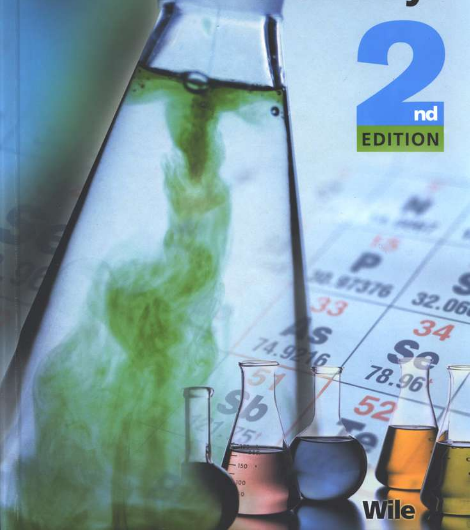
Exploring Creation With Chemistry:

2nd EDITION



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Exploring Creation With Chemistry

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MODULE #1: Measurement and Units

Introduction

What is chemistry? That's a very good question. Chemistry is, quite simply, the study of **matter**. Of course, this definition doesn't do us much good unless we know what matter is. So, in order to understand what chemistry is, we first need to define matter. A good working definition for matter is:

Matter - Anything that has mass and takes up space

If you have a problem with the word "mass," don't worry about it. We will discuss this concept in a little while. For right now, you can replace the word "mass" with the word "weight." As we will see later, this isn't quite right, but it will be okay for now.

If matter is defined in this way, almost *everything* around us is matter. Your family car has a lot of mass. That's why it's so heavy. It also takes up a lot of space sitting in the driveway or in the garage. Thus, your car must be made of matter. The food you eat isn't as heavy as a car, but it still has some mass. It also takes up space. So food must be made up of matter as well. Indeed, almost everything you see around you is made up of matter because nearly everything has mass and takes up space. There is one thing, however, that has no mass and takes up no space. It's all around you right now. Can you think of what it might be? What very common thing that is surrounding you right now has no mass and takes up no space?

You might think that the answer is "air." Unfortunately, that's not the right answer. Perform the following experiments to see what I mean:

EXPERIMENT 1.1
Air Has Mass

Supplies:

- A meterstick (A yardstick will work as well; a 12-inch ruler is not long enough.)
- Two 8-inch or larger balloons
- Two pieces of string long enough to tie the balloons to the meterstick
- Tape
- Safety goggles

1. Without blowing them up, tie the balloons to the strings. Be sure to make the knots loose so that you can untie one of the balloons later in the experiment.
2. Tie the other end of each string to each end of the meterstick. Try to attach the strings as close to the ends of the meterstick as possible.
3. Once the strings have been tied to the meterstick, tape them down so that they cannot move.
4. Go into your bathroom and pull back the shower curtain so that a large portion of the curtain rod is bare. Balance the meterstick (with the balloons attached) on the bare part of the shower curtain rod. You should be able to balance it very well. If you don't have a shower curtain rod or you are having trouble using yours, you can use any surface that is adequate for delicate balancing.

5. Once you have the meterstick balanced, stand back and look at it. The meterstick balances right now because the total mass on one side of the meterstick equals the total mass on the other side of the meterstick. In order to knock it off balance, you would need to move the meterstick or add more mass to one side. You will do the latter.
6. Have someone else hold the meterstick so that it does not move. In order for this experiment to work properly, the meterstick must stay stationary.
7. While the meterstick is held stationary, remove one of the balloons from its string (do not untie the string from the meterstick), and blow up the balloon.
8. Tie the balloon closed so that the air does not escape, then reattach it to its string.
9. Have the person holding the meterstick let go. If the meterstick was not moved while you were blowing up the balloon, it will tilt toward the side with the inflated balloon as soon as the person lets it go. This is because you added air to the balloon. Since air has mass, it knocks the meterstick off balance. Thus, air does have mass!
10. Clean up your mess.

