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WELCOME

When you look around, do you ever wonder where everything came from and how it was made? Have you ever contemplated why a tree is hard, a sponge is soft, and a breeze is invisible?

> By faith we understand that the universe was formed at God's command, so that what is seen was not made out of what was visible.
> —Hebrews 11:3, NIV

Welcome to the world of chemistry! This year you are going to take a journey that allows you to explore God's creation with the eyes of a scientist. Studying God's creation at the molecular and atomic level can enable you to understand how wonderfully everything fits together in this world God has created for us.

first reactions

What do you see when you look at the periodic table of elements? At first glance, most students see so many scientific symbols that they become intimidated. But the periodic table is the essence of chemistry. The years of discovery and knowledge summarized in it make it unlike any other common science tool.

From the galaxies in the universe to the tiniest microscopic cell, you experience the elements wherever you look!

> How many are your works, Lord! In wisdom you made them all; the earth is full of your creatures.
> —Psalm 104:24, NIV

Science is the endeavor of explaining the truth of the world around us, and God is the source of both creation and truth. You will discover that proper application of scientific principles will help you uncover how the world around you operates. Since science and faith both search for truth, they complement each other. The more you know about your world, the more you will wonder at the complex beauty of God's creation.

> He has made everything beautiful in its time. He has also set eternity in the human heart; yet no one can fathom what God has done from beginning to end.
> —Ecclesiastes 3:11, NIV

God gave humans dominion over the earth, so we can understand many things about it. This textbook is not just a compilation of facts and figures for you to memorize. This textbook is designed to take you on a remarkable journey that involves facts about chemistry, figures to help you understand the facts, and truth from your Creator. We at Apologia pray that this text will enable you to say:

> "How great are your works, LORD, how profound your thoughts!"
> —Psalm 92:5, NIV

MEASUREMENT, UNITS, AND THE SCIENTIFIC METHOD

Our understanding of life has changed more in the past 2 centuries than all the previously recorded span of human history. The earth's population has increased more than 5-fold since 1800, and our life expectancy has nearly doubled because of our ability to synthesize medicines, control diseases, and increase crop yields. Many goods are now made of polymers (plastics) and ceramics instead of wood and metal because of our ability to manipulate and manufacture materials with properties unlike any found in nature. In one way or another, all of these changes involve **chemistry**.

first reactions

When God told Noah to build an ark 300 cubits long, Noah had to know how long a cubit was in order to succeed. Imagine if Noah had built an ark 300 inches long! As you begin to learn the foundational language of chemistry, keep in mind that it is only the very beginning of true understanding.

What is chemistry? Quite simply, chemistry is the study of **matter**. Of course, this definition doesn't do us much good unless we know what matter is. So, to understand what chemistry is, we first need to define matter.

Matter—Anything that has mass and takes up space.

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

You might think that the answer is air. However, that's not the right answer. Perform experiments 1.1 and 1.2 to see what we mean.

EXPERIMENT 1.1

PURPOSE: To determine if air has mass.

MATERIALS:

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

QUESTION: Does air have mass?

HYPOTHESIS: Pick one: Either air has mass or air does not have mass.

PROCEDURE:

