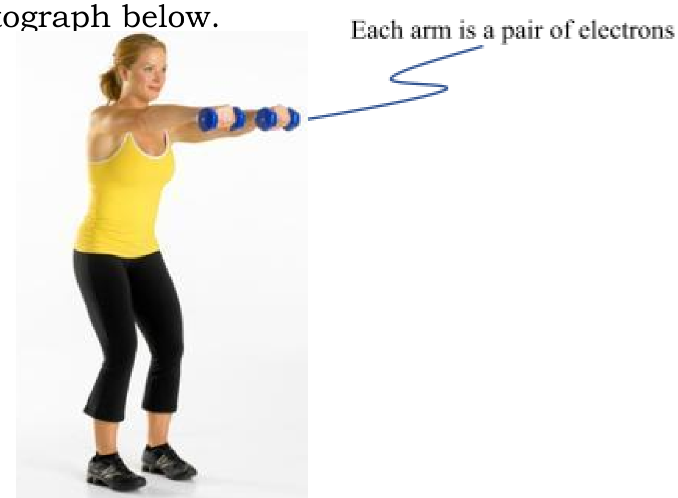
You will work in teams and individually. Always contribute your best thinking to teamwork. Place all your work for this lesson under the title "Explore: Trends in Molecular Shapes" in your notebook.

Part A: Arm and Leg simulation

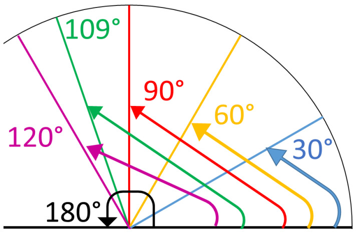
Background knowledge

You learned in Chapter 5 that valence electrons are shared in covalent bonds—sometimes equally, sometimes unequally. It is convenient to think of a covalent bond as a pair of valence electrons. When two atoms share a pair of electrons, there is a covalent bond between them. As you might expect, the location of these bonds tells us a lot about the shape of molecules. You can simulate the shape of molecules by using your arms as pairs of electrons.

1. Imagine each of your arms being a covalent bond. That means each arm will be a pair of valence electrons. Simulate what bonds do to form the shape of a molecule. You will follow the details in Steps 1a-d below.
    a. Stand with your team and hold your arms out in front of you. Your elbows almost touch as in the photograph below.



    b. Confirm with team mates whether your "electron pairs" repel or attract.



c. Imagine your "bonds" being able to move freely. As a team, simulate what electron pairs will do when allowed to move freely. You will have to move your arms (without hitting anyone else).

d. Make a sketch in your notebook of the arm positions now. Estimate the angle between the two arms. Label this angle in your sketch.

2. Complete the following statements in your textbook. They help you summarize this simulation.

   a. Each of my arms represents a(n)______________________.

   b. Electrons have a ________________ electrical charge.

   c. ________________ repel until they are as far away from each other as possible.

   d. When two pairs of electrons are ___________ degrees apart, they are the maximum distance from each other.

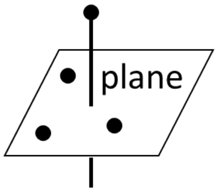
3. Work with your team to simulate more than one bonding pair of electrons. In each case below, begin with your bonding pair of electrons close together. Then move them slowly until they are as far apart as possible in three-dimensional space. You can stand back-to-back as an option.

   a. Three bonding pairs. You will have to use more than two arms in your simulation.

   b. Four bonding pairs.

   c. Make a sketch for each simulation in 3a and 3b. Label them in your notebook.

4. Answer these questions in your notebook. Your answers help you make sense of and remember the main ideas of your simulation.



   a. Do your bonding pairs lie in a plane (as on a flat piece of paper)? Answer this for two, three, and four electron pairs. Make a sketch for each case to support your answer. Your teacher will help you draw a plane to get started.

   b. Estimate the angle between bonding electrons in 4a above. Label this angle on your sketches in 4a.

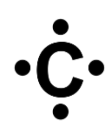
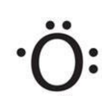
Chapter 6

Part B: Predicting Molecular Shapes

Background knowledge: Lewis dot models

Pairs of electrons repel each other. This results in molecular shape. And shape has a lot to do with properties like "bending" water. Chemists use models instead of their arms and legs to keep track of electron pairs and bonds. You will learn about two kinds of models.

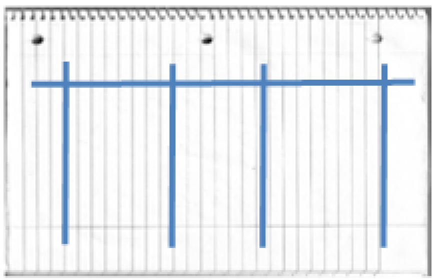
One common model shows molecules in two-dimensions. It is called the Lewis dot structure. In this model, dots (•) represent valence electrons. Lewis dot models only show valence electrons. You learned in Chapter 2 about the maximum number of valence electrons. It's eight because that's how many valence electrons there are in noble gases. (Remember, that elements in the first row of the periodic table have a maximum of two valence electrons). Below are a few examples. Get out your periodic table and find each element listed below.

Element	Group on Periodic Table	Lewis Dot Model
beryllium	2	
carbon	14	
oxygen	16	

A second type of model uses three-dimensional objects. Spherical objects represent atoms. Different colors usually mean they come from different groups on the periodic table. Holes represent the place where bonding takes place. Gray pieces represent bonds.

Look at the images of nitrogen and boron below. These images give you an idea of what to look for.

1. You will model several compounds. Record your work in your notebook. Use a table like the one below. Leave at least one full page for the table. Orient your table "sideways" (landscape format). These next steps will help you.



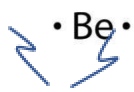
Caption: This is a notebook in landscape orientation. Use the headings from the table in Step 1a to organize your table.

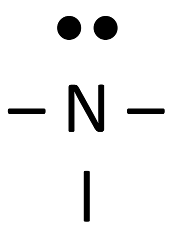
a. Copy this table in your notebook. It will look like the figure to the left. Leave lots of space for each row. You will have five rows.
Note: You will complete the table *slowly* with help from your teacher and by working with your team. Step 1b below helps you get started with a completed row.

