CHM 151LL: States of Matter: Physical and Chemical Changes

Name: ________________________
Partner(s): ______________________
Section: _________________________

Objective

In this lab you will investigate the three states of matter, explore the nature of physical versus chemical changes, and then use that knowledge to identify the type of change involved in several experiments.

Note: Bring 2 empty aluminum cans per group for this lab.

Introduction

I. States of Matter

Substances can exist in three physical states: solid, liquid, and gas. The difference between these states of matter is the atoms' or molecules' freedom of movement and the amount of space between the atoms or molecules. The physical state of a substance at a specific temperature depends on the attraction between atoms or molecules and the temperature.

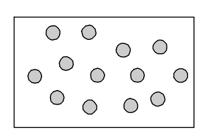
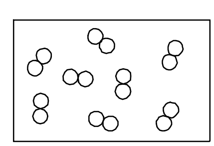
Although more than one hundred elements exist; only two naturally occur in the liquid state. All other liquids are compounds. The two liquid elements are bromine and mercury. Many elements naturally occur as gases: hydrogen, nitrogen, oxygen, fluorine, chlorine, and all the noble gases (Group VIIIA elements). The remaining elements exist as solids.

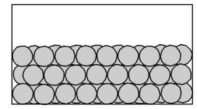
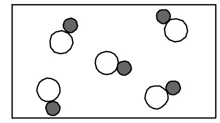
It is important to remember that some elements occur with two atoms bonded together making a molecule. We call them **diatomic** elements, and they are as follows: H_2(g), N_2(g), O_2(g), F_2(g), Cl_2(g), Br_2(l), and I_2(s). Note the subscript 2 represents how many atoms of that element are bonded together in one molecule.

In chemistry, it is important to understand the difference between atoms, molecules, and compounds as well as the difference between a pure substance and a mixture. Being able to classify a substance using these terms will help you identify the types of reactions that substance might undergo in the presence of another chemical. Try to form a mental picture of a substance so you can better understand how to describe it. For example, when someone says "atom", you should visualize a single sphere. The word molecule means that two or more atoms are held together very tightly by bonds. When you hear "molecule", you should visualize multiple atoms bonded together.

At the atomic level, it is also important to understand if a sample is pure or a mixture. If you could use an atomic-sized spoon to scoop out a sample of a pure substance in a container, every scoop of the sample would look the same. In a picture of a pure substance, every substance, or drawing, looks the same. In a picture of a mixture, not all substances are the same. There will be a mixture of atoms, molecules, and/or compounds.

A sample contains an element if there is only one type of atom in the sample. A compound occurs when there are two or more **different atoms** bonded together. A sample is pure if every atom or molecule in the sample is the same. A sample is a mixture if there are two or more different atoms and/or molecules present. We can represent elements and compounds by drawing pictures of them called **molecular-level representations**.

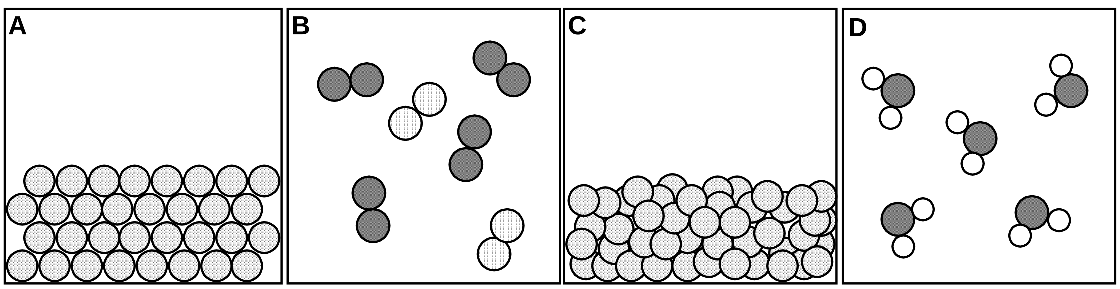
This picture could represent helium gas, He(g). The atoms are spread out like a gas and are not bonded together. The sample is pure since each atom is the same.	
This picture could represent a diatomic element like nitrogen gas, N_2(g). The molecules are spread out like a gas and contain two of the same type of atom. This sample is pure since each molecule is the same.	

This picture could represent a solid element like pure gold, Au(s), because the atoms are very ordered and are all the same type.	
This picture could represent a gas, but it would be a com-pound not an element since the bonded atoms are different from each other. The sample is pure since each molecule is the same. It could be carbon monoxide gas, CO(g).	

In the boxes below, draw **A**) molecules, **B**) a diatomic element, **C**) a pure compound, and **D**) a mixture of a compound and an atom.

A	**B**	**C**	**D**

Match the following figures with their most likely sample by putting the letter for each figure in front of each description below the images.