1. Without blowing them up, tie the balloons to the strings. Be sure to make the knots loose so that you can untie one of the balloons later in the experiment.
2. Tie the other end of each string to an end of the meterstick. Try to attach the strings as close to the ends of the meterstick as possible.
3. Once the strings have been tied to the meterstick, tape them down so that they cannot move.
4. Go into your bathroom and pull back the shower curtain so that a large portion of the curtain rod is bare. Balance the meterstick (with the balloons attached) on the bare part of the shower curtain rod. You should be able to balance it very well. If you don't have a shower curtain rod or you are having trouble using yours, you can use any surface that is adequate for delicate balancing like the upper part of a chair.
5. Once you have the meterstick balanced, stand back and look at it. The meterstick balances now because the total mass on one side equals the total mass on the other side. To knock it off balance, you would need to move the meterstick or add more mass to one side. You will do the latter.
6. Have someone else hold the meterstick so that it does not move. For this experiment to work properly, the meterstick must stay stationary.
7. While the meterstick is held stationary, remove one of the balloons from its string (do not untie the string from the meterstick), and blow up the balloon.
8. Tie the balloon closed so that the air does not escape, then reattach it to its string.
9. Have the person holding the meterstick let go. If the meterstick was not moved while you were blowing up the balloon, it will tilt toward the side with the inflated balloon as soon as the person lets it go. This is because you added air to the balloon. Since air has mass, it knocks the meterstick off balance. So air does have mass!
10. Clean up and return everything to the proper place.

CONCLUSION: What did you think? Write something about what you observed related to the fact that air has mass.

EXPERIMENT 1.2

PURPOSE: To determine if air takes up space.

MATERIALS:
- Tall glass
- Paper towel
- Sink full of water
- Safety goggles

QUESTION: Does air take up space?

HYPOTHESIS: Pick one: Either air takes up space or air does not take up space.

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

CONCLUSION: What did you think? Write something about what you observed related to the fact that air takes up space.

think about this

Air is typically used as a metaphor for nothingness. It is, however, very complex. Aristotle (384–322 BC) is generally given credit for being the first to state that air has weight, although many did not believe him. Would it surprise you to know that some 1,400 years *before* Aristotle, it was known that air had weight? It's true. The Bible tells us that God "gave to the wind its weight and apportioned the waters by measure" (Job 28:25). Think about this verse in the context of the timeline of scientific knowledge. Job may have lived anywhere from 2300 to 1700 BC. God created everything visible and invisible, including air. The Bible is His word, and we can trust it to be true. We explore science to understand what God already knows about His creation.

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

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

UNITS OF MEASUREMENT

Let's suppose you are making curtains for a friend's windows. You ask him to measure the window and give you the dimensions so that you can make the curtains the right size. Your friend tells you that his windows are 50 by 60, so that's how big you make the curtains. When you go over to his house, it turns out that your curtains are more than twice as big as his windows! Your friend tells you that he's certain he measured the windows correctly, and you tell your friend that you are certain you measured the curtains correctly.

How can this be? The answer is quite simple. Your friend measured the windows in centimeters. You, on the other hand, measured the curtains in inches. The problem was not caused by measuring incorrectly. Instead, the problem was the result of measuring with different **units**.

think about this

"Who has measured the waters in the hollow of his hand and marked off the heavens with a span, enclosed the dust of the earth in a measure and weighed the mountains in scales and the hills in a balance?" Isaiah 40:12

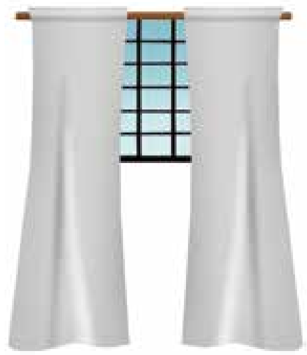
Can you determine what the author is trying to do here? He is trying to describe the greatness of God by using measurements that would have been understood by anyone living at this time. How would scientists of this day try to describe the greatness of God?

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

Scientists should never simply report numbers. They must always include units so that everyone knows exactly what the numbers mean. That will be the rule in this chemistry course.

If you answer a question or solve a problem and do not list units with the numbers, your answer will be considered incorrect.

FIGURE 1.1
Two Consequences of Not Using Units Properly
Window illustration by David Weiss. Mars Climate Orbiter image courtesy of NASA/JPL/Caltech



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

The Mars Climate Orbiter did not successfully make it into orbit because 2 engineering teams involved used different units in their designs.