EXPERIMENT 1.2
Air Takes Up Space

Supplies:
- A tall glass
- A paper towel
- A sink full of water
- Safety goggles

1. Fill your sink with water until the water level is high enough to submerge the entire glass.
2. Make sure the inside of the glass is dry.
3. Wad up the paper towel and shove it down into the bottom of the glass.
4. Turn the glass upside down and be sure that the paper towel does not fall out of the glass.
5. Submerge the glass upside down in the water, being careful not to tip the glass at any time.
6. Wait a few seconds and remove the glass, still being careful not to tilt it.
7. Pull the paper towel out of the glass. You will find that the paper towel is completely dry. Even though the glass was submerged in water, the paper towel never got wet. Why? When you tipped the glass upside down, there was air inside the glass. When you submerged it in the water, the air could not escape the glass. Thus, the glass was still full of air. Since air takes up space, there was no room for water to enter the glass, so the paper towel stayed dry.
8. Repeat the experiment, but this time be sure to tip the glass while it is underwater. You will see large bubbles rise to the surface of the water, and when you pull the glass out, you will find that it has water in it and that the paper towel is wet. This is because you allowed the air trapped inside the glass to escape when you tilted the glass. Once the air escaped, there was room for the water to come into the glass.
9. Clean up your mess.

Now that you see that air does have mass and does take up space, have you figured out the correct answer to my original question? What very common thing that is surrounding you right now has no mass and takes up no space? The answer is *light*. As far as scientists can tell, light does not have any mass and takes up no space. Thus, light is not considered matter. Instead, it is pure energy. Everything else that you see around you, however, is considered matter. Chemistry, then, is the study of nearly everything! As you can imagine, studying nearly everything can be a very daunting task. However, chemists have found that even though there are many forms of matter, they all behave according to a few fundamental laws. If we can clearly understand these laws, then we can clearly understand the nature of the matter that exists in God's creation.

Before we start trying to understand these laws, however, we must first step back and ask a more fundamental question. *How* do we study matter? Well, the first thing we have to be able to do in order to study matter is to measure it. If I want to study an object, I first must learn things like how big it is, how heavy it is, and how old it is. In order to learn these things, I have to make some measurements. The rest of this module explains how scientists measure things and what those measurements mean.

Units of Measurement

Let's suppose I'm making curtains for a friend's windows. I ask him to measure the window and give me the dimensions so that I can make the curtains the right size. My friend tells me that his windows are 50 by 60, so that's how big I make the curtains. When I go over to his house, it turns out that my curtains are more than twice as big as his windows! My friend tells me that he's certain he measured the windows correctly, and I tell my friend that I'm certain I measured the curtains correctly. How can this be? The answer is quite simple. My friend measured the windows in *centimeters*. I, on the other hand, measured the curtains in *inches*. Our problem was not caused by one of us measuring incorrectly. Instead, our problem was the result of measuring with different **units.**

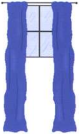
When we are making measurements, the units we use are just as important as the numbers that we get. If my friend had told me that his windows were 50 centimeters by 60 centimeters, then there would have been no problem. I would have known exactly how big to make the curtains. Since he failed to do this, the numbers that he gave me (50 by 60) were essentially useless. Please note that a failure to indicate the units involved in measurements can lead to serious problems. For example, the Mars Climate Orbiter, a NASA (National Aeronautics and Space Administration) spacecraft built for the exploration of Mars, vanished during an attempt to put the craft into orbit around the planet. In an investigation that followed, NASA determined that a units mix-up had caused the disaster. One team of engineers had used metric units in its designs, while another team had used English units. The teams did not indicate the units they were using, and as a result, the designs were incompatible.

In the end, then, scientists should never simply report numbers. They must always include units with those numbers so that everyone knows exactly what those numbers mean. That will be the rule in this chemistry course. If you answer a question or a problem and do not list units with the numbers, your answer will be considered incorrect. In science, numbers mean nothing unless there are units attached to them.

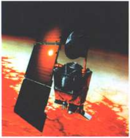
Window illustration by Megan Whitaker

FIGURE 1.1
Two Consequences of Not Using Units Properly

Mars Climate Orbiter image Courtesy of NASA/JPL/Caltech



These curtains are too long for this window because the window was measured in centimeters, but the curtains were made assuming the measurements were in inches.



