Exploring Creation With Physical Science

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MODULE #1: The Basics

Introduction

In this course, you are going to learn a lot about the world around you and the universe it is in. We will study things as familiar as the air around you and others as mysterious as radioactivity and distant galaxies. We will learn about the structure of the earth as well as its place in the solar system and the universe. The study of these topics and many others like them are all a part of what we call **physical science**.

In order to make sure we are both starting on the "same page," I need to discuss some basic concepts with you. It is quite possible that you have learned some (or all) of this before, but it is necessary that we cover the basics before we try to do anything in depth. Thus, even if some of the topics I cover sound familiar, please read this module thoroughly so that you will not get lost in a later module. In fact, many of the subjects I will cover in later modules are probably familiar to you on one level or another. After all, most students your age know something about air, the construction of our planet, weather, and astronomy. Nevertheless, I can almost guarantee you that you have not learned these subjects at the depth in which I will discuss them in this course. So, despite how much you might *think* you know about a given topic, please read the material I present to you carefully. I doubt that you will be disappointed.

If, on the other hand, all this is completely new to you, don't worry about it. As long as you read the material carefully, perform the experiments thoroughly, and really *think* about what you are learning, everything will be fine. Although this course might not be *easy* for you, there are very few things in life that are both easy *and* worthwhile. I promise you that if you *work* at learning this course, you will gain a great deal of knowledge, a solid sense of accomplishment, and a grand appreciation for the wonder of God's creation!

Atoms and Molecules

In this course, I am going to illustrate as many concepts as possible with experiments. Hopefully, the "hands on" experience will help bring those concepts home better than any discussion could. In some cases, of course, this will not be possible, so we will have to make do with words and pictures. To start our discussion of atoms and molecules, I want you to perform the following experiment:

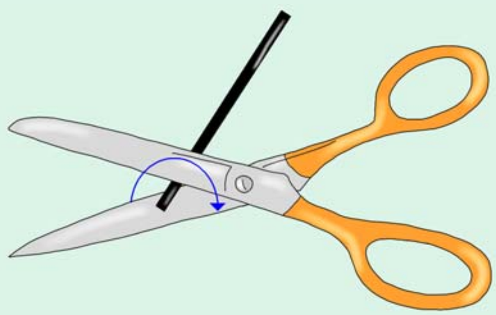
EXPERIMENT 1.1
Atoms and Molecules

Supplies:
- A small, clear glass (like a juice glass)
- Baking soda
- Tap water
- A 9-volt battery (the kind that goes in a radio, smoke detector, or toy. DO NOT use an electrical outlet, as that would be quite dangerous! A 1.5-volt flashlight battery will *not* work.)
- Two 9-inch pieces of insulated wire. The wire itself must be copper.
- Scissors
- Some tape (preferably electrical tape, but cellophane or masking tape will work.)
- A spoon for stirring
- Eye protection such as goggles or safety glasses

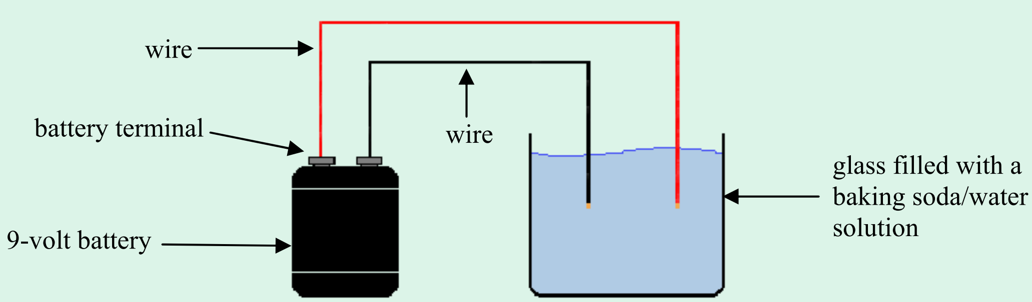
Introduction: Atoms and molecules make up almost everything that surrounds us. Individually, they are too small to see. However, you can distinguish between different kinds of atoms and different kinds of molecules by examining the substances they make up, as well as how those substances change. In this experiment, we will observe molecules breaking down while other molecules are built up. By observing these changes, you will learn about the difference between atoms and molecules.

