**Chemical Bonding, Part 2: The Impacts of Chemical Bonding**

**Read this next!**

**Why does shape matter?**

**All particles are constantly in motion**, bouncing around back and forth interacting with one another. With all this movement, the particles tend to bump into one another. **When two particles hit each other, it’s called a “collision.”** This is where the real action happens! ***If* two particles hit each other in the right way and *if* they hit each other hard enough (with enough energy), a chemical reaction *might* take place.** If all of these things happen correctly, the collision is “effective,” meaning that a chemical change is possible. But it takes a lot of work to make that chemical change actually happen… It’s kind of a miracle that reactions happen at all!

Because of all these requirements for collisions to be effective, the shape of the molecule plays a *huge* role in whether or not a chemical reaction can happen. **For any molecule to do its job, it must have the right three-dimensional shape.** The shape is determined by interactions of electrons inside the molecule.

**What controls a molecule’s shape?**

**The three-dimensional shape of a molecule is a critical factor in what it can do. A molecule's shape is determined by its electrons.**

The electrons are constantly caught in a balancing act. Electrons are negatively charged. The nucleus of all atoms is positively charged. So, the electrons are *attracted* to the nucleus of their own atom *and* the nuclei of other nearby atoms, especially if they’re bonded together. But the electrons are also *repelled* by the negative charges of all the other electrons. *And* to make things even worse, the more atoms bonding together, the more electrons there are repelling one another and fighting over the space around the different nuclei. All of this attracting and repelling sounds frustrating! **This forces the electrons to stay as close to the nucleus as they can, and also spread out from the other electrons as much as possible.** (Chemists explain how this works in the “**VSEPR Theory**.”) If the electrons fall out of balance between all the different positive and negative charges, their entire atom could become unstable…

However, the electrons have found the answer! There are a few **specific arrangements** in molecules that make everybody “happy” – each of the electrons get to be close enough to their nucleus *and* spread out from one another. These arrangements, called “**molecular geometries**,” give rise to some special three-dimensional shapes in stable molecules. The shapes, in turn, give rise to the phenomena we see in everyday life: from drugs that fight diseases to the man-made materials we use to make clothes, homes, and technologies.

*Adapted from “Molecular Geometry” by Concord Consortium*

**What do these molecular geometries actually look like?**

**Watch the** [**second video segment**](https://www.youtube.com/watch?v=_7r5_WGhnaY&t=3s)**, “VSEPR Theory and Molecular**

**Geometry,” to find out more.**

(Use your **Chemistry Help Guide** for molecular geometry to help you keep

track of important information in this video.)

**Answer the following questions about molecular shapes:**

1. Summarize the **VSEPR theory** in your own words.
2. Chemists have identified **at least 18 different molecular geometries** that show up in different chemical compounds, but we will only we be focusing some of the most common ones in our class. **List the six molecular geometries we will use** in the space below: (You might want to draw a simple diagram to help you keep them all organized as well)
3. Find **at least 2 other molecular geometries** that exist naturally. Write their **names** and draw an **image** for each one below:

**Using a molecular model kit, build several three-dimensional models of simple molecules to see how their molecular geometry actually looks.**

1. Build a model of each of the substances listed in the **“Molecular Models” chart**, on another page. Fill in the chart to organize important information about each molecule and determine its molecular geometry. When you finish, move on to question #4 below. (Keep the model kit…you’ll need it later!)
2. **Propane**, C3H8, is a hydrocarbon fuel used in small, portable gas tanks (like gas grills or camping supplies).

**Draw a Lewis structure** for propane.

In your diagram, **circle** each atom that **shares more than 1 bond**.

**Read this next!**

Larger molecules tend to have **more than 1 “central atom.”** Each central atom **has its own molecular geometry** and its own chemistry. The molecule’s overall shape and the location of its central atoms will determine its **properties**, **stability**, and **behavior**.

1. Any atom that shares more than 1 bond is a “central atom.” For each of the central atoms in propane, **label their molecular geometries** in the diagram you drew above in question #4.
2. Use the model kit to build a model of a **propane** molecule. **Find each of the central atoms** you identified before and **check if the molecular geometry looks like what you expected** based on how you named it. **Annotate** (label) each of the central atoms in your model with its molecular geometry and **take a photo** to show your teacher later.

**Read this next!**

**How can we actually see all of this “chemical bonding” stuff in the “real world” around us?**

Using what Scientists have learned about chemical bonding and the structure of atoms to create new substances and materials has become an important focus among researchers today. Medicines for complex human illnesses, eliminating landfill waste with new biodegradable materials and plastics that are more easily recycled, metal alloys that can be used to build faster and more efficient technologies – these are all examples of synthetic (man-made) materials that Scientists are working right now to create, all based on the chemistry of bonding.

