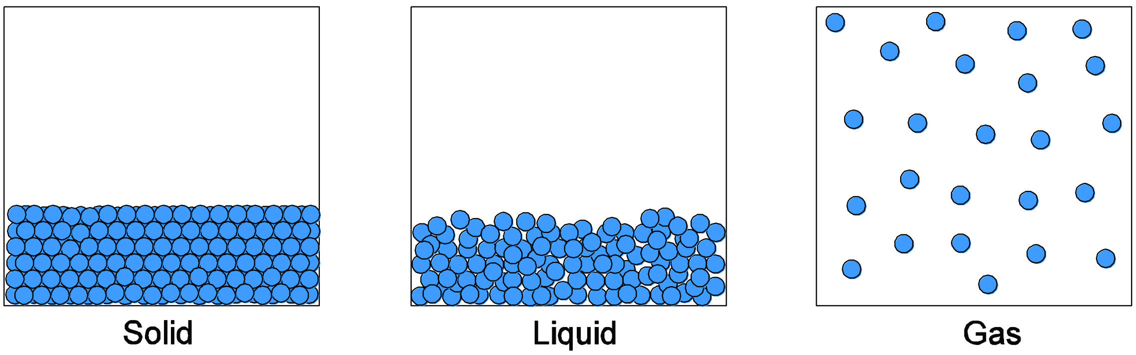
CHM 130LL: States of Matter and Physical Changes

You must bring 1-2 empty pop cans to lab this week.

Substances can exist in three physical states: solid, liquid or gas. The main difference between these physical states is the the **amount of space between molecules**. This is related to the attraction between molecules (intermolecular forces) and the temperature. Consider the molecular-level images for a solid, a liquid, and a gas below:



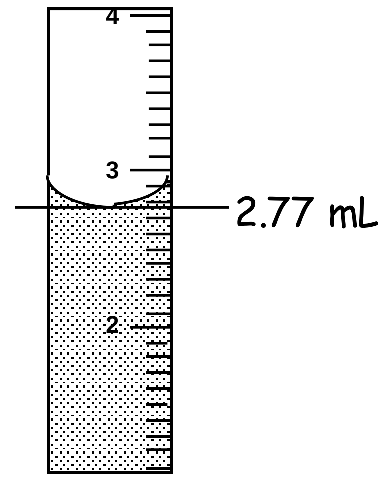
In the **solid** state, molecules are close together in a rigid structure and vibrate in place. This keeps both the shape and the volume of the solid constant. Molecules in a **liquid** are also close together but can move around, sliding back and forth, and still feel the attraction of adjacent molecules. Thus, liquids flow, but are restricted to a constant volume. **Gas** molecules are **far apart** from each other with lots of empty space between them. Gases move quickly and independently, feeling very little attraction to other molecules in the same container. Note the amount of empty space between atoms and molecules in a gas. Thus, a gas will fill a container completely and assume its shape. Compressing a gas reduces the amount of empty space between molecules, and under enough pressure, gases can be forced to condense or liquefy. In this experiment, you will explore and compare the relative compressibility of liquids and gases, and you will compare the densities of various solids, liquids, and gases.

Matter can gain or lose energy. When heat is applied to a substance, its molecules move faster, so they experience an increase in their ***kinetic energy*** (i.e. energy associated with the motion). Increasing the rate of molecular motion increases the temperature of a substance. If the temperature is raised to the melting or boiling point of the substance, applying more heat causes the substance to melt or boil. Conversely if we reduce the kinetic energy we can cause the substance to condense or freeze. These are physical changes.

Physical changes occur when a substance changes from one state of matter to another. When enough kinetic energy is added or removed from a substance such a change can occur. Melting is when a solid becomes a liquid. Freezing is when a liquid becomes a solid. Boiling is when a liquid becomes a gas. Condensation is when a gas becomes a liquid. Sublimation is when a solid becomes a gas. And deposition is when a gas becomes a solid.

When a substance undergoes a physical change, the molecules stay the same and the chemical formula remains unchanged. For example boiling water can be written as $H_2O(l) \rightarrow H_2O(g)$. Notice the formula of water remains unchanged on the product side.

