

Molecular Models

Introduction

Covalent bonds are formed when electrons are shared between atoms. Hydrogen, for example, can share one pair of electrons with another atom, so we say that it forms one bond. Similarly, oxygen forms two, nitrogen usually forms three, and carbon forms four. (Remember the "HONC" rule...H=1, O=2, N=3, C=4, but note that unstable molecules can form, creating exceptions.) The ratios of atoms in various molecules are expressed by their chemical formulas. For example, "H₂O" represents water, and "C₆H₁₂O₆" represents glucose. However, this is only part of the story. In biology, the shape of a molecule is often just as important as its chemical formula. Enzymes, for example, need a precise 3-dimensional fit to their substrates, just like a baseball and a well-worn outfielder's glove. In this investigation we will attempt to construct molecular models of some common substances from biology. In several cases, unusual properties will emerge that couldn't have been predicted from the flat projections that are usually drawn on paper.

Hints: an *ether* is formed when an oxygen has a carbon on both sides such as C-O-C. An *aldehyde* is formed when a carbon is attached to a hydrogen and double bonded to an oxygen such as H-C=O. A *ketone* is formed when the C=O is in the middle of a chain of carbons. A *carboxylic acid* is formed when a carbon is double bonded to one oxygen and attached to a second oxygen by an -O-H group, such as H-O-C=O. The -O-H group on its own makes an *alcohol*. The prefixes *meth-* *eth-* *prop-* *but-* *pent-* *hex-* *hept-* *oct-* *non-* *dec-* represent increasing numbers of carbons, from 1 to 10.



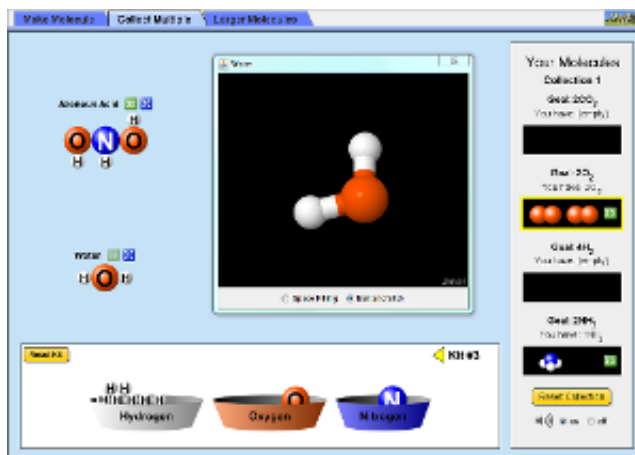
Ball and Stick Molecule Building Kit

Methods

If you do this lesson *in person*, use a [molecule building kit](#).

- We will work with wooden balls to represent atoms. Hydrogens (white or yellow) have one hole, oxygens (red) have two holes, nitrogens (blue) have three holes, and carbons (grey) have four holes. Use wooden dowels for single bonds, and flexible plastic tubing for double bonds. Each hole must be filled, each "bond" must be capped. For some of the larger examples, it may be necessary to share pieces with other groups.
- Experiment with each of the following examples until you are satisfied that you have the one correct solution.
- On a separate piece of paper, draw each of these examples as a 3-D shape, not just as a stick figure. Color-code each sketch as needed.

If you do this lesson *online*, use the **Build a Molecule java applet** to construct the molecules listed below. You will be moving from simpler to more complex structures. Use the Larger Molecules tab, and click the yellow arrows to move between atom kits to find one that has all the materials you'll need for each structure. Just drag and drop atoms near each other and a bond will form. Click between atoms to break a bond. Throw unneeded pieces back in the tray and they will sort themselves out. Click Refill Kit to clear the entire screen. The [teachers' guide](#) has more instructions on using the tool, but it's fairly intuitive and you can probably figure it out after a few minutes of exploring.



Click on the image or [this link](#) to start building molecules.

Troubleshooting:

Mac Users:

1. If the Java applet doesn't launch automatically, look in your web browser's **Downloads** folder and double-click on the file called "**build-a-molecule-en.jar**."
2. Still not working? Go to **Apple menu/System Preferences/Security and Privacy/General** and Allow Apps Downloaded from "**Anywhere**" or click the "**Open Anyway**" button and try again.

Build the following

(First, try to build them using just the hints below. Then, check your work by looking them up on [Wikipedia](#).)

1. **Hydrogen** gas is the simplest and smallest possible molecule.
2. **Oxygen** gas requires a double bond.
3. **Ozone** has a chemical formula of O_3
4. **Carbon dioxide** requires two double bonds. (Hint: di- means 2).
5. You are familiar with water (H_2O), but **hydrogen peroxide**, used for bleaching hair and disinfecting cuts, has one more oxygen.
6. Add a single carbon to water and you get **formaldehyde**, a carcinogen and preservative.
7. **Ammonia** is the simplest possible molecule made with nitrogen and hydrogen.
8. **Methane** is the simplest possible molecule made of carbon and hydrogen.
9. **Methanol** is like methane, but it also has one oxygen atom as well. Also called wood alcohol, it is toxic to drink.
10. **Ethanol** has a formula of C_2H_6O . (Hint: it requires one O-H bond!). Ethanol is the alcohol found in beer, wine, and spirits.
11. **Dimethyl ether** is an isomer of ethanol; that is, it has the same chemical formula but a different structure. (Hint: it has no O-H bond!)
12. **Carbonic acid** has a formula of H_2CO_3 , and is a critical pH buffer in your blood. (Hint: it requires one double bond, and no 3-atom rings!)
13. **Acetic acid**, when mixed with water, forms vinegar, and has the formula $C_2H_4O_2$
14. **Urea** has a formula of CH_4N_2O . This is how your body voids excess nitrogen from proteins that you eat. (Hint: the left and right sides are symmetrical!)
15. **Alanine** is one of the simpler amino acids, from which proteins are made. Attached to its central carbon are: a hydrogen atom, an amino group (NH_2), a methyl group (CH_3), and a carboxyl group (CO_2H). See if you can build a second one which is a mirror-image of the original.

Discussion

1. Why was carbon at the core of all the larger examples? Why not some other atom, such as hydrogen or oxygen?
2. If you found a mirror-image of your alanine model, was there some way you could turn or rotate the two versions to make them identical? Why or why not?
3. Why could there be right- and left-handed versions of alanine, but not urea or carbonic acid?
4. How can molecules with the same chemical formula, such as ethanol and dimethyl ether, have distinct physical properties?
5. When wine or beer is exposed to oxygen, the *ethanol* changes to *acetic acid*, and water is produced. Compare these two compounds and write out the conversion equation.
6. In sci-fi movies, sometimes the idea of silicon based life is proposed as an alternate to carbon. Can you guess why? Hint: It's near Carbon on the periodic table.

Further investigation

Explore the [Periodic Table](#) of the elements with your Mac or use this [online periodic table](#). For a more powerful Molecule Builder, try [Jmol](#).

Critical Thinking Exercise: Learn about [Di-hydrogen Monoxide](#), the silent killer.