Chapter 1: Basic Concepts Required to Study Earth Science

If you have not read the introduction to the book (pp. i-vii), do so now. You can count it as your first day of science, and you can start reading what's below tomorrow.

Introduction

This picture, taken by astronaut William Anders, shows the earth as seen from a spacecraft orbiting the moon. It is rotated by 90 degrees so that it looks like it was taken from the moon's surface.

Have you ever seen the picture shown on the right? It's usually called "Earthrise," and it was taken by astronaut William Anders on Christmas Eve in 1968, when he and his team were orbiting the moon in a spacecraft. The bottom of the picture shows the surface of the moon, and the gorgeous blue-and-white ball above the moon's surface is the earth. While you can find lots of color pictures of the earth as seen from space, this is one of the first that was taken, and it had a profound effect on many people, because it showed the earth from a completely new perspective. On Christmas Eve fifty years after taking the picture, Anders declared, "We set out to explore the moon and instead discovered the earth." (https://www.space.com/42848-earthrise-photo-apollo-8-legacy-bill-anders.html, retrieved on 5/27/2020). In this course, I hope to show you the earth from a completely new perspective so that you can discover truths about its design and the One who designed it.

Now there are a lot of things to learn about this picture. Why is only half of the earth visible? Why don't you see any stars, even though the "sky" above the moon's surface is black? In a later chapter, I will answer those questions. For right now, just notice the shape of the earth. Only a portion of the earth is visible, but based on that portion, the earth is clearly a sphere. Actually, it's not a perfect sphere. Technically, it's an **oblate** (oh blayt') **spheroid** (sfear' oyd), which means it looks like a ball that has been squashed by something pushing down on its top and up on its bottom.

The Earth's Shape

We all know that the earth is a sphere, but you might not be aware that people have known this for more than 2,500 years. While you may have heard that people in ancient times believed the earth was flat, that's really not true. I am sure if you go back far enough in history, you can find some people who believed the earth was flat, but the earliest historical records we have indicate that most people understood it is a sphere.

For example, Aristotle (air' ih stot' uhl) was a natural philosopher (an older term that essentially means "scientist") who lived from 323 to 385 BC. He concluded that the earth was a sphere based on several different observations that he could make. He was considered one of the greatest minds of his time, so pretty much everyone agreed with him. Around 200 BC, another natural philosopher, Eratosthenes (air' uh tas' thuh neez'), measured the shadow cast by a stick in one location on a specific day at a specific time. He then walked about 500 miles southeast and measured the same stick's shadow on the same day the next year at the same time. Using geometry based on the fact that the earth is a sphere, he actually determined the distance around the earth, and it turns out that his value was very close to the satellite-measured value we have today!

Of course, Aristotle and Eratosthenes were well-educated people, so it's not surprising that they could figure out that the earth is a sphere. However, to the average, poorly-educated person back then, it looked pretty flat. Thus, you might think that most people believed the earth was flat, right? Probably not. We can't say for sure, of course, but we know that sailors and people who lived near the ocean, most of whom were poorly educated, understood that the earth is a sphere. Why? Because of something they saw regularly. The following experiment will help you understand what they saw.

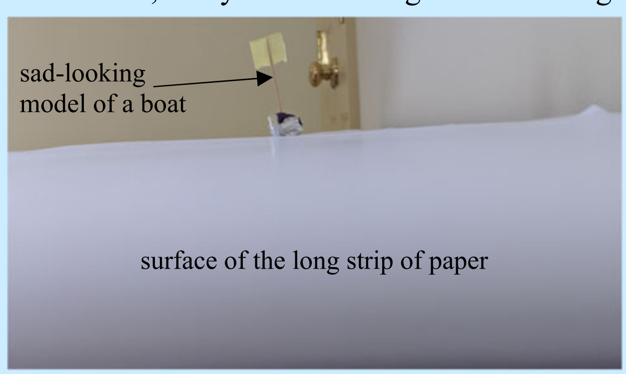
Experiment 1.1: Hull Down

Supplies:

- Five sheets of plain paper
- Tape
- Many books of different thicknesses
- A flat table or desk that is at least as long as four of the sheets of paper laid end-to-end
- Play-Doh or modeling clay
- Aluminum foil
- A toothpick
- Someone to help you

Instructions:

1. Make a rough cube of clay that is a little over 1 cm (about half an inch) on each side. It doesn't have to be a really good cube. Just make sure the bottom is flat.
2. Tear off a small piece of aluminum foil and wrap it around the Play-Doh.
3. Put the bottom on the flat surface and stick the toothpick into the clay so it stands on its own.
4. Tear off a small piece from one of the sheets of paper and tape it near the top of the toothpick so that you have a pretty sad-looking model of a boat (see the top picture below).
5. Tape the other four sheets of paper end-to-end.
6. Lay the long strip of paper you just made on the flat table or desk.
7. Have your helper hold the model of the boat near the center of the long strip of paper.
8. Position your head so that one eye is level with the flat surface, and you are looking down the long strip of paper. Close the other eye. You should see something like the picture on the top right.
9. Hold the paper strip to the surface so it doesn't move.
10. Have your helper move the boat model close to you and then slowly pull it away from you until it reaches the end of the paper strip. How did the model's appearance change?
11. Arrange stacks of books on the floor as shown in the picture on the bottom right. They should slowly decrease in height so that the long strip of paper forms a slope. The first stack of books should be about twice as tall as the boat model.
12. Lay the long strip of paper on the stack of books.



13. Have your helper hold the model of the boat.
14. Position your head so that one eye is level with the highest stack of books and you are looking down the long strip, just like you did in step 8. Once again, close the other eye.
15. Hold the edge of the paper strip against the stack of books so that the strip doesn't move.
16. Have your helper move the boat model close to you and then slowly move it down the slope of the paper strip. How does the model's appearance change? The change should be noticeably different from what you saw when the paper strip was on the flat surface. If you don't see the difference, repeat both parts of the experiment.
17. Clean up your mess.

What difference did you see in how the boat model's appearance changed? You should have seen that the model appeared to get smaller as it moved away from you on the flat surface, but that's about it. However, on the sloped surface, things should have been rather different. The boat appeared to get smaller, but also, you eventually stopped seeing the foil part of the boat. It "disappeared" as the boat moved away. However, you could still see the sail on top of the toothpick, even after you couldn't see the foil part of the boat. That's because the boat was following the slope made by the books, and the slope hid the bottom of the boat before it hid the sail of the boat.

This is something sailors and people who lived near the ocean have seen since people first traveled on the ocean. As a ship traveled away from the shore, the bottom of the ship (the hull) would disappear before the top (the sails). As a ship travelled towards the shore, the sails would appear first, and the hull would appear later. This is because the ships are traveling along a slope. The ocean looks flat, but if it were, a boat would appear smaller and smaller as it traveled away from shore, but you would continue to see the entire boat, just like you did in the first part of the experiment. But the ocean is actually sloped, because it follows the curve of the earth's sphere. As a result, boats traveling toward or away from shore appear like the model did in the second part of the experiment.

Because of this, sailors have a term called "hull down." When a ship is "hull down," it is far enough away that the curve of the earth's sphere hides its hull but not its sails (or smokestacks and antennas in modern boats). This is something even ancient sailors experienced, so even though they didn't have the benefit of being taught by people like Aristotle, they knew that the earth is a sphere.

But wait a minute. Wasn't Christopher Columbus's plan to sail around the world opposed because people thought he would sail off the edge of the earth? No! While that's a popular myth, it is completely false. In Christopher Columbus's day, European people knew the earth was a sphere because the church taught that the earth is a sphere, and the people believed the church's teachings. If you study actual history, you will find that Christopher Columbus's plan was opposed because Eratosthenes's measurement of earth was known. People knew how far Columbus would have to travel to go around the world, and they didn't think such a long journey was possible.

Comprehension Check

1.1 If the ocean is curved because it follows the earth's sphere, why does it appear to be flat?

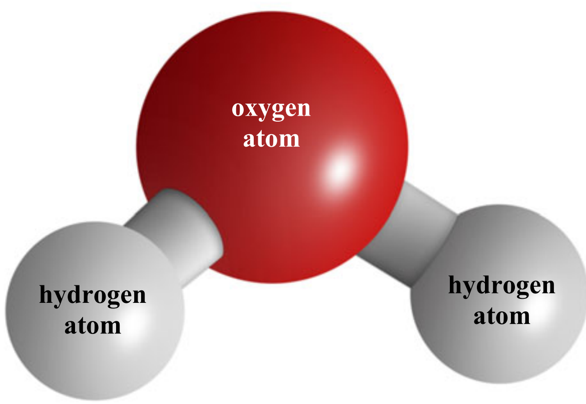
1.2 If you look at a flat map of the world, you will see that Greenland looks almost as big as Africa. On a globe, however, Africa looks a lot bigger than Greenland. In reality, is Africa larger than or roughly the same size as Greenland?

Chemicals

Once again, you probably knew that the earth is spherical, but I want to make sure we are all on the "same page," so I want to cover a few more basic concepts that will be necessary to understand the rest of the course. Some of them will be review for you, but some might not be. Be sure to study this chapter carefully even if you recognize the material, because throughout the rest of the course, I will be assuming that you understand everything presented in this chapter.

Everything that makes up the earth is composed of **chemicals**. In fact, almost all of creation (except light) is made up of chemicals, so you will need to understand chemicals if you want to understand earth science. Chemicals are made up of one or more **atoms**, which you can think of as tiny building blocks. Some chemicals, like the carbon found in diamonds, are made up of individual atoms. Most chemicals, however, are made up of atoms that are joined together.

Consider a chemical with which you are very familiar: water. It is formed when one oxygen atom attaches to two hydrogen atoms. The attachments are called **chemical bonds**, and they keep the atoms together. When atoms are joined together by chemical bonds, we usually call them **molecules** (mol' ih kyoolz). The drawing below, for example, represents a molecule of water.



A molecule of water is made of two hydrogen atoms attached to an oxygen atom with chemical bonds.

Under certain circumstances, the chemical bonds in a water molecule can be broken down, making hydrogen and oxygen. This is called a **chemical reaction**. Interestingly enough, hydrogen and oxygen are nothing like water. At room temperature, for example, hydrogen is a gas that burns violently, and oxygen is a gas that makes fire possible. At room temperature, however, water is a liquid that can be used to put out many kinds of fire! When atoms join together to make a molecule, then, the molecule they make behaves differently from the atoms themselves. I want to emphasize this by having you do an experiment.

Experiment 1.2: Very Similar but Very Different!