Name (formula)	Information from Periodic Table	2-dimensional (Lewis dot)	3-dimensional (Model Kit)	Shape
Beryllium hydride BeH_2				
5 rows in total *Wait until you are finished with one row before you start the next one.*				

b. Place the molecular covalent compound beryllium hydride (BeH_2) in the first row. An example first row is below. Use knowledge from the periodic table and your "arm and leg" simulation to fill in as many blanks as possible in the first row.

Chapter 6

Name (formula)	Information from Periodic Table	2-dimensional (Lewis dot)	3-dimensional (Model Kit)	Shape
beryllium hydride (BeH_2)	Be has ________ valence electrons. Each H has _____ valence electrons There are ______ bonds. There are 0 pairs of non-bonding electrons.	 *(place two hydrogen atoms with valence electrons in model)*	*(use model kit to "build" BeH_2 with two bonds; sketch the molecule; label bond angle on sketch)*	*Use everyday terms like "in a line", or "like a triangle". Your teacher will tell you the formal names later.*



c. Use boron hydride (BH_3) in the second row. Use the first row to guide you. Work with your team to complete each cell in the row. Don't forget to use the "arm and leg" simulation, too.
d. Use methane (CH_4) for the third row.
e. Use ammonia (NH_3) for the third row. Ammonia is different. It has three pairs of electrons involved in bonds between nitrogen and hydrogen. It has one pair of electrons that is not involved in bonding. This pair is called a "lone pair" of electrons. You represent it like this (••) in a 2-dimensional model.
f. Use water (H_2O) for the last row. Be careful. Non-bonding electron pairs repel each other, too. You can use *both* arms and *both* legs to represent all the pairs of electrons.

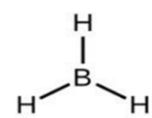
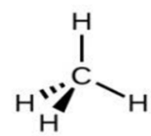
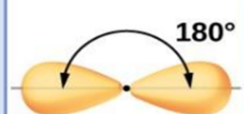
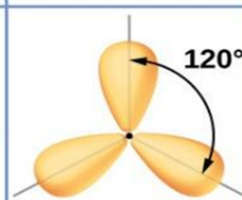
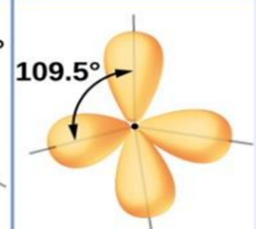
2. Talk with one other team to check your completed table. Resolve any differences by referring to the models you built or to the "arm and leg" simulation.
3. Your teacher will tell you the formal science terms for each shape. Write these names in the correct table cell. Your teacher will also confirm the correct bond angle for each molecule.
4. Practice making the 2-dimensional and 3-dimensional models of the following compounds. Sketch your answers in your notebook.
    a. Carbon tetrachloride (CCl_4)
    b. Hydrogen gas (H_2)

c. Boron trifluoride (BF_3)
d. Beryllium difluoride (BeF_2)
e. Phosphine (PH_3)
f. Ammonium ion (NH_4^+)

Part C: Trends in Molecular Shapes

Background knowledge

Molecular geometry depends on electron pairs repelling. For 2, 3 or 4 pairs of electrons, each has 1 arrangement where electrons are farthest apart. The sketch below helps you visualize these arrangements and resulting angles.

Electon Pair Geometry	Linear; 180 angle	Trigonal planar; all angles 120	Tetrahedral; all angles 109.5
Line-dash-wedge notation			
Spatial arrangement			
Number of regions	Two regions of high electron density (bonds and/or unshared pairs)	Three regions of high electron density (bonds and/or unshared pairs)	Four regions of high electron density (bonds and/or unshared pairs)

Non-bonding electron pairs influence shape. That's because they repel, too. Non-bonding pairs of electrons depress or "squeeze" the bond angle of bonding electrons. That's what makes water a bent shape. The bond angle in water is a little more than 104 degrees. This is less than the expected 109 degrees associated with four pairs of electrons.

1. Confer with your team to write three general trends used to predict molecular shape. To help, the main ideas are listed below. You can make a rule for each idea or combine ideas.
    a. Electron pairs repel.
    b. Electron pairs get as far from each other as possible.
    c. Both bonding and non-bonding pairs influence shape.
    d. The greatest angle among four pair is slightly greater than 109 degrees.
    e. Non-bonding electron pairs (lone pair) decrease the 109-degree angle if there are four pair of electrons.
2. Meet with another team. Discuss both sets of rules. Try to reduce the number of rules to the fewest possible and still account for all the ideas. Record your final set of rules in your notebook.

Reflect and Connect

Work with your teacher to decide how and where you will answer these questions.

1. Look back at the basketball player shown in the beginning of your Engage lesson. He was dribbling a cube-shaped basketball. How silly! Shape matters. Think of as many examples in your everyday life as possible of when shape matters. At the end of your list, tell why you think shape matters in microscopic objects like molecules.

2. Octopuses live in San Francisco Bay. They have eight legs (like 8 electrons). Draw an octopus simulating the following molecules: methane, ammonia, water.

3. Use a search engine to look up synonyms of lopsided. Synonyms are words with similar meaning. Use at least

three of these words to describe a water molecule. Write your sentence in your notebook.

4. What do you think it is about the shape of water that makes it bend toward a positive object as well as a negative object? Show your idea in a sketch with a stream of water molecules.
5. Thinking back over the activities and learning from this section, what activities from the "How Science Works" chart did you engage in?

End of Explore lesson.

Chapter 6

Explain

Polar Molecules

Introduction

You have knowledge. You know that molecular shape depends on electrons repelling. That seems reasonable. After all, negative charges repel each other. This results in electron pairs getting as far from each other as possible in 3-dimensional space. Charge is important, too. When molecules have charge, there is a force of attraction to other molecules. This force of attraction leads to interesting behavior, like the water you see "overfilling" the glass below.

Caption: You've seen this before. Water can overfill a glass without spilling. How does that happen? What is true about the water molecules that results in this effect? What would happen if you tried the same thing with rubbing alcohol?