**Let’s go see for ourselves!**

We will spend the rest of our study of chemical bonding looking at three specific types of applications where researchers are trying to better create new materials to improve the human experience:

**Category A: Biomedical molecules**

* Medicines and other substances used to treat human illness, disease, or discomfort
* *Illicit* drug substances that are used to manipulate the human brain’s natural processes
* Food and nutrients important for providing energy and molecules the human body needs for health and survival

**Category B: Materials for building new technologies and providing energy**

* Metals and *alloys* useful for building *microprocessors*, *superconductors*, and other electronics and hardware parts
* Silicon- and carbon-based materials (such as graphene) that can be used in new ways to build onto existing technologies, allowing for innovative uses and abilities
* *Hydrocarbon* fuel sources, how to more efficiently use their energy, how to control the negative environmental, social, and economic impacts of their usage, and how to use new technologies to reduce human dependence on fossil fuels and harness innovative, sustainable energy sources instead

**Category C: Complex, large-molecule *polymers* and unique versions of elements with useful properties**

* Man-made fabrics, such as nylon, polyester, rayon, spandex, and others, can be used to create more comfortable, useful, and safe clothing options
* Plastics have been used over the last 50 years more and more commonly to make human’s daily lives easier and more affordable, but they have also created a global waste problem.
* Glass and other man-made materials that are made from minerals naturally found on earth have drastically changed the kinds of building materials and products humans rely on
* *Allotropes* are different forms of elements that are stable enough to exist naturally, such as *graphite* and diamond – both natural versions of carbon – or *ozone* and *diatomic* elemental oxygen

(These descriptions are not completely inclusive. There are many other examples of man-made materials from these three categories and others. If you have a particular interest that you have trouble connecting to one of these topics, talk with your teacher for extra guidance, suggested resources, or clarification about whether or not your idea is appropriate for our study of chemical bonding.)

*Note:* Terms written in *italics* are helpful vocabulary terms that you have probably not encountered before. Students should take time to understand each of these and how they connect to the bigger ideas of chemical bonding and the uses of man-made materials.

**Choose one of the categories above that interests you**

**and continue with the next part of this activity so you can**

**actually see these kinds of molecules in action…**

**Go to the** [**third weblink**](http://www.worldofmolecules.com/3D/index.html) **to look at how the different three-dimensional molecular geometries show up in some common natural and man-made molecules. Use the links, information, and graphics to fill in the chart and answer the questions below.**

1. The website lists links to **three-dimensional images of many different common chemical substances**, from **fuels and foods**, **drugs and dyes,** to **fabrics and glass**. In the “drugs” section, for example, there are many medicines as well as illicit drugs. **Aspirin, Tylenol, and Ibuprofen are all common house-hold medications for pain.**  To learn how to site works, go look at each of these three molecules by clicking and following their links. What **similarities and differences** do you see in these molecules’ **chemical structures**? What is the name of the **group of medicines** that Aspirin, Tylenol, and Ibuprofen all belong to? Generally, **what do these medicines do** for our bodies? How do you think all of these biochemical properties are related to the bonding among the atoms in these different molecules?
2. Based on your interests from the categories on the last page, **choose one of the complex molecules** shown on this site and use the links to **look at its chemical structure**. Write its name under “Molecule #1”and **fill in important information** and notes in the chart below:

|  |  |  |
| --- | --- | --- |
| **Molecule** | **Molecule #1:**(For question #9 - Write about the moleculeyou chose in this column…)**\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_** | **Molecule #2:**(For question #12 - Write about the moleculefrom your classmates in this column…)**\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_** |
| **Chemical name** |  |  |
| **Molecular formula** |  |  |
| **2D****structure** |  |  |
| **3D****structure** |  |  |

1. Using a modeling kit, **build a 3D model of the molecule you chose** to look at, **molecule #1** from the chart above. **Take a picture** of your molecule that shows all of its atoms, bonds, and shapes.
2. In your model of molecule #1, **find each of the central atoms** and **identify the molecular geometry around each one**. **Annotate** (label) each of the central atoms in your model with its molecular geometry and **take a photo** to record your work and show your teacher later.

Go back to your drawings in your chart from question #9, **label your sketch of molecule #1**, identifying the central atoms and molecular shapes you have found.

*Keep your model of molecule #1; you’ll need it in the steps below.*

**Before you move on…**

Think about this important question: **How do these chemical bonds and their shapes actually lead to the properties that make these molecules useful?** (You’ll be asked to actually go and find the answer to this question later…)

1. Now that you’ve investigated a molecule of your own choosing, **pair up** with another student or small group and try the same process *backwards*, this time looking at the molecule they chose to work with.

**Exchange models** with the other student(s) and write the correct name of the new substance under “molecule #2” in your chart from question #9 above. **Take a photo** of the model of molecule #2.