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

THE METRIC SYSTEM

We need to measure many different things when studying matter. First, we must determine how much matter exists in the object that we want to study. We know that there is a lot

This process of using certain physical measurements to define the scale of a measuring device is called calibration. This particular calibration makes use of a surprising fact in chemistry:

If ice and water are thoroughly mixed, the temperature of the mixture will stay the same (0.0°C or 32.0°F), regardless of the amount of ice or water present.

This might sound rather surprising, but it is true. Even though you might think that a little water with a lot of ice is colder than a lot of water with a little ice, they are actually the same temperature! Equally surprising is this fact:

Boiling water is always at the same temperature (100.0°C or 212.0°F at standard atmospheric pressure) whether it is boiling rapidly or hardly boiling at all.

Now that we know how the Celsius temperature unit is defined, we can learn how it relates to the Fahrenheit unit. It makes sense that Fahrenheit and Celsius relate to one another since they both measure the same thing: temperature. They are related by a very simple equation:

$$°C = \frac{5}{9}(°F - 32) \qquad \text{Equation 1.1}$$

In this equation, °C represents the temperature in degrees Celsius, and °F stands for the temperature in degrees Fahrenheit. So if you must use a Fahrenheit thermometer in your experiments, you can use this equation to convert your measurements into Celsius. Please note one very important thing about this equation: The 5, 9, and 32 are all exact. Therefore, you need not consider their significant figures. They have infinite precision and an infinite number of significant figures. The only significant figures you must consider are those of the original measurement. Using this equation, we will report our answer using the multiplication rule even though there is a subtraction in the equation. Example 1.8 will help show you how this is done.

EXAMPLE 1.8

A student uses a Fahrenheit thermometer to do a chemistry experiment but then must convert his answer to Celsius. If the temperature reading was 50.0°F, what is the temperature in Celsius?

To solve this one, we simply use equation 1.1:

$$°C = \frac{5}{9}(50.0 - 32)$$

$$°C = 10.0$$

There are 3 significant figures in the original measurement. Since the other numbers in this equation are exact, the answer must have 3 significant figures. Therefore, the answer is **10.0°C**.

We usually say that room temperature is about 25°C. What is this temperature in Fahrenheit?

To solve this one, we must first rearrange equation 1.1 using algebra. Once we do this, we get the following equation:

$$°F = \frac{9}{5}(°C) + 32$$

$$°F = \frac{9}{5}(25) + 32$$

$$°F = 77$$

The presence of only 2 significant figures in the original number means only 2 significant figures in the end; therefore, the temperature is **77°F**.

Try "On Your Own" questions 1.15–1.16 to see whether or not you fully understand this type of conversion.

ON YOUR OWN

1.15 Normal body temperature is 98.6°F. What is this temperature in Celsius?

1.16 Rubbing alcohol boils at 180.5°C. What is the boiling temperature of water in Fahrenheit?

What about the other unit mentioned earlier? The Kelvin temperature unit is a special unit that we will use quite a bit in later modules. It is special because we can never reach a temperature of 0 Kelvin or lower, for reasons we will see in a later module. This fact makes the Kelvin temperature scale different from most others. After all, anything colder than ice water has a negative temperature in Celsius units. This means that temperatures less than 0 are quite common in the Celsius scale. Although not quite as common, it is possible to reach temperatures less than 0 in the Fahrenheit scale as well. It is impossible for anything in nature to reach 0 Kelvin or below. Since we can never get to or go below 0 Kelvin, the Kelvin temperature scale is often called an **absolute temperature scale**.

Once we have a temperature in units of degrees Celsius, converting it to Kelvin is simple. All we do is add 273.15 to the measurement. In mathematical terms, we would use this equation:

$$K = °C + 273.15 \qquad \text{Equation 1.2}$$

K is the temperature in units of Kelvin, and °C is the temperature in units of Celsius. In this equation, the 273.15 is *not* exact. Its precision plays a role. Note that since this equation involves adding, we use the rules of addition and subtraction when determining the significant figures involved. Those rules are *different* from the ones for multiplication and division, so be aware of that. Example 1.9 will show you how to use this equation.