Laboratory Techniques



Graduated cylinders are used to contain and deliver measured amounts of liquid. They are available in many sizes. You will use the 10 mL and 100 mL sizes. Always use the smallest graduated cylinder that will hold the entire volume. The 10-mL graduated cylinders are always read to 2 decimal places (e.g. 5.50 mL) and the 100-mL graduated cylinders are always read to 1 decimal place (e.g. 50.5 mL).

- When water is placed in a glass cylinder, a concave surface forms; this curve is called the ***meniscus***. Glass graduated cylinders are manufactured so that the line at the bottom of the meniscus gives the most accurate reading. In order to read any graduated cylinder accurately, it must be level (sitting on the counter, **NOT** hand-held). Your eye must also be perpendicular to the water level. Note that the graduations on all cylinders rise from the bottom up. That is, they indicate the volume **contained** in the cylinder.

- The **10-mL graduated cylinder** above is read to ***two decimal places*** (to the nearest 0.01 mL). Thus, the volume of liquid is read to be 2.77 mL.

- Note that **100-mL graduated cylinders** have markings for each mL, so they are read to ***one decimal place*** (to the nearest 0.1 mL).

Balances: In most chemistry labs, balances are used to determine the mass of a sample. The metric unit of mass is the gram. You will use electronic balances. These balances are very expensive, very sensitive and must be used very carefully to avoid damage. The general procedure follows. The most important rule is **NEVER place any chemical directly on the balance pan. Use a beaker, a watch glass, a plastic weighing cup, or weighing paper.**

- The balances are to remain "ON" at all times.
- All doors or lids are to remain closed at all times, except when loading or unloading the balance.
- Do not lean on the balance table. (The balance is sensitve enough to measure vibrations on the countertop due to students leaning on it.)
- Material to be weighed should be placed in a container on the balance pan. The container may be either pre-weighed or "tared" or zeroed out (as explained later).
- Before weighing, be sure the doors/lid are closed and the digital scale reads all zeros. If zeroes are not displayed on the scale, gently click the zero button or bar until the balance displays all zeros.
- To weigh an item, open the door, and carefully place the item on the center of the pan. Read and record **all the numbers** in the digital readout. (***Never*** *round any numbers reported on any electronic instrument.*) Remove the item and close the doors/lid before leaving.
- If you are using a container to hold chemicals, you may ***tare or zero*** the container. To do that, place the container carefully in the center of the pan. Briefly click on the zero button or bar. Zeros should appear. The container is now "tared out," and the balance is set to read the weight of any material added to the container. Remove the container from the balance, add material to it, and carefully place the container back on the center of the pan. (Do NOT re-zero the balance during this process.) Read the digital scale when stabilized as before. After you have removed the container, shut the doors and gently push the zero button to remove the tare and return the scale to zero.

***Density* –** We will explore density more fully in a different experiment. For now, density is the ratio of an object's mass to volume. You usually calculate density by diving the mass in grams by the volume in milliliters giving units of g/mL. Generally speaking we expect the density of a solid to be greater than that of a liquid, which is much greater than that of a gas. Density is related to how many atoms are in a given volume. As we just learned, solids are tightly packed with the atoms close together. Liquids also have the atoms packed touching each other and close together. But gases have a large amount of empty space between the atoms, giving rise to a very small density compared to liquids and solids.

$$d = m / V$$

Procedure

A. Compressibility of Gases and Liquids

1. Obtain a syringe and fill with air to 10.0 mL. Place the tip snugly against your fingertip. You now have a "trapped" air sample. Record the volume of the syringe to **one decimal place** always.
2. Hold the syringe vertically (needle down) and increase the pressure on the top of the syringe by pushing directly down on the barrel. Record the smallest volume obtained for the air sample.
3. Using the markings on a 50-mL beaker, pour about 20 mL of deionized water into the beaker. Fill the syringe with deionized water to 10.0 mL. Remove any air bubbles when you invert the syringe. Record the volume of the water sample. Place your fingertip against the tip and push down on the barrel to obtain the smallest volume possible. Record the volume obtained under maximum pressure for the water sample to one decimal place.
4. Answer the question on compressibility and explain based on your observations.