**Identify each of molecule #2’s central atoms and identify its molecular geometry.** **Annotate** each central atom and **take a photo** to record your work.

Now, go back to the same website from question #8 and **find the digital model of molecule #2**. Draw a **sketch** of its 3D and 2D shape in your chart, with **labels** for all of the central atoms and their molecular geometries.

Use the digital models to **check** that the model of molecule #2 (that your classmates made) is correct. If you find a problem, use a model kit to **correct** it.

Make sure the column for molecule #2 is completely filled-in in your chart above.

*When you’ve finished working with the model your classmates built, give it back to them and get back your original model that you put together; you might need it one more time in the steps below.*

1. Using models from your own work and from your classmates, find **examples of each of the 6 major molecular geometries** in the molecules our class is investigating. **Take a picture of each shape** and make sure you document what molecule the example came from and how you knew it was that shape. Now, you’ve created your own **personal visual glossary** of examples of these three-dimensional shapes.

**Save these and all of your photos from this activity in an organized place**, such as a shared Google Document so you can refer back to them in the future.

**Read this next!**

(Use your **Chemistry Help Guide** for polarity to help you understand important background information for this next section.)

**A molecular balancing act…**

Polarity is all about balance. **Polarity refers to the balance between positive charges and negative charges** in and around a molecule. When the charges don’t really balance out, the **electrons** tend to get **pushed** and **pulled** around… This **stress** ends up making the molecule **less stable**. So, **polar molecules are always more reactive than nonpolar molecules**.

**When atoms in a molecule don’t share electrons evenly, they form polar bonds.**  If a molecule has enough polar bonds, it might **throw off the balance** of the entire structure. **Nature does a pretty good job** of keeping everything in balance. In a large molecule, a few polar bonds can’t make a big difference; But in smaller molecules, a little polarity can go a *long* way…

**Polar personalities**

**Most molecules in nature are polar** (or at least *kind of* polar).And most of the time, molecules are **only polar in certain areas**... especially in large molecules like medicines, drugs, or food compounds. These polar “regions” are called “**polar centers**.”

The polar center (or center*s*) of a large, complicated molecule is **where all the action will take place**. This is where **chemical reactions** get started, and this is the part of the molecule that has to **collide effectively** for those reactions to ever have a chance!

**If the molecular geometry around a polar center makes effective collisions difficult**, the molecule might never get the chance to actually react. **But if the geometry of a polar center makes effective collisions easier**, the molecule will probably react more often and more quickly.

1. **A central atom is polar is if it has unshared electrons *OR* if its bonds are not symmetrical.** In the diagrams in your chart from question #9, **put a square around all of the polar centers** in molecules #1 and #2.

In your own words, describe how **polarity** might impact the **properties** (or chemical behavior) of a molecule:

**Deeper thinking**

Let’s go back to this question from earlier: **How do these chemical bonds, their shapes, and polarity actually lead to the properties that make these molecules useful?**

1. Think about the two molecules whose chemical bonding you’ve looked at in depth during this activity. What properties (characteristics) do these substances have that make them useful and important for humans? Use **reliable sources** to **gather some basic information** about each of these substances and their uses. Then, take your research one step further by trying to uncover **exactly what gives these substances their valuable properties**. **Combine what you find in your research and what you’ve learned about chemical bonding to answer the “big idea” question above.**

Use the chart below to **organize** what you find in your **background research**:

|  |  |  |
| --- | --- | --- |
| **Molecule** | **Molecule #1:**(For question #9 - Write about the moleculeyou chose in this column…)**\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_** | **Molecule #2:**(For question #12 - Write about the moleculefrom your classmates in this column…)**\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_** |
| **Chemical name** |  |  |
| **Molecular formula** |  |  |
| **Properties and uses:**What “category” does this molecule represent?Is it found naturally, or is it man-made?How is it useful or important to humans? |  |  |
| **How does this molecule’s structure**(its bonding,3D shape, and polarity)**all influence its properties and its usefulness?** |  |  |

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Molecular Models** | **Structure** | **Molecular Geometry** |  |  |  |  |  |  |
| **3D Drawing** |  |  |  |  |  |  |
| Number of **lone pairs** of electrons around the central atom |  |  |  |  |  |  |
| Number of **bonding “zones”** around the central atom |  |  |  |  |  |  |
| Total number of **“electron zones”** around the central atom |  |  |  |  |  |  |
| Lewis Structure(2D Drawing) |  |  |  |  |  |  |
| **Substance** | Molecular Formula |  |  |  |  |  |  |
| Chemical Name | **Methane**(carbon tetrahydride) | **Ammonia**(nitrogen trihydride) | **Water**(dihydrogen monoxide) | **Carbon dioxide** | **Elemental chlorine** | **Elemental oxygen** |