In this Explain lesson, *Polar Molecules*, you will learn how to determine which atoms in a bond attract electrons the strongest. When you combine this knowledge with shape, you will explain interesting properties of several important compounds.

Process and Procedure

Place the title "Explain: Polar Molecules" at the top of a new page in your notebook. Place all your work for this lesson under this title.

Part A: Electronegativity and Polar Molecules

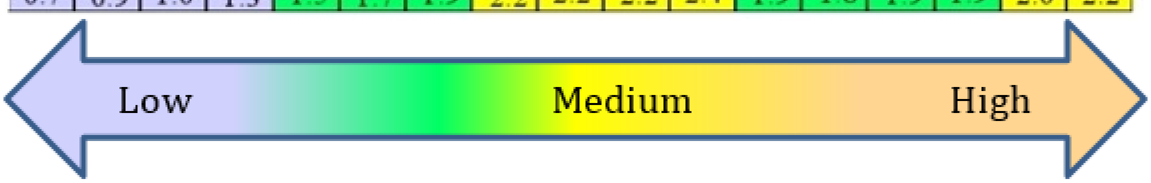
Background knowledge: Electronegativity

You know from the Explore lesson that water molecules have a bent shape. You also know that somehow water has electric charge associated with it. is charged. That's because a trickle of water attracts to charged objects. But why does it have a charge? It has to do with the ability of elements to attract electrons, specifically valence electrons. This ability to attract valence electrons is called electronegativity. The electronegativity scale goes from 0 to 4. Here's a graphic to help you remember.

	Electronegativity Scale	
Low electronegativity (weak attraction for valence electrons)	0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0	High electronegativity (strong attraction for valence electrons)
Example elements	Cs Fe O	
Section of periodic table	far left metals; middle transition metals; far right nonmetals (not noble gases)	

Here's the entire periodic table. Look for metals, nonmetals, transition metals, and noble gases.

1A	2A	3B	4B	5B	6B	7B	8B	8B	8B	1B	2B	3A	4A	5A	6A	7A
H 2.1																
Li 1.0	Be 1.5											B 2.0	C 2.5	N 3.0	O 3.5	F 4.0
Na 0.9	Mg 1.2											Al 1.5	Si 1.8	P 2.1	S 2.5	Cl 3.0
K 0.8	Ca 1.0	Sc 1.3	Ti 1.5	V 1.6	Cr 1.6	Mn 1.5	Fe 1.8	Co 1.9	Ni 1.9	Cu 1.9	Zn 1.6	Ga 1.6	Ge 1.8	As 2.0	Se 2.4	Br 2.8
Rb 0.8	Sr 1.0	Y 1.2	Zr 1.4	Nb 1.6	Mo 1.8	Tc 1.9	Ru 2.2	Rh 2.2	Pd 2.2	Ag 1.9	Cd 1.7	In 1.7	Sn 1.8	Sb 1.9	Te 2.1	I 2.5
Cs 0.7	Ba 0.9	La 1.0	Hf 1.3	Ta 1.5	W 1.7	Re 1.9	Os 2.2	Ir 2.2	Pt 2.2	Au 2.4	Hg 1.9	Tl 1.8	Pb 1.9	Bi 1.9	Po 2.0	At 2.2

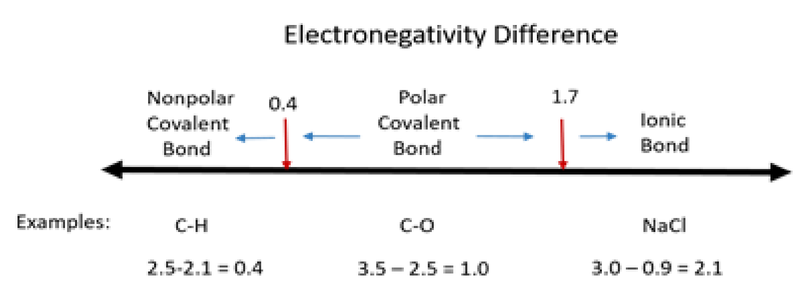


Chapter 6

When the difference in electronegativity between two atoms is small, the molecule often forms a molecular covalent substance. You saw molecular covalent compounds in Chapter 5 when you sorted sucrose and ethanol into one group. Oxygen gas and methane are also examples. These substances have low melting points, do not conduct electricity, and have low or slight solubility in water. They are formed by nonmetals.

When the electronegativity difference is large, the substance forms an ionic material. Sodium chloride is an example. These substances have high melting points, dissolve in water, and conduct electricity both as a liquid and when dissolved. When the electronegativity difference between atoms in a bond is between these two extremes, a different type of bond results. It's called a polar covalent bond.

1. Work as a team to make sense of the graphic below. Sketch it in your notebook. Demonstrate your ability to make sense by *listing three more example bonds under each section.* Use the electronegativity values from the background knowledge section above.



Place three examples here.

Electrons spend equal time around each atom	Electrons spend more time around atom with highest electronegativity.	Electrons spend most of the time around high electronegativity atom.

2. Think about *one* hydrogen-oxygen bond in water. Look

O – H

at the sketch of it in the margin.

a. Label the electronegativity of each atom (in your book).
b. Invent a way to show in the sketch where electrons spend most of their time in this bond.
c. Draw an arrow from the center of hydrogen to the center of oxygen. Place a big plus sign on the end of the arrow you think is the positive end of this bond. Place a big negative sign on the end you think is negative. Label this arrow "dipole".

3. Read these facts about dipoles, then do tasks 3a through 3c. For each fact, sketch a tug-of-war to help you visualize the fact.
   - Dipoles result from a physical separation of charge.
   - Dipoles can work against each other. This cancels any permanent charge for the full molecule.
   - Dipoles can work together. This makes a permanent, overall dipole. That means the molecule has a plus part and a minus part.

These molecules are called *polar* molecules.

a. Sketch BeH_2 and H_2O next to each other in your notebook. Leave plenty of white space around each sketch. Look back to the Explore lesson, Step 1b. Use your 3-dimensional drawing from that step.
b. Work with your team to decide which molecule has a permanent dipole *for the entire molecule.* To support your answer, draw a dipole arrow for each bond then draw an overall dipole for the entire molecule.
c. Write a caption under your sketches that explains your answer. Here is one way to start your caption:
   I think that _______________ is the molecule with the permanent dipole. I say this because _____________.

