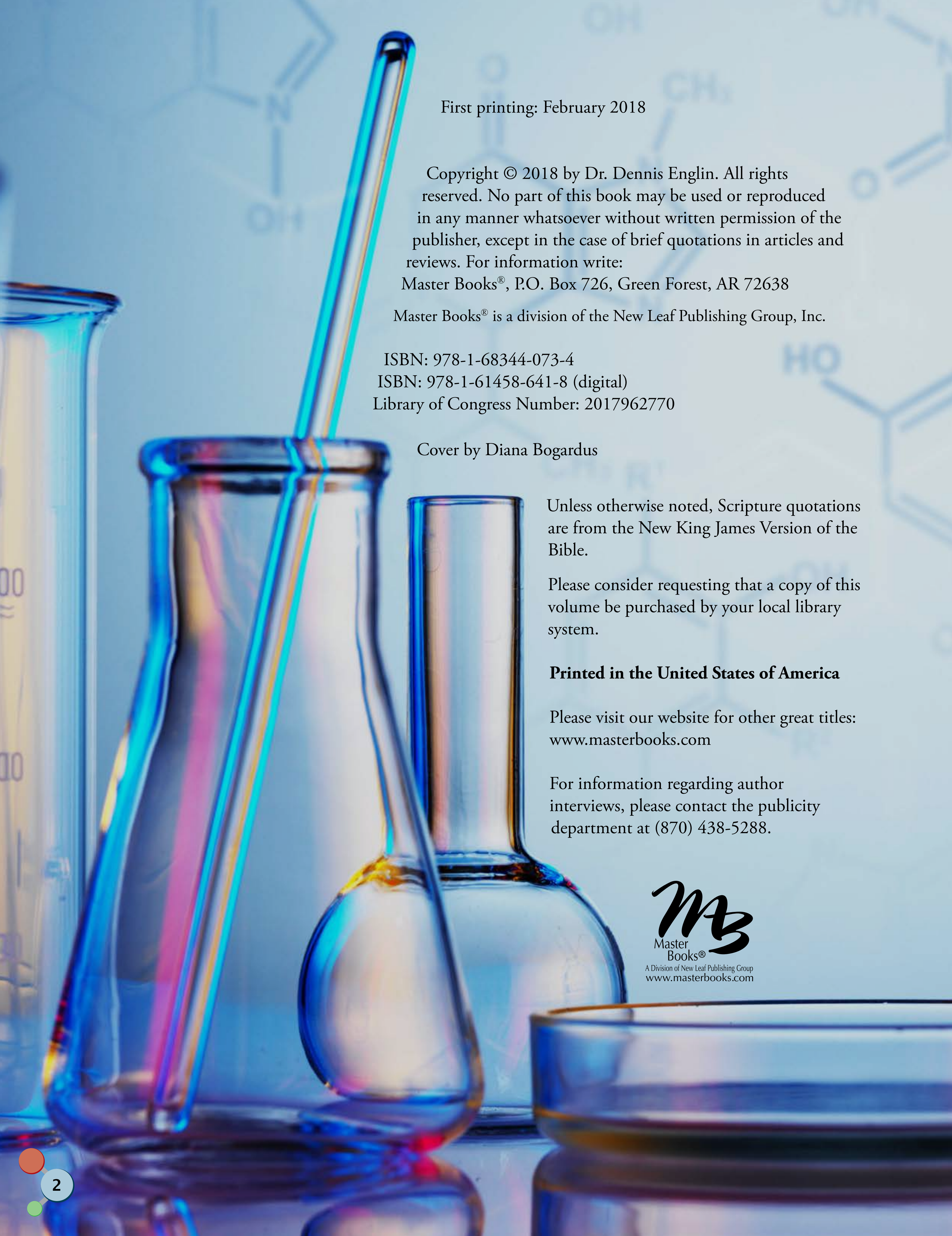
Chemistry

MASTER'S CLASS

THE STUDY OF MATTER FROM A CHRISTIAN WORLDVIEW

Dr. Dennis Englin



First printing: February 2018

Master Books®, P.O. Box 726, Green Forest, AR 72638

Master Books® is a division of the New Leaf Publishing Group, Inc.

ISBN: 978-1-68344-073-4
ISBN: 978-1-61458-641-8 (digital)
Library of Congress Number: 2017962770

Cover by Diana Bogardus

Unless otherwise noted, Scripture quotations are from the New King James Version of the Bible.

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Dedication

To the homeschool students over the years who have helped test and refine this text, and to my wife, Judy, for her patience and many helpful suggestions.

PRAISE FOR DR. ENGLIN'S CHEMISTRY COURSE

I was a student in Dr. Dennis Englin's high school chemistry class for homeschool students. I found the curriculum easy to understand and thoughtfully organized. The concepts I learned made my transition to university-level chemistry seamless, as every major topic had already been thoroughly covered by Dr. Englin. As a graduate from a pre-health program and now a biology professor, I would heartily recommend this curriculum to anyone looking to jump-start their undergraduate career.

~ Christopher Craig Chambers, M.S. computer science, California State University

Presented from a thoroughly and unashamedly biblical perspective, Dr. Englin's curriculum engages with both the fundamental basis and practical application of chemistry, all the while highlighting how it showcases the orderliness and intricacy of God's created world. The curriculum's principal content and easy-to-follow organizational structure is the outgrowth of Dr. Englin's own experience in teaching high school- and college-level science classes for nearly five decades. This book's content, paired with the accompanying laboratory studies, makes for an all-inclusive and well-rounded approach to high school chemistry, sure to benefit students and parents alike, all the while magnifying the glory of the Creator.

~ Lee Anderson, Jr., Christian Apologist and Writer

Dr. Englin has the amazing gift of making seemingly difficult subjects easy to understand. Through his classes, science came to life and I always looked forward to coming back the next week! I appreciated the detail, hard work, and love he poured into each student; it inspired me to want to learn.

~ Amy Mack Dinsmoor, former student from 2006–2010

The scientific information Dr. Englin presents in his homeschool chemistry course is rooted in a biblical worldview. It is informative and readily understandable to the high school student; it stimulates and challenges. Dr. Englin provides all of the scientific information and mathematical procedures necessary for students to complete this course. The curriculum is sufficient in scope for a year's education in chemistry, and able to pique the student's curiosity so that they desire to learn more. His laboratory studies are enjoyable and instructive, complementing the coursework presented in the lecture material. I heartily recommend this course to any family seeking science curricula for a year of chemistry.

~ Phillip A., former student

I am the parent of three young men who have been immensely blessed by the teaching of Dr. Dennis Englin. My sons have taken all four of Dr. Englin's high school science courses, with chemistry being their favorite. Implementing the high school chemistry curriculum, written by Dr. Englin, in my homeschool was indeed a joy. This chemistry curriculum will guide users on a captivating tour through God's chemical world. The materials are written in such a way as to make them exceptionally understandable, and user-friendly to all, even those without a strong background in the sciences. The clear introduction of the concepts, build one upon another as to incorporate all material through a spiral learning approach. The daily lessons are written directly to the student, and not only are they scientifically accurate, but are often presented with awe, insight and humor. Using this phenomenal curriculum certainly made my role as a homeschool educator easier. I highly recommend it for the Christian homeschooling family!