The Mars Climate Orbiter did not successfully make it into orbit because two of the engineering teams involved used different units in their designs.

Since scientists use units in all of their measurements, it is convenient to define a standard set of units that will be used by everyone. This system of standard units is called the **metric system**. If you do not fully understand the metric system, don't worry. By the end of this module, you will be an expert at using it. If you do fully understand the metric system, you can probably skip ahead to the section labeled "Converting Between Units."

The Metric System

There are many different things that we need to measure when studying nature. First, we must determine how much matter exists in the object that we want to study. We know that there is a lot more matter in a car than there is in a feather, since a car is heavier. In order to study an object precisely, however, we need to know *exactly* how much matter is in the object. To accomplish this, we measure the object's **mass.** In the metric system, the unit for mass is the **gram**. If an object has a mass of 10 grams, we know that it has 10 times the matter that is in an object with a mass of 1 gram. To give you an idea of the size of a gram, the average mass of a housefly is just about 1 gram. Based on this fact, we can say that a gram is a rather small unit. Most of the things that we will measure will have masses of 10 to 10,000 grams. For example, this book has a mass of about 2,300 grams.

Now that we know what the metric unit for mass is, we need to know a little bit more about the concept itself. I said in the beginning that we could think of mass as weight. That's not exactly true. Mass and weight are two different things. Mass measures how much matter exists in an object. Weight, on the other hand, measures how hard gravity pulls on that object.

For example, if I were to get on my bathroom scale and weigh myself, I would find that I weigh 170 pounds. However, if I were to take that scale to the moon and weigh myself, I would find that I weighed only 28 pounds there. Does that mean I'm thinner on the moon than I am at home? Of course not. It means that on the moon, gravity is not as strong as it is in my house.

On the other hand, if I were to measure my mass at home, I would find it to be 77,000 grams. If I were to measure my mass on the moon, it would still be 77,000 grams. That's the difference between mass and weight. Since weight is a measure of how hard gravity pulls, an object weighs different amounts depending on where that object is. Mass, on the other hand, is a measure of how much matter is in an object and does not depend on where that object is.

Unfortunately, there are many other unit systems in use today besides the metric system. In fact, the metric system is probably not the system with which you are most familiar. You are probably most familiar with the English system. The unit of pounds comes from the English system. However, pounds are not a measure of mass; they are a measure of weight. The metric unit for weight is called the **Newton**. The English unit for mass is (believe it or not) called the **slug**. Although we will not use the slug often, it is important to understand what it means, especially when you study physics.

There is more to measurement than just grams, however. We might also want to measure how big an object is. For this, we must use the metric system's unit for distance, which is the **meter**. You are probably familiar with a yardstick. Well, a meter is just slightly longer than a yardstick. The English unit for distance is the **foot**. What about inches, yards, and miles? We'll talk about those a little later.

We also need to be able to measure how much space an object occupies. This measurement is commonly called "volume" and is measured in the metric system with the unit called the **liter**. The main unit for measuring volume in the English system is the **gallon**. To give you an idea of the size of a liter, it takes just under four liters to make a gallon.

Finally, we have to be able to measure the passage of time. When studying matter, we will see that it has the ability to change. The shape, size, and chemical properties of certain substances change over time, so it is important to be able to measure time so that we can determine how quickly the changes take place. In both the English and metric systems, time is measured in **seconds.**

Since it is very important for you to be able to recognize which units correspond to which measurements, Table 1.1 summarizes what you have just read. The letters in parentheses are the commonly used abbreviations for the units listed.

TABLE 1.1
Physical Quantities and Their Base Units

Physical Quantity	Base Metric Unit	Base English Unit
Mass	gram (g)	slug (sl)
Distance	meter (m)	foot (ft)
Volume	liter (L)	gallon (gal)
Time	second (s)	second (s)

Exploring Creation with Chemistry: Second Edition

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