Supplies:

- Hydrogen peroxide from the laboratory kit made for this course
- Active dry yeast (Yeast for a bread machine will also work.)
- Water
- Two smaller (like "snack sized") plastic bags that can be zipped shut (like Ziploc bags)
- Two larger (like "quart sized") plastic bags that can be zipped shut (like Ziploc bags)
- A measuring cup
- A measuring tablespoon
- Somewhere outside that you can get messy

Instructions:

1. Add a cup of water to one of the small bags and zip it shut.
2. Put the small bag of water into one of the larger bags.
3. Add a tablespoon of yeast to the larger bag that you just put the small bag into.

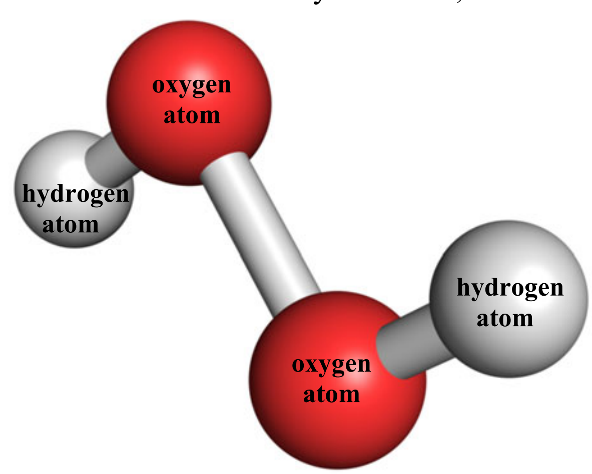
4. Zip the big bag shut. You should now have a larger, zipped-shut bag that holds a smaller, zipped-shut bag of water and some yeast.
5. Repeat steps 1-4 with the other bags, but use hydrogen peroxide in the small bag instead of water.
6. Take both bags outside to the place that you can get messy.
7. Set the bag that holds the small bag of hydrogen peroxide down carefully, making sure that you don't break or open the small bag inside.
8. Hold the bag that contains the small bag of water in both hands and use your fingers to unzip the small bag of water inside while keeping the larger bag zipped.
9. Shake the larger bag so that the water and yeast mix well.
10. Drop the larger bag on the ground and move a couple of meters (a few feet) away. Watch the bag to see if anything happens.
11. Repeat steps 8-10 with the larger bag that has hydrogen peroxide and yeast in it.
12. What's the difference?
13. Empty the bags that aren't already empty and throw them away. Also, clean up your mess inside.

What did you see in the experiment? Nothing exciting should have happened with the bag that had water in it. The water and yeast mixed, but nothing else should have happened. However, when you used the hydrogen peroxide, you should have seen a lot of bubbles. When you dropped the bag and moved away, you should have seen the bag inflate. Eventually, it should have inflated so much that it popped open, and some liquid probably sprayed out.

What's the difference between these situations? It's the hydrogen peroxide, which is a fairly unstable molecule. Over time, it will break down, and one of the things this breakdown makes is oxygen. Yeast speeds up the process quite a bit. So, when the yeast and hydrogen peroxide mixed, oxygen started being produced. Under the conditions of the experiment, oxygen is a gas, so it started inflating the bag. It inflated the bag so much that the bag became highly pressurized, and eventually, it had to pop open.

Now here's the truly remarkable thing: A molecule of water and a molecule of hydrogen peroxide are very, very similar. How similar? The drawing on the previous page tells you that a water molecule is made of one oxygen atom bonded to two hydrogen atoms. In chemistry, we can abbreviate this with a **chemical formula**. First, we abbreviate the atoms. Instead of saying "hydrogen," we just use an "H." Instead of saying oxygen, we just use an "O." Then, we put a subscript after each atom's abbreviation to indicate how many of that atom are in the molecule. If there is only one atom, we don't write any number. So, the chemical formula of water is H_2O. The subscript of "2" after the H tells us there are two hydrogen atoms, and the fact that there is no subscript after the O tells us there is only one oxygen atom.

Compare that to a molecule of hydrogen peroxide, which is shown in the drawing on the right. As you can see, it is made of two hydrogen atoms and two oxygen atoms, so it has a chemical formula of H_2O_2. Water is made up of hydrogen atoms and oxygen atoms, but so is hydrogen peroxide. Both water and hydrogen peroxide molecules have two hydrogen atoms. The only difference is that while a water molecule has only one oxygen atom, a hydrogen



This drawing shows you a molecule of hydrogen peroxide.

peroxide molecule has two oxygen atoms. Nevertheless, these molecules that have so many similarities act very differently when exposed to yeast, all because of the difference in the number of oxygen atoms in each molecule! When molecules form, then, *each atom is important*. If you change just one atom in a molecule, the properties of the molecule can change completely. Because of this, the 98 naturally-occurring kinds of atoms in creation can combine together to make an unimaginable number of chemicals.

Each of these 98 types of atoms forms its own **element**, which has its own abbreviation. So far, I have talked about two: H stands for hydrogen, and O stands for oxygen. Those make a lot of sense. However, some elements have two letters in their abbreviation. Calcium, for example, is abbreviated as Ca. If an element has two letters in its abbreviation, the first one is always capitalized, and the second one is always lower case. That way, when you look at a list of element abbreviations, you know that you have come to a new element when you come to a new capital letter. For example, the molecule CaO is composed of one calcium atom and one oxygen atom. You know this because the O is capitalized, telling you it is a new atom. Since there is no subscript after the Ca, you know there is one Ca atom. Similarly, since there is no subscript after the O, you know that there is one O atom.

While H, O, and Ca all make sense. Some element abbreviations are a bit less obvious. Sodium atoms, for example, are abbreviated as Na. Why? Because sodium's Latin name is *natrium*. Similarly, potassium atoms are abbreviated with a K, since potassium's Latin name is *kalium*. In general, we can say that the abbreviation of an atom is one or two letters from its English or Latin name. The first letter is always capitalized, and if there is a second letter, it is lower case.

Suppose, then, I told you that a certain rock contained the chemical $KAlSi_3O_8$. Even though you probably don't know all the symbols, you could tell me that this molecule contains one K atom, one Al atom, three Si atoms, and eight O atoms. You can figure this out because each capital letter starts a new atom, and you know the subscript after the atom tells you how many atoms there are in the molecule. If there is no subscript, there is only one of that atom.

Comprehension Check

1.3 Automobile exhaust contains CO. We exhale CO_2. A student reasons that since the chemical formulas are similar, the chemicals must be similar as well. Is he correct? Why or why not?

1.4 Rust has the chemical formula Fe_2O_3. How many atoms (total) are in a molecule of rust?

1.5 You might have some Epsom salt in your medicine cabinet. Each molecule has one atom of magnesium (Mg), one atom of sulfur (S), and four atoms of oxygen (O). What is its chemical formula?

It's Just a Phase

I have been using terms like "liquid" and "gas," and I am sure that you understand what they mean. However, I need to make sure you understand that those terms refer to different forms of matter which we call **phases**. In the conditions found on earth, chemicals are typically in one of three phases: **solid**, **liquid**, or **gas**. If you lower the temperature enough, you can make water a solid. This process is called **freezing**, and we call the solid water ice. If you heat up ice enough, it will turn back into a liquid. That process is called **melting**. If you heat the liquid enough, it will **boil**, changing into a gas. If you cool the gas down, it will turn back into a liquid, and we call that **condensing**.

Given the right conditions, it is possible for any chemical to attain any of the three phases listed above. For example, the photograph on the right shows a beaker that holds liquid oxygen. As a gas, oxygen has no color, but if you cool it down to a very cold temperature, it condenses and becomes a faintly blue liquid. The "smoke" you see around the beaker isn't really smoke. The liquid oxygen is so cold that it is causing gases in the air to condense into liquids as well, forming tiny droplets that look like smoke. While I don't have a picture of it, if you cooled liquid oxygen down even more, you could make solid oxygen, which is also has a blue color.

This beaker contains oxygen that is so cold it is in its liquid phase.

There are a couple of things you need to realize about the phases in which matter can exist. First, the phase doesn't change the chemical nature of the molecules. The molecules that make up liquid oxygen are the same as the molecules that make up oxygen gas. Anything that oxygen gas can do chemically, liquid oxygen can do as well. For example, oxygen gas is necessary for fire, because a fire is caused by a chemical reaction between oxygen gas and whatever fuel that is being burned. Well, despite the fact that it is very, very cold, liquid oxygen can also react with a fuel to make fire.

What's the difference between solids, liquids, and gases? In most chemicals, the molecules are closest in a chemical's solid phase, farther apart in its liquid phase, and even farther apart in its gaseous phase. In addition, the mobility of the molecules is different. In solids, molecules are only allowed to vibrate. They cannot move around. In liquids, the molecules can move around, but their movement is a bit limited. In gases, the molecules move around like crazy. We will be discussing chemical formulas and phases quite a bit in this course, and if you understand everything you have read, you will be able to grasp that upcoming material. If not, you should go to the course website, which is given in the introduction to the book. There, you will find links that explain these things in more detail.

Units

When we study the earth, we need to measure things. We might need to know how tall something is, how much space it takes up, or how much material is in it. Measurements include numbers, but the numbers are meaningless by themselves. If I told you I am 67 tall, would that mean anything to you? No. I have to tell you what I used to measure my height so that you could figure out whether I am a tall, short, or medium-height guy. You might be able to guess what I used to measure myself based on your experience with the height of adults. Nevertheless, if I don't tell you what I used, you won't know for sure.

The units of the measurement tell you what I used to measure myself. I am 67 *inches* tall. Now you know that I am a short guy, since the average adult man is 68.9 inches tall. Of course, I could use other units to measure my height. I could use feet and inches, for example. I am 5 feet, 7 inches tall. I could also use a unit called **meters**. If you have ever seen a meterstick, it has a length of one meter. I am 1.7 meters tall. I could also use centimeters, which is another unit you have probably seen before. I am 170 centimeters tall. All those measurements: 67 inches, 5 feet 7 inches, 1.7 meters, and 170 centimeters represent the same height. The numbers are different because the units are different, but all the heights they represent are the same.

When reporting measurements, then, you must report your units. A measurement without units means nothing. I remember the first time I was taught this. I was in high school, and my teacher had just gotten done explaining how important units are in science. He said that all students must report their units with each measurement, or their answer will be counted as incorrect. I wanted to earn high grades in my classes, so I took his warning to heart.

