NANO-MODULE 1. Exploring the Properties of Water (H_2O)

Name: _____ Date: _____

Objectives:

- To understand the structure of H_2O and how the structure is responsible for the chemical and physical properties of water.
- To beginning learning how to use ChemSketch to draw molecules.

Key Concepts: Hydrogen bonding, acids, bases, pH

Vocabulary:
universal solvent: describes water's ability to dissolve many substances
pH: the negative log of the hydrogen ion (H^+) concentration of a solution
corrosive: the potential to break down a material due to chemical reactions
hydrogen bond: the attraction between a hydrogen atom of one molecule to another electronegative atom

Background:

I.) What is water?

Water can be found everywhere. It makes up 71% of the Earth's surface (oceans, lakes, rivers) and 60% of the human body (70% of the brain, 90% of the lungs, 83% of the blood)[1]. Water (H_2O) is a colorless, tasteless and odorless compound consisting of two hydrogen atoms attached to a central oxygen atom.

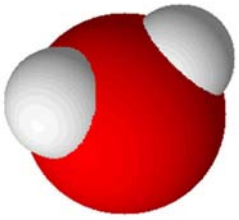

Figure 1. Space filling model of water (Small white balls = hydrogen, Large red ball = oxygen).

II.) Water as the Universal Solvent and pH, the Power of Hydrogen

Water is known as the **universal solvent** because it has the ability to dissolve many substances. This is particularly important for life because most of the body is made up of water and the water has many important substances such as vitamins, minerals and other vital material are transported throughout the body as solutes dissolved in water. Water has a neutral **pH** of 7.0 which means that it is neither acidic nor basic. **pH** is defined as the negative *logarithm* (log) of the hydrogen ion (H^+) concentration of a solution. pH itself, stands for *potential*

[1] http://ga.water.usgs.gov/edu/

or *power* of *hydrogen*. Acidic solutions have a pH below 7.0 while basic (alkaline) solutions have a pH above 7.0.

In your own words, define pH.

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_____

_____

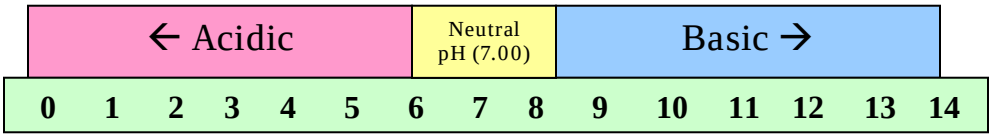

Figure 2. pH scale.

III.) Acids vs. Bases

Acids include vinegar, some soft drinks, citrus fruits (lemon, orange, lime, grapefruit), and much more. Acids taste sour and tend to sting when they get into cuts or eyes. Acids are **corrosive**, which means that they have the potential to break down a material. For example, acids can eat away at metal and rocks as seen in various monuments and rock formations. Acid rain is rain with water that has a pH of lower than 7. Acid rain is caused by pollution developed by burning of fossil fuels, volcanoes and decaying vegetation. Bases include chalk, milk, cleaning products such as soap, and other things. Bases taste bitter and tend to feel slippery between your fingers.

Can you define corrosive in your own words?

_____

_____

_____

Figure 3. Acids: Lemon, vinegar and soda.

Figure 4. Bases: chalk, soap, and milk.

When in water, both acids and bases can conduct electricity because they both form ions, or charged atoms. In water, acids produce hydrogen ions (H^+)

which interact with the water molecules (H_2O), forming the hydronium ion (H_3O^+) as seen below.

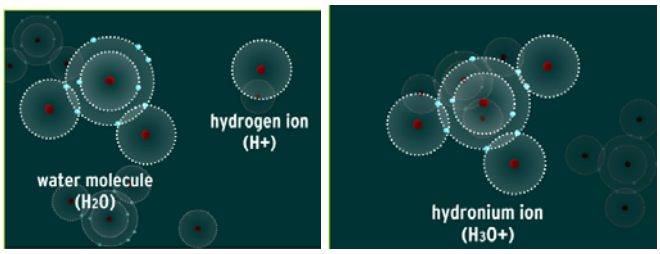

Figure 5. The formation of hydronium ions. [2]

Bases however, produce hydroxide ions (OH^-) instead of hydrogen ions when dissolved in water.