~ Mrs. S. Anderson

Having previously taken chemistry at another school, I remember walking into Dr. Englin's class expecting boring textbooks and confusing lectures. I was delightfully surprised. Dr. Englin ignited our curiosity and helped us understand complex topics through real-world explanations. He not only taught us chemistry, but also how to learn and reason through complex problems. His sense of wonder and excitement at God's creation was contagious and I will always have fond memories of that class.

~ Wendy Mack, former student from 2006–2010

ABOUT DR. DENNIS ENGLIN

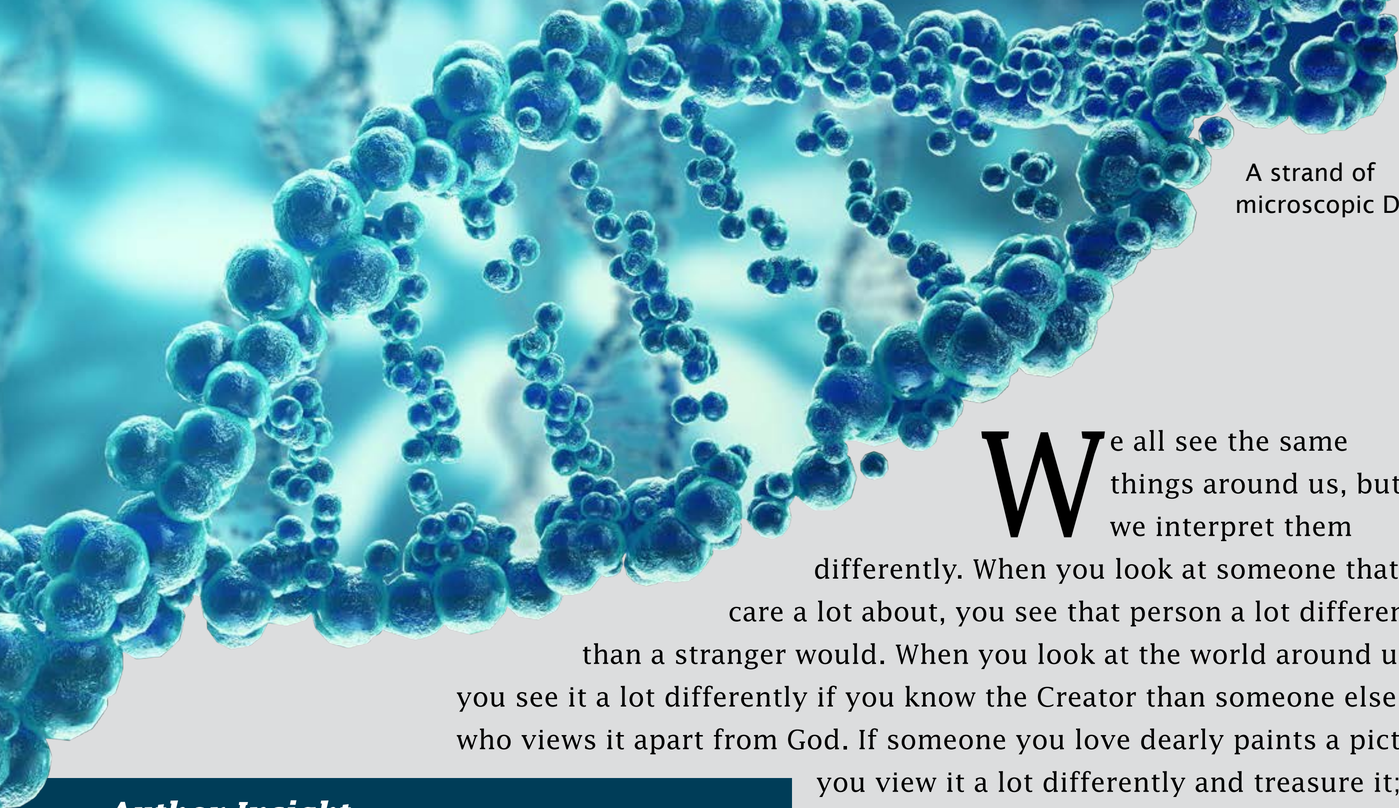
Dr. Englin enjoys teaching in the areas of animal biology, vertebrate biology, wildlife biology, organismic biology, chemistry, and astronomy. Memberships include the Creation Research Society, Southern California Academy of Sciences, Yellowstone Association, and AuSable Institute of Environmental Studies. Dr. Englin's most recent publications include a text currently used in *Principles of Biology*. His research interests are in the area of animal field studies. He is a Professor of Biology at the Center for Professional Development at The Master's University in Santa Clarita, California.

B.A., Westmont College
M.S., California State University, Northridge
Ed.D., University of Southern California

TABLE OF CONTENTS

Glossary terms

On the first page of every chapter students will find glossary words introduced, which are bolded in that chapter's text and have brief definitions found in the glossary at the back of the book. Students are encouraged to either write these out on 3 x 5 cards or to create another useful means of reviewing these throughout their course of study. Comprehension of sometimes difficult terms and concepts is very important to completing a course in chemistry or any other complex science study.

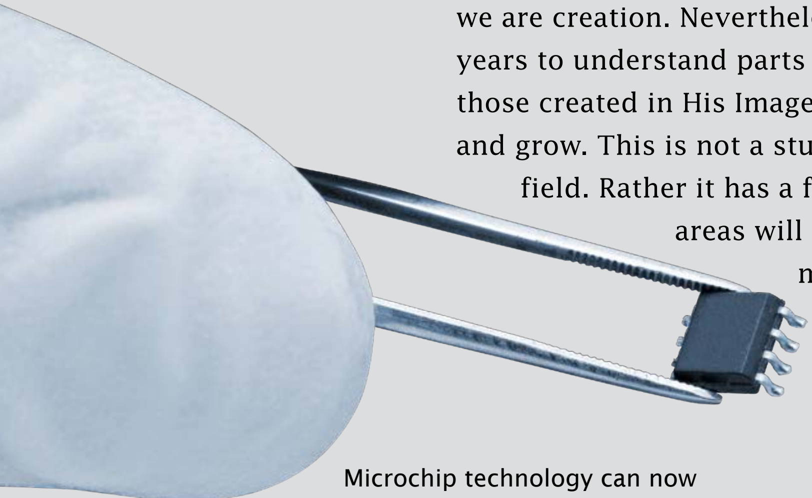


A strand of microscopic DNA.

Author Insight —
Chemistry and the Creator

We all see the same things around us, but we interpret them differently. When you look at someone that you care a lot about, you see that person a lot differently than a stranger would. When you look at the world around us, you see it a lot differently if you know the Creator than someone else who views it apart from God. If someone you love dearly paints a picture, you view it a lot differently and treasure it; to someone else, it may just be paint on a canvas. Chemistry is the study of the created universe. It is the study of matter. What are things made of? What holds them together? Why do some things react violently and others do nothing? To view the world around you as created by Someone that you feel is very important to you makes a difference more than if it is just particles that could not care if they bless or harm you. This is your worldview — or the lens through which you view the world.