________ Solid zinc metal

________ Pure liquid mercury

________ Pure H_2O in the gas state

________ Mixture of oxygen and fluorine gases

Questions:

True or False: All molecules are compounds. ____________ Explain and give examples.

True or False: All **covalent** compounds are molecules. ____________ Explain and give examples.

True or False: A sample of atoms and molecules is a pure substance. ____________ Explain and give examples.

States of Matter Animation

Animations

Go to http://web.gccaz.edu/~jstewar1/CHM151LL/Week4.htm and view the animations under Animations. Fill in the boxes below with the appropriate drawings and descriptions.

In the box below draw a picture of **ten atoms** in the solid state.	Describe the position and motion of atoms in the solid state. Do solids have a constant shape? Constant volume?

In the box below draw a picture of the **same ten atoms** in the liquid state.	Describe the position and motion of atoms in the liquid state. Do liquids have a constant shape? Constant volume?

In the box below draw a picture of the **same ten atoms** in the gas state.	Describe the position and motion of atoms in the gas state. Do gases have a constant shape? Constant volume?

Separation Methods

II. Separation Methods

A **mixture** is matter that contains two or more chemical compounds that are combined, and that have not reacted with each other to form another compound. Mixtures can be separated into their individual compounds by **physical methods,** that is, by methods that don't require the breaking or making of chemical bonds. Common separation methods include filtration, distillation, evaporation, sublimation, and chromatography.

There are two kinds of mixtures, **heterogeneous** and **homogeneous** mixtures. A homogeneous mixture has the same composition on the molecular size scale throughout the mixture. When looking at a sample of a homogeneous mixture, there is no visible sign that it is a mixture. For example, salt water looks the same as a pure sample of water. A heterogeneous mixture has varying composition throughout the mixture. An example of a heterogeneous mixture is granite.

You can tell just by looking at it that the mixture is not the same throughout the sample. In this section of the lab, you will separate a mixture of sand and salt. Obtain one vial of the sand/salt mixture per group and develop a procedure to separate the mixture.

Question: Is the mixture made up of sand and salt heterogeneous or homogenous?
_______________________ Explain.

Using the equipment in your group's plastic tub, devise a way to separate a sand and salt mixture in a vial. Once your group has proposed a method for separating the mixture, you must get your **instructor's signature on your proposed procedure.** After your group has separated the mixture, verify this with your instructor by having him/her sign off on your separated substances.

Procedure proposal (include enough detail in your procedure so that a student not in this lab could follow the steps.):
Instructor's signature on proposal: ______________________________

Instructor's signature on separated mixture: ______________________________

Physical Changes

III. Physical Changes

Matter can gain or lose energy. When heat is added to a substance, the **kinetic energy** (energy of motion) of atoms increases, and the atoms move faster. Increasing temperature causes the molecular motion of a substance to increase. Eventually, in the case of solids and liquids, the kinetic energy rises sufficiently to cause a change in physical state, also called a phase change. At the melting point a solid will melt into a liquid, and at the boiling point a liquid will boil and become a gas.

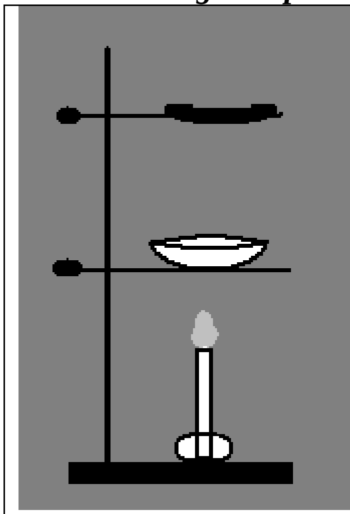
These physical changes are **reversible**. If we decrease the temperature, which decreases the molecular motion, a gas will condense into a liquid at the boiling point, and a liquid will freeze to become a solid at the melting point (which can also be called the freezing point). A few substances, such as dry ice, go directly from the solid state to the gas state (sublimation) and vice versa (deposition). Melting, freezing, boiling, condensation, sublimation, and deposition are all phase changes.

Go to http://web.gccaz.edu/~jstewar1/CHM151LL/Week4.htm and view the Phases of Water animation.

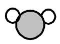
Phase changes (or physical changes) only involve a change in physical state. They do not result in the change of the composition of the atoms or molecules in the substance. The arrangement of atoms in a molecule or compound stays the same. The identity of the substance remains the same. To explore this, carry out the following two experiments.