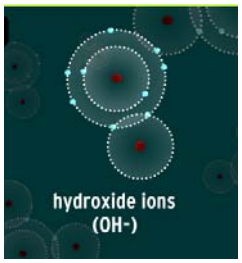

Figure 6. The formation of hydroxide ions.[3]

IV.) H_2O has a bent shape!

In addition to having 2 hydrogen atoms and 1 oxygen atom, water also has a lone pair of electrons on oxygen which causes H_2O to take on a **bent shape**. The negative charge of the electrons in the oxygen causes the molecule to bend. So instead of having a linear or straight molecule (180°), the molecule is bent (105.45°).

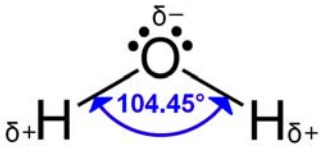

Figure 7. Lewis representation of water

VII.) Hydrogen bonding

In water, the hydrogen atom of one water molecule is attracted to an oxygen atom in another water molecule. This attraction is called a **hydrogen bond**. Hydrogen bonds are the strongest forces between molecules, but are not

[2] http://www.brainpop.com/science/matterandchemistry/acidsandbases/

stronger than ionic or covalent bonds. Other elements that can participate in hydrogen bonding include nitrogen (N) and fluorine (F), which are also highly electronegative atoms.

Hydrogen bonding between the water molecules is also responsible water's ability at storing a large amount of heat while keeping its temperature. This is better understood by how long it takes to heat the water before it actually boils. Generally, we believe that solids are denser than liquids and so when we place a solid into a liquid, it will sink to the bottom. However, due to hydrogen bonding, ice is *less dense* than liquid water because the hydrogen bonds cause the molecules to form crystal structures making more spaces between the molecules than in liquid water. So water expands upon freezing and this is why ice skating is possible.

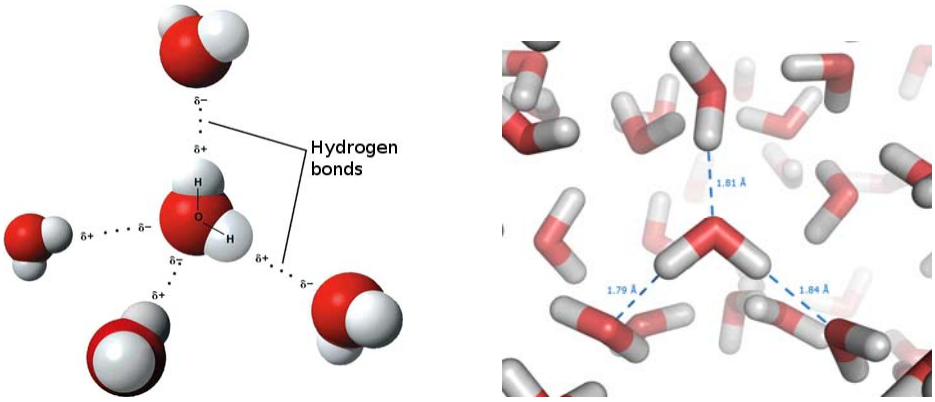

Figure 8. Two models of hydrogen bonds in water[6, 3]

Interesting Facts:

- "In 37% of Americans, the thirst mechanism is so weak that it is often mistaken for hunger." [4]
- "Some substances (sodium, lithium, calcium, potassium) emit a flammable gas (hydrogen) when wet, or react violently with water."[5]
- "Drinking too much water can lead to a condition known as water intoxication and to a related problem resulting from the dilution of sodium in the body, hyponatremia".[6]

[3] http://en.wikipedia.org/wiki/Hydrogen_bond
[4] http://www.mcvitamins.com/water.htm
[5] http://en.wikipedia.org/wiki/Water
[6] http://chemistry.about.com/cs/5/f/blwaterintox.htm

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Match-Up

Match the definition with the term.

