NANO-MODULE 2.
Understanding Chemistry through Molecular Models

Name: _____ Date: _____

Objectives:

- To understand single, double and triple bonding in molecules.
- To visualize molecules in 3D by constructing molecular models.
- To practice using ChemSketch to draw molecules.

Key Concepts: molecule, compound, reactants, products, monatomic, diatomic, polyatomic, single bond, double bond, triple bond, nanotechnology

Vocabulary:
molecule: atoms held together by covalent bonds.
molecular formulas: show the exact number of atoms from each element in the smallest unit of the substance.
Compound: a combination of two or more elements.
chemical reaction: is defined as a process that changes a set of chemicals (reactants) into a new set of chemicals (products).
reactants: the set of chemicals that enter the reaction.
products: are the set of chemicals that are produced by the reaction.
monatomic molecule: molecule containing *one* atom
diatomic molecule: molecule containing *two* atoms.
polyatomic molecule: a molecule containing more than two atoms.
single bond: a bond in which only one pair of electrons (2 electrons) is shared.
double bond: a bond in which two pairs of electrons (4 electrons) are shared.
triple bond: a bond in which three pairs of electrons (6 electrons) are shared.

Background:

I.) What are molecules?

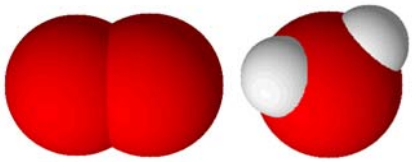


Figure 1. Oxygen gas molecule (O_2) and water molecule (H_2O).

The term **molecule** was coined by Rene Descartes in the 1620s.

Molecules are atoms held together by covalent bonds.

Can you define molecule in your own words?

_____

_____

_____

NANO-MODULE 2.
Understanding Chemistry through Molecular Models

Individual atoms are really small in comparison with the objects that we encounter. So even molecules, which are combinations of atoms, are still small. Figure 2 below shows the size of an atom relative to other things. Atoms are in the picometer (10^{-12}) range.

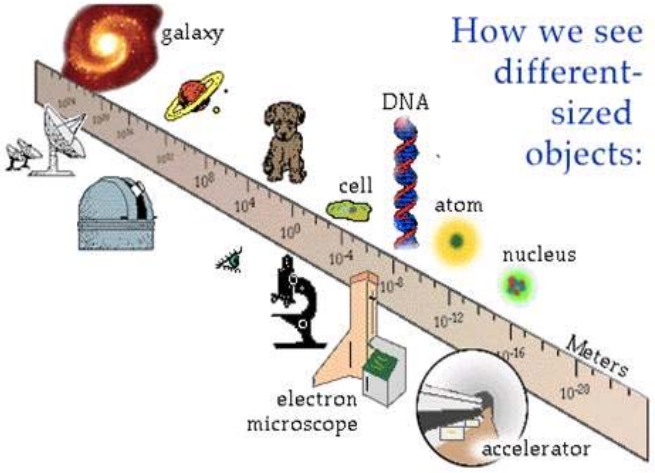


Figure 2. Size Comparison chart[1].

Prefixes with SI Units	
Femto (F)	10^{15}
Tera (T)	10^{12}
Giga (G)	10^{9}
Mega (M)	10^{6}
Kilo (k)	10^{3}
Deci (d)	10^{-1}
Centi (c)	10^{-2}
Milli (m)	10^{-3}
Micro (μ)	10^{-6}
Nano (n)	10^{-9}
Pico (p)	10^{-12}

Table 1. Prefixes with International System of Units

Chemists use **molecular models** to represent molecules because molecules are too small for us to examine. The two main types of models used are **space-filling models** and **ball-and-stick models**.

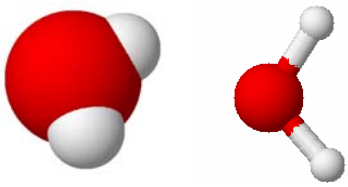


Figure 3. H_2O as space-filling model and ball-and-stick model.

[1] http://www.unca.edu/NCCCR/CFS/Instructor_pages/fincher_larry/images/size_matter.jpg

II.) What is a compound?