The first test required us to use some equations, but he didn't want us to memorize them, so he said that while taking the test, we could use a 3x5 card and write any equations we thought we might use on it (something I *will not* allow you to do in this course!). I raised my hand to confirm this. I asked, "A 3x5 card, right?" He replied, "yes." For the first test, I showed up with a poster board that was 3-feet tall and 5-feet wide. It had all sorts of equations (some that I didn't even understand) copied on it. Of course, he wanted us to use a 3-inch by 5-inch card, but he had to let me use my poster, because he had not listed his units. When I saw him years after I had graduated, he said that since then, he told his students the story of me and my poster every year to emphasize how important units are!

The Metric System

Since units are so important, all scientists try to use the same set of units so that we can easily compare our results to one another. In this class, we will use the **metric system** as our system of units. You might be familiar with the metric system already, but if not, that's fine. You just need to know the basic units of the metric system and how to modify them.


A guitar is about a meter long.

Let's start with the metric unit I already mentioned: the meter. It is abbreviated with "m" and measures distance. The distance between the bottom of my feet to the top of my head is my height: 1.7 meters. As a way of visualizing a meter, consider a guitar. The distance from one end of a guitar to the other is about a meter. If that doesn't help, most standard doorways are just under a meter wide. Most countertops are one meter high.

Besides learning how tall, wide, or high something is, we might want to know how much **matter** is in it. If you aren't familiar with that term, "matter" can refer to any substance. This book is made of matter, you are made of matter, everything you see around you (except light) is made of matter. The amount of matter in a substance is called its **mass**.

Mass – A measure of how much matter is in an object

This book has a certain amount of matter in it (you might think it is a lot!), but a car has more matter in it. A house has even more matter in it. Thus, a house's mass is larger than a car's mass, which is larger than this book's mass. In general, the more mass something has, the heavier it is. Mass and weight are not the same thing, but they are related. So, the more something weighs, the more mass it has, which means the more matter it has in it.

The fact that this balance in not tilted towards either side tells you that the mass of the things in each pan are the same.

Mass is often measured using a balance, like the one pictured on the right. The silvery objects in the pan on the far right each have a known mass. The mass of the yellow material in the left pan is being measured. If the mass of the yellow material were larger than the total mass of the silvery objects, the balance would tilt towards the yellow material. If the total mass of the silvery objects was larger, it would tilt towards the silvery objects. Since the balance is not tilted either way, we know that the mass of the yellow material is the same as the mass of the silvery objects. Even though they are very different, this tells you the total amount of matter in the yellow material is equal to the total amount of matter in the two silvery objects.

The metric unit for mass is the **gram**, which is abbreviated "g." An American dollar bill has a mass of about one gram. So does a standard metal paper clip. That means even though one is made of paper and ink, while the other is made of metal, the total amount of matter in a dollar bill is the same as the total amount of matter in a standard metal paper clip.

You might also need to know how much time it takes for something to happen. The metric unit for time is one with which you are already familiar: the **second**, which is abbreviated with an "s." There are other ways to measure the passage of time, such as hours, minutes, days, etc. However, they are not considered part of the metric system.

This gives us three things we can measure: length (in meters), mass (in grams), and time (in seconds). But what happens when I am measuring something for which those units don't make much sense? For example, suppose I want to measure the thickness of a page in this book. That's pretty small – a lot less than a meter. Isn't there a better unit? Yes, there is. In the metric system, when we want to measure something really big or really small, we modify the unit with a prefix. If we are measuring something that is really small, we use a prefix that makes the unit small. If we want to measure something that is really big, we use a prefix that makes the unit big.

In the metric system, the prefixes are all based on powers of ten. If I wanted to measure the thickness of this page of paper, for example, I would probably choose the millimeter. The prefix "**milli**" means one thousandth (0.001), so a millimeter is one thousandth of a meter. If I used that unit, I would find that this page is 0.1 millimeters thick. On the other hand, if I wanted to measure the distance between cities, I would need a much bigger unit, so I might choose the kilometer. The prefix "**kilo**" means one thousand (1,000), so a kilometer is 1,000 meters. The distance between New York City and Washington, DC, for example, is 370 kilometers.

There are lots and lots of prefixes that can be used to make a metric unit meet your measurements needs. The table on the next page lists several of them.

Metric Prefixes and Their Meanings

Prefix	Abbreviation	Meaning		Prefix	Abbreviation	Meaning
mega	M	1,000,000		**centi**	**c**	**0.01**
kilo	**k**	**1,000**		**milli**	**m**	**0.001**
hecto	H	100		micro	μ	0.000001
deca	Da	10		nano	n	0.000000001

Don't worry. You don't need to remember all of these. I only want you to remember the three in boldface type: **kilo** (1,000), **centi** (0.01), and **milli** (0.001). If you don't already know them, don't worry about memorizing them right now. The next time you do science, you will see these prefixes in use, and that should help make then more familiar to you.

Suppose, then, you want to measure the mass of a car. If you were limited to the three prefixes I want you to know (kilo, centi, milli), what measurement unit would you use? Well, since you are measuring mass, you would use some form of the gram, because the gram is the metric unit for mass. However, the mass of a dollar bill is a gram, and a car has *a lot* more mass than a dollar bill. Thus, you would use the kilogram. The mass of the car that I drive (a Jeep Liberty) is 1,900 kilograms. Notice that the abbreviation for "kilo" listed in the table is "k." That means I could abbreviate the unit and say that my car has a mass of 1,900 kg.

Suppose you wanted to measure something that happens in a really short amount of time, like a lightning strike. Since you are measuring time, you would use the second, but a lightning strike is a lot shorter than a second. Using the three prefixes I want you to know, you would choose milliseconds. A lightning strike usually lasts 0.03 milliseconds, or 0.03 ms.

Math With Units

We need to measure a lot of things besides just mass, length, and time. Interestingly enough, however, most of the other things we need to measure are the result of mathematics being done with measurements of mass, length, and time. Consider, for example, comparing the areas of two different rooms. One of the rooms is 10 meters long and 3 meters wide. The other is 7 meters long and 5 meters wide. Which is the bigger room? You might think that's a hard question to answer. One room is longer, but the other is wider. Does the increased width of the second room make up for the decreased length? You might consider adding the measurements. The first room's measurements add to 13, while the second room's measurements add to 12. Does that mean the first room is bigger? No. The first room is actually smaller.

How do I know? Because I can determine the **area** of the room, which is a measure of how much space exists within the room's boundaries. The area of a rectangle is the rectangle's length times its width:

$$\boxed{\text{Area} = (\text{length})\cdot(\text{width})}$$

You have probably seen that formula before. If not, it is one that you will have to remember and be comfortable using. That's why it is in a pink box. As you were told in the introduction to the book, you need to memorize anything you see in pink boxes. If you haven't seen it before, the "·" in the box is one way to abbreviate multiplication. You are probably used to abbreviating it with "x," but scientists often use "x" for other things, so we typically abbreviate multiplication using a "·".

If we use that formula to determine the first room's area, we end up with this equation:

$$\text{Area} = (\text{length})\cdot(\text{width}) = (10\text{ meters})\cdot(3\text{ meters})$$

I have to keep the units with the number, because a measurement without units means nothing. But how do I deal with them in the equation? I do the numbers separately from the units. 10 times 3 is 30, so the number I get is 30. But what happens to the units? I multiply them together as well. I can't get a number for an answer, but I can say the units is meters·meters. Thus, my answer is:

$$\text{Area} = (\text{length})\cdot(\text{width}) = (10\text{ meters})\cdot(3\text{ meters}) = 30\text{ meters}\cdot\text{meters}$$

But what does that mean? Well, what happens when I multiply 2·2? I could just get the answer, which is 4, or I could say that 2·2 is the same as 2^2, which is read as "two squared." The superscript tells me I multiply 2 by itself. Well, if 2·2 is two squared, what is meters·meters? It's meters squared, which we can write as m^2. Remember, meters can be abbreviated with an "m," and the superscript just means multiply it by itself. So m^2 is really meters·meters. That means my answer is:

$$\text{Area} = (\text{length})\cdot(\text{width}) = (10\text{ meters})\cdot(3\text{ meters}) = 30\text{ meters}\cdot\text{meters} = 30\text{ m}^2$$

So, if I want to measure the area of something, I multiply length times width, and if I am using meters, the unit for area is m^2. Compare this area to the area of the second room:

$$\text{Area} = (\text{length})\cdot(\text{width}) = (7\text{ meters})\cdot(5\text{ meters}) = 35\text{ meters}\cdot\text{meters} = 35\text{ m}^2$$

This tells me that the second room is bigger, because it has more area. More importantly, we now know that we can express the unit for area in terms of meters. It's m^2.

It turns out that we will be using units in math from time to time, so you need to get comfortable doing it. If you aren't quite comfortable yet, that's fine. You will see examples throughout the rest of this chapter.

Comprehension Check

1.6 In my research, I often have to heat solid metal. If I heat it long enough, what phase will it become? If I heat it a lot more, what phase will it become?

1.7 Suppose you want to measure how much time you work on this course to finish it. If you want to use a metric unit with one of the three prefixes you need to know, what unit would you use?

1.8 A page from this book has a length of 28 cm and a width of 22 cm. In case you don't recognize it, "cm" stands for "centimeters." What is its area, including the units?

Volume

Area tells you how much space exists within a specific boundary, but something that scientists measure much more frequently is **volume**, which indicates how much total space an object takes up. If I want to put an object into a container, for example, the only way the object will fit into the container is if the object's volume is smaller than the container's volume. For example, in the late 1800s, a Russian woodcarver made a set of hollow dolls that are now called "nesting dolls." A modern example is shown in the photo below. Notice that starting from the far left, each doll gets smaller. In other words, the volume of each doll decreases. Because of this, the dolls fit inside one another, so they can all be "nested" inside the largest one. Nesting dolls work because each doll's volume is smaller than the previous one, which ensures that each doll fits inside the previous one.

The volume of each doll decreases from left to right. That means each smaller doll can fit in the doll on its left. Since they are all hollow and can be opened, you can put each doll inside the doll on its left, so that all of them will be "nested" inside the largest one.

What do you need to know to determine an object's volume? It's not enough to know how long the object is and how wide it is. That will give you the area, but not the volume. The total amount of space that an object takes up depends on its length, its width, and its height. When you know those three measurements, you can determine the volume by multiplying them together according to the formula:

$$\boxed{\text{Volume} = (\text{length})\cdot(\text{width})\cdot(\text{height})}$$

Let's suppose you have a box that measures 1.2 m long, 1.5 m wide, and 2.5 m high. The volume of the box would be:

$$\text{Volume} = (\text{length})\cdot(\text{width})\cdot(\text{height}) = (1.2\text{ m})\cdot(1.5\text{ m})\cdot(2.5\text{ m}) = 4.5\text{ m}\cdot\text{m}\cdot\text{m}$$

Notice once again that I did the numbers separately from the units. I multiplied the numbers together to get 4.5, and then I multiplied the units together to get m·m·m. How do we abbreviate that? Well, what is 2·2·2? It's 2^3, right? That means m·m·m is m^3, which is usually referred to as "cubic meters" or "meters cubed," because when you multiply something by itself three times, mathematicians say that you are "cubing" it. So, the box has a volume of 4.5 m^3.