EXAMPLE 1.9

What is the boiling temperature of water in Kelvin?

This conversion is a snap. We just realize that water boils at 100.0°C. If we put that temperature into equation 1.2, we get this:

$$K = 100.0 + 273.15 = 373.15$$

The original temperature goes out to the tenths place, while 273.15 goes out to the hundredths place. The rules for significant figures in adding tell us that the answer must have the same precision as the least precise number in the equation. Therefore, our final answer is **373.2 K**.

The lowest temperature that has ever been recorded in the United States of America is -80.0°F. What is this temperature in Kelvin?

Since the only way we can get to Kelvin is by adding 273.15 to the temperature in Celsius, we must first convert °F into °C:

$$°C = \frac{5}{9}(-80.0 - 32)$$

$$°C = -62.2$$

Now that we have the answer in °C, we can easily convert to Kelvin:

$$K = -62.2 + 273.15 = 210.95$$

Our final answer is **211.0 K**. Our rules for adding tell us that the precision must be kept to the tenths place because that is the same precision as the least precise number in the equation. That's why our final answer goes out to the tenths place. So you see, even very, very cold temperatures in the Celsius and Fahrenheit temperature scales are still rather large numbers in the Kelvin temperature scale!

ON YOUR OWN

1.17 What is the Fahrenheit equivalent of 0.00 Kelvin? (Use 3 significant figures for this measurement.)

Now cement your knowledge of temperature conversions with "On Your Own" question 1.17.

THE NATURE OF A SCIENTIFIC LAW

One way to approach chemistry or any other science is to look around you and try to think of logical explanations for what you see. You would certainly observe, for instance, that different substances have different forms and appearances. For example, some substances are gases, some are liquids, and some are solids. Some are hard and shiny, but others are soft and dull. You would also observe that different substances behave differently. Iron rusts, but gold does not; copper conducts electricity, but sulfur doesn't. How can you explain these and a vast number of other observations?

God made our world far too complex for us to understand by looking and thinking alone. We need to ask specific questions and conduct experiments to find answers. Scientists develop laws through experimentation and observation. After experimenting on or observing some facet of nature, they formulate a hypothesis to explain their observations. A **hypothesis** is no more than an educated guess that attempts to explain some aspect of the world around us. For example, when early scientists observed rotting meat, they always saw maggots crawling around on it. This led them to form the hypothesis that maggots are created from rotting meat.

Once a hypothesis has been formulated, scientists test it with more rigorous experiments. For example, after forming the hypothesis that maggots are created from rotting meat, early scientists did experiments to make sure that the maggots were not coming from something else. They would put rotting meat on a shelf high in the air to make sure that no maggot could crawl up to it. Even when the rotting meat was put high in the air, maggots still appeared on it. To early scientists, such experiments confirmed their hypothesis. Although there was no way for maggots to crawl up to the rotting meat, they did indeed appear on it. Many similar experiments convinced early scientists that their original hypothesis was correct.

Once a hypothesis is confirmed by more rigorous experimentation, it is considered a **theory**. After numerous experiments, the theory may be considered a **scientific law**. A scientific law is really nothing more than an educated guess that has been confirmed over and over again by experimentation. The problem with putting too much faith in a scientific law is that the experiments that established it might be flawed, making the scientific law itself flawed.

science and creation

We study science to learn more about creation and, ultimately, the Creator. God is the one who holds it all in His hands and uses it for His glory. Early scientists who were experimenting with rotting meat and maggots called their theory the theory of spontaneous generation. As the centuries passed, many more experiments were done to test the theory. Those experiments seemed to support the idea that life, such as maggots, could be created from nonlife, such as rotting meat. All of the experiments done to confirm this theory, however, were flawed. For example, Francesco Redi, an Italian physician, showed that if the rotting meat was completely isolated from the outside world, no maggots would appear; however, microscopic organisms did. French scientist Louis Pasteur eventually performed careful experiments that overturned the theory of spontaneous generation. His work showed that even microscopic organisms could not arise from nonlife but came to the meat by dust particles that blew in the wind.