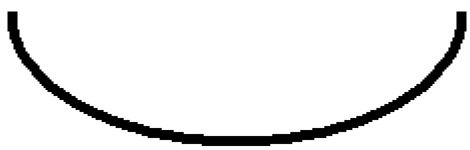
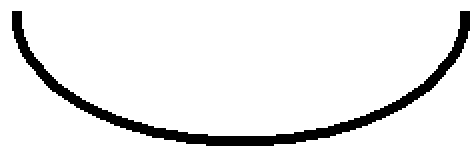
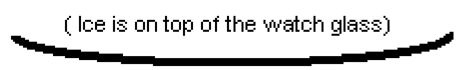
Physical Changes Experiments

1. Phase Changes Experiment:



1. Clamp an evaporating dish to a ring stand and fill with pieces of ice found near the instructor's station. (See the figure to the left.)
2. About five inches above the evaporating dish, place a watch glass on another ring clamp.
3. Using a Bunsen burner, heat the ice in the evaporating dish. Eventually the ice will melt.
4. Continue heating the liquid in the evaporating dish until the liquid begins to boil.
5. Put several pieces of ice on the watch glass. Observe the underside of the watch glass until liquid droplets form.
6. Turn off the Bunsen burner, pour all samples down the drain, and clean and replace your equipment.

Use  to represent a molecule of H_2O, where  represents a hydrogen atom and  represents an oxygen atom. Draw **<u>5 molecules</u>** of the following at the molecular level:

The ice in the evaporating dish before heating 	The liquid in the evaporating dish after the ice melted 
The gas resulting from the liquid boiling in the evaporating dish. 	The liquid that condensed on the **bottom** of the watch glass. 

2. Can Experiment:

1. Obtain 2 clean, dry aluminum cans. Get a blue tub and fill ¾ full with water, adding several pieces of ice to make the water cool.
2. Take one can and hold it with crucible tongs upright over a lit Bunsen burner flame for two minutes keeping the can in motion so it does not melt. Immediately invert the can in a bucket of cool water. Record your observations on your report sheet.
3. Add 10 mL of water into another can, then repeat the procedure in step 2. Heat until steam is coming out of the top of the can. Again immediately invert the can in the bucket of cool water. Record your observations in the data table below.

Data Table

Observations of the **empty can** when placed in the cool water after heating:
Observations of the **can with 10 mL of water** when placed in the cool water after heating:

Chemical Changes

IV. Chemical Changes

Every pure substance can be described by its unique chemical and physical properties. Every sample of the same substance will behave in an identical fashion. Table salt will have the same physical properties and chemical behaviors whether it is in your kitchen or in someone else's kitchen in Russia.

Chemists in industry and research are interested in the changes substances undergo in order to provide better products to the marketplace and to discover new potentially useful substances. There are two types of changes that can be involved: physical, which you have just observed, and chemical. **Chemical changes *do*** change the composition of the atoms or molecules in the substance. They result in new substances with a different arrangement of atoms. The products (substances formed by the chemical change or reaction) are different from the starting materials (called reactants), so they have different chemical and physical properties.

One example of a chemical change is the slow decomposition of hydrogen peroxide H_2O_2 (H-O-O-H) into water H_2O (H-O-H) and oxygen gas O_2. Light speeds up this reaction, which is why hydrogen peroxide is sold in brown containers. Although both water and hydrogen peroxide appear as colorless liquids, their other physical and chemical properties are very different. Just pour them on an open wound to observe their different behavior!

Chemists cannot actually see the individual atoms or molecules of a substance to determine if new molecules formed, so they must instead rely on evidence that can be observed. In general, if the properties of a substance change, one can assume the change was chemical and not physical. Remember, appearances can be deceiving - hydrogen peroxide and water *appear* to be the same! Tests of reactivity or chemical behavior are much better indicators of chemical versus physical changes.

Chemical versus Physical Changes Experiments

In the following four experiments you will cause changes in several substances. You will observe the changes and test the behavior of the substances before and after the change to determine if a physical or chemical change occurred. Record your observations carefully and pay attention to any change in appearance (color, texture) or form (fizzing or bubbling indicates a gas give off and cloudiness indicates solid precipitate formation), which will indicate that a chemical change has occurred.

For each experiment the following general procedure will be followed:

- Obtain two identical samples of the substance to be tested.
- Cause a change in the first sample.
- Compare the behavior of the changed first sample to the second unchanged sample.

Before you begin, answer the following two questions.

- If the changed sample and the unchanged sample behave similarly, the change the first sample underwent is most likely _______________. (chemical or physical)
- If the changed sample and the unchanged sample behave differently, the change the first sample underwent is most likely _______________. (chemical or physical)

Waste disposal:

Dispose of all waste in the waste container in the hood.
Wash and rinse all of your test tubes, shake out any excess water from the inside of each, and dry the outside of each.
Make sure the gas in your area is turned off.
Use paper towels to wash then wipe up your entire lab bench before leaving lab.