Although a molecule can contain atoms of the same element or atoms of two or more elements combined in a fixed ratio, a molecule is not necessarily a **compound**. A compound is defined as a combination of two or more elements. For example, hydrogen gas (H_2) is just an element but it contains two hydrogen atoms for each molecule while water (H_2O) is a molecular compound containing two hydrogen atoms and one oxygen atoms. Like elements, molecules are neutral.

Can you define compound in your own words?

_____

_____

_____

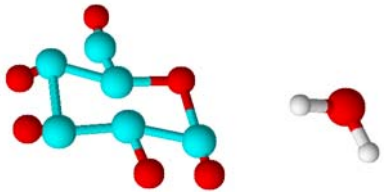


Figure 4. Ball-and-stick model of glucose and water molecule.

Compounds and molecules are formed by chemical reactions. A **chemical reaction** is defined as a process that changes a set of chemicals (reactants) into a new set of chemicals (products). **Reactants** are the set of chemicals that enter the reaction while **products** are the set of chemicals that are produced by the reaction. The breaking of bonds in the reactants and the formation of new bonds in the products is always involved in chemical reactions. An example of a chemical reaction is shown below where 2 molecules of hydrogen gas react with one molecule of oxygen to form two molecules of water:

$$2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(l)}$$

We can denote the states of matter of the reactants and products by using a subscript (gas = $_{(g)}$, liquid = $_{(l)}$, solid = $_{(s)}$). It is important to note that the number of atoms of each chemical species is equal on both sides of the reaction.

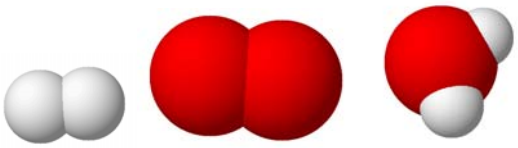


Figure 5. Hydrogen gas, oxygen gas, water.

NANO-MODULE 2.
Understanding Chemistry through Molecular Models

III.) Oxidation States of elements and Ionic Bonding

Elements undergo reactions to obtain a stable octet in its valence shell, which is the outermost shell of atoms. To achieve a stable octet, elements either transfer or share their valence electrons. All elements have an **oxidation state**, which is represented by whole number integers (...-3,-2,-1,0,+1,+2,+3...).

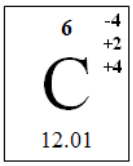


Figure 6. Carbon with oxidation states (-4, +2, +4) shown on the top right corner.

In an **ionic bond**, electrons are <u>transferred</u> from a metal to a nonmetal, to form ions (charged atoms) with stable octets that develop electrostatic attraction to one another. For example, a metal like sodium (Na) has an oxidation number of +1, so it will lose one electron to a nonmetal like chlorine (Cl) who has an oxidation number of -1 resulting in Na^+ and Cl^-. Na^+ and Cl^- have opposite charges, so are attracted to each other electrostatically, forming a "bond." This is not a true bond because it is just an electrostatic attraction between opposite charges. In a **covalent bond**, the moving electrons are <u>shared</u> by moving in the space where the orbitals of the two atoms overlap.

What is the difference between ionic and covalent bonding?

_____

_____

_____

_____

Lewis structures of elemental hydrogen and covalently bonded hydrogen.

Lewis structures of elemental oxygen and covalently bonded oxygen.

Lewis structures of elemental nitrogen and covalently bonded nitrogen.

Figure 7. Demonstration of single, double and triple bonding.

IV.) Classification of Molecules

Chemists classify molecules by the # of atoms the molecule contains. The noble gases only exist as **monatomic molecules** because they do not react with other substances and therefore only contain *one* atom: He, Ne, Ar, Kr, Xe, and Rn. H_2, is a **diatomic molecule** because it has only *two* atoms. Other diatomic molecules that are naturally occurring include: O_2, N_2, and the halogen group (F_2, Cl_2, Br_2, and I_2). Diatomic molecules can also contain atoms from different elements; for instance, carbon monoxide (CO) and hydrogen chloride (HCl). Many other molecules are called **polyatomic molecules** because they contain more than two atoms. Again, the atoms can be from the same element like ozone (O_3) or from different elements like H_2O.