Procedure:

1. Fill your small glass ¾ full of tap water.
2. Add a teaspoon of baking soda and stir vigorously.
3. Use your scissors to strip about a quarter inch of insulation off both ends of each wire. The best way to do this is to put the wire in your scissors and squeeze the scissors gently. You should feel an increase in resistance as the scissors begin to touch the wire. Squeeze the scissors until you feel that resistance and then back off. Continue squeezing and backing off as you slowly turn the wire round and round, as shown below:



Be careful. You can cut yourself if you are not paying proper attention! You will eventually have a cut that goes through the insulation all the way around the wire. At that point, you can simply pull the insulation off. It will take some practice to get this right, but you *can* do it. Make sure there is at least ¼ inch of bare wire sticking out of both ends of the insulation.
4. Once you have stripped the insulation off both ends of each wire, connect the end of one wire to one of the two terminals on the battery. Do this by laying the wire over the terminal and then pressing it down. Secure it to the terminal with a piece of tape. It need not look pretty, but the bare wire needs to be solidly touching one terminal and not in contact with the other terminal.
5. Repeat step 4 with the other wire and the other battery terminal. Now you have two wires attached to the battery, one at each terminal. **Do not allow the bare ends of these wires to touch each other**!
6. Immerse the wires in the baking soda/water solution that is in the small glass so that the bare end of each wire is completely submerged. It doesn't really matter how much of the insulated portion of the wire is immersed; just make sure that the entire bare end of each wire is fully submerged. Once again, don't allow the ends to touch each other. In the end, your experiment should look something like this:



7. Look at the bare ends of the wires as they are submerged in the baking soda/water solution. What do you see? Well, if you set everything up right, you should see bubbles coming from both ends. If you don't see bubbles, most likely you do not have good contact between the wires and the battery terminals. Try pressing the ends of the wire hard against the terminals to which they are taped. If you then see bubbles coming from the submerged ends of the wire, then you know that electrical contact is your problem. If not, then your battery might be dead. Try another one.
8. Once you get things working, spend some time observing what's going on. Notice that bubbles are forming on *both* wires. That's an important point that should be written in your laboratory notebook.
9. Allow the experiment to run for about 10 minutes. After that time, pull the wires out of the solution and look at the bare ends. What do you see? Well, one of the wires should not look very different from when you started. It might be darker than it was, but that should be it. What about the end of the other wire? It should now be a different color. What color is it? Write that color down in your notebook.
10. If you let the experiment run for 10 minutes, it's very possible that your solution became slightly colored. Write in your notebook whether or not that happened and what color, if any, the solution became.
11. Looking at the wire that changed color, trace it back to the battery and determine the terminal (positive or negative) to which it is attached. Write that in your laboratory notebook as well.
12. **Clean up:** Disconnect the wires from the battery, dump the solution down the sink, run tap water to flush it down the drain, and wash the glass thoroughly. Put everything away.

Now, to understand what went on in the experiment, you need a little background information. Nearly everything you see around you is made up of tiny little units called **atoms**.

<u>Atom</u> – The smallest chemical unit of matter

Atoms are so small that you cannot see them. They are so small, in fact, that roughly 1,000,000,000,000,000,000 atoms are contained in the head of a pin. If we can't see them, how do we know they exist? Well, lots of experiments have been done that can only be explained if you *assume* that atoms exist; thus, there is a lot of *indirect* evidence that atoms exist. All this indirect evidence leads us to believe that atoms are, indeed, real.

When you stripped the insulation off the ends of each wire, you saw the familiar red-orange color of copper wire. Well, it turns out that copper is a type of atom. Thus, the copper that you observed in the wire was really just a bunch of copper atoms lumped together. You couldn't see the *individual* atoms, but when billions and billions and billions of them are put together, you can see the substance they make. When you have billions of billions of billions of copper atoms, you get the flexible, electricity-conducting, red-orange metal called copper.

We currently know that there are about 116 basic kinds of atoms in creation. This number increases as time goes on because every once in a while, scientists discover a new kind of atom. In a few years, then, the number of basic kinds of atoms in creation will probably be a little larger. That's why I say "about" 116 different kinds of atoms in creation.

