Chemistry 121 Name(s):

Exercise 1: A chemical and mathematical overview

You may work on these exercises individually or in groups; they may also be turned in individually or in groups, but, if you work in groups, you may wish to keep a copy for yourself for use on exams (no sharing of exercises during exams!).

Chemical overview

In this part of the 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?

5. At room (Earth) temperatures, ammonia is a **liquid**. From your own experience, what **phase** (solid, liquid or gas) are water, carbon dioxide and methane?

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*.

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

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. **Intermolecular forces** are what make molecules in liquids and solids stick to each other (as opposed to no forces that hold molecules in larger groups in gases). Of course, at high enough temperatures, all liquids and solids will change into a gas phase. Combine these ideas, along with the answers to questions 5 and 6, and determine do **polar** molecules or **non-polar** molecules have stronger intermolecular forces?

Mathematical overview

Perform the following calculations, giving the result with the proper number of significant figures.

9. In future, we will be using a unit called "the **mole**". One mole of any thing is 6.022×10^{23} of that thing (like a dozen of a thing is 12 of that thing). **How many iron atoms** are in exactly six moles of iron? Be careful about **significant figures**.

10. Each iron atom weighs 9.274×10^{-23} grams. How much does exactly one mole of iron **weigh**? Be careful about **units**.

11. In a capillary, blood flows at a rate of 0.300 cm/s. The typical capillary is 1.0 mm long; what is the length of **time** blood takes to traverse a typical capillary? (Source: www.mas.ncl.ac.uk/~sbrooks/book/nish.mit.edu/2006/Textbook/Nodes/chap09/node22.html)

12. All of the capillaries in the human body have a total cross-sectional area of 2.5×10^3 cm^2. Given that volume = cross-sectional area times length, what is the blood flow **rate** through the capillaries in cm^3/s?

13. Given that the typical adult human has 6.0 L of blood, on average, how **long** does it take to cycle all of the body's blood supply through the capillaries? You might have to look up a conversion factor here.

14. From Fraknoi, Morrison and Wolff, *Voyages to the Planets*, 2^{nd} ed. (2001):

mass of the Earth = 5.977×10^{24} kg

radius of the Earth = 6.378×10^{6} m

Calculate the density of the Earth in kg/m^3. You may find the formula for the volume of a sphere to be useful: $V = 4\pi r^3/3$. Be careful about **significant figures**.

15. Convert your answer to question 14 into g/cm^3, using **conversion factors**.