Chemical Changes

Name(s) ___________________________________

In the particle model of matter, individual atoms can be bound tightly to other atoms to form molecules. For example, water molecules are made up of two hydrogen atoms bound to one oxygen atom. In symbols, this is written as H_20, where the "H" represents a hydrogen atom, and the "O" represents an oxygen atom. The small "2" after the "H" indicates that there are two hydrogen atoms in the molecule. H_20 is said to represent the **chemical formula** for water, because it tells us exactly what atoms we would need if we wanted to make a molecule of water.

A **chemical change** (or a **chemical reaction**) is said to have occurred if the atoms making up a molecule are rearranged. This can happen if a molecule loses some of its atoms, if some atoms are added to a molecule, or if some of the atoms in a molecule get replaced by other atoms.

An example of a chemical change (reaction) is the combining of two hydrogen molecules with one oxygen molecule to form two water molecules. This is a chemical change, because the molecules that you end up with are not the same as the ones with which you started. This change (reaction) can be written symbolically in the following way:

An oxygen molecule is written as O_2, indicating that oxygen molecules are made by binding two oxygen atoms together. A hydrogen molecule is written as H_2, indicating that this molecule is made out of two hydrogen atoms. If you wish to indicate that you have two hydrogen molecules, you would write $2H_2$, where the first "2" indicates that we are talking about two molecules instead of one. The chemical reaction can then be written as

$$2H_2 + O_2 \rightarrow 2H_2O$$

In one of the previous activities in this course, a chemical reaction occurred when vinegar was combined with baking soda. Several different types of molecules were made in that reaction, including carbon dioxide. The activities presented here will allow you to investigate that reaction in detail.

Measuring a Chemical Reaction

1. Put about a teaspoon full of baking soda into a cup, and pour a little vinegar on top. Describe the reaction you observe taking place.

The scientific name for baking soda is sodium bicarbonate. Its chemical formula is given by $NaHCO_3$. In this formula "Na" stands for sodium and "C" stands for carbon.

Vinegar is a mixture of water and acetic acid. The chemical formula for acetic acid is $HC_2H_3O_2$. In the formula for acetic acid "H" is listed twice, so there are actually a total of four hydrogen atoms in every molecule of acetic acid. (Chemists list hydrogen twice in this formula in order to indicate which atoms are directly connected to each of the four hydrogen atoms. We will not have to concern ourselves with this minor detail.)

When baking soda and acetic acid react, three new molecules are formed: water (H_2O), carbon dioxide (CO_2), and sodium acetate ($NaC_2H_3O_2$). [Sodium acetate is also the chemical substance inside the heat packs that we use.]

The chemical reaction that occurs when baking soda and vinegar mix is written below.

$$\underset{\text{baking soda}}{NaHCO_3} + \underset{\text{acetic acid}}{HC_2H_3O_2} \rightarrow \underset{\text{sodium acetate}}{NaC_2H_3O_2} + \underset{\text{water}}{H_2O} + \underset{\text{carbon dioxide}}{CO_2}$$

2. Place about 100 ml of vinegar in a clean plastic cup. Carefully weigh the cup and the vinegar together, and write down the mass.

   Mass of cup plus vinegar ____________ g.

3. Carefully weigh about 4 ml of baking soda, and write down the mass. (Do not include the mass of the container holding the baking soda.

   Mass of baking soda ____________ g.

4. Now add up the mass of the baking soda with the mass of the cup plus the vinegar.

   Total mass of cup plus vinegar plus baking soda ____________ g.

5. <u>Slowly</u> pour the baking soda into the cup of vinegar. Just add a little at a time in order to insure that the liquid does not bubble over the top of the cup. When the reaction is completely finished, weigh the cup and its contents again, and record the mass.

   Mass of cup and contents *after* the reaction ____________ g.

6. The mass you just measured is *not* the same as the amount you calculated to be the sum of the cup plus the vinegar plus the baking soda in question #4. Why not? What happened to the missing mass?

Counting Atoms in a Chemical Reaction

The mass of a single atom is very small. (For example, a one-gram piece of aluminum consists of about 22,000,000,000,000,000,000,000 atoms of aluminum.) Since atomic masses are so very small, it is not convenient to measure them using the unit of grams. Instead, we use something else called an atomic mass unit (abbreviated as **a.m.u.**). In this unit of measurement, a hydrogen atom has a mass of 1 a.m.u. Below you will find a table of some common atoms along with their masses as measured in a.m.u.