The point of this story is to illustrate that when you read about scientific results, you must keep in mind that scientific theories are not laws of nature and can never be absolutely proven. There is always a chance that a new experiment might give results that can't be explained by a present theory. All a theory can do is provide the best explanation available at the time. If new experiments uncover results that present theories can't explain, the theories will have to be modified or perhaps even replaced. Science experiments are a good way to try to understand the nature of God's creation, but they are not absolute truth. Remember that.

salt and light

Bishop Robert Grosseteste (1175–1253) was an English statesman, philosopher, theologian, and scientist. He was one of the first scientists to establish a framework for what would later become the scientific method. Besides being a great scientist, Grosseteste was a strong Christian. He taught that the purpose of inquiry was not to come up with great inventions, but instead to learn the reasons behind the facts. In other words, he wanted to explain why things happened the way they did. That's the essence of science. He said that "just as the light of the sun irradiates the organ of vision and things visible, enabling the former to see and the latter to be seen, so too the irradiation of a spiritual light brings the mind into relation with that which is intelligible" (Stevenson 1899, 52).

Stained glass window by William Morris (to the designs of Burne-Jones) [Photo: public domain]

EXPERIMENTATION AND THE SCIENTIFIC METHOD

As we go about studying chemistry, you will conduct experiments to help you understand the concepts being presented in this course. You should use the scientific method to document the results of your experiments. The scientific method includes techniques for investigating, acquiring new knowledge, or correcting and integrating previous knowledge.

1. **Purpose:** What is your goal? What do you want to answer? Example: I would like to know what phase water is at room temperature.
2. **Hypothesis/Prediction:** What do you think will happen in this experiment? Example: I believe that water is liquid at room temperature.
3. **Experiment:** Test the hypothesis with systematic observations, measurements, and laboratory techniques.
4. **Analysis:** Determine what the results of the experiment show and decide on the next actions to take.
5. **Conclusion:** Describe what the results of the experiment show and the next actions to take.

As we do experiments, we will use this experimental method to document our findings.

Now that you have read this module and answered the "On Your Own" questions, it is time for you to shore up your new skills and knowledge with the practice problems and review questions at the end of this module. As you go through them, check your answers with the solutions provided and be sure you understand any mistakes you made. If you need more practice problems, you can find them in appendix B. Once you are confident in your abilities, take the test. If you do not score at least 70% on the test, then you should probably review this module before you proceed to the next one.

SUMMARY OF KEY EQUATIONS AND TABLES IN MODULE 1

Equation 1.1: $°C = \frac{5}{9}(°F - 32)$ Converting °F to °C

Equation 1.2: $K = °C + 273.15$ Converting °C to K

Table 1.1: Physical Quantities and Their Base Units

Table 1.2: Common Prefixes Used in the Metric System

Table 1.3: Relationships between English and Metric Units

Table 1.4: Examples of Significant Figure Rules

ANSWERS TO THE "ON YOUR OWN" QUESTIONS

1.1 $\frac{9{,}321\ \cancel{g}}{1} \times \frac{1\ kg}{1{,}000\ \cancel{g}} = 9.321\ kg$

1.2 $\frac{0.465\ \cancel{L}}{1} \times \frac{1\ mL}{1{,}000\ \cancel{L}} = 465\ mL$

1.3 $\frac{724.0\ \cancel{cm}}{1} \times \frac{0.01\ m}{1\ \cancel{cm}} = 7.240\ m$

1.4 $\frac{8.465\ \cancel{sl}}{1} \times \frac{14.59\ kg}{1\ \cancel{sl}} = 123.5\ kg$