This study is presented through the eyes of one who has walked with the Creator and Lord of the universe for many years. I pray that you will see it that way, too. Chemistry as Christ would have us see it is the goal of this study. I hope that it does not strike you as strange to think that the Holy Spirit of God can guide you through this study. He has infinite wisdom that went into the creation. We have limited understandings because we are creation. Nevertheless, He has enabled people down through the years to understand parts of His creation to show His care and love to those created in His Image. He develops our skills as we study, practice and grow. This is not a study that you can just walk through like a grassy field. Rather it has a few cliffs to climb and streams to ford. Some areas will come easier than others and some will take more time and practice. As you study each lesson, you will have to complete practice exercises and take a weekly quiz. You will conduct a laboratory procedure and write a report dealing with that week's lesson. About every 3 or 4 weeks you will stop and review and take an examination. Concepts and skills



Microchip technology can now perform chemical reactions in the search for new drug therapies.

build upon each other as you go through the study. As you go through, you will be provided with applications from Scripture as to how the material reflects the truth and mind of God in His creation. These are not just Bible verses inserted without context. They deal directly with the material studied and are a guide to keep your focus through the Mind of God.

You will see God's never changing nature and absolute control of the physical universe through the natural laws. Christ is the only explanation for the protons and electrons of atoms holding together when they should fly apart as happens in an atomic explosion. We see accountability when we violate the use of materials as I saw in high school when a teacher placed sodium metal in water and it violently exploded. We see grace in the safeguards that God gave us by revealing principles of chemistry to protect us from harm and greatly enrich our lives–like the elements making up the microchips in a computer.

As you study you are walking through the art gallery of God's wonderful creation. It is beautiful even in a fallen world. Now that is grace! The title *Chemistry Through a Christian Worldview* is to be taken seriously. A basic principle of the Christian walk is that God never leads you down useless pathways. Sometimes we take detours in our sin but He brings us back. You are in this study by divine appointment. You and I do not know how He is going to use it in your life but He certainly does.

Note: The *Master's Class Chemistry Teacher Guide* includes worksheets with weekly assignments, lab charts, and lab journaling pages, as well as answer keys for worksheets, quizzes, labs, and exams.

A violent reaction when sodium (Na) metal is added to water.

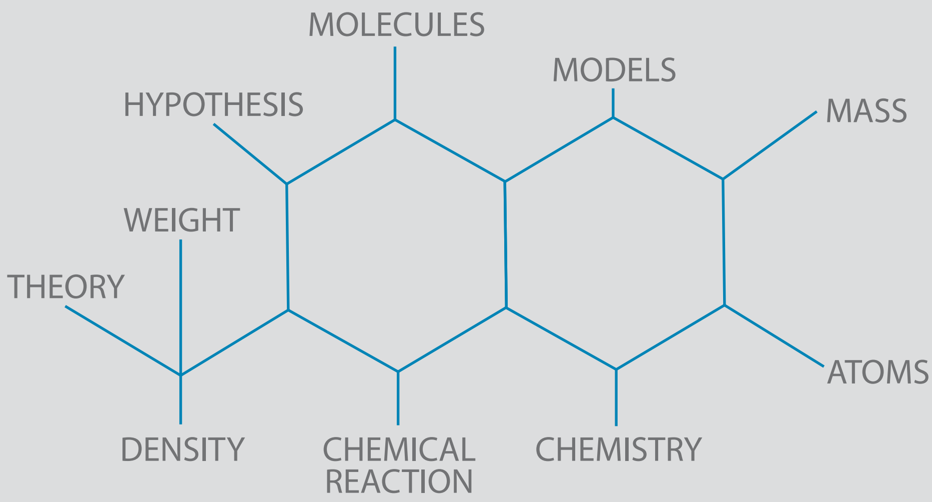
CHAPTER 1

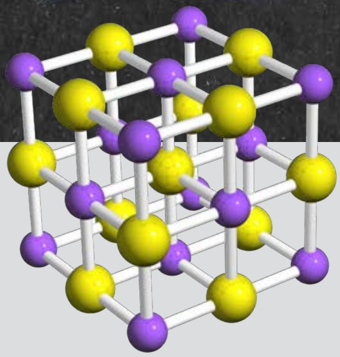
INTRODUCTION

OBJECTIVES AND VOCABULARY

At the conclusion of this lesson the student should have an understanding (as evidenced by successfully completing the quiz at the end of this lesson) of:

1. The concepts of chemistry, scientific models, atoms, and molecules
2. The meanings of the terms mass, weight, density, chemical reactions, hypotheses, and theories
3. The differences between the sources of knowledge of chemistry and the Scriptures.



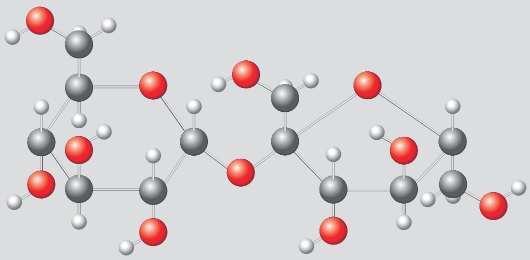


Chemistry is the study of matter, which is the “stuff” that we are made of and everything around us. Matter can be broken down into very small parts that we cannot see called **atoms**. In science, we use **models** to describe what we cannot see but whose effects we can see. Table salt is composed of **molecules,** each of which are composed of one atom of sodium and one atom of chloride. We cannot see these molecules but we can taste them when we have enough of them together in one place. We describe its effects upon the taste buds of our tongues. We describe the sodium chloride molecule (NaCl) with a model of what we call a molecule. We do not know what it really looks like, but we do know its effects.

If something has a foul odor and we cannot see it, we can still smell it. I hope we cannot see it. We know it is there by its odor. The particles of the substance that goes into our noses are too small to be seen, but we still know that they are there. This is especially true when a skunk goes by. When we try to measure these particles, we have to have a lot of them. The units of measurement that we use in chemistry have this idea in mind. We cannot weigh one NaCl (sodium chloride) molecule, but we can weigh a large quantity of them.

The amount of matter in a sample is its **mass** (the mass of all of its atoms added together). The pull of gravity on the mass is its **weight**. Can the weight of an object change without changing its mass? Yes it can. If you go into orbit around the Earth in the International Space Station, your mass remains the same but your weight becomes much less. A helpful application of this concept is that if you know the mass of a sample and the mass of each of the atoms in the sample, you can find out how many atoms are in the sample. We will do this in later lessons.

Early studies of atoms demonstrated that many substances are made up of larger (but still very small) particles called molecules. An example is table sugar (sucrose) that is composed of 12 carbon atoms, 11 oxygen atoms, and 22 hydrogen atoms bonded together. When they come apart and are put back together in a different combination, a **chemical reaction** has occurred.



A structural formula of the chemical compound sucrose (table sugar).

We describe the size of an object by its volume, which is the amount of space it occupies.

Have you ever woken up in the middle of the night wondering why ice floats? If it did not, fish in northern lakes would die in the winter when the water froze from the bottom up. But unlike almost all other molecules, God created water molecules so that they would move farther apart from each other as water freezes into a crystal that we call ice. When the water molecules move farther apart from each other as water freezes, there are fewer water molecules in the same volume. This means that a cubic inch of ice has fewer water molecules than a cubic inch of liquid water. Therefore, a cubic inch of ice has less mass (and weight) than a cubic inch of liquid water. The mass of matter divided by its volume is its **density**. In this situation, ice has a lower density than liquid water.

Try this experiment. Take two equal volumes of water (½ cup) and dissolve about ½ of a teaspoon of table salt in one of them. Place them both in the freezer and see which one freezes first. Try to explain what happened by thinking about what happens when the salt molecules get in between the water molecules as they are trying to form ice crystals.