Atom	Mass in a.m.u.
Hydrogen (H)	1
Carbon (C)	12
Oxygen (O)	16
Sodium (Na)	23

The mass of one water molecule can be found with the use of this table in the following way:

Water (H_20) has two hydrogen atoms and one oxygen atom.

Mass of H_20 = 2 x (mass of H) + 1 x (mass of O) = **18 a.m.u.**

A. Find the mass of each of the following molecules:

Baking soda ($NaHCO_3$)

Acetic acid ($HC_2H_3O_2$)

Sodium Acetate ($NaC_2H_3O_2$)

Carbon dioxide (CO_2)

The reaction between baking soda and vinegar is described by the following equation

$NaHCO_3$	+	$HC_2H_3O_2$	$\rightarrow$	$NaC_2H_3O_2$	+	H_2O	+	CO_2
baking soda		acetic acid		sodium acetate		water		carbon dioxide

This equation indicates that as a baking soda molecule and an acetic acid molecule react, one molecule of carbon dioxide gas is produced. As this happens in your cup, the carbon dioxide gas leaves the solution.

B. Suppose you add one molecule of baking soda to your vinegar. *Before* the baking soda has time to react with the vinegar, by how much would the mass of your solution <u>increase</u>?

C. By how much will the mass of your solution <u>decrease</u> when a carbon dioxide molecule is produced?

D. If one gram of baking soda is added to a cup of vinegar and allowed to react, how much (overall) will the mass of the cup change?

E. Compare your answer to letter D. above to the results you obtained for questions #4 and 5 in the first activity. Are these answers consistent with each other?

Chemical and Physical Changes Content Overview

All substances are made out of atoms. A few substances are composed of individual atoms that are not bound (attached) to any other atoms. An example of this would be helium gas. However, most substances are more properly thought of as consisting of molecules; a combination of two or more atoms bound together. Molecules themselves may be made of all identical atoms (oxygen gas, for example, consists of two oxygen atoms bound together), or they may be composed of two or more different atoms. Water molecules, for example, consist of two hydrogen atoms attached to an oxygen atom.

When a molecule changes, by either gaining or losing atoms or by binding to another molecule, a **chemical reaction** or **chemical change** is said to have occurred. In general, the molecules formed in a chemical reaction have properties different from the original molecules. Therefore, when chemical reactions occur, the observable properties of the substances present also change. For example, when solutions of starch and iodine react, the color of the resulting liquid is different from the color of the original liquids. When vinegar (a liquid) reacts with baking soda (a solid), carbon dioxide (a gas) is given off. These types of property changes often indicate when a chemical reaction has occurred. Other property changes often associated with chemical changes include changes in odor, and the warming up or cooling off of the reacting substances.

When the physical properties of a substance change without a corresponding change in the kind or number of particles making up the substance, it is said that a **physical change** has occurred. For example, in liquid water, the water molecules are free to move around, but each individual water molecule remains unbroken as one oxygen atom and two hydrogen atoms bound together. Water vapor (gas) also consists of water molecules, with each water molecule consisting of one oxygen atom and two hydrogen atoms. Water vapor molecules are free to move about, but the structure of each molecule remains the same. When water forms ice, the water molecules do not break up, they simply attract each other so strongly that the individual molecules can no longer move about. In all three of these examples, however, the individual molecules remain the same. You can change water back and forth between these different **phases** simply by heating it and cooling it, but you would not change the fact that there is still one oxygen atom associated with two hydrogen atoms. Changes like these, in which the atoms within a molecule are not altered, are called physical changes.

It is not always possible to specify unambiguously whether a change is physical or chemical simply by observing changes in the properties of substances. You really need to know whether or not individual molecules have changed. This is not always obvious, because molecules are too small to be seen. However, a general rule to follow is that if the change observed is easily reversible, then a physical, and not a chemical change has likely occurred.

For example, when candle wax melts, a physical change has occurred. The molecules making up the wax have gone from the solid state to the liquid state. You can reverse this process simply by cooling off the hot wax. The liquid wax will turn back into a solid.

On the other hand, when candle wax burns, a chemical change occurs. The wax combines with oxygen molecules in the air to form (primarily) carbon dioxide and water. That this is a chemical change and not a physical change is most evident if you try to reverse the change by cooling the gas and the water given off from the burning. The gas and the water will not revert back to solid wax.