B. Density Comparison

***Note**: Gases cannot be weighed directly in air because of the "buoyancy effect"—the same effect that causes you to feel "lighter" in the water than out of it. You will produce a gas with a chemical reaction, and weigh all the products **except** the gas. By subtracting the mass the products (except the escaped gas) from the reactants, you can calculate the mass of the gas produced.*

CAUTION: Hydrochloric acid is corrosive and can burn skin and damage clothing. Rinse spills on your skin immediately with water for 15 minutes. Neutralize, wash up, and wipe up spills on the lab bench immediately.

CAUTION: If you are allergic to latex, do NOT touch the balloon.

1. Obtain a vial of calcium carbonate from the central cart.
2. Check the balloon provided for holes. If there are holes, replace the balloon. Add the sample of $CaCO_3$ to the balloon. ***Do not wash or rinse the test tube.*** Return the unwashed, dry test tube to the central cart.
3. Pour about 20 mL of 2 M hydrochloric acid, HCl*(aq)*, into a 50-mL beaker. Use the markings on the beaker to estimate 20 mL. Transfer the acid to the Erlenmeyer flask. Do NOT use the syringe for this.
4. Place the balloon over the neck of the Erlenmeyer flask without getting any $CaCO_3$ into the flask. Weigh the entire setup. Record all the numbers as the "mass of the apparatus + reactants".
5. Remove the apparatus from the balance. Invert the balloon over the flask opening, and shake the powdered $CaCO_3$ into the acid. The gas produced is CO_2 (carbon dioxide).
6. When the balloon stops expanding, **estimate** its volume to **2 sig figs** by comparing it to the volumetric flasks provided near the instructor's station. For example, if the volume of the balloon is between the 250 mL flask and the 500 mL flask, estimate the volume as 350 mL, or 410 mL, etc.
7. Slip the balloon off the Erlenmeyer flask to allow the CO_2 gas to escape and push all the gas out of the balloon. Now reattach the balloon and weigh the setup again recording all the numbers. This is the "mass of the apparatus + all products except the CO_2". **Do not throw away the balloon!** It can be used by the next group.

8. Calculate the mass of the CO_2 using conservation of mass.

$$\text{mass of } CO_2 = \begin{pmatrix} \text{mass of apparatus} \\ + \text{ reactants} \end{pmatrix} - \begin{pmatrix} \text{mass of apparatus} \\ + \text{ all products except } CO_2 \end{pmatrix}$$

9. Next, calculate the density of the CO_2 gas in g/mL by dividing the mass of CO_2 by the volume of CO_2. Round to 4 decimal places (have 4 numbers after the decimal place).

Waste: Dispose of all used solutions and reagents in the waste container in the hood.

Liquids: Liquids can be weighed in a container, and the mass of the container subtracted to obtain the mass of the liquid. (DI water is the black knobbed faucet handle)

1. Weigh an empty 10-mL graduated cylinder, and record the complete mass.
2. Use a DI squirt bottle to add 10.00 mL of DI water. Reweigh, and record the new mass.
3. Calculate the mass of just the 10.00 mL of water.
4. Calculate the density of water in g/mL by diving the mass of the water by **10.00 mL** of water. Round your density to 3 decimal places (have 3 numbers after the decimal place).

Solids: Nonreactive solids (glass, pieces of metal, plastic) can be weighed directly on the balance. However, chemicals used for experiments must be weighed in containers.

1. Choose a solid from the tray on the cart and weigh it recording all the numbers. Each solid has a volume of 10.0 mL. Circle the material used.
2. Calculate the density of your solid in g/mL by dividing the mass of the solid by 10.0 mL. Round the density to 2 decimal places.
3. Answer the question comparing the densities of gases to the densities of liquids and solids.

C. Observation of water's mass with time.

1. Fill your 50 mL beaker with about 20 mL of water. Go to the balance and put it on the scale.
2. Observe what happens to the mass with respect to time. Watch for at least 3 minutes. This may take longer in PS 155 to see a change due to the balances in that room so stay there until you see a change.