Suppose I have another box that is 1 m long, 2 m wide, and 2.2 m high. It's shorter in length and height than the previous box, but it's wider. Which box can hold more stuff? All you have to do is compare the volumes. The first box has a volume of 4.5 m^3, and the second box has a volume of:

$$\text{Volume} = (\text{length})\cdot(\text{width})\cdot(\text{height}) = (1\text{ m})\cdot(2\text{ m})\cdot(2.2\text{ m}) = 4.4\text{ m}^3$$

The first box can hold a bit more stuff, because its volume is a bit larger.

Units like m^2 and m^3 might seem strange to you, but they are very common in science. In fact, they are so common that they have a name – **derived units**.

Derived unit – A unit of measurement produced by the mathematical combination of simpler units

The meter, for example, is a simple unit telling you distance. When you multiply length and width, you get the derived unit for area, m^2. When you multiply length, width, and height, you get the derived unit for volume, m^3.

While cubic meter is the standard unit for volume, it isn't used nearly as much as another metric volume unit with which you are familiar – the **liter**, which is abbreviated as "L." Many consumable liquids like bottled water, juice, and soda are sold in ½-liter, 1-liter or 2-liter bottles. Where does this unit come from? Believe it or not, it comes from the formula for volume that is on the previous page. However, instead of using meters (m) as the unit in the equation, it uses centimeters (cm). What unit would you get if you measured length, width, and height in cm and then multiplied them together to get volume? You would get cm·cm·cm, or cm^3. This is called a **cubic centimeter**, and it is often abbreviated as "cc." The volume of medicines is often measured in cm^3, so you might hear a doctor say something like, "administer 10 cc's of Penicillin." That means the patient is supposed to be injected with a dose of Penicillin whose volume is 10 cm^3.

This needle could be used to inject medicine into a patient. Notice that the unit listed is "cc." That means the marks measure the volume of the medicine in cubic centimeters.

But what does this have to do with liters? Well, the liter is defined as 1,000 cubic centimeters. So even though the metric unit of liter doesn't look like a derived unit, it is. It is based on the cubic centimeter, which is what results when you measure length, width, and height in cm and then multiply them together to get volume. Of course, since liter is a metric unit, it can have prefixes as well, so you can measure very large volumes in kiloliters (kL) and very small volumes in centiliters (cL) or milliliters (mL), with mL being the most common.

Converting Between Metric Units

Now you know the metric units for length (m), mass (g), time (s), and volume (m^3 or L). But since they are metric units, you can modify them with prefixes. While this is convenient, it can also lead to issues when comparing one measurement to another. For example, suppose you want to put curtains on your windows. You need to know the length and width of your windows, so you measure them to be 1.2 m high and 1.2 m wide. You then go shopping for curtains, but you find that all the lengths and widths listed are in cm, not m. Do you have to go back home and remeasure the windows using cm as the unit? No. Since centimeters and meters are both units of length, they can easily be converted into one another.

How do you do the conversion? Different people do it in different ways, but in this course, I want to teach you a very specific way. While it might seem a little annoying, it is important to learn the method, because it is used quite frequently in science. In addition, once you understand the method, you can apply it to any set of units, whether or not you are familiar with them. This method is called the **factor-label method**, and it is based on a very simple mathematical fact. Suppose you are faced with the math problem below:

$$\frac{17}{2} \cdot \frac{5}{17} =$$

How would you solve it? You *could* multiply 17 by 5 to get the numerator, multiply 2 by 17 to get the denominator, and then simplify. However, it's much easier to recognize that when multiplying fractions, like terms in the numerator and denominator cancel. In other words, you can just cancel the 17's:

$$\frac{\cancel{17}}{2} \cdot \frac{5}{\cancel{17}} = \frac{5}{2}$$

Now remember, in equations, you treat the units separately from the numbers, but the units still go through the same mathematical steps. We can use this to our advantage.

Remember, your windows are 1.2 m high and 1.2 m wide. However, the measurements on the curtains in the store are in cm. You can convert between meters and centimeters by starting with the definition of the prefix "centi." It means "0.01." That tells you:

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

Notice what I did. I started with the unit that has the prefix: 1 cm. After the equal sign, I replaced the "c" in "cm" with the number it represents, 0.01. This is called a **conversion relationship**. It tells you how these two units of distance compare to one another.

Now that I have the conversion relationship, I can convert between units by setting things up like I am multiplying fractions. Remember that I can make any number a fraction by just putting it over 1. So a measurement of 1.2 m can be turned into a fraction this way:

$$\frac{1.2 \text{ m}}{1}$$

This is still the same measurement: 1.2 m. I have just turned it into a fraction. Now I need to multiply this fraction by another fraction that will convert the meters into centimeters. Not surprisingly, I use the conversion relationship to build that second fraction. I will do this by putting one side of the equation over the other side. The way I do that is very important, however. I need to make the fraction so that "m" cancels and "cm" ends up being the final unit. I can do that if I put the "1 cm" on the top and the "0.01 m" on the bottom:

$$\frac{1.2 \text{ m}}{1} \cdot \frac{1 \text{ cm}}{0.01 \text{ m}}$$

Remember, we do the numbers and the units separately, but they each go through all the mathematical steps. Before doing the numbers, then, look at the units. There is a "m" in the numerator and a "m" in the denominator. Those are the same, so they cancel each other out:

$$\frac{1.2\,\cancel{\text{m}}}{1} \cdot \frac{1\text{ cm}}{0.01\,\cancel{\text{m}}}$$

That leaves us with "cm" as our only unit. That's good, because we want to know the height and width in cm. Now we just need to deal with the numbers. Once you have cancelled everything you can, you multiply the numerators together, multiply the denominators together, and then divide the numerator by the denominator:

$$\frac{1.2\,\cancel{\text{m}}}{1} \cdot \frac{1\text{ cm}}{0.01\,\cancel{\text{m}}} = \frac{1.2\text{ cm}}{0.01} = 120\text{ cm}$$

We now know that 1.2 m is the same as 120 cm. You might be able to do that in your head. However, in this course, I want you to learn how to do it this way because later on, you will deal with units like parts per million (ppm) and carats (ct), and you will have a hard time converting those kinds of units in your head. However, this method always works, regardless of whether or not you know the units. Study the following example problem so you can get more experience with this method.

Example 1.1

The highest mass a regulation golf ball can have is 46 grams. How many kilograms is that?

First, we use the prefix to determine the conversion relationship. The prefix "kilo" means "1,000," so we put a "1" next to the unit with the prefix, and then on the other side of the equal sign, we replace the prefix with its meaning: 1,000:

1 kg = 1,000 g

Now we set up the conversion like we are multiplying fractions. The original measurement we have goes over 1:

$$\frac{46\text{ g}}{1}$$

Now we multiply by a fraction made from the conversion relationship. However, we need to get rid of the "g," so the "1,000 g" needs to go on the bottom of the fraction. That way, the g's will cancel:

$$\frac{46\,\cancel{\text{g}}}{1} \cdot \frac{1\text{ kg}}{1{,}000\,\cancel{\text{g}}} = \underline{0.046\text{ kg}}$$

To get the number part of the answer, we multiply 46 by 1 and divide the result by 1 times 1,000. In other words, it's 46 divided by 1,000, which is 0.046.

I strongly recommend that you use a calculator when you do problems like these. There are so many other things you need to think about, I don't want you to have to think about the multiplication and division. You should even use a calculator on the tests.

In case you are wondering why we can take a measurement and multiply by the conversion relationship in fraction form, remember that the two sides of the conversion relationship are the same. That's what the equal sign means. In the example, the conversion relationship was 1 kg = 1,000 g. That means 1 kg and 1,000 g are equal. When you take two equal things and divide one by the other, what do you get? You always get 1. So, when you multiply by the conversion relationship in fraction form, you are really just multiplying by 1, which doesn't change anything. The original measurement remains the same value, just in the new unit. Let's do one more just so you have some more practice.

Example 1.2

The volume of a regulation golf ball is at least 40.7 milliliters. How many liters is that?

Remember, we start with the conversion relationship. The prefix "milli" means "0.001," so we put a "1" next to the unit with the prefix, and then on the other side of the equation, we replace the prefix with 0.001:

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

Now we set up the conversion like we are multiplying fractions. The original measurement we have goes over 1:

$$\frac{40.7 \text{ mL}}{1}$$

Now we multiply by a fraction made from the conversion relationship. However, we need to get rid of the "mL," so the "1 mL" needs to go on the bottom of the fraction. That way, the mL's will cancel:

$$\frac{40.7\ \cancel{\text{mL}}}{1} \cdot \frac{0.001 \text{ L}}{1\ \cancel{\text{mL}}} = \underline{0.0407 \text{ L}}$$

To get the number part of the answer, we multiply 40.7 by 0.001 and divide the result by 1 times 1. In other words, it's 40.7 times 0.001 divided by 1, which is 0.0407.

Make sure you understand what you learned today by answering the questions that follow.

Comprehension Check

1.9 What is the volume of a tiny box that is 16 mm long, 20 mm wide, and 15 mm tall? Don't forget to include the unit!

1.10 The maximum mass of a regulation bowling ball is 7.3 kg. How many grams is that?

1.11 Light can travel once around the earth in 13.4 centiseconds. How many seconds is that?

Converting Between Unit Systems

Scientists tend to use metric units, but depending on the country in which you live, they may not be familiar to you. If you live in the United States, for example, you don't measure distances in meters, millimeters, centimeters, and kilometers. Instead, you use inches, feet, and miles. Those are distance units, but they are part of the **imperial unit system**.

Imperial units – Measurement units defined by Great Britain in 1825

Obviously, imperial units are different from metric units. For example, an inch is longer than a centimeter, but it is shorter than a meter. Nevertheless, inches (abbreviated with "in") and centimeters measure the same thing: distance. Thus, there must be a relationship between them. It turns out that an inch is 2.54 times longer than a centimeter. In other words, it takes 2.54 cm to make 1 in. We could express this mathematically as follows:

$$1 \text{ in} = 2.54 \text{ cm}$$

Based on what you have learned so far, what is that? It's a conversion relationship! That equation allows us to convert between centimeters and inches (or inches and centimeters), as shown in the example below:

Example 1.3

The length of a piece of string is 16.51 cm. How many inches is that?