A. Silver Nitrate and Copper Metal

CAUTION: Silver nitrate stains skin and clothing. Rinse spills immediately.

Note: You may use a wet test tube for this test as long as it is clean.

1. Clean a small piece of copper wire with sandpaper, coil it, and drop it into a small test tube. Add enough 0.1M $AgNO_3$ to completely cover it. Also add an approximately equal volume of the 0.1M $AgNO_3$ to a second test tube. Wait a few minutes and observe the contents of the first test tube carefully.
2. Pour the $AgNO_3$ solution off the piece of copper into a third test tube. Add 3-4 drops of 3M NH_4OH to this solution, and also to the $AgNO_3$ solution that was not in contact with the copper metal. Compare the results.

	Before exposure to $AgNO_3$ solution	After exposure to $AgNO_3$ solution
Appearance of Copper Metal		

	$AgNO_3$ exposed to Cu	$AgNO_3$ not exposed to Cu
Appearance of Solution		
sample + 3M NH_4OH		

The evidence indicates that mixing silver nitrate and copper metal results in a ______________ change. Explain your reasoning.

B. Magnesium Ribbon and Heat

Note: You may use a wet test tube for this test as long as it is clean.

1. Obtain two short strips of Mg ribbon. Record the appearance of the metal.
2. Holding a test tube with a clamp, place one strip into the test tube. Carefully add 10 drops of 2M HCl into the test tube. Record your observations.
3. Grasp one end of the other strip with your crucible tongs, and hold the strip in the flame of your burner until the magnesium ignites. **Do NOT look directly at the burning Mg.**
4. Collect any combustion product (ignoring unburned metal), and record its appearance.
5. Put the product (**minus any unburned metal**) in a test tube and treat it with HCl as above. Record your observations.

	Heated Mg Sample	Unheated Mg sample
Appearance		
sample + 2M HCl (aq)		

The evidence indicates that heating magnesium metal results in a ________________ change. Explain your reasoning.

C. Ammonium Chloride and Heat

Note: You may use a wet test tube for this test as long as it is clean.

1. Cover the bottom of your evaporating dish with a thin layer of NH_4Cl (ammonium chloride). Support this on a ring stand and wire gauze. Cover the evaporating dish with a watch glass.
2. Heat the bottom of the evaporating dish with your bunsen burner until you notice white fumes escaping from the spout of the evaporating dish or until a white coating forms on the watch glass. Turn off your bunsen burner, and **let the equipment cool.** You should notice a white deposit on the underside of the watch glass.
3. Wait at least 5 minutes for the watch glass to cool, and then carefully remove it with your hand. Holding the edges of the watch glass securely over a test tube, scrape a pea-sized amount of the white deposit into the test tube. Dissolve this in a **minimum** amount of deionized water.
4. In a second test tube, place a small, pea-sized amount of unheated NH_4Cl, and also dissolve this in a **minimum** amount of deionized water.
5. Add two drops of $AgNO_3$ solution to each test tube and compare the results.

	Heated NH_4Cl Sample	Unheated NH_4Cl Sample
Appearance		
sample + $AgNO_3$		

The evidence indicates that heating ammonium chloride results in a __________________ change. Explain your reasoning.

D. Electrolysis of Water: Demonstration

Your instructor will demonstrate the electrolysis of water to produce hydrogen and oxygen gas.

In your groups, heat 100 mL of water in the 150-mL beaker over the Bunsen burner to a **gentle** boil. Hold a lit splint over the gently boiling water. Repeat with a glowing (not burning) splint.

	Boiling water		Water after Electrolysis	
	Lit Splint	Glowing Splint	Left Buret	Right Buret
splint held over sample				

The observations indicate that the electrolysis of water produces a _____________ change. Explain your reasoning.

Post-Lab Questions

Post-lab questions:

1. What is the only naturally occurring liquid element that is not diatomic? ________
2. What element occurs naturally as a diatomic solid? ______________
3. Draw a molecular representation of ozone, $O_3(g)$, in the box.
4. Explain the difference in behavior of the heated cans with AND without the water. How is a **phase change** involved in what you observed for the can with water?
5. If the can were a solid cylinder of aluminum metal, instead of being hollow, describe and explain the result if it were heated then plunged into cool water. Would it behave more like the aluminum can with water or the can without water? Why?
6. A white sample of solid potassium chlorate is heated strongly for 30 minutes. The sample melts, and bubbles of gas escape during the heating. Upon cooling, the heated sample is solid white. When a sample of unheated solid is dissolved in water and 10 drops of silver nitrate solution are added, the solution remains clear. When a sample of the heated solid is dissolved in water and treated with 10 drops of silver nitrate, the solution becomes very cloudy. Thus, heating potassium chlorate is a _____________ (chemical or physical) change. Explain your answer based on the observations.