D. Can Experiment

1. Prepare a tub of ice water by adding 2 large scoops of ice to the tub, then filling ¾ full with tap water.
2. Hold an empty can with tongs palm up above a flame (Bunsen burner) for 30 seconds MOVING the can around so the flame does not burn a hole in the can, then plunge the can quickly upside down into the tub of ice water. Observe what happens if anything.
3. Use your 50 mL beaker to estimate 10 mL of tap water and pour into the second can. Repeat step 2 with this can making sure you see lots of steam coming out of the can **before** you plunge it into the ice water which will take 2-3 minutes.

E. Post lab questions – answer the questions on the last page of your report

Wash your hands and wipe your bench with a wet paper towel!!!

CHM 130LL: States of Matter

Name: ______________________

Partner: ______________________

Section Number: _______________

A. Compressibility of Gases and Liquids

Volume of air sample: (Note: 1 cc ≡ 1 cm^3)

original sample ______________ cm^3 under maximum pressure _____________ cm^3

Volume of water sample:

original sample ______________ cm^3 under maximum pressure _____________ cm^3

Which is more compressible? (Circle one) water air

Explain why based on how particles exist at the molecular level.

B. Density Comparison of Solids, Liquids, and Gases

Gases: Mass apparatus + reactants _____________

Mass apparatus + all products except CO_2 _____________

Mass CO_2 produced _____________

Estimated volume of CO_2 in balloon _____________

Show calculation for density:

Density of CO_2 gas to 4 decimal places =_____________

Liquids: Mass of empty graduated cylinder _____________

Mass graduated cylinder + 10.00 mL of H_2O _____________

Mass of 10.00 mL of H_2O _____________

Show calculation for density below (using **10.00 mL** for the volume of H_2O):

Density of H_2O to 3 decimal places = ______________

Solids:

Material used: (Circle one) metal glass plastic

Mass of solid sample ________________

Show calculation for density below (using **10.0 mL** for the volume of the solid) :

Density of solid to 2 decimal places (in g/mL) = ________________

Explain why the density of CO_2 (and other gases) is so much lower than the density of liquids and solids based on how the particles exist at the molecular level.

C. Observation of water's mass with time.

What happens to the mass of the water with respect to time?

What is happening to the water?

Is this a physical change? Circle YES or NO

D. Can Experiment

What is the difference between the empty can and the can with the 10mL of water inside when plunged into the ice water?

Explain why the can with water crushes more. (Hint: it involves a physical change of the water inside the can)

E. Post lab questions

1. Of all the elements in the periodic table, which two are liquids at room temperature?

2. Which elements in the periodic table are gases at room temperature?

3. Which state of matter has no shape or volume of its own? ___________________

4. Which state of matter has a definite shape and volume? ____________________

5. What is the symbol for the following elements?

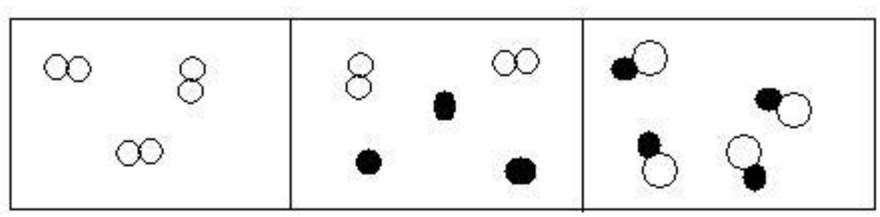
   a. Hydrogen_____ b. Mercury_____ c. Potassium_____ d. Sodium_____

6. What is the name for the following elements?

   a. Pb _____________ b. Br_______________ c. Ca________________ d. Ne_______________

7. Which of the following is a metal? Cu H B Kr Ge

8. Label the following as element, compound or mixture:



_______________ _______________ _______________

9. Which element is a diatomic solid? ________________________

10. Which element is a diatomic liquid? ________________________

11. Is this a physical or chemical change: $NH_3(l) \rightarrow NH_3(g)$ ________________________