Remember, we start with the conversion relationship, which was given above:

$$1 \text{ in} = 2.54 \text{ cm}$$

Now we set up the conversion like we are multiplying fractions. The original measurement we have goes over 1:

$$\frac{16.51 \text{ cm}}{1}$$

Now we multiply by a fraction made from the conversion relationship. However, we need to get rid of the "cm," so the "2.54 cm" needs to go on the bottom of the fraction. That way, the cm's will cancel:

$$\frac{16.51 \cancel{\text{cm}}}{1} \cdot \frac{1 \text{ in}}{2.54 \cancel{\text{cm}}} = \underline{6.5 \text{ in}}$$

To get the number part of the answer, we multiply 16.51 by 1 and divide the result by 1 times 2.54. In other words, it's 16.41 divided by 2.54.

To make the example above a bit easier, I chose the string measurement so that it worked out to a fairly simple number of inches. However, when you are converting between systems, that doesn't always happen. For example, the average adult male in the United States is 175 cm tall. How many inches is that? Well, if we followed the same procedure given above, we would find that it is:

$$\frac{175 \cancel{\text{cm}}}{1} \cdot \frac{1 \text{ in}}{2.54 \cancel{\text{cm}}} = 68.897637795 \ldots$$

Those three dots mean that the answer continues with a lot more digits. Obviously, you don't want to write all those digits, so you need to stop somewhere. When you take high school chemistry, you will find that there are rules for when to stop reporting the digits in an answer like that one. Fortunately, you don't have to worry about that here. For this class, just keep three digits in your answer.

Because you will be dropping digits, there is one more thing you need to worry about: rounding your answer. When you drop digits, you look at the first digit you are going to drop. If it is 0-4 just drop it and all the remaining digits and don't do anything. That's called **rounding down**, because the actual answer is just a bit bigger than the answer you are reporting. However, if it is 5-9, you need to add one to the last digit you are not dropping. That's called **rounding up**, because the answer you are reporting is just a bit larger than the actual answer. Rounding up and rounding down ensures that the answer you give is closer to the actual answer given by the calculator. In this case, the calculator answer was 68.897637795…, and we need to keep three digits, so we need to drop the first "9" in the number. Because we are dropping a "9," we round up, and the answer is 68.9 cm.

Of course, each unit in the metric system has a unit in the imperial system to which it can be related. Inches, for example, can be related to cm, as I just showed you. In fact, any length unit in the metric system can be related to any length unit in any other system, including the system used in the United States, which is similar to the imperial system. This is true for mass units, volume units, etc. Below you will find a few of those relationships.

Relationships Between Some Metric and U.S. Units

Physical Quantity	Metric Unit	U.S. Unit	Relationship
Distance	centimeter (cm)	inch (in)	1 in = 2.54 cm
Mass	gram (g)	slug (sl)	1 sl = 14,594 g
Volume	liter (L)	gallon (gal)	1 gal = 3.785 L

You will not need to know any of these relationships. You won't even need to know the names of the U.S. units. If you need them to solve a problem or answer a question, they will be given to you. Let's do one more conversion between metric and U.S. units before we move on.

Example 1.4

A regulation basketball has a volume of 1.88 gallons. How many liters is that?

Remember, we start with the conversion relationship, which is given in the table:

$$1 \text{ gal} = 3.785 \text{ L}$$

Now we set up the conversion like we are multiplying fractions. The original measurement we have goes over 1:

$$\frac{1.88 \text{ gal}}{1}$$

Now we multiply by a fraction made from the conversion relationship. However, we need to get rid of the "gal," so the "1 gal" needs to go on the bottom of the fraction. That way, the gals will cancel:

$$\frac{1.88\ \cancel{\text{gal}}}{1} \cdot \frac{3.785 \text{ L}}{1\ \cancel{\text{gal}}} = \underline{7.12 \text{ L}}$$

The calculator's answer is 7.1158. However, I told you to keep three digits, so you need to drop the "58." Since the first digit you are dropping is a 5, you must round the answer up.

The Importance of the Factor-Label Method

Hopefully, the previous example gives you an idea of why it is important to learn the factor-label method. When you are familiar with the unit, you can often do conversions in your head. Many people have no problem realizing that 150 cm is the same as 1.5 m, because they know that a cm is 100 times smaller than a meter, so if you divide 150 by 100 (which many people can do in their heads), you convert from cm to m. Of course, if you aren't thinking really clearly, you might end up multiplying by 100, which would give you the wrong answer. More importantly, the factor-label method works regardless of whether or not you are familiar with the unit.

In the previous example problem, you know that 1 gal = 3.785 L, so you know that in order to convert from gallons to liters, you need to do something with 3.785. But what do you do? Do you divide or multiply? Well, if you are familiar with the units, you can usually reason it out. However, the more unfamiliar the unit, the harder it is to figure out. Consider, for example, the way God instructed Noah to build the ark: "This is how you shall make it: the length of the ark three hundred cubits, its breadth fifty cubits, and its height thirty cubits" (Genesis 6:15, NASB). Since God is listing length, breadth (width), and height, you know that the cubit is a unit for measuring distance. It was defined as the distance from a man's elbow to the end of his fingertips. While that varied from person-to-person, a commonly-used value is 0.517 m. So that tells us:

$$1 \text{ cubit} = 0.517 \text{ m}$$

You probably aren't very familiar with the cubit, but you can still convert the ark's measurements into meters, because you know the factor label method. For example, the length of the ark is 300 cubits. You put that over 1 to make it a fraction, and then you multiply by a fraction made from the conversion relationship. That fraction is made so that cubits cancel. When you do that, you get:

$$\frac{300\ \cancel{\text{cubits}}}{1} \cdot \frac{0.517 \text{ m}}{1\ \cancel{\text{cubit}}} = 155 \text{ m}$$

The answer is really 155.10 meters, but remember, you only keep three digits. So the ark was 155 m long. An American football field is 91.4 m long, so the ark was more than 1.5 times as long as an American football field. If you do this with the other measurements, you find that the ark was also 25.9 m wide and 15.5 m tall.

That gives you a better idea of how big the ark was, doesn't it? In fact, there is an organization in the United States, Answers in Genesis, that has built a life-sized model of Noah's ark, which is pictured below:

So that you have an idea of how big it is, look at the people in the foreground or the cars on the right! Of course, when they had the ark built, Answers in Genesis didn't use the unit cubits to guide its construction. They converted cubits to units that the builders knew how to use.

The point I am trying to make is that you don't have to be familiar with what a cubit is in order to use the factor-label method to convert it into a different unit, as long as you know the relationship between them. This is important, because in this course, you will be using some units with which you are not familiar, like parts per million (ppm) and carats (ct). When you study chemistry and physics in high school, you will use even less-familiar units, like moles. If you learn the factor label method now, it will make dealing with those units *much* easier.

Identifying Measurements Based on Units

Units are important for many reasons. Not only are they necessary for the measurements themselves, but they also tell you what is being measured. For example, consider the basic metric unit for mass – the gram. If you read a measurement whose unit is grams, (or mg, cg, kg, etc.), then you know it is a mass measurement, because that's what grams measure. Thus, I don't have to say, "An object whose mass is 15 g." I could just say, "A 15-g object." Because of the unit, you would know that I am telling you the mass of the object. In the same way, if I said "A 2.5-kL object," you would know that I am giving you the volume of the object. The metric unit liter measures volume, so any unit based on liters (mL, cL, kL, etc.) measures volume.

This baby is being weighed, but the scale is indicating kg, which is mass, not weight.

While scientists are very careful about this, people often aren't. In everyday language, for example, people often confuse units. For example, a doctor tends to track a patient's weight, since a person's weight is related to his or her health. This is especially important for babies, so there are special scales used to weigh them. On the right, you see a picture of a baby being weighed. Notice what the scale says the weight is: 8.89 kg. What's wrong with that? The unit kg does not measure weight; it measures mass.

As I told you already, mass and weight are related, but they are not the same thing. Mass is a measure of how much matter is in something. You will learn more about this when you take high school physics, but weight is a measure of how strong the planet's gravity pulls on an object. Since they are different things, they are measured with different units. In the metric system, the unit for weight is the Newton. Thus, since the scale is measuring the baby's weight, it should give an answer in Newtons, not kg. The U.S. unit for mass (as shown in the table on page 18) is the slug. What's the U.S. unit for weight? It's the pound. So, if I report something in pounds or Newtons, I am reporting weight. If I report it in grams (or kg, mg, etc.) or slugs, I am reporting mass.

Why does this confusion exist? Because as long as you stay near the surface of the earth, a person's mass can be calculated from his or her weight, and vice-versa. For example, I can tell you that this baby's actual weight is 87.2 Newtons (which is also 19.6 pounds). Since nearly everyone stays near the surface of the earth, the distinction between mass and weight is not all that important.

Nevertheless, for the metric system, you need to know what is being measured simply by the unit. So when you see one of the units I want you to recognize (gram, meter, seconds, liter, along with any of the three prefixes you are supposed to know), you have to be able to tell me what is being measured.

Comprehension Check

1.12 As you determined earlier, the maximum mass of a regulation bowling ball is 7,300 g. What is that mass in slugs? (1 sl = 14,594 g)

1.13 A furlong is another imperial unit for distance. If the distance between Washington, DC and New York, NY is 1,840 furlongs, what is it in meters? (1 furlong = 201 m)

1.14 You are reading a laboratory notebook, and you see several pieces of data: 14.5 mL, 16.2 kg, and 1.2 cm. For each piece of data, indicate (based on the unit) what was being measured.