If that were the end of the story, creation would be pretty boring. After all, if everything that you see were made up of atoms, and if there are only about 116 different kinds of atoms in creation, there are only 116 different substances in creation, right? Of course not! Although God used atoms as building blocks in creation, He designed those atoms to link together to form larger building blocks called **molecules**.

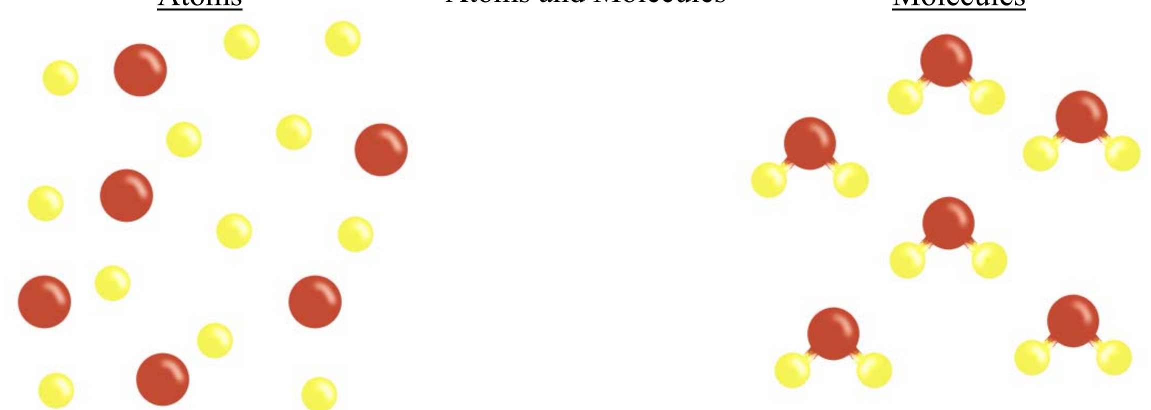
Molecule – Two or more atoms linked together to make a substance with unique properties

It turns out that the water you used in your experiment is made up of molecules. Although molecules are bigger than atoms, you still cannot really see them. Thus, the water you see is made up of billions and billions and billions of water molecules, just like the copper wire is made up of billions and billions and billions of atoms of copper. A water molecule is formed when an oxygen atom links together with two hydrogen atoms. When these atoms link together in a very specific way, the result is a water molecule. The difference between atoms and molecules is illustrated below.

Illustration by Megan Whitaker

FIGURE 1.1
Atoms and Molecules

Atoms | Molecules



A bunch of oxygen atoms (red) and hydrogen atoms (yellow) grouped together. This is a mixture of two different substances, each with its own properties.

The same oxygen and hydrogen atoms linked together to make water molecules. They all have the same properties, which are quite different from the properties of oxygen and hydrogen atoms.

Now we are ready to really discuss the results of the experiment. When you filled the glass with water, you were filling it with billions and billions and billions of water molecules. When you placed the wires (which were connected to the battery) into the water, the electricity from the battery began flowing through the water. When this happened, the energy from the electricity flow actually broke some of the water molecules down into hydrogen and oxygen, which began bubbling out of the water, because hydrogen and oxygen are gases!

This tells us something about molecules. Each water molecule is made up of two hydrogen atoms and an oxygen atom linked together. When these atoms link together in that way, an odorless, colorless, tasteless liquid we call water is formed. When electricity is used to break the water molecules down, hydrogen and oxygen are formed. Hydrogen is an explosive gas, while oxygen is the gas we breathe to stay alive. Think about that. Oxygen and hydrogen are each gases with particular properties. When the atoms that make them up link together so that two hydrogen atoms are linked to one oxygen atom, however, these individual properties are lost, and a new substance (water) with new properties (odorless, colorless, tasteless liquid) is formed.

In one part of the experiment, then, you saw a molecule (water) breaking down into two gases made up of its two constituent atoms (hydrogen gas and oxygen gas). Well, when you pulled the wires out of the water after 10 minutes, you saw that the wire connected to the positive terminal of the battery had turned a bluish-green color. In this case, the copper atoms in the wire interacted with water molecules and baking soda molecules, aided by the energy contained in the electricity. The result was a bluish-green substance called copper hydroxycarbonate (hi drok' see car' buh nate). Copper hydroxycarbonate is formed when a copper atom links together with oxygen atoms, carbon atoms, and hydrogen atoms. In this experiment, the hydrogen and oxygen atoms came from both the water and the baking soda, the carbon atoms came from the baking soda alone, and the copper atoms came from the wire. In this case, then, you observed atoms (copper) linking up with other atoms (oxygen, carbon, and hydrogen) to make a molecule (copper hydroxycarbonate).