A. pH
B. electronegativity
C. hydrogen bond
D. polar
E. universal solvent
F. adhesion
G. phase
H. cohesion
I. corrosive
J. translational motion

1. the “pull” or “desire” for electrons ____

2. the negative logarithm of the H^+ concentration of a solution ____

3. property describing the uneven sharing of electrons ____

4. the attraction between a hydrogen atom of one molecule to another electronegative atom ____

5. movement in straight line

6. the ability to dissolve many substances ____

7. “stickiness” of molecules ____

8. a state of a system, i.e. solid ____

9. property that makes capillary action possible ____

10. the breakdown of a material due to chemical reactions with its surroundings ____

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Pre-Lab Questions

Name: _____ Date: _____

Please answer the following questions to the best of your ability (use your own brain and outside sources if needed) in the space provided below.

1) What is water? How would you best describe what water is in chemical terms?

_____

_____

_____

_____

_____

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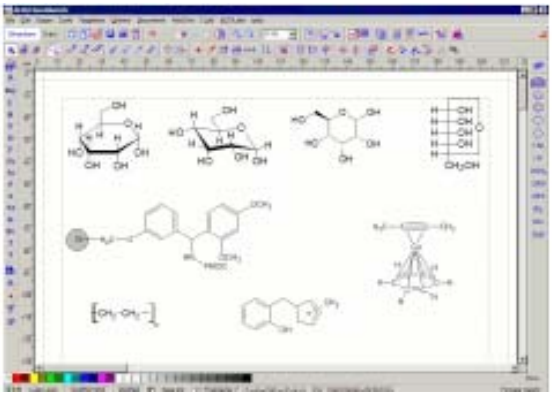
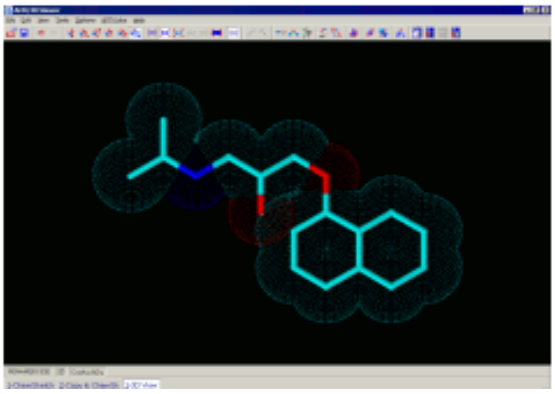
_____

2) Circle the elements that can participate in hydrogen bonding.

Se H Cl P N S O F Br

Introduction to ChemSketch





Images courtesy of ACD/ChemSketch.

Most of the things we use – furniture, cars and trains, hairbrushes, houses and organisms we interact with – insects, people, pets are all large enough for us to see with the naked eye. As we learn about our world in more detail, we learn that there are organisms that are even hundreds of times smaller than our garden spider and require a microscope to see. We learn about the dust mites, our seemingly invisible neighbors. In awe, we discover that a smooth may appear jagged and rough under the microscope, something that we could not have thought of by observation with the naked eye. Just imagine, a single cell is 10,000 times smaller than the average dog, and an atom is 100,000,000 times smaller than a single cell. Since we cannot see how an atom of hydrogen or lead actually looks like, we will use molecular visualization programs and hands-on molecular models to better understand chemistry.