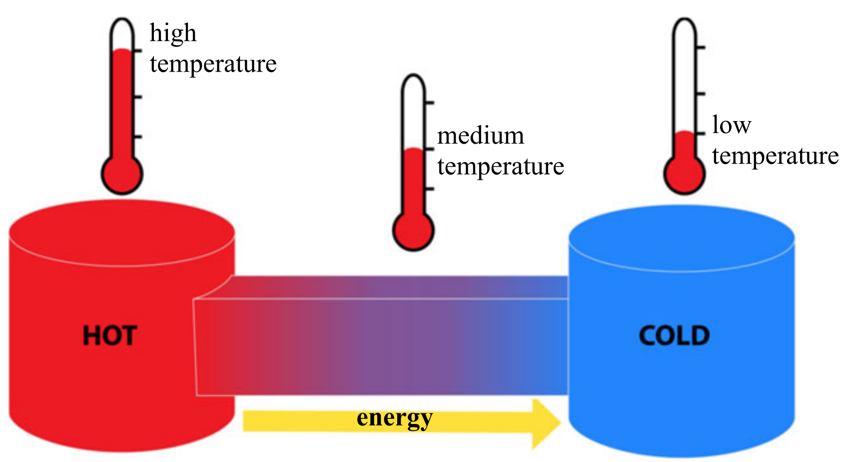
It's Not the Heat

When studying the earth, another very important thing you need to measure is temperature, and while we tend to monitor temperature regularly, most people don't understand what it measures. Many students (and unfortunately, even some textbooks) say that temperature is a measure of heat. After all, when the temperature goes up, we say that it is "hot." Thus, temperature measures heat, right? Wrong! Heat has a very specific definition:

Heat – Energy that is exchanged because of a difference in temperature or a change in phase

As I discussed already, when you "heat up" ice, it melts. The reason we say "heat up" is because you are adding energy to change the phase. That means energy is being given to the ice (being exchanged) to change its phase. That's heat. If you cool something down, you are also causing energy to be exchanged, so once again, you are using heat. It is just being exchanged in the opposite direction.

So, heat is energy that is being exchanged. One reason it might be exchanged is to change phase. Another reason is because of a difference in temperature. If you have something hot (like a fire) and something cooler (like your body), energy will be exchanged. It will leave the fire and be absorbed by your body, as shown in the diagram on the right. The flow of energy illustrated by the yellow arrow is heat. Temperature, then, does not measure heat. However, it does determine the direction in which energy travels. Heat is the flow of energy from something at a higher temperature to something else at a lower temperature.



When energy is exchanged because of a temperature difference, it always flows from the hotter object to the cooler object.

So far, I have only told you want temperature *does not* measure. It doesn't measure heat. What does it measure? To help you understand the answer to that question, I want you to perform an experiment.

Experiment 1.3: Movement You Do Not See

Supplies:
- M&M candies (You need two each of four different colors. See the photo below.)
- Water
- Ice
- A pan for boiling
- A bowl that holds roughly as much water as the pan (They just need to be close.)
- Two plates that are either metal or ceramic and can sit comfortably on top of the pan and bowl (The closer to white they are, the better.)
- A large serving spoon
- A stove or hotplate

Instructions:
1. Fill the pan about half full of hot water from the tap. Put it on the stove and get the water boiling.
2. Fill the bowl with ice and water until it is almost completely full.
3. Put the two plates on a flat surface and arrange four M&M candies, each with a different color, in a square at the center, as shown in the pictures below.
4. Once the water is boiling, turn off the stove and move the pan to a part of the stove that is no longer hot so the water stops boiling.
5. Use the serving spoon to take ice-cold water out of the bowl.
6. Gently add the water from the spoon to one of the plates, far from the M&Ms. You want the water to flow to the candies, but you don't want them to move. You need to have a thin layer of water in the plate. It should not cover the candies, but it should completely surround them. If you need more than one spoonful of cold water, that is fine.
7. Put the plate on top of the bowl so that it rests there.
8. Use the serving spoon to take hot water from the pan. **Be careful, it is hot!**
9. Add that water to the other plate, just like you added the cold water to the first plate. Once you have a thin layer of water that surrounds the candies but doesn't cover them, put the plate on top of the pan. **Once again, be careful! The plate will be warm, and the pan is hot!**
10. Your experiment should now look something like the picture on the right.

11. Watch how things change over the next few minutes. What differences do you note?
12. You can leave this experiment set up for a while if you want to come back later and see what happens after a long time. However, whenever you are finished, clean up your mess.

What did you see in your experiment? In both plates, you should have seen colors spreading out away from the candies. That should probably make sense to you. The candy coating dissolved in the water, so the water started taking on the colors of the candy coatings. As time went on, what differences did you see in each plate? You should have seen that the colors spread much farther from the candies on the hot plate than they did on the cold plate. Also, while the colors stayed partly separated from each other, after a while, they did begin to mix. However, they mixed to a much greater extent on the hot plate than on the cold plate.

What caused the difference? The temperature of the water. Even though the water wasn't moving on the plate, the *water molecules* were. As you learned earlier, molecules in liquids can move around. In your experiment, the candy coating on the M&Ms dissolved in water because the water molecules were moving around and slamming into the candies. The water molecules and the molecules that make up the candy coating were attracted to one another, so after the collision, some of the molecules from the candy coating "wanted" to stay close to the water molecules that slammed into them, so they followed the water molecules. As a result, the molecules from the candy coating started spreading out into the water.

Well, at higher temperatures, water molecules move faster. In your experiment, then, the water molecules in the hot water slammed into the candies harder and pulled the molecules from the coating off more quickly. As a result, the colors spread out more quickly. That's what temperature is really a measure of. It is a measure of the energy associated with the motion of a substance's molecules.

<u>Temperature</u> – A measure of the energy associated with the random motion of a substance's molecules

But wait a minute. How does that make you hot or cold? If you had put your hand in the ice water, it would have gotten uncomfortably cold. If you had put your hand in the hot water, you would have gotten burned. How does the motion of the molecules do that? Well, think about it. The water molecules collide with whatever is in the water, so if you put your hand in the hot water, they would collide with your skin. Since the water molecules in the hot water move very quickly, the collision would be violent enough to damage cells in your skin, causing a burn.

Now remember, the molecules in your skin cells are moving as well. So, if you put your hand in cold water, the molecules in your skin cells would be moving faster than the molecules in the water. As a result, when a collision occurred, energy would be transferred from your skin to the water. As your skin loses energy, the molecules in your skin cells slow down, which reduces the temperature of your skin. That makes your skin cold.

In the end, then, temperature is *not* a measure of heat. It is a measure of how quickly a substance's molecules are randomly moving around. Now remember, even the molecules of a solid move. They don't move from place to place, but they do vibrate back and forth. Thus, regardless of whether it is a solid, liquid, or gas, the higher the temperature, the more quickly the molecules that make up the substance are moving.

You might still be wondering about one thing you observed in the experiment. Why did it take so long for the colors to start mixing? Well, the molecules that make up the dyes that give the candies their colors are much larger than water molecules. In order to spread, the dye molecules must move through other molecules, and it is easier for them to move through the smaller water molecules than the other dye molecules. At first, then, the color didn't mix much. However, as time went on, the dye molecules did move a bit through the other dye molecules, so there was some color mixing. However, once again, the colors mixed more in the hot water, because those dye molecules were moving faster, which made it easier for them to move through the other dye molecules.

Comprehension Check

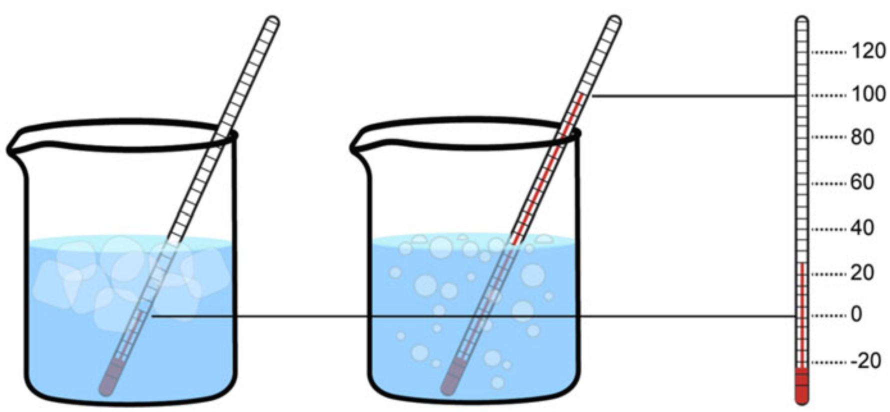
1.15 You are watching the molecules of a substance and notice that over time, their random motion gets slower and slower. Is the substance increasing in temperature, decreasing in temperature, or remaining at the same temperature?

Measuring Temperature

Now that you know what temperature measures, we can discuss how we measure it and what units we will use. Let's start with how we measure temperature. As you already know, we use **thermometers**, to measure temperature. But how? Well, there are different kinds of thermometers, but the most common kind is illustrated in the drawing below. It consists of a tube of glass that contains a colored liquid. When you put the thermometer in something, the molecules of the substance start colliding with the molecules in the glass. If the molecules in the substance have more energy than the molecules in the glass, energy goes from the substance to the glass. If the molecules of the substance have less energy than the molecules in the glass, energy goes from the glass to the substance.

As the energy moves, the liquid inside the thermometer warms up or cools down, depending on whether the thermometer is gaining energy or losing energy. If the liquid warms up, it expands. This causes it to rise in the tube. If it cools down, the liquid contracts, which causes the liquid to lower in the tube. Based on the final height of the liquid, you can read the temperature. The higher the liquid has risen, the higher the temperature.

But how does the height of liquid in a tube tell us the temperature? We define a temperature scale and then mark a thermometer so it reads that scale. For example, the temperature scale that we will use in this course is the Celsius (sell' see us) temperature scale, named after Anders Celsius, a natural philosopher who lived in the first half of the 18th century. In this scale, water freezes at 0 degrees and boils at 100 degrees. To make the thermometer read that scale, you put it in water that is in the process of freezing, and you make a mark that represents 0. Then, you put it in boiling water and make a mark that represents 100. You then divide up the rest of the thermometer so that there are an even number of marks between 0 and 100. You now have a thermometer that reads the temperature in degrees Celsius.



The Celsius temperature scale is defined so that water freezes at 0 degrees and boils at 100 degrees.

There are other kinds of thermometers. Some use the flow of electricity through a metal to determine the temperature. Others use the way solids expand and contract to measure temperature. In addition, there are different temperature scales. The one with which you might be more familiar is the Fahrenheit scale, named after Daniel Gabriel Fahrenheit (fair' uhn height'), a natural philosopher who was 15 years older than Anders Celsius. On that scale, water freezes at 32 degrees and boils at 212 degrees. To distinguish between the two, we used "°C" to represent temperatures in the Celsius scale and "°F" to represent temperatures in the Fahrenheit scale.

Because both scales measure temperature, you can convert between them. However, I don't want you to worry about doing that, because the conversion doesn't use the factor-label method, and I want to concentrate on that in this course. However, I do want you to get a general idea of how the scales relate to one another, so study the following example problems.

Example 1.5

Which is colder: 4 °C or 31 °F?