4. Look at your sketches from the Engage activity (Part 2, Step 2). Make sure each team member does the same. You are about to explain what you saw.
   Note: Remember that a trickle of water bent toward

both a negative and positive charge. Here's what you do.

a. Similar to Engage Part B, Step 2, draw two sketches side by side. One sketch involves the balloon and the other sketch involves the glass. Use at least a half page. Show the burette and charged object in both sketches.
b. Make the trickle of water look like individual water molecules coming out of the burette. Your water molecules must show what you think is happening with charge.
c. Remind each other that water is a liquid at room temperature. That means it can rotate freely in response to charged objects.
d. Work as a team to write a caption to place directly under your sketches. Your caption will explain the "bending water" results. Use these words in your caption: polar, dipole, permanent, rotate, do not cancel, and overall.

Stop and Think: Part A

Write answers to the following questions in your notebook under the heading, "Explain: Stop and Think: Part 1" These questions help determine how you are doing.

1. Draw the 3-dimensional model for the molecules listed here. On each model, draw arrows to represent dipoles. Indicate the electronegativity of each atom. By each drawing, tell the shape name and whether the overall molecule is polar or not.
    a. $SeCl_2$
    b. HI
    c. $AsBr_3$
    d. SiF_4
    e. F_2
2. Chloroform ($CHCl_3$) is a dense liquid that was used as an anesthetic (numbs pain during medical procedures). Imagine chloroform draining out of a burette. Pretend that it has no permanent dipole. For each charged object below, make a detailed, labeled sketch of

chloroform molecules flowing past the charged object. Include all the important labels you have learned about in this Explain lesson.

   a. Charged balloon
   b. Charged glass flask

3. Explain to someone that missed today's lesson how you would use the electronegativity scale to determine both the direction and the degree of polarity of a bond between two different atoms.
4. Arrange these 4 bonded pairs in order of increasing polarity from the least polar to the most polar: CH, HO, NH, and HF.

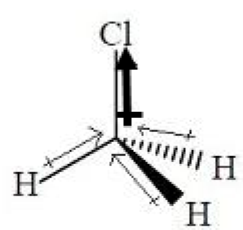
Part B: Explaining Two Puddles

Background knowledge

Polar molecules, like water, have an overall positive part and an overall negative part. These charged parts form "ends" of the molecule and remain charged. Chemists say that polar molecules have a permanent dipole. But the strength of the dipole varies. It varies for three reasons:

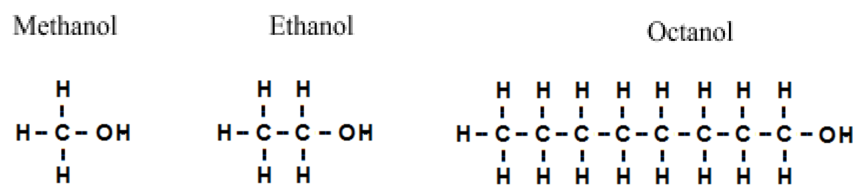
Reason 1: Electronegativity difference: When the electronegativity difference between atoms is in the range of 0.4 to 1.8 the bond is polar. At the high end of this range, the dipole is strong. At the low end, it is weak.

Reason 2: Shape: In some shapes, dipole forces cancel each other. For example, in methyl chloride, CH_3Cl, there are four "atom-to-atom" dipoles. One is stronger than the others. The strongest one is between carbon and chlorine. This makes the overall molecule "lopsided" or asymmetrical when considering charge.



Caption: Dipoles are shown with arrows pointing to the most electronegative atom. The chlorine end of this molecule has a permanent negative charge.

Reason 3: non-polar parts: If the molecule has nonpolar parts, those parts tend to weaken the overall dipole strength.



Caption: The OH part of each alcohol is polar. It is the negative end of the molecule. The carbons and hydrogens make up the non-polar part. As the size of the non-polar end increases, the overall dipole strength decreases. The non-polar parts attract, too. You'll learn about this attraction in Chapter 7.

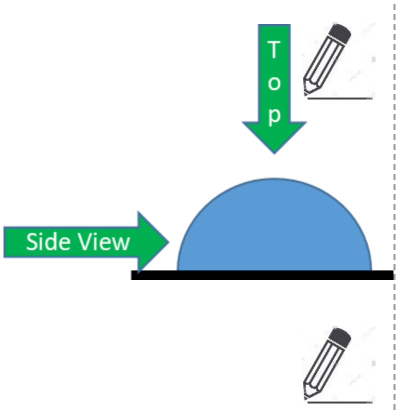
Molecules with strong polar bonds behave differently from molecules with weak polar bonds. That's because strong polar bonds form strong forces of attraction. Weak polar bonds form weak forces of attraction.

Materials	Cautions
Part 2 For each team of four students: • 3x5 inch sheet of wax paper • 300 mL water • 1- pipette • 25 mL-Isopropyl alcohol •	Wear goggles in Part 2

Safety

Once you have read through the procedures for this experience, determine the safety hazards, precautions, and procedures you will use to minimize the risk for harm in this activity, based on your four safety questions.

Hazard	**Precaution**	**Emergency Procedure**
What could go wrong in this experience? What is the worst thing that could happen?	*What can you do to prepare and to prevent the hazards? What protective equipment could you use?*	*What emergency procedure(s) will you utilize to minimize harm if a problem happens?*
1.	*1.*	*1.*
2.	*2.*	*2.*
3.	*3.*	*3.*



1. Meet with your team. Make two "puddles" on a flat 3x5" sheet of wax paper. You'll follow these steps:
   a. Use a clean pipette. Place about 10 drops of water on the right side of the wax paper.
   b. Rinse the pipette.
   c. Place ten drops of isopropyl alcohol (C_2H_6O) on the left side of the wax paper. Make sure the two puddles do not touch.
2. Record two sketches of your two puddles. Use about ¼ page. Label these two sketches "macroscopic views."
   a. One sketch should be from above (top view).
   b. The other sketch should be eye level with the wax paper (side view).
   c. Write short descriptions below your sketches. Be certain to draw attention to any major differences between the two liquids.
3. Make two more sketches. Use about ½ page. One sketch is of the water puddle and the other of the

alcohol puddle. Label them "microscopic view side view". Include the following:
   a. Draw several water molecules in a water puddle.
   b. Draw several alcohol molecules in a puddle.
   c. For each molecule in each puddle, draw a dipole arrow. Use this key:
      i. Strong dipole: thick, dark arrow
      ii. Weak dipole: thin, light arrow
4. Work with your team to write a caption. It goes under your "microscopic view" sketch. It must explain why the two puddles behave the way they do. *Important fact: Wax is non-polar.* Debrief your sketches and caption with the whole class. Your teacher will help everyone by leading the discussion.