Interestingly enough, copper hydroxycarbonate is the same substance that you see on many statues, such as the Statue of Liberty. You see, if a structure made of copper (like the Statue of Liberty) is exposed to weather, a process similar to the one you observed turns the copper atoms in the statue into copper hydroxycarbonate. As a result, the structure turns bluish-green, just like one of the copper wires did in your experiment.

FIGURE 1.2
The Statue of Liberty and a Civil War Cannon

Photos © Daniel Slocum (left) and Geoffrey Kuchera (right) Agency: Dreamstime.com

The Statue of Liberty (left) turned bluish-green because hydrogen, oxygen, and carbon atoms from various substances in the air have combined with copper atoms to make copper hydroxycarbonate. This Civil War cannon (right) is made of bronze, which is a mixture of copper and tin. The copper in the mixture has also reacted to form copper hydroxycarbonate.

Chemical reactions like the ones you observed in your experiment are how we get all the incredible substances you see around you. Some substances (copper, aluminum, and some others) are made of billions and billions and billions of the same atom. These substances are often called **elements**. Other substances we see (water, salt, sugar, and many others) are made up of billions and billions and billions of molecules. They are often called **compounds**. Finally, many substances we see (wood, cereal, plastics, and many others) are actually **mixtures** of several different substances, each of which is made up of either atoms or molecules.

Okay, I am finally done discussing the experiment. Now that you know what the experiment shows, you can write a summary in your laboratory notebook. Write a brief description of what you did, followed by a discussion of what you learned. You will need to do each experiment in this way. Once you have done an experiment and written down any data and observations that come from the experiment, you need to read the discussion that relates to it. Once you have read the discussion, you can then write a summary explaining what you did and what you learned. This will help you get the most from your laboratory exercises.

Now that I am done presenting the concept of atoms and molecules, you need to answer the following "On Your Own" problems in order to make sure you understand what you have read. These kinds of problems will show up periodically, and you should answer them as soon as you come to them in the reading.

ON YOUR OWN

1.1 A molecule is broken down into its constituent atoms. Do these atoms have the same properties as the molecule?

1.2 When salt is dissolved in water, it actually breaks down into two different substances. Is salt composed of atoms or molecules?

Before you go on to the next section, I want to dispel a myth you might have heard. In many simplified science courses, students are told that scientists have actually seen atoms by using an instrument called a "scanning tunneling electron microscope." Indeed, students are shown figures such as the one below and are told that the conical shapes you see in the picture are atoms.

FIGURE 1.3
A Scanning Tunneling Electron Microscope Image of the Surface of a Nickel Foil

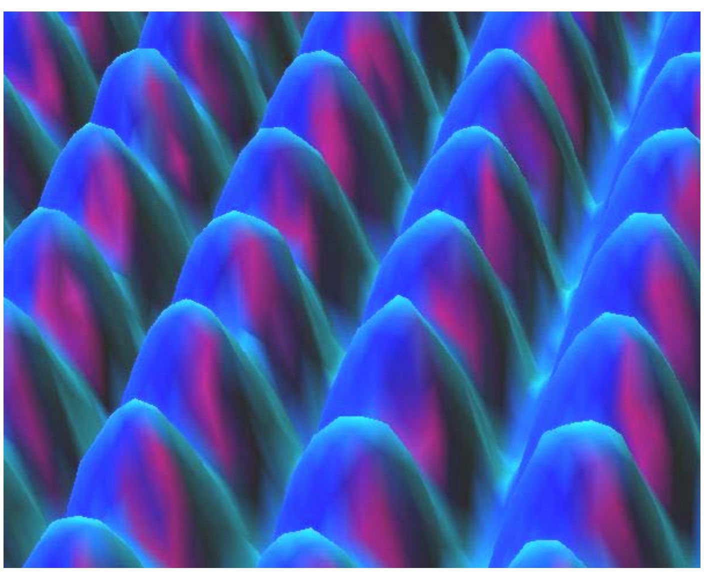


Photo courtesy of the IBM research division glass, but there was also half as much volume. Thus, the concentration (how much exists in a *given volume*) of vinegar in the second glass was the same as it was in the first glass. In the second part of the experiment, however, there was half as much vinegar *in the same amount of volume* as the first glass. Since there was half as much vinegar in the same volume, the concentration of vinegar was half as much. As a result, the neutralization of acid by the Tums went much more slowly.