Your suggested explanation is called a **hypothesis**. Science is based upon making observations and proposing hypotheses. If a hypothesis is supported by many other observations and experiments, it becomes a **theory**. This is very different from a fact because a hypothesis or theory will be later replaced when someone comes up with a better hypothesis that does a better job of explaining the observations. Facts and truth do not change. A hypothesis and theory are temporary because they are stages in our learning process. This is the difference between science and Scriptures of the Christian Bible. The Bible was given to us by God sharing His wisdom with us. Science is a gift that God gave us to better understand the world that He made. Science is good because it gives us many blessings if it is not used for evil purposes.

Facts and truth do not change. A hypothesis and theory are temporary because they are stages in our learning process.

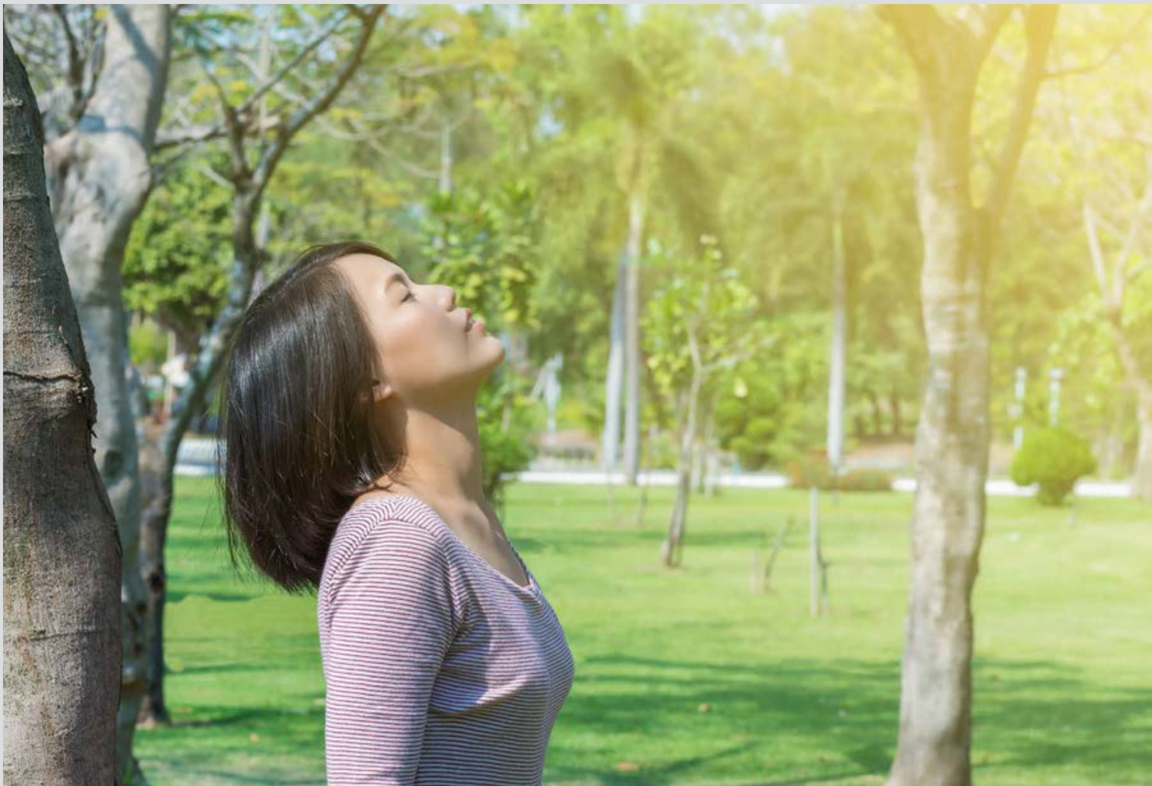
The process of observation, hypothesis, testing the hypothesis and theory is called the scientific method. In some ways, this is what we do all the time. If you got up one morning and found a horse in your kitchen, you would start asking some questions. Why is the horse there and where did it come from and did it eat my breakfast? These are your observations. When you came up with possible explanations, they would be your hypotheses. Then your neighbor from down the street comes up and asks if you saw his horse who snuck off. Now you have information to test your hypotheses. In the scientific community, when a hypothesis is proposed it is published in a scientific journal and read by many interested in that topic. Many will test your hypothesis and if it stands up well with their further testing, it becomes recognized as a theory. Later, someone proposes a better hypothesis and everyone proclaims it to be the theory that replaces yours. Here today, gone tomorrow. Science is good but it is a growth process. Just consider how computers have changed in the last ten years. It is humans trying to understand the physical world.

In science, it is usually emphasized that the observations and experiments be reproducible. A criticism sometimes made against the idea of creation is that you cannot reproduce it and take a closer look at it. But that is also the case in forensics (the study of a crime scene) and the discussions of the evolution of life. It is, however, in science more reliable if you can reproduce the procedures and get the same results.

It is emphasized in science, as well, that your conclusions be falsifiable. For example, you cannot show a hypothesis to be true, because you cannot think of every possible hypothesis to test. Sometime later someone will come up another hypothesis that fits the data much better and replaces all earlier hypotheses. But you can show a hypothesis to be false. A number of years ago a group in Utah claimed to have developed cold fusion. That means that they claimed to be able to fuse the nuclei of two atoms of hydrogen to make a heavier atom with the release of nuclear energy that could be used to heat water into steam to drive an electric turbine. Theoretically and practically the procedure takes a lot of heat energy to slam the atoms together. That is the basis for a hydrogen bomb. When asked to duplicate their results they could not do it. It was determined that their hypothesis was false. Some state that creation cannot be included as an alternative to evolution because it is not reproducible nor falsifiable. That is true. Just like evolution, creation is neither reproducible nor falsifiable. But to reject creation on that basis is to reject God Himself, and the natural world He created. We study God through the Scriptures that He gave us to come to understand Him.

We do not use chemistry to study God but we can see evidence of God in chemistry.

We do not use chemistry to study God but we can see evidence of God in chemistry. Just the mathematical relationships in chemistry attest to the intricate design in creation. As well, the consistency of the structures of the elements and their properties testify of His superior intelligence. Oxygen behaves like oxygen no matter where it comes from. These Laws of Nature are the foundation that has to be there before we can proceed any further in our study. This is something we should not take for granted.



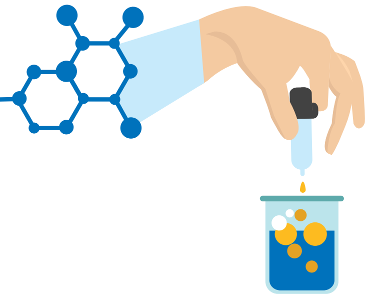
In Scripture, God is not testing and refining His thoughts. He had full knowledge and understanding before the beginning of creation. Our understanding of Scripture improves as we mature and grow closer to Christ but the Scripture itself never has to mature or change. Many stumble when they confuse the authority of science with that of Scripture. Some say that science is something that we can see and test and Scripture is not, so they place their faith in sight rather than God. Our study of science is good but our level of knowledge and understanding is much less than God's. As well, with science we can only study the physical reality. God was before there was a physical reality and life. We have to seek spiritual answers for the origin of physical reality. Before matter was created, there was God, so we have to go to Him and He instructs us through the Scriptures for us to understand the origin of the physical universe. God designed and created matter so when you struggle to understand chemistry, ask Him to come along side of you and be your guide and super Tutor. Wow!

It is also important to distinguish between observation and measurements and hypotheses and theories.