Reflect and Connect

Write answers to the following questions in your notebook under the heading, "Explain: Reflect and Connect." These questions ask you about bonding types.

1. Draw a rectangle to represent the periodic table.
   a. What happens to the electronegativity values across each period from left to right? Draw an arrow in the direction that values increase.
   b. What happens to the electronegativity values of each group from bottom to top? Draw an arrow in the direction that values increase.
2. Here are two facts about the periodic table you sketched in Question 1.
   a. As atomic number increases, the number of protons in the nucleus increase. This results in a greater positive charge. A greater positive charge draws electrons closer to the nucleus.
   b. As atomic number increases, atoms have more electrons. As a result, atoms become larger to "fit" in all the electron shells. This increases the distance between the nucleus and outer shell, valence electrons.

Use these two facts to explain the direction of your two arrows from Question 1.

3. Ammonia (NH_3) is a gas at room temperature. It is

dissolved in water to make a household cleaner.

   a. Draw a 3-dimensional model of ammonia in the center of a page in your notebook. Leave plenty of space around it for more molecule drawings. Label the electronegativities of each atom.
   b. Decide whether there is an overall dipole for the molecule. If there is, draw an arrow to represent the location and direction of that overall dipole. The dipole points toward the negative end of the molecule.
   c. Sketch several (at least four) 3-dimensional water molecules around your ammonia molecule. Arrange your water molecules according to plus-minus attractions.
   d. Write a caption under your drawings. Your caption explains why ammonia is highly soluble in water from the microscopic view point. Use the following essential "concept" words in your caption: polarity, electronegativity, bond, dipole, force of attraction, and shape.

4. Thinking back over the activities and learning from this section, what activities from the "How Science Works" chart did you engage in?

End of Explain lesson.

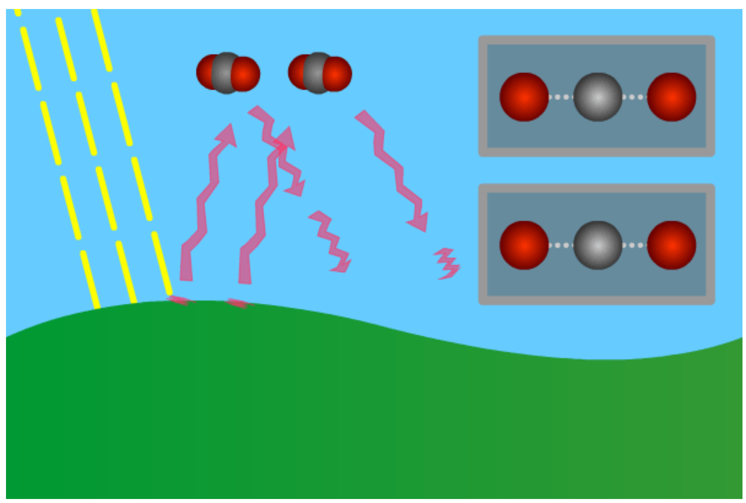
Chapter 6

Elaborate

Shape, Dipole, and Greenhouse Gases

Introduction

Molecules behave in certain ways. They have unique properties. We can predict and explain behavior based on shape and dipole. That's how you explained the behavior of water and isopropyl alcohol. How can you *apply* your knowledge of shape and polarity to other molecules—especially those molecules important in global climate change? Many of these gases are what we call greenhouse gases. Greenhouse gases have a lot to do with global climate, and it's all due to their shape and polarity.



Caption: Look at the two molecules shown in the blue sky above. They represent carbon dioxide. The yellow lines represent sunlight. The wavy, red lines represent "heat waves". It is the shape and of these molecules that makes them *take in* and *give off* heat.

In this Elaborate lesson, *Shape, Dipole, and Greenhouse Gases*, you will use your knowledge about molecular shape and dipole charge to predict the behavior of gases common in our atmosphere. The gases you will study are important in global climate change.

Materials

- Molecule kits (optional)

- The Greenhouse Effect simulation: https://phet.colorado.edu/en/simulation/greenhouse

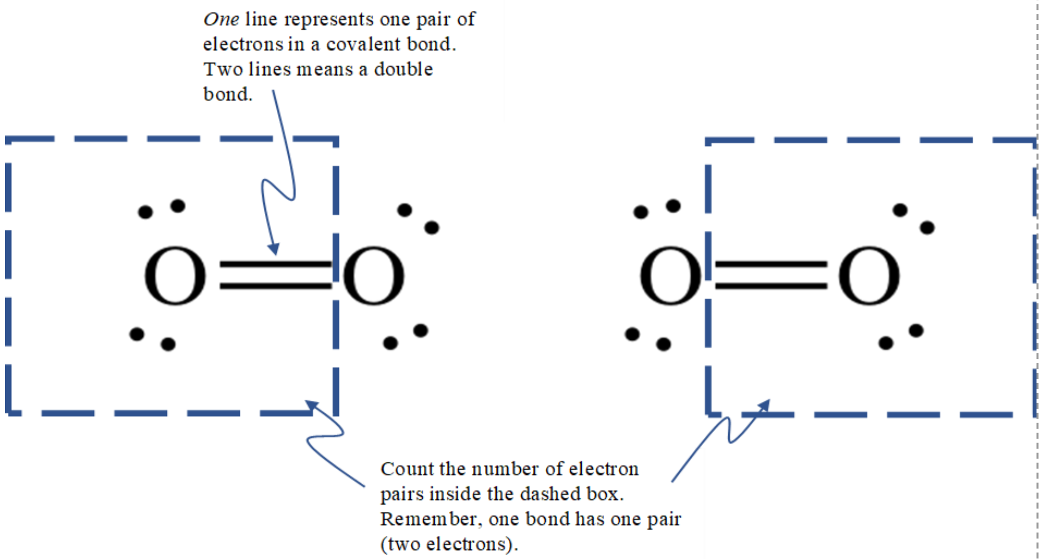
Process and Procedure

You will work with others and individually. Be sure to place all your work for this lesson under the title "Elaborate: Shape, Dipole, and Greenhouse Gases" in your notebook.