In the third glass, the concentration of vinegar was so small that the Tums tablet seemed to not disappear at all. So, this experiment shows us that the way chemicals behave depends on their concentration. When the concentration of vinegar is large, the neutralization of the acid in vinegar by a Tums tablet proceeds rather quickly. When the concentration of vinegar is low, however, that same process proceeds slowly or not at all. This is perhaps the single most important thing that you can learn about chemicals. At certain concentrations, chemicals behave in one way. At other concentrations, those same chemicals can behave in a different way.

The multimedia CD has a video demonstrating how concentration can affect a chemical's behavior.

Consider, for example, vitamins. Certain vitamins are often called "fat soluble vitamins." These vitamins (A, D, E, and K) get stored in your body's fat reserves if your body has more than it needs. As time goes on, those vitamins build up. If they get too concentrated, they can actually become *toxic* to the human body! Think about that for a moment. Vitamins, which are very good for you, can become toxic to you if they reach high concentrations. It is possible, in fact, to get very sick or even die as a result of taking *too many* vitamins!

Now don't get paranoid about this! If you take one or two times the recommended daily allowance of vitamins A, D, E, and K, they will probably not reach toxic concentrations in your body. Only if you take several times the recommended daily allowance of these vitamins do you risk a buildup to toxic concentrations. The point, however, should not be lost. The behavior of chemicals depends on their concentration. Certain chemicals are good for you at one concentration and toxic for you at another. In the same way, chemicals we call poisons are not necessarily bad for you at low enough concentrations!

This discussion has relevance to many issues in modern society. Consider, for example, the cigarette smoking debate raging in the United States. For years, scientists have been able to directly link cigarette smoking to cancer. Scientific study after scientific study shows that smoking cigarettes dramatically increases your risk of getting lung cancer.

As the link between cigarette smoking and lung cancer became very clear, people began wondering about the effect of breathing someone else's smoke. After all, consider the person who does not smoke but has a friend who does. This person spends a great deal of time with his friend, and any time his friend smokes, he ends up inhaling the smoke as well. Scientists have called this phenomenon "second-hand smoke." Can the person who is continually inhaling second-hand smoke be at risk for contracting lung cancer? Well, many studies have been done to answer this question, and the answer is surprising. The studies indicate that *if* inhaling second-hand smoke increases a person's likelihood of getting cancer, the increased risk is very, very small. In fact, even in experiments where non-smokers who *lived with* smokers were studied, the increased risk for cancer caused by second-hand smoke was extremely small.

How can this be? If smoking significantly increases your risk of contracting lung cancer, why can't we see a similar link between second-hand smoke and lung cancer? The answer once again is concentration. When a smoker inhales cigarette smoke, the toxins in the smoke are very concentrated. When the smoke leaves either the cigarette or the smoker's mouth, it quickly spreads out into the surrounding air. This reduces the toxin concentrations significantly, in turn reducing the damage to anyone who inhales the smoke second-hand. As a result, second-hand smoke does not increase your risk of getting lung cancer much, if at all.

Of course, this is in no way an excuse for smokers who want to smoke around non-smokers. Even if a person's increased risk of lung cancer due to second-hand smoke is tiny (if it exists at all), it is simply unpleasant for non-smokers to breathe in smoke coming from a cigarette. Also, it is possible that second-hand smoke increases your risk of other illnesses. Thus, you should never feel bad about asking a smoker to put out his or her cigarette. In fact, you are doing the smoker a favor, since science has conclusively shown a direct link between smoking and lung cancer!

The information contained in the last four paragraphs might have surprised you. If you follow politics in the United States at all, you might have heard people claim that second-hand smoke causes cancer. Unfortunately, it seems that people can claim almost anything these days and rarely get challenged by the major media outlets if those claims happen to support a particular political agenda. It turns out that there have been *many* studies done on second-hand smoke, and the data simply say that there is little to no increased risk of contracting lung cancer, even for someone who inhales second-hand smoke on a regular basis. If you are interested in looking into this controversy a little more, you might look at the course website, which is described in the "Student Notes" section at the beginning of this book. There are links to several resources that discuss the science of second-hand smoke.