It is also important to distinguish between observation and measurements and hypotheses and theories. I can measure the length of a table or the mass of a sample of NaCl. But if I talk about the structure of the NaCl molecule, I am dealing with a hypothesis about something that I cannot see. Observations and measurements are more like facts, while hypotheses and theories expound on them and provide explanations for the behavior that was observed. Hypotheses can be thought of as tentative explanations, and theories are explanations based on multiple sources with strong evidence. Interesting that some will reject the God that they cannot see but accept the description and reality of a NaCl molecule that they also cannot see.

God created everything we can see and the invisible structures within them that we cannot see. And we are still only beginning to understand how intricate, amazing, and purposeful the Creator's designs truly are!

LABORATORY 1



SCIENTIFIC MODELS

REQUIRED MATERIALS

- Small Box
- Random item that fits in the box

INTRODUCTION

A scientific model is a description of the behavior of something that you have no means of ever seeing with current technologies. You cannot see an atom but you can see the effects of many atoms. You cannot see a proton and you cannot see an electron. But there is something there that is identified by these names. This is a difficult concept because it is contrary to our everyday way of thinking. Can you imagine getting into and riding in an invisible car? Kind of silly, isn't it? But that is what we do with many things in science. We have a model that is a description of something that would behave just like something that we cannot see. The model of an atom is not an actual description of what an atom looks like. It cannot be because we do not know what an atom looks like. The description is the description of something that would behave just like an atom. From this model, we can predict what an atom would do under other circumstances. Our goal is not to describe what an atom actually looks like but rather what it will do.

PURPOSE

This lab exercise is designed to demonstrate how scientific models are designed and used to understand things that cannot be directly observed such as atoms and molecules.

TEACHER NOTE

This lab requires that you prepare a small, sealed box with an object, unknown to the student, inside for them to analyze.

PROCEDURE

This lab is an exercise in constructing a scientific model. Perhaps this will give you a better idea of what a model is and its limitations. You have a sealed box. It has an object in it. You can do almost anything to your box except alter, destroy, or open it. You are not at any time to state or guess what you think is in the box. You will not be shown what is in the box. That is the way it is with atoms and their parts. You are to describe as many properties of the object as you can — but never to identify it! For example, tilt the box and determine if the object slides or rolls in the box. How fast does it roll or slide? What if you tilt it the other way? Does it respond differently? As you hold the box, does the object feel heavy?

Remember that your description cannot have anything to do with what you might think is in the box. Describe at least 6 procedures you perform with the box, your observations, and conclusions. Always use complete sentences. You are not just writing this report for yourself. One of the purposes of the laboratory reports is to improve your writing skills. Part of the grade on the report is how well you follow instructions. At the end of the report, summarize the properties that you can identify for the object in the box. Your report will also be graded on how neat and well organized it is. It can be hand written, but it must be clear.

REPORT

Scientific models

Give a unique name to the object in the box even though you do not know what it is.

For each procedure: describe the procedure and state your observations and conclusions.

Summarize the properties of the object in the box. Remember — do not try to identify what is in the box.

How do you think that this is similar to the way atoms and molecules are studied?

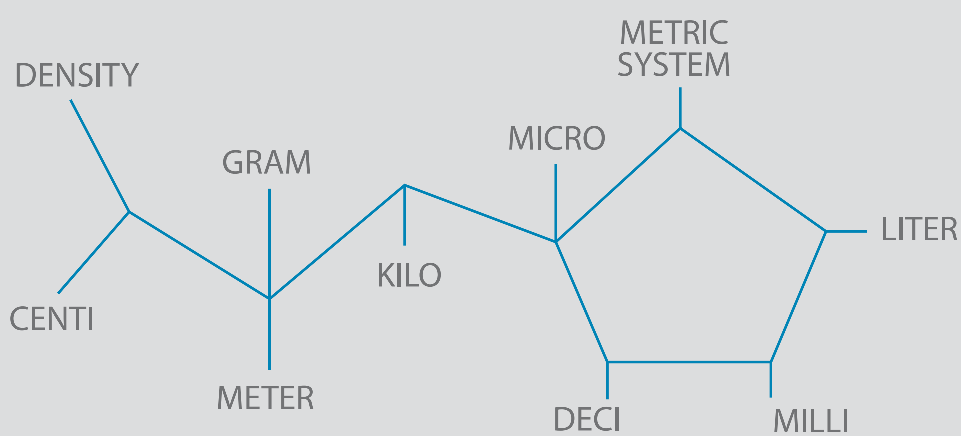
CHAPTER 2

METRIC MEASUREMENTS IN CHEMISTRY

OBJECTIVES AND VOCABULARY

At the conclusion of this lesson the student should have an understanding (as evidenced by successfully completing the quiz at the end of this lesson) of:

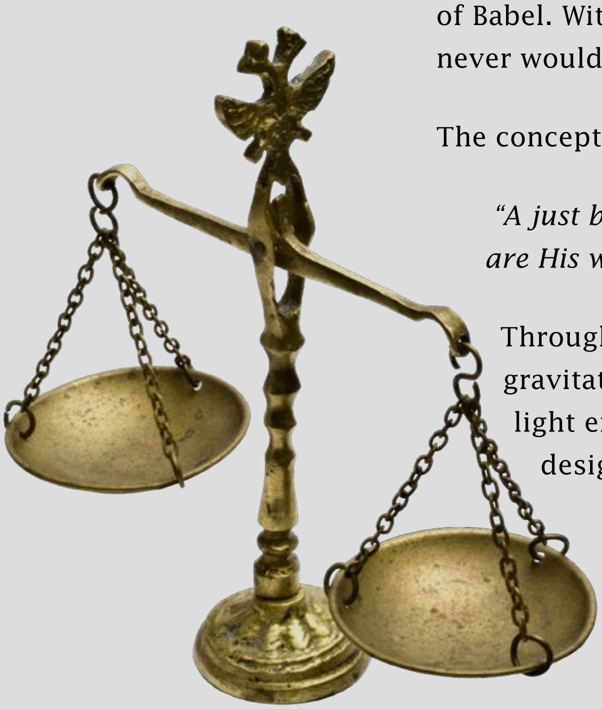
1. Common units used in the metric system
2. Units of density and how density is used to explain flotation patterns
3. Application of the prefixes milli-, centi-, deci- and kilo- in the metric system.



Measurements are very important in all of the sciences and everyday life. If you take a medication, it has to be very carefully measured out. That has not always been the case. Can you imagine some of the results of that? The use of measurements probably go back to Adam. They definitely had to be used in building the Tower of Babel. Without accurate means of measuring and planning, the tower never would have stood.

The concept of accurate measurements came from the mind of God.

> *"A just balance and scales are the Lord's; all the weights in the bag are His work." (Proverbs 16:11)*



Throughout the universe, numbers are important, such as the gravitational forces holding galaxies together and the wavelengths of light emitted from the distant edges of the universe. God's wisdom designed the forces and elements at the beginning of creation.