Part A: Double and Triple Bonds

Background knowledge: Multiple bonds

Covalent bonds involve a pair of valence electrons. But often, more than one pair of electrons is involved in bonding. That is, multiple pairs of electrons are shared between atoms. When this happens, the bonds are called double or triple bonds. It is still true that each atom can have 8 valence electrons around it. That makes each atom have a noble gas-like outer shell configuration. Look at the example of oxygen gas below. It uses a Lewis dot model to show oxygen gas.



Caption: Each oxygen atom can have 8 electrons. This happens because two pairs of electrons are "in" the covalent bond between oxygen atoms. When you see two lines between atoms, it's a double bond.

Double bonds are part of the 3-dimensional shape of a molecule. They still form a straight line between 2 atoms. Molecules with double bonds can be linear, bent, and trigonal planar shapes.

Chapter 6

1. Meet with your team to debrief the figure above. You will complete the table below in your notebook as you debrief.
   a. Each team member will complete a row. Make sure each row is 3 lines tall in your notebook. Use labeled sketches.
   b. Take turns reading and explaining your row.
   c. Check with a different team if you have questions.

Part of the figure to explain	Your explanation (refer to background knowledge)
1) Lewis dot structure of a single oxygen atom	
2) Highlight comment just above the Lewis dot structures	
3) Highlight comment just below the Lewis dot structure	
4) Caption for the entire figure.	

2. Your teacher will help the class debrief this table. Use the discussion to revise your table.
3. Apply your knowledge about multiple bonds by completing the following table in your notebook. The table contains some greenhouse gases and one that is not. Start the table on new page in your notebook so you have plenty of room.

Molecule	Lewis Dot Structure	Predicted 3-dimensional shape (draw any dipoles that exist)

CO_2		
N_2		
SO_2		
O_3		

4. Write the "type" of bond or bonds (single, double, or triple) involved with each molecule above. Write this directly under the formula in the table. There can be more than one type of bond in a molecule.
   Note: If your teacher suggests, you can use molecule kits to build the 3-dimensional model. This can help you visualize the molecule.
5. Which molecule(s) in the table are likely to be soluble in water? Explain this in your notebook. Use the concepts of forces of attraction in your explanation. Provide at least one labeled sketch to support your explanation.
   Note: It will help if you to think about whether the molecule would be attracted to water, repelled by water, or experience no force.

Part B: **Greenhouse Gases: Why Shape and Charge Matter**

Background knowledge: Greenhouse gases and dipoles

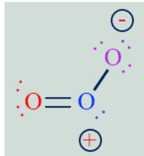
An essential characteristic property of greenhouse gases deals with the way these molecules *take in* and *give off* heat. The heat energy that these molecules take in (absorb) and give off (emit) is in the form of infrared radiation. IR is the shorthand way to say infrared. IR is non-ionizing radiation. It is sometimes called "heat waves". In order to be a greenhouse gas, the molecule needs to be IR active. That means the molecule can absorb and emit IR radiation. In contrast, non-IR active gases are transparent to IR radiation. That means IR passes through them with no effect.

Your teacher will show you a computer simulation. It will help you visualize how visible *and* infrared radiation interacts with greenhouse and non-greenhouse gases in our atmosphere. Your goal is to record what you see and then make a summarizing statement of what you saw.

Greenhouse gases have specific properties than depend on shape and charge. You will apply what you know about solubility, electronegativity, dipoles, and 3-dimensional shape to make sense of these important compounds.

1. Copy the large table below in your notebook. Some cells are provided to you. Some are missing. Work with your team to fill in the Lewis dot structures and electronegativity differences.

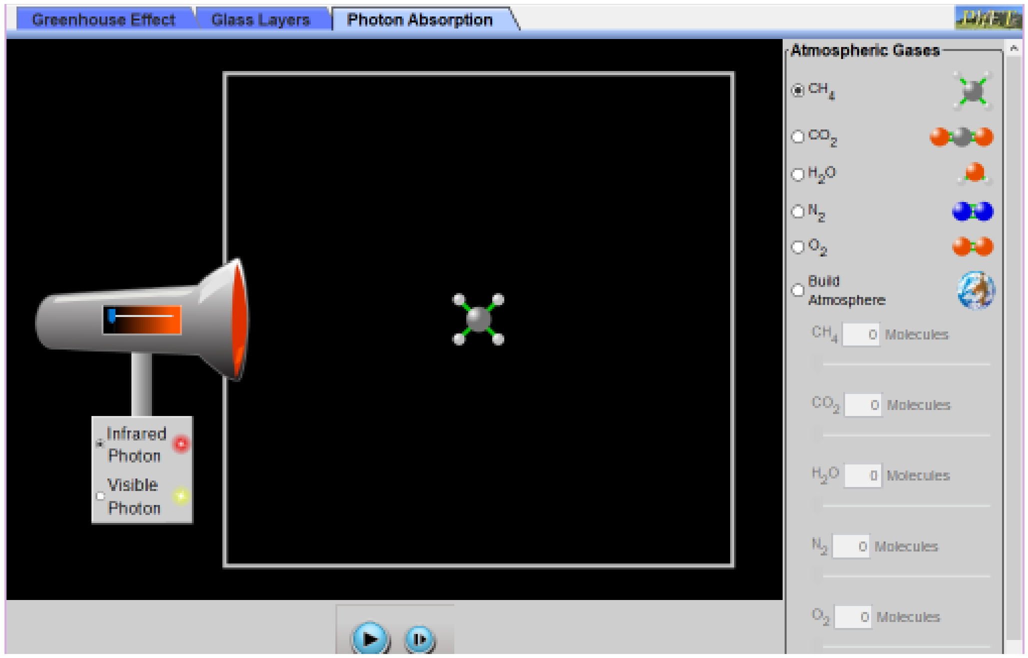
Formula	Lewis Dot Structure	Electronegativity difference between atoms	Overall dipole*	Solubility in water (g/kg)	IR active
H_2O			1.84	n/a	
SO_2		S–O bond 1.0	1.61	86	yes