1.5 $\frac{6.1236\ \cancel{L}}{1} \times \frac{1\ gal}{3.78\ \cancel{L}} = 1.62\ gal$

1.6 $\frac{1{,}500\ \cancel{mL}}{1} \times \frac{0.001\ \cancel{L}}{1\ \cancel{mL}} \times \frac{1\ kL}{1{,}000\ \cancel{L}} = 0.0015\ kL$

1.7 $\frac{2\ \cancel{km}}{1} \times \frac{1{,}000\ \cancel{m}}{1\ \cancel{km}} \times \frac{1\ cm}{0.01\ \cancel{m}} = 200{,}000\ cm$

1.8 $\frac{.01\ \cancel{Mg}}{1} \times \frac{1{,}000{,}000\ \cancel{g}}{1\ \cancel{Mg}} \times \frac{1\ mg}{0.001\ \cancel{g}} = 10{,}000{,}000\ mg$

1.9 $\frac{0.00555\ \cancel{hr}}{1} \times \frac{60\ \cancel{min}}{1\ \cancel{hr}} \times \frac{60\ sec}{1\ \cancel{min}} = 19.98\ sec$

That is not a long time to hold one's breath. So we would not be impressed.

1.10 $\frac{0.0091\ \cancel{kL}}{1} \times \frac{1{,}000\ \cancel{L}}{1\ \cancel{kL}} \times \frac{1\ mL}{0.001\ \cancel{L}} = 9{,}100\ mL = 9{,}100\ cm^3$ (mL and cm^3 equivalent)

1.11 The relationship between m and mm is easy:

$$1\ mm = 0.001\ m$$

To set up the conversion, we start with:

$$\frac{32\ m^2}{1} \times \frac{1\ mm}{0.001\ m}$$

This expression *does not cancel m²*. There is an m^2 on the top of the first fraction and only an m on the bottom of the second fraction. To cancel m^2 (which we must do to get the answer), we have to square the conversion fraction:

$$\frac{32\ m^2}{1} \times \left(\frac{1\ mm}{0.001\ m}\right)^2$$

Then we get:

$$\frac{32\ \cancel{m^2}}{1} \times \frac{1\ mm^2}{0.000001\ \cancel{m^2}} = \mathbf{32{,}000{,}000\ mm^2}$$

1.12 (a) All 3 nonzero digits are significant figures, as are both zeros. One 0 is between 2 significant figures, and the other is at the end of the number to the right of the decimal. There are **5 significant figures**.

(b) The first 3 zeros are not significant because they are not between 2 significant figures. The 6 is a significant figure, as is the last 0 because it is at the end of the number to the right of the decimal. So there are **2 significant figures**.

(c) All digits are significant figures here. The first 2 zeros are between significant figures, and the last 0 is at the end of the number to the right of the decimal. Therefore, there are **6 significant figures**.

(d) All digits are significant figures. The 0 is between 2 significant figures. There are **5 significant figures**.

(e) All the zeros are not significant in this number. **There is 1 significant figure**.

1.13 **(a) 2.6089×10^{7}** **(b) $1.2000000003 \times 10^{10}$**
(c) 9.870×10^{-5} **(d) 9.80×10^{-1}**

1.14 **(a) 345,600,000,000,000** **(b) 1,234.1**
(c) 0.0000345 **(d) 0.310**

1.15 To solve this one, we simply need to use equation 1.1:

$$°C = \frac{5}{9}(°F - 32)$$

$$°C = \frac{5}{9}(98.6 - 32)$$

$$°C = 37.0$$

Our measurement starts with 3 significant figures, and the other numbers in the equation are exact, so we must end up with 3 significant figures. The answer is **37.0°C**.

1.16 This one requires that we use algebra to rearrange equation 1.1 so that we can solve for °F:

$$°F = \frac{9}{5}(°C) + 32$$

$$°F = \frac{9}{5}(180.5) + 32$$

$$°F = 356.9$$

Since 180.5 has 4 significant figures and everything else in the equation is exact, our answer is **356.9°F**.