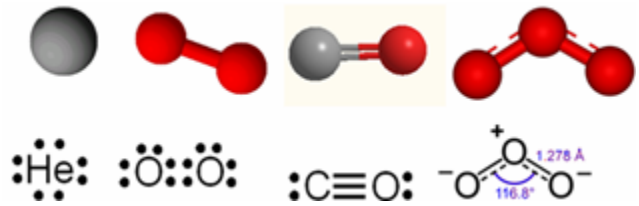


Figure 8. He atom/molecule, O_2 molecule, CO molecule, and O_3 molecule.

V.) Types of Bonds

Atoms can either have single, double, or triple bonds. In a **single bond**, atoms share only 1 pair of electrons (2 electrons). In a **double bond**, atoms share 2 pairs of electrons (4 electrons). In a **triple bond**, atoms share 3 pairs of electrons (6 electrons.)

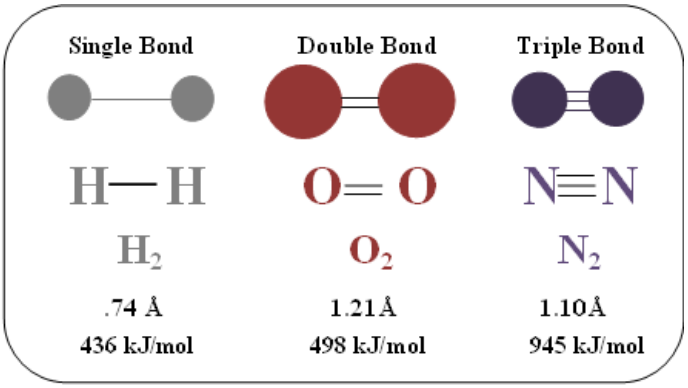


Figure 9. Bond lengths, bond energies for single, double, triple bonding in H_2, O_2, and N_2, respectively.[2]

How many electrons are shared in a double bond? _____

[2] http://www.science.uwaterloo.ca/~cchieh/cact/c120/bondel.html

NANO-MODULE 2.
Understanding Chemistry through Molecular Models

VI.) Nanotechnology

There has been a lot of research in nanotechnology, which aims to be able to control matter on the nanometer scale (10^{-9}). We have manipulated and controlled matter that is our size and larger through the construction of various structures, advances in tissue engineering for skin grafts and plastic surgery, as well as the invention of various electronics. However, a lot of processes in our body occur in the atomic or molecular scale.

Figure 10. An ant carrying a 1 mm square microchip[3]

From the movie Transformers, the robots were the size of trucks and cars. Nowadays, heart surgeons are being aided by small robotic arms. NASA is looking into the potential of nanotechnology to use in space.[4] The army is conducting research on colloidal quantum dots, which blink at a very specific wavelength and its potential to be put onto clothing to help tag soldiers as friend or foe. Many structures that both resemble our products and are functional are being produced at the nanometer scale.

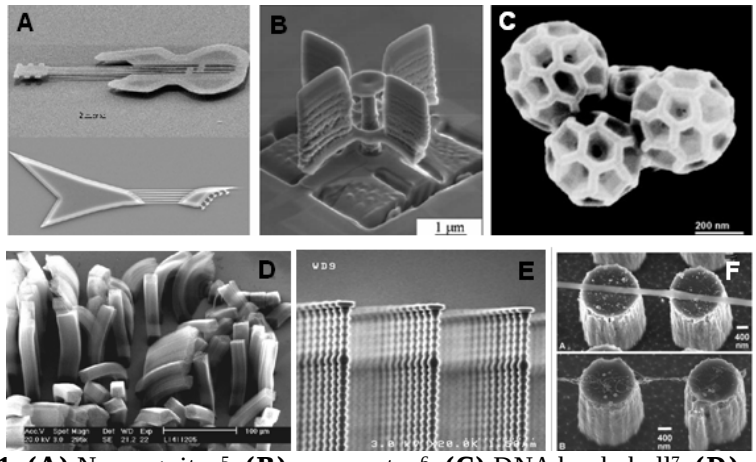


Figure 11. (A) Nano-guitar[5], **(B)** nano rotor[6], **(C)** DNA buckyball[7], **(D)**nanotubes[8], **(E)** nanonails[9], **(F)** nano airbridge[10]

