Chemistry 140 Name(s):

Exercise 1: A chemical overview

In this exercise, you will use a set of simplified rules for bonding between atoms in molecules. Obtain a molecular model kit from the cart.

The **rules**: Yellow represents hydrogen
Red represents oxygen
Black represents carbon
Blue represents nitrogen (some of these blue balls have five holes but use only **three adjacent holes**)
Sticks and springs represent chemical bonds (which are merely a pair of shared electrons between atoms); length doesn't matter
For a molecule to be "happy" (i.e., have all of its bonding requirements satisfied), all holes must be filled with bonds

1. So a nitrogen atom can only bond to three other atoms **maximum** (because you can only use three holes). What is the maximum number of atoms that **carbon** could bond to (hint: count holes)? That **oxygen** could bond to? That **hydrogen** could bond to?

2. Create the following molecules: water (H_2O), ammonia (NH_3) and methane (CH_4). What are the shapes of these molecules? Don't just draw the molecules; **describe** their shapes! Possible shape choices: **linear**, **bent**, **pyramidal**, **tetrahedral**.

3. By writing the chemical formula CH_4, what information about methane are you losing (so always keep this loss of information in mind)?

4. Create the molecule CO_2 (carbon dioxide). What type of bonds need to be used to fulfill the "fill every hole rule" (hint: you will need springs)? Is there more than one way to do this? The correct structure will not have any oxygen-oxygen bonds. What is the shape of carbon dioxide?

More rules: Oxygen and nitrogen have a slight negative charge (even when the atoms are neutral)
Carbon and hydrogen have a slight positive charge (even when the atoms are neutral)
A molecule is called **polar** if the distribution of positive and negative charges is asymmetric (not symmetrical).
A molecule is called **non-polar** if the distribution of positive and negative charges is symmetric.

5. So, for instance, ammonia is a polar molecule but carbon dioxide is non-polar. What about methane and water?

6. At room (Earth) temperatures, what phase (solid, liquid or gas) are water, ammonia, carbon dioxide and methane?

7. Another basic rule is that "like dissolves like"; in other words, polar gases dissolve in polar liquids and non-polar gases dissolve in non-polar liquids. Given this rule, of the four compounds you've made, which **gases** will **dissolve** in which **liquids**?

8. Try to build a model of **glycine** (chemical formula: H_2NCH_2COOH) from the chemical formula. Is there only **one** way to hook up the ten atoms? If you're getting frustrated, look at page 1036 in Chapter 24 and find the model of glycine. Why was the chemical formula of glycine written as H_2NCH_2COOH, rather than $C_2H_5O_2N$?

9. Notice how all of these amino acids are arrayed around a "central" carbon atom. **What shape** does glycine basically have (hint: remember methane and question 3)?

Some **more rules**: A bond (either a stick or a spring) represents two electrons shared between two adjacent atoms. Suppose you have two sets of bonded atoms A-B and C-D. The bond between A and B is said to be **equivalent** to the bond between C and D if:

- A is the same **element** as C and B is the same element as D, and
- the number of bonds between atoms A and B is the same as the number between atoms C and D

10. True or false:

The bonds in water are equivalent.

The bonds in carbon dioxide are equivalent.

11. Do a "bond inventory" of glycine by filling in the following table:

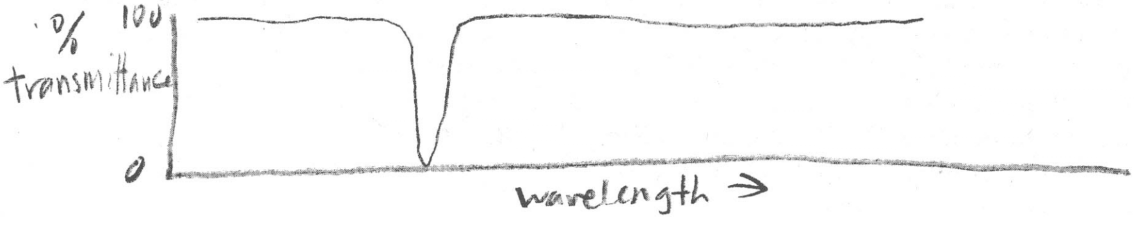
Bond type	N—H						
Number of equivalent bonds	2						

12. The reason we are obsessing about equivalent bonds is that each set of equivalent bonds will **absorb** the energy of a specific set of **electromagnetic** (EM) radiation wavelengths. Therefore, different sets of equivalent bonds will be affected by different wavelengths of light. Let's make a gross simplification: suppose each set of equivalent bonds absorbs exactly one wavelength of light.

How many different wavelengths of light will be absorbed by a water molecule?

How many different wavelengths of light will be absorbed by a glycine molecule?

Below is a schematic (made-up) **spectrum** of water, using our simplified rules from question 10; notice that the spectrum is a graph, with wavelength as the x-axis and intensity (on a scale of 0 to 100%) of the transmitted light as the y-axis.



13. a. Why does the graph line stay on 100% transmitted intensity for most of the wavelengths?

b. What is the significance of the "peak" where the transmitted intensity of light drops close to 0%?

14. Draw a *schematic* spectrum for glycine, using the same kind of graph set up as in the question above.

Even more rules: The substances listed above are called **covalent** (or molecular) because the bonds (sticks) you used to keep atoms together represent shared electrons. In other words, electrons within a bond may come from one or the other or both atoms bonded together.