1.17 The only way we can convert to Fahrenheit is if we have a temperature in Celsius. Before we can get the answer, we must first convert 0.00 K to degrees Celsius by rearranging equation 1.2:

$$°C = K - 273.15$$

$$°C = 0.00 - 273.15 = -273.15$$

Since we are subtracting, we look at precision. The original measurement goes out to the hundredths place, as does 273.15. Therefore, our answer should go out to the hundredths place. Now we can convert to Fahrenheit:

$$°F = \frac{9}{5}(°C) + 32$$

$$°F = \frac{9}{5}(-273.15) + 32$$

$$°F = -459.67$$

Since 273.15 is the only number in the equation that is not exact, the answer must have the same number of significant figures. The answer is **–459.67°F**.

STUDY GUIDE FOR MODULE 1

REVIEW QUESTIONS

1. Which of the following contains no matter?
   a. A baseball
   b. A balloon full of air
   c. Heat
   d. A light ray

2. List the base metric units used to measure length, mass, time, and volume.

3. In the metric system, what does the prefix *milli-* mean?

4. All conversion factors, when in the form of a fraction, must equal __________.

5. Which has more liquid: a glass holding 0.05 kL or a glass holding 12,000 mL?

6. How long is the bar in the picture below?

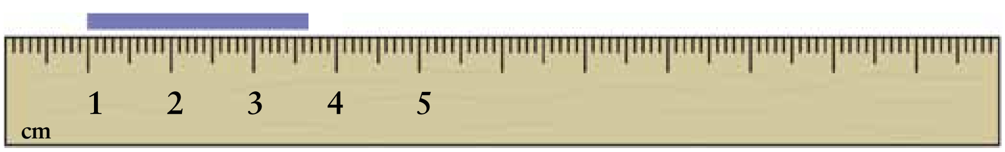


Illustration by Megan Whitaker

7. Two students measure the mass of an object that is known to be 50.0 grams. The first student measures the mass to be 49.8123 grams. The second measures the mass to be 50.1 grams. Which student was more precise? Which student was more accurate?

8. Explain what a significant figure is.

9. How many significant figures are in the following numbers?
   a. 120350   b. 10.020   c. 0.000000012   d. 7.20×10^2

10. A student measures the mass of object A to be 50.3 grams and measures the mass of object B to be 200.24 grams. She then reports the combined mass to be 251 grams. Is this student correct? Why or why not?

11. What would be the units on the following calculations? You do not have to do the math since this question only wants to know the units.
    a. 8 cm + 2 cm =
    b. 4 g ÷ 2 mL =

12. Which answer for question 11 will be a derived unit?
13. What are the 2 basic rules for using scientific notation?

14. Which is colder: 50.0 grams of water at 0.00°C or 50.0 g of water at 32.00°F?

PRACTICE PROBLEMS

Be sure to use the proper number of significant figures in all of your answers!

1. Convert 2.4 mL into L.

2. Convert 69.00 km into m.

3. Convert 0.091 kg into cg.

4. If an object has a volume of 69.2 mL, how many kL of space does it occupy?

5. A box is measured to be 23 cm by 45 cm by 38 cm. What is its volume in cubic meters?

6. A nurse injects 71.0 cc of medicine into a patient. How many liters is that?

7. Convert the following decimal numbers into scientific notation:
   a. 12.45000
   b. 3,040,000
   c. 6,100.500
   d. 0.001234

8. Convert the following numbers back into decimal:
   a. 6×10^{9}
   b. 3.0450×10^{-3}
   c. 1.56×10^{21}
   d. 4.50000×10^{-7}

9. Convert 85.6°C into Fahrenheit.

10. The temperature of the moon during its day is 396 K. What is that in Celsius? In Fahrenheit?

11. The average low temperature of International Falls, MN, in January is –7.0°F. What is that in °C?