[3] http://www.theage.com.au/articles/2004/12/08/1102182359368.html
[4] http://mmptdpublic.jsc.nasa.gov/jscnano/
[5] http://www.news.cornell.edu/releases/Nov03/NEMSguitar.ws.html
[6] **Microelectronic Engineering** Volume 83, Issues 4-9, April-September 2006, Pages 1221-1224 Micro- and Nano-Engineering MNE 2005

NANO-MODULE 2.
Understanding Chemistry through Molecular Models

Useful Links:
NIH Center for Molecular Modeling
http://cmm.info.nih.gov/modeling/

Knowledge by Design: Visualization of Molecular Structures
http://www.knowledgebydesign.com/tlmc/tlmc_cg.html#viz

Putting the nano into nanotechnology
http://www.rsc.org/chemistryworld/Issues/2005/December/nano.asp

nanotechweb.org | Science · Applications · Industry
http://nanotechweb.org/cws/home

[7] http://www.news.cornell.edu/stories/Aug05/DNABuckyballs.ws.html
[8] http://www.nccr-nano.org/nccr/media/gallery/gallery_01/gallery_01_03/index_html_print
[9] http://nanotechnologytoday.blogspot.com/2008/02/with-jolt-nanonails-go-from-repellant.html
[10] Cohn, Robert W., Sidorov, Anton., Berry, Scott M., Yazdanpanah, Mehdl M., Keynton, Robert S., Sumansekera, Gamini U., Cohn, Robert W. Oriented Nanomaterial Air Bridges Formed from Suspended Polymer-Composite Nanofibers. ACS Nano Vol. 1. 57-62. 2007

NANO-MODULE 2.
Understanding Chemistry through Molecular Models

Name: _____ Date: _____

Match-up: Match the definition with the term.

A. molecule
B. compound
C. reactants
D. polyatomic
E. chemical reaction
F. ionic bond
G. covalent bond

1. a bond formed by the sharing of electrons in the space where the orbitals of two atoms overlap ____

2. a neutral group of atoms held together by chemical bonds ____

3. a process that changes a set of chemicals (reactants) into a new set of chemicals (products) ____

4. describing a molecule containing more than two atoms ____

5. an electrostatic attraction between two ions formed by the transfer of electrons between two atoms each desiring a stable octet ____

6. the set of chemicals that are put into the reaction ____

7. defined as a combination of two or more elements ____

NANO-MODULE 2.
Understanding Chemistry through Molecular Models

Pre-lab Questions
Name: _____ Date: _____
Group: _____

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 a molecule?

_____

_____

_____

_____

_____

_____

2) Describe single, double, and triple bonding.

_____

_____

_____

_____

_____

_____

3) Of single, double, and triple bonding, order them from strongest to weakest .

____ Single

____ Double

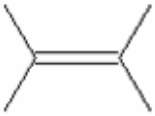
____ Triple

NANO-MODULE 2.
Understanding Chemistry through Molecular Models

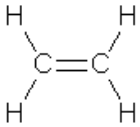
Extra Credit
Name: _____ Date: _____
Group: _____

Instructions: Draw the chemical structures of the showing the hidden carbon and hydrogen atoms.

Example (*hint*: how many bonds can carbon have?):

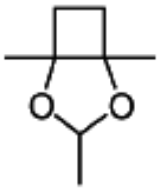


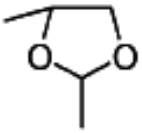
Answer:

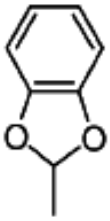


Attempt the following:

NanoPilgrim ***NanoGreenBeret*** ***NanoChef***







Your Answers*:*
NanoPilgrim:

NanoGreenBeret:

NanoChef:

NANO-MODULE 2.
Understanding Chemistry through Molecular Models

Post-lab Questions

1) Based on the periodic table, predict what will form as a result of H and S reacting.

2) Using ChemSketch, draw the product formed in question 1) and email the saved file to cbtl.poly@gmail.com

3) Draw a Lewis-dot structure of fluorine (F) and beryllium (Be).