O_3			0.53	0.109	yes
CO_2			0	1.50	
CH_4			0	0.035	
O_2		O-O bond Zero electro-negativity difference	0	0.04	
N_2	:N≡N:		0	0.02	

*units on dipole are the same as charge x distance. The most common name for this unit is Debye.

2. Make a sketch of the primary components of the simulation screen. Here are the parts to label in your notebook. Make your sketch at least ½ page in size.
   a. Photon gun
   b. Intensity slider on photon gun
   c. Visible or infrared photon

d. Type of molecule



3. Below are several questions to answer. To help you answer them, your teacher will operate the simulation. You will record what you see. Use a sketch along with a short caption to record your observations.
   Note: Write each question in your notebook. Then place your sketch and caption directly under your sketch.
   a. How does a single CO_2 molecule interact differently with visible versus infrared photons (light)?
   b. How do visible and infrared photons interact with N_2 and O_2?
   c. Do CH_4, H_2O behave more like CO_2 or O_2 and N_2?
4. Based on the information in the background reading above, which gases are greenhouse gases? Which gases are transparent to IR radiation?
5. Pretend you are writing a chemistry textbook. Write a general rule for determining if a gas molecule is IR active (a greenhouse gas). Give two examples. One example will be of a molecule that is IR active and the other example molecule will not be IR active.
   Note: Your teacher will debrief the entire class. Revise

your summary statement based on the whole class discussion.

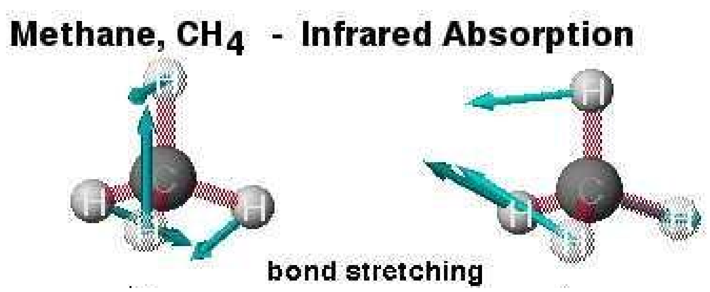
6. Imagine a classmate saying, “Only lopsided (asymmetrical) gas molecules are greenhouse gases.” Work with your team to decide if this student is correct or incorrect. Use evidence from the table above in your answer.

   Pretend you are a dedicated, caring teacher. Write a response to this student. Your “teacher” feedback will help the student figure out what is correct and what is incorrect about his or her answer.

Reflect and Connect

Answer the following questions. Work as a team, but report your own answers. Record your answers in your science notebook under the heading “Elaborate: Reflect and Connect.”

1. Carbon dioxide is linear and so is nitrogen. Why do their IR activities differ? Use labeled sketches to strengthen your answer.
2. Carbon dioxide and methane are both greenhouse gases. But neither has an overall molecular dipole. Apply your knowledge to make sense of this. Use numbers, sketches, and sentences to construct a convincing answer. If you need help, study the sketch below. Feel free to add highlight comments to it for your answer.



3. Apply what you know about bonding, polarity, shape, and dipoles to answer this question. Study the molecules below. Predict if they are greenhouse gases. Complete this

table in your notebook. You can omit the solubility column. Your goal is to predict whether each molecule is a greenhouse gas.

Compound	Facts about compound	Electronegativity difference between atoms	Lewis Dot (with dipole arrows)	Greenhouse gas prediction	Reason for prediction?
N_2O (nitrous oxide)	Used as sedative. It is also called "laughing gas".				
Ar (argon)	Noble gas element that is about 1% of our atmosphere.				
CCl_4 (carbon tetrachloride)	Used as solvent.				
H_2 (hydrogen gas)	Most abundant gas in space				
CCl_2F_2 (dichloro-difluoro-methane)	Is a chlorofluorocarbon (CFC). Industry name is Freon (refrigerant).				

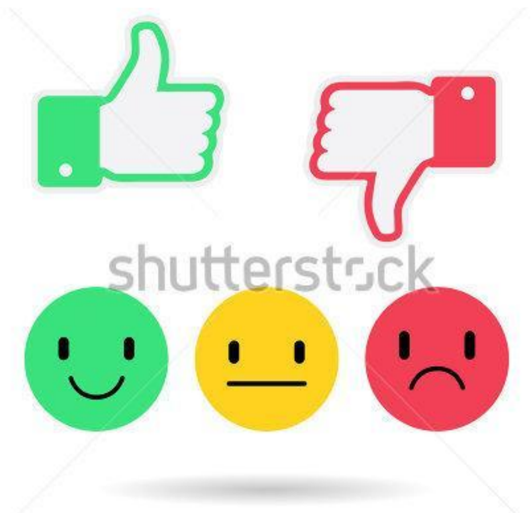
4. Re-read your general rule for predicting whether a gas is a greenhouse gas or not (Part B, Step %). Revise your rule based on your answers to the first three Reflect and Connect questions.
5. Thinking back over the activities and learning from this section, what activities from the "How Science Works" chart did you engage in?

End of Elaborate

Evaluate | Video Feedback

Introduction

Think of all the ways you can show what you know. In language class, you can write a story. That demonstrates skill. You could also evaluate someone else's story—give them feedback. Of course, that feedback would be based on your knowledge and skills in language. Your feedback would likely be different from your language teacher's. The same option can happen in chemistry. You can look at a video tutorial about molecular shapes and give the authors feedback. Your feedback helps them grow. That is a big part of evaluation.