You might be tempted to just choose the smaller number, assuming it represents the lower temperature. However, think about the phase of water. At 4 °C, water is a liquid, because it freezes at 0 °C. However, at 31 °F, water is frozen, because it freezes at 32 °F. The temperature at which water is frozen will be lower than the temperature at which it is still a liquid, so <u>31 °F is the colder temperature</u>.

Which is warmer: 200 °F or 101 °C?

You might be tempted to just choose the larger number, but once again, think about the phase of water. At 101 °C, water is a gas, because it boils at 100 °C. However, at 200 °F, water is a liquid, because it boils at 212 °F. The temperature at which water is a gas will be higher than the temperature at which it is still a liquid, so <u>101 °C is the warmer temperature</u>.

Obviously, you can't compare all Celsius and Fahrenheit temperatures that way. For example, water is a solid at -1 °C and 5 °F. Thus, unless you convert one temperature to the other scale, it would be hard for you to tell that 5 °F is the colder temperature. However, if I ask you to compare Celsius and Fahrenheit temperatures, there will always be a difference in the phase of water. Thus, all you need to know for this course is how both scales are defined. If you know that, you will be able to answer any questions I ask using the same reasoning found in the two example problems above.

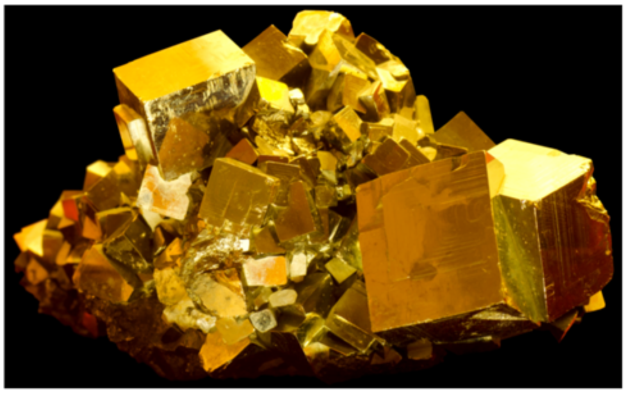
<u>Measuring Density</u>

You have probably learned about density already, but it is an important thing to measure in earth science, so I need to make sure you understand it. Density tells us how tightly-packed the matter in an object is. There is a simple equation that allows you to calculate the density of any object:

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

If you know the mass of an object, you know how much matter it has in it. If you then divide the mass by the volume, you have a number that tells you how tightly-packed that matter is.

Think about the units for density. Mass can be measured in grams, for example, while volume can be measured in liters. Now remember, when units are in an equation, you do the math with them as well. Some of them might cancel, like they do in conversions, but if they don't cancel, the results of the math are the units. If you divide grams by liters, you get $\frac{\text{grams}}{\text{liter}}$ $(\frac{\text{g}}{\text{L}})$, which is called "grams per liter." That's one unit for density. In earth science, however, it is much more common to measure volume in milliliters (mL), so the more common density unit is what results when grams are divided by milliliters: $\frac{\text{grams}}{\text{milliliter}}$ $(\frac{\text{g}}{\text{mL}})$.


This looks like gold, but its density indicates it's not.

The density of an object is important because it is different for different substances. Consider, for example, the picture on the left. What does that look like to you? It looks like gold, doesn't it? Well, at room temperature, gold has a density of 19.3 $\frac{\text{g}}{\text{mL}}$. If that really is gold, it would have the same density at room temperature. If I take the mass of that sample and divide by its volume, however, I get 4.9 $\frac{\text{g}}{\text{mL}}$, which tells me it's not gold. In fact, that's a picture of iron pyrite, which is often called "fool's gold" because it looks like gold but isn't.

Density can be useful in another way as well. It can tell you whether or not something will float in water. At room temperature, water has a density of 1.0 $\frac{\text{g}}{\text{mL}}$. Anything that has a lower density than that will float in water, and anything that has a higher density will sink. For example, the iron pyrite pictured above will sink in water, because its density (4.9 $\frac{\text{g}}{\text{mL}}$) is higher than 1.0 $\frac{\text{g}}{\text{mL}}$. However, a cork has a density of 0.2 $\frac{\text{g}}{\text{mL}}$, which is lower than water's density. That means it will float. In the same way, ice has a density of 0.9 $\frac{\text{g}}{\text{mL}}$, which explains why ice cubes float in your drink. Make sure you can use this kind of reasoning by studying the following example.

Example 1.6

A 45-gram object takes up 65 mL of space. Will it float or sink in water?

To determine whether something floats or sinks in water, you must calculate its density. Now remember, you can recognize what is being measured just by the units. So even though I didn't tell you that the mass is 45 grams, you see that it is, because a measurement with a unit of grams must be a mass measurement. In the same way, L (or any prefix with L, like mL) measures volume, so the 65 mL measurement must be the volume. Now that we know mass and volume, we simply stick them into the equation:

$$\text{density} = \frac{\text{mass}}{\text{volume}} = \frac{45\text{ g}}{65\text{ mL}} = 0.69\ \frac{\text{g}}{\text{mL}}$$

Now remember, we do the numbers and the units separately. When you divide 45 by 65, you get 0.69230769…. However, you only need to keep three digits (even when the one left of the decimal is 0), so that means you should drop the "2" and everything after it. Since you are dropping a two, you round down, so the number is 0.69. For the units, you do the same math, so g divided by mL is $\frac{\text{g}}{\text{mL}}$. Since the density is less than 1.0 $\frac{\text{g}}{\text{mL}}$, <u>it will float in water</u>.

I need to make two more points about this. First, I told you that an object will sink in water if its density is higher than that of water, and it will float if its density is lower. But what happens if its density actually equals the density of water? That doesn't happen very often, because each substance has its own density. However, if you are clever, you can make an object with a density equal to that of water. If you do, the object will stay wherever you place it in water. If you put it on the surface, it will completely submerge, but it will stay on the surface. If you put it 10 cm below the surface, it won't rise or sink; it will continue to stay 10 cm below the surface.

The balloons that are floating are less dense than air, while the balloons that aren't floating are denser than air.

The other point is more important. This works for any substance in which floating is possible, not just water. Consider the picture on the right. Why are some of the balloons floating, while the others rest on the floor? You know the answer – the balloons that are floating are filled with helium, while the balloons that are not floating are filled with air. But what makes helium-filled balloons float? The mass of helium is low, so when you take the total mass of the helium plus the mass of the balloon itself and divide by the volume of the balloon, the density is lower than the density of the air around it, so the helium balloon floats. When you fill a balloon with air, the total mass of the air plus the mass of the balloon itself divided by the volume is greater than the density of air, so it sinks.

Measuring Concentration

Suppose you are hosting a party. You make some snacks so that your guests can have something to eat, and you decide to make lemonade for them to drink. You get out the lemonade mix and read the instructions. It says to add one packet of lemonade mix to two liters of water and stir so that it all dissolves. The problem is that you have only one packet left, and you know that two liters will not be enough for all your guests. You decide to add one packet of lemonade mix to four liters of water. That way, there is plenty for everyone. What's wrong with that reasoning? You will, indeed, have four liters of "lemonade" to drink, but it won't taste right, will it? The "lemonade" will taste too weak.

But why will it taste weak? Because in order for it to taste right, the chemicals in the lemonade mix must have a specific **concentration**.

Concentration – The amount of a substance in a defined volume

In the scenario I just described, you took chemicals that were supposed to go into two liters of volume and instead put them into four liters of volume. That spread the chemicals over too large a volume, reducing their concentration, which reduced the strength of their taste.

It turns out that concentration is incredibly important when it comes to understanding how chemicals behave. For example, you know that you are supposed to have a diet that is rich in vitamins, right? Your body needs vitamins, and if you don't get enough of them, their concentration becomes too low, and you can get sick. However, you might not realize that for some vitamins, too high a concentration can also make you sick! Think about the lemonade. If the concentration of the mix is too low, it tastes weak. What if you added an entire packet to only one liter of water instead of the recommended two liters? It would taste too strong. For the lemonade to taste right, it needs to be at the right concentration. In the same way, for vitamins to work right, they have to be at the right concentration.

There are lots of different ways to measure concentration, but one of the most commonly-used units is **percent (%)**. When you hear that word, you probably think about buying something on sale and getting a discount. However, the word "percent" actually means "per hundred." Thus, it can be a concentration unit as well. For example, suppose I dissolve salt in water. Suppose further that I count the molecules of salt and the molecules of water after I am done. If I count 100 total molecules and find that 15 of them are salt, I could say that the concentration of salt is 15 molecules of salt per 100 molecules in the mixture. That means it is 15% salt. The "%" symbol actually means "per hundred." If there were 40 molecules of salt in 100 molecules of the mixture, the mixture would be 40% salt, which is more concentrated.


The colors tell you the concentration of drink mix in these cups.

Thinking about percent as a concentration unit, then, consider the picture on the left. Each drink was made from the same mix. Which cup holds the highest percentage of mix in it? Which holds the lowest? You can tell from the color. The darker the color, the more concentrated the mix is in the drink, so the percent of drink mix in the middle cup is the highest, and the percent of drink mix in the cup on the right is the lowest. As we study things like rocks, soil, and the air we breathe, we will discuss the concentration of chemicals in terms of percent as well as other units that I will introduce later on in the course.

Comprehension Check

1.16 Which is warmer: 215 °F or 99 °C?

1.17 At room temperature, silver has a density of $10.5\,\frac{\text{g}}{\text{mL}}$. If you find a 20-mL, 210-g object that looks like it is made of silver. Is it?

1.18 Will a 125-mL, 90-g object float in water, which has a density of $1.0\,\frac{\text{g}}{\text{mL}}$?

1.19 You are blindfolded and asked to taste two drinks. Each one is made by mixing lemon juice and water. Neither is as sour as pure lemon juice, but the first one is a lot more sour than the second. Which was made with the higher percent of lemon juice?

You are now done covering the material in the first chapter of the course. In order to prepare for the test, answer the Chapter Review questions on pages 33 and 34. Then have your parent/teacher check your answers. Correct and make sure you understand anything you got wrong, and then take the test. Recall that for the test, you need to remember anything that is in pink boxes in the chapter, including equations. You must also remember the definitions presented in the chapter.

Answers to the Comprehension Check Questions

1.1 It appears to be flat because the curve is very gentle. The bigger the sphere, the more gently its surface curves. The earth is a big sphere, so its curve is very gentle.

1.2 Africa is larger than Greenland. Since the earth is a globe, a flat representation distorts it. Things near the equator are less distorted than things far from the equator. Since Greenland is far from the equator, it is distorted a lot. If you can't picture this in your mind, that's fine. Just realize that a globe is a better representation of the earth, since the earth is actually a sphere. Thus, the globe will have a better representation of the continents than something that is flat.