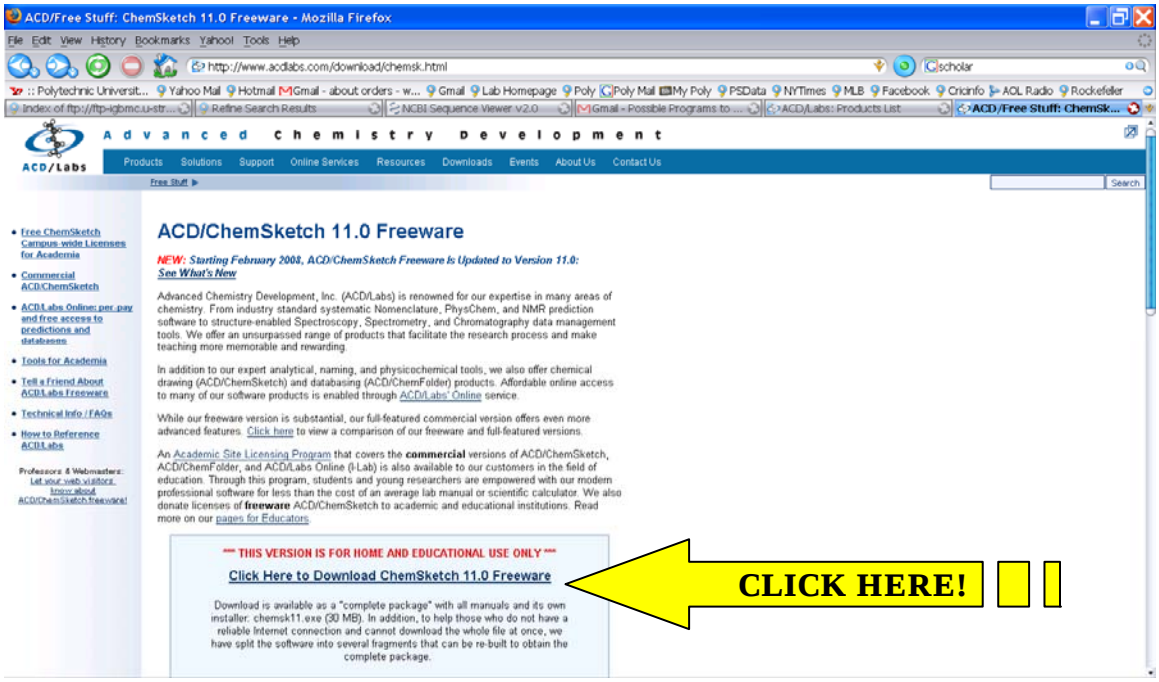
In this course, we will be using ACD/Chemsketch, a free program developed by Advanced Chemistry Development, Inc., (ACD/Labs), to draw chemical structures and render or transform these structures into 3-D pictures that we can visualize.

Info Link: http://www.acdlabs.com/products/chem_dsn_lab/chemsketch/

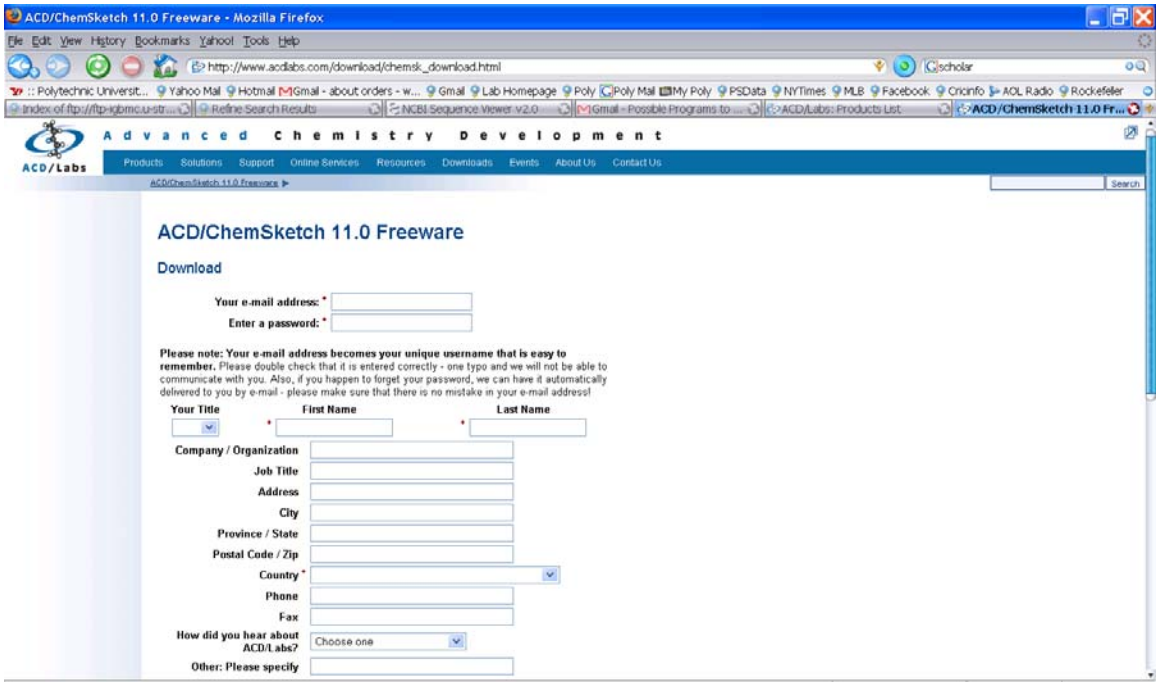
To download Chemsketch:

1) Go to http://www.acdlabs.com/download/chemsk.html.

2) Click on the link that says:
"**Click Here to Download ChemSketch 11.0 Freeware**"

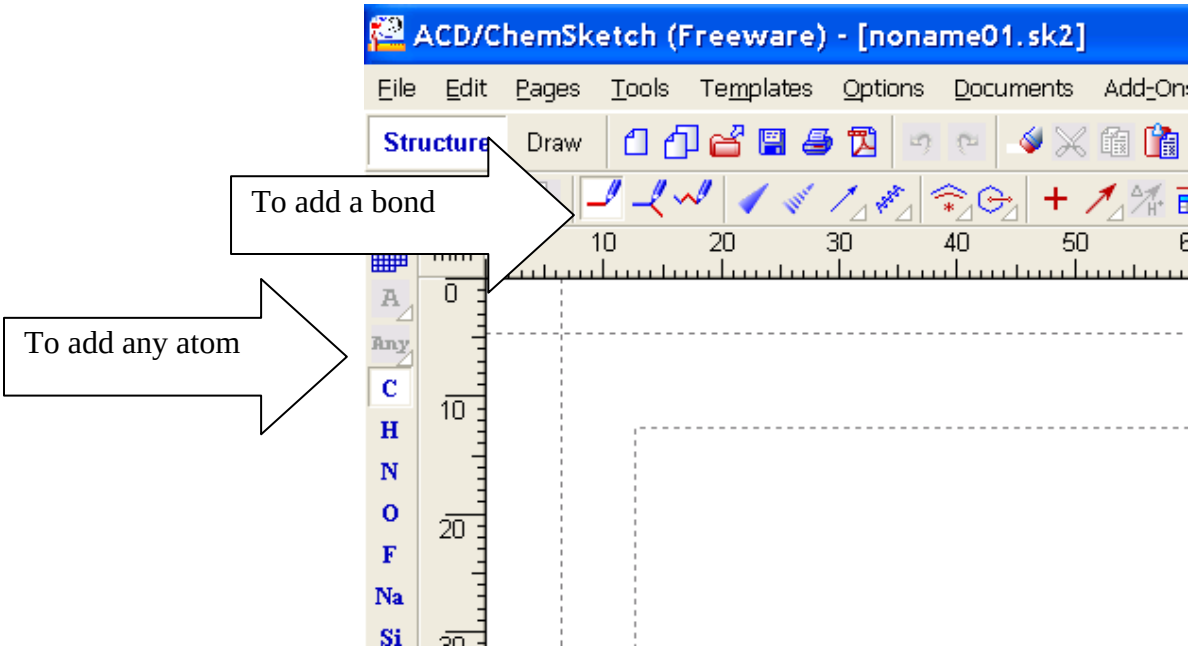


3) Fill out the information with the dark red diamond on the left side of the box and click on "**Submit Form**" on the bottom.



4) Check your email and follow the directions in the email to get the software.