ON YOUR OWN

1.9 Muriatic acid is sold in hardware stores for use in cleaning. Pool owners, for example, use it to clean hard water stains and algae stains from their pools. Its active ingredient is hydrochloric acid. The Works® is a toilet bowl cleaner with hydrochloric acid as its active ingredient. There are approximately 350 grams of hydrochloric acid in a liter of muriatic acid, and there are approximately 30 grams of hydrochloric acid in a liter of The Works. Why is muriatic acid a more powerful cleaner than The Works?

1.10 Sodium (so' dee uhm) is a necessary part of a healthy diet. If a person does not ingest enough sodium every day, that person will get sick and perhaps die. Nevertheless, some people try to limit their sodium intake by eating a low-salt diet. How can it be good to limit your sodium intake, even though sodium is a necessary part of body chemistry?

Now that you are done with the first module of this course, solve the study guide so that you will be reminded of the important concepts and skills in this module. Then you can take the test. The study guide is a very good indicator of what information you will be responsible for on the test. Please note that if a question on the study guide provides you with certain information (like the conversion factors between metric and English units), that information will be provided on the test. However, if a study guide question requires information that it does not give you (such as the meaning of the abbreviation mL), you will be required to memorize that information for the test.

ANSWERS TO THE "ON YOUR OWN" PROBLEMS

1.1 The atoms do not have the same properties as the molecule. When atoms join to make a molecule, their individual properties disappear and the molecule takes on its own, unique properties. When the molecule is broken down into its atoms, the atoms regain their individual properties.

1.2 Salt is composed of molecules. Since atoms are the smallest chemical units of matter in creation, if salt can be broken into smaller parts, it must be made of atoms linked together. Thus, it is made of molecules. Now you might think that since molecules are made by linking atoms together, you could also say that salt is made of atoms. However, that is not really correct. The atoms that link together to form salt molecules have their own, unique properties, but those properties completely disappear when the atoms join to form salt molecules. Thus, it is not the *atoms* that give the salt its properties; the *molecules* do.

1.3 We need to do this conversion the way the example showed us. First, we find the relationship. Since we want to convert from grams to kg, we need to remember that since "kilo" means "1,000," one kilogram is the same thing as 1,000 grams. Remember, the "1" goes with the unit that has the prefix, and the base unit gets the "1,000," since that's what "kilo" means.

$$1\text{ kg} = 1{,}000\text{ g}$$

Next, we put the number in fractional form:

$$\frac{12{,}321\text{ g}}{1}$$

Now our conversion relationship tells us that 1 kg = 1,000 g. Since we want to end up with kg in the end, we must multiply the measurement by a fraction that has grams on the bottom (to cancel the gram unit that is there) and kg on the top (so that kg is what's left). Remember, the numbers next to the units in the relationship above go with the units. Thus, since "g" goes on the bottom of the fraction, so does "1,000." Since "kg" goes on the top, so does "1."

$$\frac{12{,}321\ \cancel{\text{g}}}{1} \times \frac{1\text{ kg}}{1{,}000\ \cancel{\text{g}}} = 12.321\text{ kg}$$

Thus, 12,321 g is the same as 12.321 kg.

1.4 We solve this the same way we solved problem 1.3. First, we find the conversion relationship. Since we want to convert from liters to mL, we need to remember that "milli" means "0.001." So, we write down our relationship, keeping the "1" with mL (since it is the unit with the prefix) and putting the definition of "milliliter" (0.001) with the base unit:

$$1\text{ mL} = 0.001\text{ L}$$

Then we put the number in fractional form:

$$\frac{0.121\text{ L}}{1}$$

Our conversion relationship tells us that 1 mL = 0.001 L. Since we want to end up with mL, we must multiply the measurement by a fraction that has L on the bottom (to cancel the L unit that is there) and mL on the top (so that mL is the unit with which we are left):

$$\frac{0.121\ \not{\text{L}}}{1} \times \frac{1\ \text{mL}}{0.001\ \not{\text{L}}} = 121\ \text{mL}$$

Thus, 0.121 L is the same as 121 mL.