1.3 The student is not correct. A change of just one atom makes a profound difference in the chemistry of the molecule. Since we breathe out CO_2, it is only bad for us when there is a lot of it. Small amounts of CO, however, can be deadly because of the way it interacts with our blood cells.

1.4 There are five atoms. "Fe" is one atom, because it has one capital letter. There is a "2" subscript after it, so there are two Fe atoms. O is the only other atom, because it is the only other capital letter. There is a "3" subscript next to it, so there are three O atoms. That makes a total of five atoms.

1.5 $MgSO_4$. Since we don't write 1's, there is nothing after Mg and nothing after S. Since there are four atoms of oxygen, there is a "4" subscript after the O.

1.6 It will become a liquid and then a gas. Yes, you can make metals into gases. You have to be careful, and it must be done without any oxygen present, but it can be done. In fact, that's why I heat metals in my research. I have to make them gases. Like all chemicals, metals can reach all three phases, if the conditions are correct.

1.7 You would use kiloseconds. A second is a short amount of time compared to the length of time you will be working on this course. The only prefix you need to know to measure large things is kilo. If you are like most students, you will spend about 700 kiloseconds on this course. That doesn't sound like much, does it?

1.8 The area is 616 cm^2. Area is length times width, so:

$$\text{Area} = (\text{length})\cdot(\text{width}) = (28\text{ cm})\cdot(22\text{ cm}) = 616\text{ cm}^2$$

Remember, you do the numbers and units separately. $28\cdot 22 = 616$, and cm·cm is cm^2. If you are worried about why the unit isn't m^2 like it was in the room example I gave, remember that a unit with a prefix measures the same thing as the unit without a prefix. It is just smaller or larger than the basic unit. Since cm is a way of measuring smaller lengths than m, cm^2 is a way of measuring smaller areas than m^2. If you had measured the page in meters, you would have gotten an answer of 0.0616 m^2.

1.9 The volume is 4,800 mm^3. All we have to do here is plug the measurements into the formula for volume and then do the numbers and units separately:

$$\text{Volume} = (\text{length})\cdot(\text{width})\cdot(\text{height}) = (16\text{ mm})\cdot(20\text{ mm})\cdot(15\text{ mm}) = 4{,}800\text{ mm}^3$$

That may sound like a lot, but a mm^3 is a very small volume unit, so 4,800 mm^3 isn't a lot of volume.

1.10 <u>It is 7,300 g</u>. First, we use the prefix to determine the conversion relationship. The prefix "kilo" means "1,000," so we put a 1 next to the unit with the prefix, and then on the other side of the equal sign, we replace the prefix with 1,000:

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

Now we set up the conversion like we are multiplying fractions. The original measurement we have goes over 1:

$$\frac{7.3 \text{ kg}}{1}$$

Now we multiply by a fraction made from the conversion relationship. However, we need to get rid of the "kg," so the "1 kg" needs to go on the bottom of the fraction. That way, the kg's will cancel:

$$\frac{7.3 \cancel{\text{kg}}}{1} \cdot \frac{1{,}000 \text{ g}}{1 \cancel{\text{kg}}} = 7{,}300 \text{ g}$$

To get the number part of the answer, we multiply 7.3 by 1,000 and divide the result by 1 times 1. In other words, it's 7.3 times 1,000, divided by 1.

1.11 <u>It is 0.134 s</u>. First, we use the prefix to determine the conversion relationship. The prefix "centi" means "0.01," so we put a "1" next to the unit with the prefix, and then on the other side of the equal sign, we replace the prefix with 0.01:

$$1 \text{ cs} = 0.01 \text{ s}$$

Now we set up the conversion like we are multiplying fractions. The original measurement we have goes over 1:

$$\frac{13.4 \text{ cs}}{1}$$

Now we multiply by a fraction made from the conversion relationship. However, we need to get rid of the "cs," so the "1 cs" needs to go on the bottom of the fraction. That way, the cs's will cancel:

$$\frac{13.4 \cancel{\text{cs}}}{1} \cdot \frac{0.01 \text{ s}}{1 \cancel{\text{cs}}} = 0.134 \text{ s}$$

To get the number part of the answer, we multiply 13.4 by 0.01 and divide the result by 1 times 1. In other words, it's 13.4 times 0.01, divided by 1.

1.12 <u>It is 0.50 sl</u>. First, we write down the conversion relationship:

$$1 \text{ sl} = 14{,}594 \text{ g}$$

Now we set up the conversion like we are multiplying fractions. The original measurement we have goes over 1:

$$\frac{7{,}300 \text{ g}}{1}$$

Now we multiply by a fraction made from the conversion relationship. However, we need to get rid of the "g," so the "14,594 g" needs to go on the bottom of the fraction. That way, the g's will cancel:

$$\frac{7{,}300\ \cancel{\text{g}}}{1} \cdot \frac{1\ \text{sl}}{14{,}594\ \cancel{\text{g}}} = \ 0.50\ \text{sl}$$

The calculator says the answer is 0.50020556…, but keeping only three digits means dropping the second "0" and everything that comes after it. Since it's 0-4, we round down, making the answer 0.50.

1.13 <u>It is 370,000 m</u>. First, we write down the conversion relationship:

$$1\ \text{furlong} = 201\ \text{m}$$

Now we set up the conversion like we are multiplying fractions. The original measurement we have goes over 1:

$$\frac{1{,}840\ \text{furlongs}}{1}$$

Now we multiply by a fraction made from the conversion relationship. However, we need to get rid of the "furlong," so the "1 furlong" needs to go on the bottom of the fraction. That way, the furlongs will cancel:

$$\frac{1{,}840\ \cancel{\text{furlongs}}}{1} \cdot \frac{201\ \text{m}}{1\ \cancel{\text{furlong}}} = \ 370{,}000\ \text{m}$$

The calculator says the answer is 369,840, but keeping only three digits means dropping the "8" and everything that comes after it. Since that's between 5 and 9, we round up. That means turning the "9" into a "10," which makes the answer 370,000. If it bothers you that there are actually six digits in the answer, not three, remember that you can't drop any of those zeroes, because it would change the size of the number. When you drop digits, you can keep zeroes if you need to in order to keep the size of the number correct.

1.14 <u>14.5 mL is volume, 16.2 kg is mass, and 1.2 cm is distance</u>. The units tell you what is being measured. Liters (with or without prefixes) measure volume, grams (with or without prefixes) measure mass, and meters (with or without prefixes) measure distance.

1.15 <u>It is decreasing in temperature</u>. Temperature measures how quickly a substance's molecules are moving. The slower molecules move, the lower the temperature.

1.16 <u>215 °F is warmer</u>. It's not because the number is higher. It's because water boils at 212 °F and 100 °C. At 215 °F, water is a gas, but ag 99 °C, it is a liquid.

1.17 <u>Yes, it is made of silver</u>. You need to check its density. To do that, you use the formula:

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

Even though you aren't told which is mass and which is volume, you know from the units. Grams measure mass, and mL measures volume:

$$\text{density} = \frac{\text{mass}}{\text{volume}} = \frac{210\text{ g}}{20\text{ mL}} = 10.5\ \frac{\text{g}}{\text{mL}}$$

Since that equals the density of silver, it is probably made of silver.

1.18 Yes, it will float. Remember, you compare the density of the object to that of water. If its density is lower than water's density, it floats. If it is higher, it sinks. You know that 90 g must be the mass and 125 mL must be the volume because of the units:

$$\text{density} = \frac{\text{mass}}{\text{volume}} = \frac{90\text{ g}}{125\text{ mL}} = 0.72\ \frac{\text{g}}{\text{mL}}$$

Since that is lower than the density of water ($1.0\ \frac{\text{g}}{\text{mL}}$), it floats.

1.19 The first one is made with a higher percent of lemon juice. Remember, percent is a way to measure concentration. Since pure lemon juice is sour, the one that is more sour has more lemon juice in it, so it has the higher concentration and therefore the higher percent.

Chapter Review

1. Define the following terms:

   a. Mass
   b. Derived unit
   c. Imperial units
   d. Heat
   e. Temperature
   f. Concentration

2. Why did ancient sailors and people who lived near the ocean understand that the earth is spherical in shape?

3. What made people think that Christopher Columbus couldn't sail around the world?

4. N_2O gas is often called "laughing gas," because it can be used to help people ignore pain that occurs during medical procedures. NO_2 gas is a pollutant found in the air. Does NO_2 have the same effect on people as laughing gas?

5. Sometimes, coal can be contaminated with a chemical whose formula is $CuFeS_2$. How many of each atom is in a molecule of this chemical?

6. The main chemical in limestone is made of one calcium (Ca) atom, one carbon (C) atom, and three oxygen (O) atoms. What is its chemical formula?

7. A chemical is in its liquid phase. Are its molecules closer together or farther apart compared to when it is in its gas phase? Do the atoms move around more or less when it is a liquid as compared to when it is a gas?

8. If you have a gas and want to turn it into a liquid, do you need to heat it up or cool it down?

9. You see the following measurements: 1 kg, 34 ms, 17%, 3 L, 5 g/mL, and 14 cm. Identify each as a measurement of mass, distance, time, volume, concentration, or density.

10. What is the area of a room that measures 3 meters wide and 2 meters long?

11. What is the volume of a cube that is 12 cm long, 10 cm wide, and 5 cm high?

12. On the surface of the earth, an object that weighs 1 pound has a mass of 454 g. How many kilograms is that?

13. An adult human finger is about 20 mm wide. How many meters wide is it?

14. A regulation fencing sword is 90 cm long. If 1 in = 2.54 cm, how many inches long is it?

15. You are watching the molecules in an object move. Suddenly, they start moving faster than before. Was object cooled down or heated up?

16. Water is at a temperature of 95 °C. Someone tells you that's the same as 230 °F. Should you believe that person? Why or why not?

17. You see an object (190 g, 30 mL) that looks like it is made of copper. If copper has a density of 8.96 g/mL, is the object made of copper?

18. The density of air at 25 °C is 0.01 g/mL. You let go of a 500-mL balloon whose total mass is 10 g. Will it float away or fall to the floor?

19. If you could count the molecules in air, you would find that out of 100 molecules, 21 of them are oxygen, 78 are nitrogen, and 1 is another chemical. What percent of air is nitrogen?

20. Another common temperature scale in science is the Kelvin scale. On this scale, water freezes at 273 K and boils at 373 K. Which is warmer: 300 K or 110 °C?