However, some atoms can lose or gain electrons readily, especially when heated or dissolved in water. By losing or gaining electrons, the atoms are no longer neutral (electrically speaking) and end up with a **positive** or **negative** charge, respectively. These charged atoms are called **ions**. Positively charged ions are called **cations** and negatively charged atoms are called **anions**. Some substances, such as table salt, are held together because their atoms have ionized, and the "opposites attract" rule of electricity holds: the anions and the cations not only balance out to make the whole substance electrically neutral, but also their arrangement fixes each ion in place and thus makes a **crystal** out of the structure. These substances are called **ionic**.

- When an atom loses one electron, the resulting ion has a 1+ charge; when an atom loses two electrons, the resulting ion has a 2+ charge, and so forth.
- When an atom gains one electron, the resulting ion has a 1– charge; when an atom gains two electrons, the resulting ion has a 2– charge, and so forth.
- Most atoms form only one or two types of ions; exactly what charge a given atom's ion will be depends largely on its position on the **periodic table of elements**.
- Atoms of elements in the far left column typically form 1+ ions when they ionize.
- Atoms of elements in the second column from the left form 2+ ions.
- Atoms of elements in the second column from the right form 1– ions.
- Atoms of elements in the third column from the right form 2– ions.
- Atoms in the "transition metals" (low middle part) portion of the periodic table typically form 2+ or 3+ ions.
- When ions combine to form an ionic substance, the resulting net electrical charge of all ions must be **zero** (i.e., the substance is neutral).

As an example, calcium fluoride (which is the mineral fluorite) has the formula CaF_2 because calcium (second column from left) has a 2+ charge and fluorine (second column from right) has a 1– charge, so you need two fluorines for each calcium in order to maintain electrical neutrality.

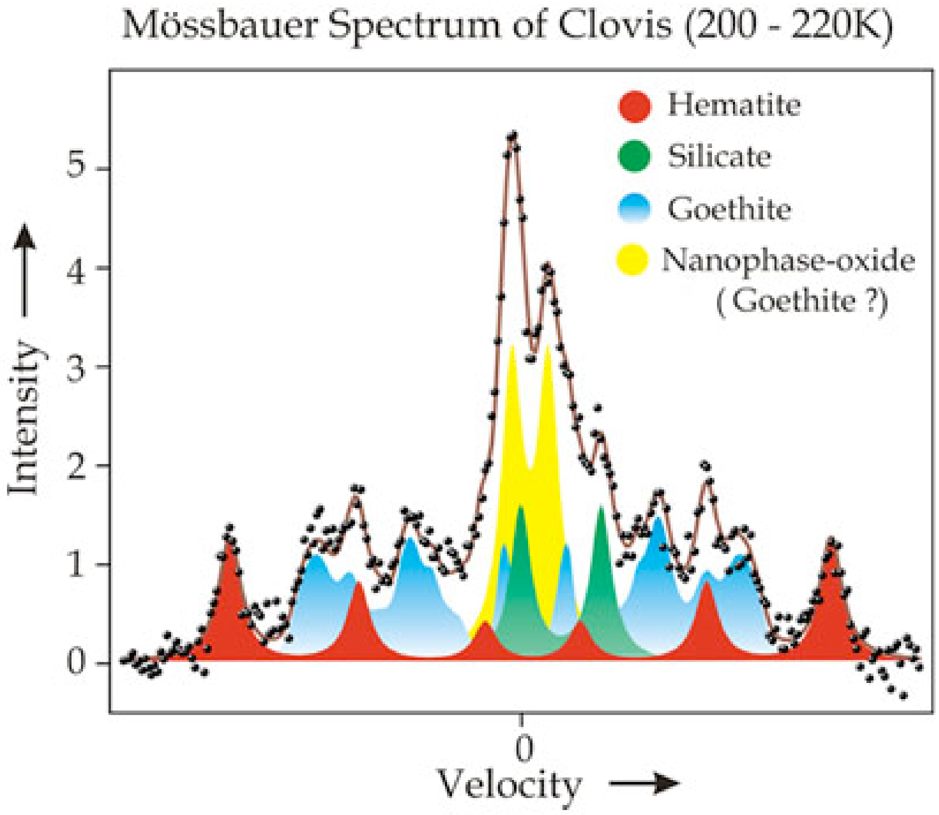
15. Given the rules above, write the **chemical formula** for the following named substances:

a. sodium chloride (table salt)

b. hydrogen sulfide ("rotten egg smell" gas)

c. iron oxide (the mineral called hematite; iron in this case has a 3+ charge)

The Mars Mossbauer Group at the University of Mainz in Germany (http://iacgu7.chemie.uni-mainz.de/klingelhoefer/mer.html) provides the following spectra for various minerals found in a rock called "Clovis" in the Columbia Hills of Mars. These spectra were obtained by the Mars Exploration Rover Spirit's on-board **Mossbauer spectrometer**. Mossbauer spectroscopy can detect **iron atoms only**.



Goethite has a chemical formula FeO(OH) and hematite has the formula Fe_2O_3.

16. Can the two minerals be distinguished by Mossbauer spectroscopy? So what other factor seems to be important, even though Mossbauer spectroscopy is only sensitive to iron atoms?

17. Though it's a little hard to tell, a chemical reaction converts goethite to hematite and vice versa. What simple molecule connects the two? Hint: consider two goethite molecules becoming one hematite molecule and what atoms are left over.

18. Why is the answer to question 17 exciting for scientists studying Mars?