Caption: Think of all the opportunities you have to give feedback. You can "like" all sorts of things. But chemists want more than just a thumbs up or a thumbs down. They want meaningful analysis that helps them grow and improve. Now that's feedback that makes a difference!

In this Evaluate lesson, *Video Feedback*, your goal is to give authors high-quality feedback. First, you will learn what you are looking for by familiarizing yourself with a feedback sheet. This feedback sheet is called a rubric. Then you will "click through" a series of slides and animations. This is where you really try to make sense of what the authors are doing. After you are done, you will complete the feedback sheet.

Materials

Handout: Molecular Shapes Tutorial Rubric

Link to tutorial **https://tinyurl.com/C6-Evaluate-Video**

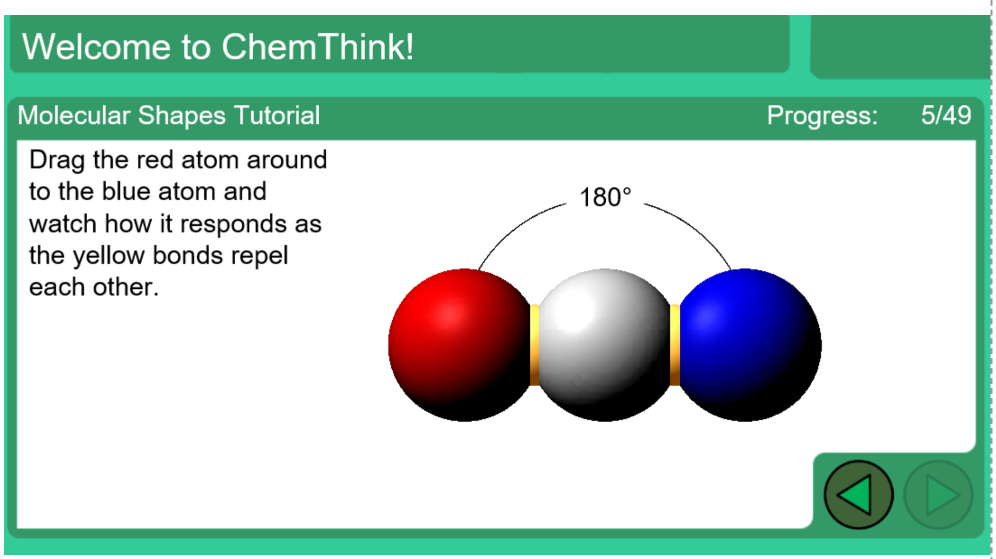
Process and Procedure

Start a new page in your notebook. Write the title "Video Feedback." Carefully record all your thinking for this lesson under this title.

1. Familiarize yourself the feedback sheet (rubric) that your teacher gives you. Perform Step 1a-b before looking at the video tutorial. These steps help you know what you will be looking for.
   a. Read the performance level key at the top of the rubric handout. Make sure you know how to tell the difference between a score of 1 and a score of 3.
   b. Read through each feature you are evaluating. Discuss them with your team. If you have questions, ask your teacher for clarifications.

2. Your teacher will tell you how to access the web site for the video tutorial. An example screen shot of slide number 5 is below.

Note: the slide number is in the upper right corner. The slide number is listed as a number out of the total (5/49). You will not have to evaluate all 49 slides.

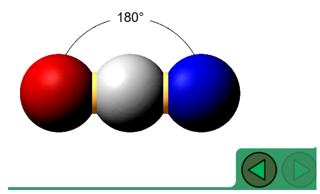


3. Your teacher will tell you which slides to evaluate. When the program loads, click through your assigned slides. Talk with team members about any slide that you do not understand. Below are the groups of slides your teacher might assign. Mark in your notebook which slides your teacher assigns.

Group Number	Slides to evaluate	Topic
1	1-13	VSEPR rules
2	34-36	CH_4
3	37-39	NH_3
4	40-42	H_2O
5	14-19	CO_2

4. Score each feature on your rubric handout. Be certain to provide concrete evidence from the video. The rows below show some examples. One example shows a high-scoring feature. Another example shows a low-scoring feature. **Note:** The last sample row demonstrates the type of answers to avoid.

Feature you are evaluating	Performance Level	Evidence	Suggestions
1. Provides practice problems	1 2 3	*(give evidence from the tutorial with specific examples. Use sketches if you prefer)*	*Include ideas for making the tutorial better regarding the feature to the left.*
2. Gives hand-on opportunities	1 2 (3)	Yes, I use my hands to move the mouse and cause bonds to move around. For example, in the red-gray-blue molecule on	Could have 3-D model kits nearby to

		slide number 6, I could move the red atom to see how the blue atom responded.  	practice making the shapes on the screen.
8. Allow you to draw overall molecular dipole	1 2 3	I did not see any place where I am supposed to draw an overall dipole. I did not see any on-screen tool that would allow me to even do that.	If the tutorial wants to teach about dipoles, then there needs to be a way for the user to draw dipole on the molecules.
7. Gives experience with lone pairs of electrons	1 2 3	*(this is NOT an acceptable answer)* I really liked the all the lone pairs.	*(this is NOT an acceptable answer)* This was great!

5. Calculate your total score. Meet with at least one other team or classmate and compare total scores. Discuss any differences you have. Focus on the exact evidence you have as you talk.
6. Imagine you are posting an overall review for this tutorial on a popular feedback site. Write that review in your notebook now. Begin your review with an overall rating. You can use a "thumbs up" versus "thumbs down" rating or a "number of stars" rating.

Reflect and Connect

Answer these questions in your notebook.

1. Think about three ways of demonstrating what you know: 1) taking a test, 2) making up a test, and 3)

grading a test. Which way is the most accurate? Explain your answer with a personal experience.

2. Find the lowest and highest overall score on the rubric for this lesson. List as many things you can think of to reduce this difference.
3. What is the best way to evaluate yourself? Why would you want to evaluate yourself?
4. Congratulations on completing Chapter 6! Now it's your time to provide SFUSD Science with feedback on Chapter 6 by completing the short student survey at https://tinyurl.com/SF-Chemistry

End of Evaluate lesson
End of Chapter 6