Tutorial: Using ChemSketch



1. Click on the letter of the first atom (from left side buttons) you want to draw.

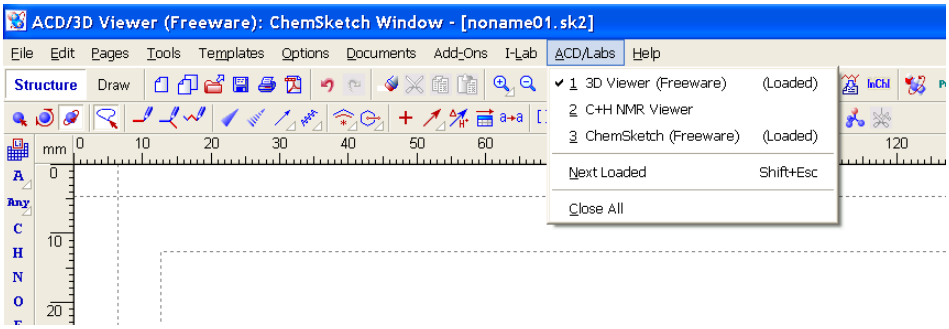
2. Click on the white drawing space to put the atom there.

3. Repeat first two steps to add other atoms.

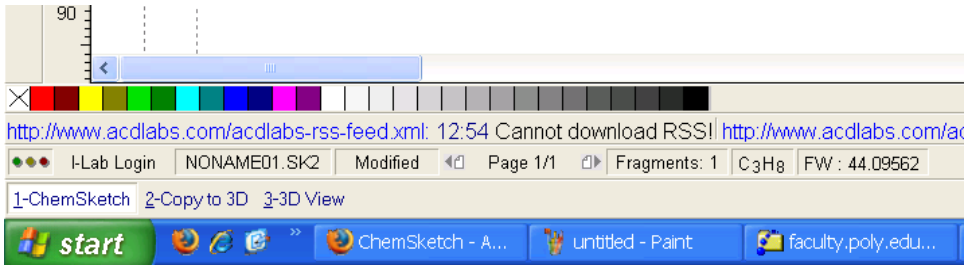
4. Click on the button with the "to add a bond" arrow pointing at it to add bonds between atoms.

To view molecules in 3D:

1. On the top menu, click on "ACD/Labs" and select "1 3D Viewer (Freeware)"



2. Click on “Tools” on the top and click on 3D optimization.



3. On the bottom of the window, click “Copy to 3D”

4. Click on 3D view to see the molecule in 3D. The molecule can be rotated with the mouse.

Useful Links:

Water Science for Schools (USGS): All about water!
http://ga.water.usgs.gov/edu/

The World's Water
http://www.worldwater.org/

Water, our need for it and why
http://www.mcvitamins.com/water.htm

US EPA Acid Rain
http://www.epa.gov/acidrain/index.html

Post-lab Questions

For our next meeting, please hand-in a lab report with the given template.

1) What is hydrogen bonding?

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_____

_____

_____

_____

_____

2) Keeping in mind that water is the universal solvent, why is water important for the body?

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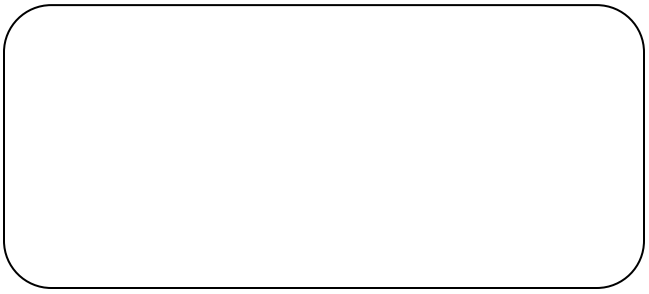
3) Draw the chemical structure of water and explain why it has a bent shape.



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4) What is ChemSketch? And why is it useful in our study of molecules?

_____

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5) Using ChemSketch, draw H_2S, Cl_2, CCl_4, and $HCCl_3$. Please email the saved file to cbtl.poly@gmail.com.