"I, wisdom, dwell with prudence, and I find knowledge and discretion. The Lord possessed me at the beginning of His work, the first of His acts of old. Ages ago I was set up, at the first, before the beginning of the earth… when He made firm the skies above, when He established the fountains of the deep, then I was beside Him, like a master workman, and I was daily His delight, rejoicing before Him always, rejoicing in His inhabited world and delighting in the children of men." (Proverbs 8: 12, 22, 23, 28, 30, 31)

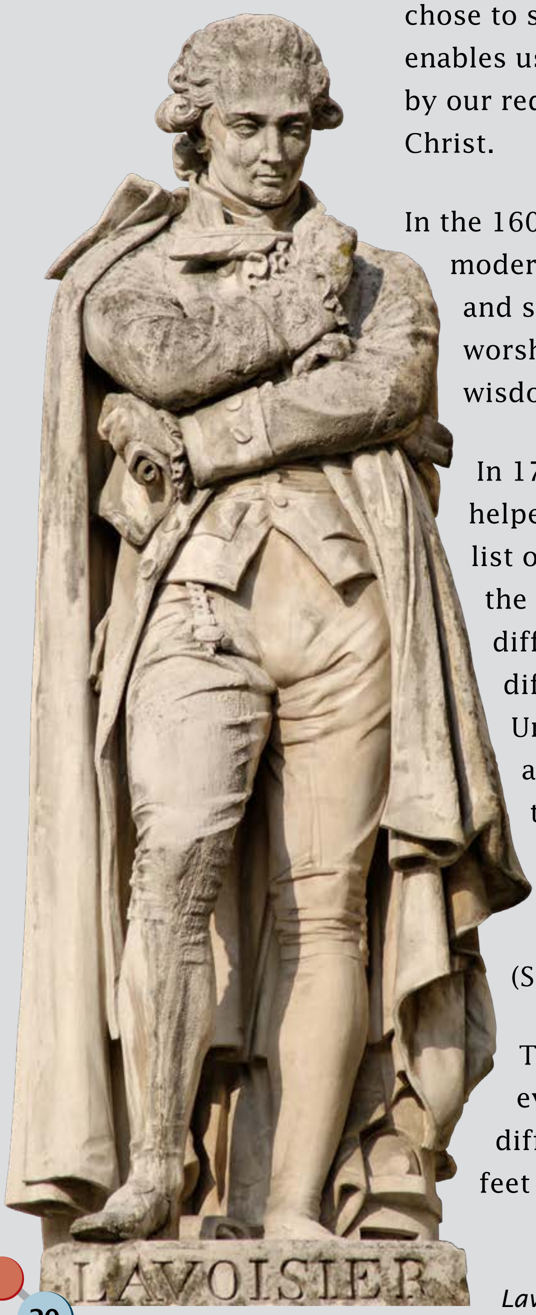
The universe functions like well-designed clock work. All of the forces in the universe are balanced mathematically to keep every galaxy, star, planet, moon, and molecule in perfect positions in relation to each other to give us a beautiful place to live. These forces are seen as well in the diverse elements making up the universe, our world and bodies. God chose to share this wisdom with us who are created in His image. He enables us to see the wisdom of His handiwork when our eyes are opened by our redemption from the blinding effects of sin through faith in Jesus Christ.

In the 1600s most of the early scientists that laid the foundations of modern science were born-again Christians. When you can stand back and see the patterns of the nature of the elements, you cannot help worshipping the Creator who spoke it all into being showing us the wisdom of His mind.

In 1791, Antoine Lavoisier (called the Father of Modern Chemistry) helped develop the metric system. He also developed an extensive list of elements and made major contributions to the naming of the elements and compounds. Prior to this different countries had different measuring systems. For example, different countries had different lengths for measuring a foot. This was very confusing. Unfortunately, Lavoisier was a member of the French aristocracy and involved in designing the system of taxation right before the French Revolution. He was one of the first ones to go to the guillotine.

The metric system is called the Systeme International d' Unites (SI system) or International System of Units.

The **metric system** is used in scientific measurements because everything comes in units of tens. In the English system there are different numbers of units used such as 12 inches in a foot and 3 feet in a yard.



Lavoisier by Jacques-Léonard Maillet, ca. 1853.

The standard unit for length in the metric system is the **meter** (about 39 inches), the standard unit of volume is the **liter** (about 1.06 quarts), and the standard unit of mass is the **gram**.

The universe functions like well-designed clockwork.

The size of a unit of measurement is known by its prefix. **Deci**- means 1/10 (one tenth). **Centi**- means 1/100 (one hundredth). **Milli**- means 1/1,000 (one thousandth). **Micro**- means 1/1,000,000 (one millionth) and **Kilo**- means 1,000 (one thousand).

Prefix	Numerical Meaning
micro (μ)	0.000001
milli (m)	0.001
centi (c)	0.01
deci (d)	0.1
	1
deca (D)	10
hecto (H)	100
kilo (k)	1,000

A decimeter (dm) is .1 m (m stands for meter and dm stands for decimeter). A centimeter (cm) is .01 m and a millimeter (mm) is .001 m. A kilometer (Km) is 1,000 m.

A deciliter (dl) is .1 L (L and l stand for liter). A centiliter (cl) is .01 l and a milliliter (ml) is .001 l. Kiloliters are not usually used in chemistry. A thousand liters is a lot.

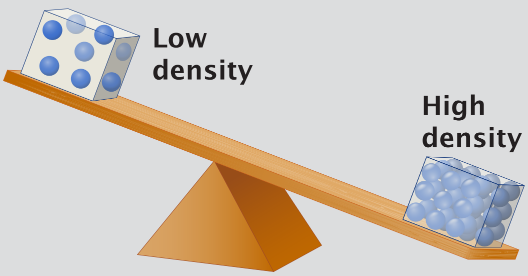
A decigram (dg) is .1 g (g stands for gram). A centigram (cg) is .01 g. A milligram (mg) is .001g and a kilogram (Kg) is 1,000 g.

meter (m)
length

liter (l)
volume

gram (g)
mass

In the metric system, the standard unit of measurement for weight (force of gravity) is the Newton — named after Isaac Newton who expressed the Laws of Motion. In chemistry, when you weigh something on a balance the units used are usually milligrams. But milligrams are not weight. The balance is actually measuring the weight but the scale of the balance is adjusted to give mass (milligrams). Milligrams are used in chemistry because of the small quantities of materials used.



Comparing the mass of equal volumes demonstrates the density of the two objects.

The **density** of an object is measured as mass divided by volume, which is g/ml (the number of grams making up each milliliter). In chemistry the units of grams and milliliters are more often used because small quantities are used. A ml of iron is much heavier than a ml of Jell-O® because the density of iron is much greater than that of Jell-O®. Ice floats in liquid water because the density of ice is less than that of liquid water. This is also why a several-hundred-ton aircraft carrier floats in water. Most of the volume of the aircraft carrier is air, which is much lighter than water. The total weight of the aircraft carrier is less than the same volume of water so the aircraft carrier floats. When the king of Sweden had a war ship (*Vasa*) built, he insisted that they put more bronze cannons on the ship. When they launched the ship for the first time, it sank just outside of the harbor in 1628. It was later salvaged in 1961 and placed in the Vasa Museum in Stockholm, Sweden, in 1988.

REACTIONS IN ACTION

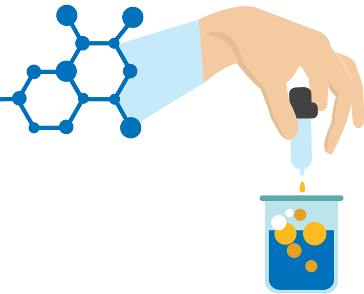
Do the following exercise to test your understanding of density. Liquid A has a density of 1.05 g/ml; liquid B has a density of 1.10 g/ml; liquid C has a density of 0.97 g/ml; and liquid D has a density of 1.00 g/ml. When all 4 liquids are poured together into a tall glass, they do not mix; instead they settle out forming 4 layers.