1.5 Since we want to convert from centimeters to meters, we need to remember that "centi" means "0.01." So the "1" goes with the centimeter unit, and the "0.01" goes with the base unit. Thus, our conversion relationship is:

$$1\ \text{cm} = 0.01\ \text{m}$$

Next, we write the measurement as a fraction:

$$\frac{723.9\ \text{cm}}{1}$$

Since we want to end up with meters in the end, we must multiply the measurement by a fraction that has centimeters on the bottom (to cancel the cm unit that is there) and meters on the top (so that m is the unit we are left with):

$$\frac{723.9\ \not{\text{cm}}}{1} \times \frac{0.01\ \text{m}}{1\ \not{\text{cm}}} = 7.239\ \text{m}$$

The three-point line is 7.239 m from the basket.

1.6 We use the same procedure we used in the previous three problems. Thus, I am going to reduce the length of the explanation.

$$\frac{3.00\ \not{\text{in}}}{1} \times \frac{2.54\ \text{cm}}{1\ \not{\text{in}}} = 7.62\ \text{cm}$$

The yarn is 7.62 cm long.

1.7

$$\frac{12\ \not{\text{kg}}}{1} \times \frac{1\ \text{slug}}{14.59\ \not{\text{kg}}} = 0.82\ \text{slugs}$$

There are 0.82 slugs in 12 kg. Note that I rounded the answer. The real answer was "0.822481151," but there are simply too many digits in that number. When you take chemistry, you will learn about significant figures, a concept that tells you where to round numbers off. For right now, don't worry about it. If you rounded at a different spot than I did, that's fine.

1.8

$$\frac{3.2\ \cancel{\text{gal}}}{1} \times \frac{3.78\ \text{L}}{1\ \cancel{\text{gal}}} = 12\ \text{L}$$

The object has a volume of 12 L. Once again, don't worry if you rounded your answer at a different place from where I rounded my answer.

1.9 Muriatic acid is the more powerful cleaner because the active ingredient is more concentrated. In the same amount of volume, muriatic acid has more than 10 times as much active ingredient. Since the active ingredient is more concentrated, it will clean better.

10.10 Sodium is necessary for the body at a certain concentration. If you eat too much sodium, you raise the concentration too much. In the same way, if you eat too little sodium, you lower its concentration too much. Either way, your body suffers. Thus, you need to keep the sodium concentration in your body at the right level. Too little sodium intake will reduce the sodium concentration to critical levels, while too much sodium intake will raise it to toxic levels.

STUDY GUIDE FOR MODULE #1

1. Write out the definitions for the following terms:

a. Atom
b. Molecule
c. Concentration

2. Fifty grams of a carbon disulfide can be broken down into 42.1 grams of sulfur and 7.9 grams of carbon. Is carbon disulfide made up of atoms or molecules?

3. If you put iron near a magnet, the iron will be attracted to the magnet. Rust is made up of molecules that contain iron atoms and oxygen atoms. Rust is not attracted to a magnet. If rust contains iron atoms, and iron is attracted to a magnet, why isn't rust attracted to a magnet?

4. A statue is made out of copper and displayed outside. After many years, what color will the statue be?

5. Have scientists actually seen atoms?

6. Give the numerical meaning for the prefixes "centi," "milli," and "kilo."

7. If you wanted to measure an object's mass, what metric unit would you use? What English unit would you use?

8. If you wanted to measure an object's volume, what metric unit would you use? What English unit would you use?

9. If you wanted to measure an object's length, what metric unit would you use? What English unit would you use?

10. How many centimeters are in 1.3 meters?

11. If a person has a mass of 75 kg, what is his or her mass in grams?

12. How many liters of milk are in 0.500 gallons of milk? (1 gal = 3.78 L)

13. A meterstick is 100.0 centimeters long. How long is it in inches? (1 in = 2.54 cm)

14. Ozone is a poisonous gas that can build up in the air in dense cities. Thus, there are many environmental initiatives to lower the amount of ozone in the air we breathe. One way you can make ozone, however, is by baking bread. The nice smell you associate with baking bread is actually due, in part, to ozone. If ozone is poisonous, why is baking bread not considered a dangerous activity?