Liquid A	1.05 g/ml
Liquid B	1.10 g/ml
Liquid C	0.97 g/ml
Liquid D	1.00 g/ml

Which liquid will be on the bottom? Which one will be second, floating on the bottom layer? Which liquid will be third up from the bottom and which one will be on top?

Form a hypothesis (a principle or explanation that you make from your observations) explaining how you came up with your answer. Afterwards, and not before, compare your answer to the one below.

Answer: the bottom layer is B because it has the greatest density (1.10 g/ml). On top of B is liquid A (1.05 g/ml). On top of A is liquid D (1.00 g/ml) and liquid C is the top layer with the lowest density (0.97 g/ml). How did you do?



THE METRIC SYSTEM

REQUIRED MATERIALS

- Square or rectangular object
- Ruler with measurements in inches
- Graduated cylinder (10 ml)
- Weighing boat
- Scale

INTRODUCTION

The metric system was developed on the basis of the number 10. The following prefixes are commonly used:

- *milli* meaning 1 thousandth
- *centi* meaning 1 hundredth
- *deci* meaning 1 tenth
- *kilo* meaning 1 thousand

The meter is the metric system's unit of length. It is equivalent to about 39 inches in the English system. By the list above: a decimeter is a ____________ of a meter, a centimeter is a ____________ of a meter and a millimeter is a ____________ of a meter. A kilometer is ____________ meters.

See the chart below for the units for length, volume, mass, and force in both the metric and English systems.

Quantity	Metric Unit	English Unit
length	meter	foot (12 inches)
volume	liter	gallon
mass	gram	slug (32.174 lb)
force (weight)	newton	pound

PURPOSE

This exercise is designed to familiarize you with the use of metric units. The sciences exclusively use metric standards of measurement.

PROCEDURE

You will find the following English–metric conversions helpful for this exercise.

English		Metric
1 inch	=	2.54 cm (centimeters)
1 gallon	=	3.8 liters
1 mile	=	1.61 km (kilometers)
1 pint	=	0.473 liter

1. Solve the following:
   A. If a gas station charges $1.25 for a liter of gasoline, how much is it for a gallon of gasoline?
   B. If you travel 10 miles, how many kilometers have you traveled?
   C. If you have 3 pints of fruit juice, how many liters do you have?

2. Find a square or rectangular object.
   A. Measure its length, width, and height in inches.
   B. What is its volume in cubic inches? (length x height x depth)
   C. Convert each of the measurements into cm.
   D. What is the volume of the object in cubic centimeters (cc)?
   E. A cubic centimeter is exactly the same as a milliliter (ml). What is the object's volume in milliliters and liters?

3. Mass / Density Measurements

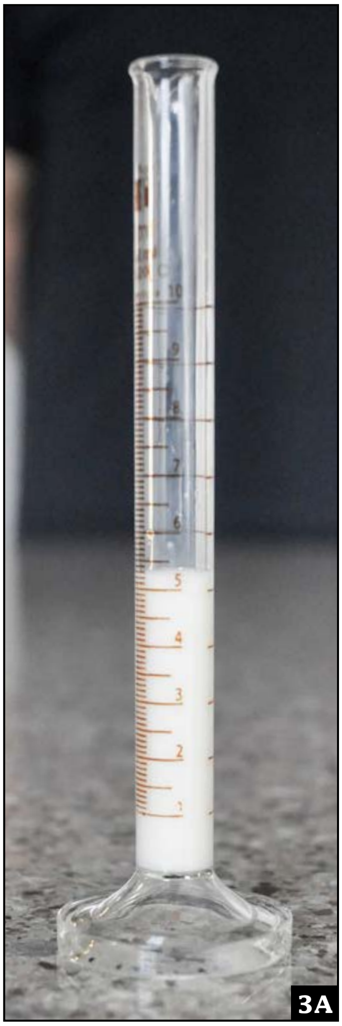
   A. Measure out 5 ml of a liquid other than water with a 10 ml graduated cylinder. Line up the middle, not the edge, of the surface of the liquid (the meniscus) with the markings on the graduated cylinder.

   B. Place a weighing boat on a scale and find its mass in grams.

   C. Add the 5 ml of liquid to the weighing boat and find the mass of the 5 ml of liquid including the mass of the weighing boat.

   D. Calculate the mass of the liquid by subtracting the mass of the weighing boat from the combined mass.

   E. Divide the mass of the liquid in g by the volume in ml. This gives you the density of the liquid in units of g/ml.



3A

3B

3C

LAB INSIGHTS

In chemistry, volumes of liquids are typically measured with graduated cylinders, burets, pipets, and volumetric flasks.

The graduated cylinders measure volumes as small as ml (milliliter); pipets can measure volumes as small as 0.1 ml; and a volumetric flask can only measure a set volume — such as 100 ml.

Left to right: graduated cylinders, pipet, and volumetric flask, and buret (not to scale).

SIGNIFICANT FIGURES

The level of measurement made with a tool in chemistry determines the level of accuracy (how close you are to the true value) of any calculations using the measurement. For example, if three people each measure the volume of the same liquid and get 50. ml, 49. ml, and 50. ml, you cannot express the average as 49.7 ml because the graduated cylinders cannot measure a tenth of a ml. If your measurements were made with pipets instead (which can measure a tenth of a ml), the answer 49.7 ml would be fine because the measurements in a pipet would be expressed as 50.0, 49.0, and 50.0. In the answer 49.7 ml, when based off the 50., 49., and 50. numbers, the numbers 49. would be called the significant figures.

If you used a scale that measures down to a tenth of a gram and you got the measurements of 30.2 g, 30.0 g, 31.0 g, and 30.9 g for the same sample, the average would be 30.525 g., but the scale can only measure down to the level of a tenth of a gram, so the answer needs to be rounded off to 30.5. The trailing 25 is uncertain and the significant figures are 30.5.

Suppose you measured the following volumes of HCl (hydrochloric acid) that reacted with another substance: 20.5 ml, 25.4 ml, 22.7 ml, and 24.2 ml. The average of these results is 23.2 ml. This number is fine because the last number is a tenth of a ml and that is the limit of the measurement of the buret.

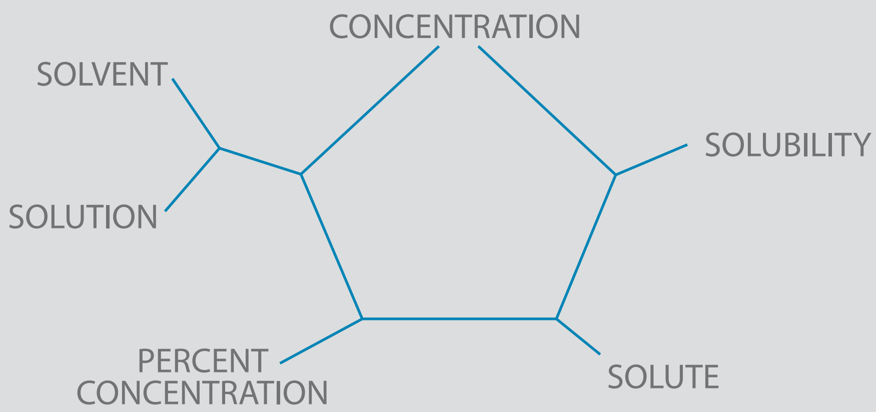
CHAPTER 3

CHEMICAL SOLUTIONS-PERCENT CONCENTRATIONS

OBJECTIVES AND VOCABULARY

At the conclusion of this lesson the student should have an understanding (as evidenced by successfully completing the quiz at the end of this lesson) of:

1. The nature of a solution as being a solute dissolved into a solvent
2. How to determine the amount of solute and solvent to use to prepare a solution of known percent concentration.



A solution is a mixture. We normally think of a solution as something dissolved in water. But it could be something dissolved in oil as well.

Imagine that you have 4 glasses that appear to each contain water. The first has just water; the second has water and salt; the third has water and sugar; and the fourth has water and quinine (very bitter). They all look alike. Does that mean that they really are alike? Appearance may not always be the best judge. Suppose you taste each (which you never do in a chemistry lab). Now are they all alike? Obviously not. What if you have 2 clear glasses of water and one has a little salt and the other has a lot of salt? Could you tell the difference? It would be quite obvious that what a liquid contains and how much it contains are both very important. Along the same line of thought, have you ever taken a large drink of pickle juice?

An easy way to describe a solution is that a **solute** is dissolved into a **solvent** to make a **solution**. Most substances studied in chemistry are dissolved in water. This makes water the solvent. When you prepare a salt water solution, salt is the solute, water is the solvent, and salt water is the solution. Some important solutions include sea water, fresh water, rain water, and the body fluids that bathe your cells.

How well something dissolves is called its **solubility.** The amount of solute divided by the amount of solution is the **concentration**. When you go to a doctor's office they often take a blood sample. The concentrations of several solutes in your blood are used to determine the health of your body and cells. This is a lot better than going after you with a scalpel.

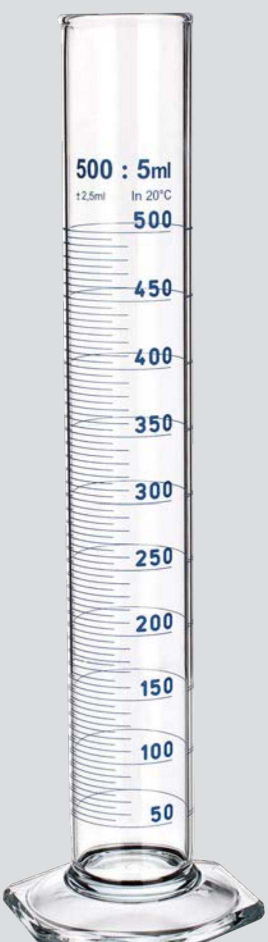
A common method of indicating concentrations is the **percent concentration.** This is found by dividing the mass of the solute by the total mass of the solution and multiplying it by 100 to get a percent.

REACTIONS IN ACTION

If you dissolve 10 grams of NaCl (sodium chloride, table salt) in water to make 100 grams of solution, you get a 10 percent NaCl solution.

10 divided by 100 is 0.1.
0.1 multiplied by 100 is 10 percent.

If you add 10 grams of NaCl to 90 grams of water, you will have a total of 100 grams of solution.



It is easier to measure out NaCl (a solid) on a balance than water, which is a liquid. One gram of water at room temperature is very close to the mass of one milliliter of water. So, instead of measuring out 90 grams of water on a balance, it is easier to measure out 90 ml of water in a graduated cylinder.

To prepare the solution, measure out the 90 ml of water and add the 10 grams of NaCl to it. Even though you only get a volume of 90 ml of solution, it is 90 ml of a 10 percent NaCl solution.

Study this example.

How would you prepare 90 ml of a 10 percent sucrose (table sugar) solution? Add 10 grams of sucrose to 90 ml of water. This gives 100 grams of solution and 10 out of the 100 (10 percent) is sucrose.

Add 10 grams of sucrose to 90 ml of water. 10 grams of sucrose and 90 grams (ml) of water give 100 grams of solution.

$$\frac{10}{100} \text{ x } 100\% = 0.1 \text{ x } 100\% = 10\%$$

How would you prepare a 20 percent solution of NaCl?

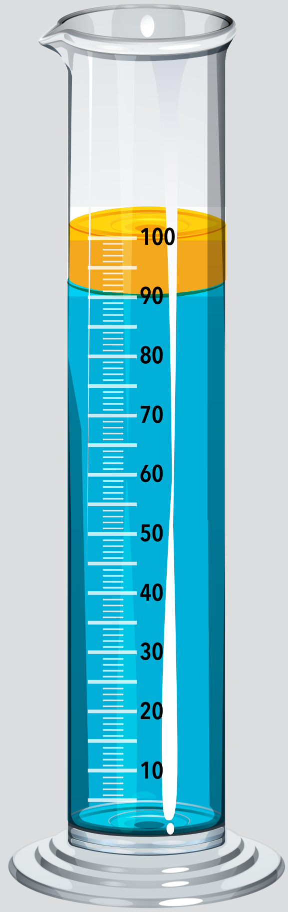
Add 20 grams of NaCl to 80 ml (grams) of water to make 100 grams of 20 percent NaCl solution. 20 grams of NaCl and 80 grams of water equal 100 grams of solution.

$$\frac{20}{100} \text{ x } 100\% = 0.2 \text{ x } 100\% = 20\%$$

If you need more than 80 ml of 20 percent NaCl solution, double the amounts. Add 40 grams of NaCl to 160 ml (grams) of water to make 200 grams of NaCl solution.

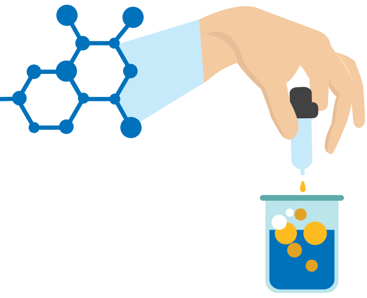
$$\frac{40}{200} \text{ x } 100\% = 0.2 \text{ x } 100\% = 20\%$$

NON-SOLUBLE LIQUID



The oil represents 10 percent of the total liquid in the graduated cylinder.

LABORATORY 3



PREPARING PERCENT CONCENTRATION SOLUTIONS

REQUIRED MATERIALS

- Graduated cylinder (10 ml)
- Stirring rod
- Weighing boats / weigh paper
- Scale
- Table salt
- Beaker (100 ml)
- Beaker (250 ml)
- Laboratory scoop

INTRODUCTION

Percent concentrations are not difficult to understand but can be challenging to prepare. Percent concentrations are used more often in medical or physiological applications rather than in a chemistry lab. If you do not pursue chemistry further in college, you will use percent concentrations and probably not use molar concentrations.

PURPOSE

The purpose of this lab exercise is to gain experience with percent concentrations and to get comfortable with their preparation.

PROCEDURE

1. Water & Salt (Part 1)

   A. Measure out 9 ml of water with a graduated cylinder.

   (1 ml of water has a mass of 1 gram, so 9 ml of water has a mass of 9 grams.)

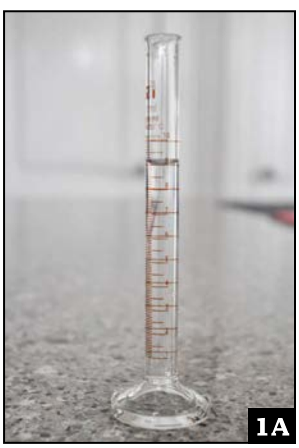
   B. Place the weighing boat onto the scale. (Important: See "Weighing" in Appendix 1 on page 272)

   C. Measure out 1g of NaCl (see lab procedures: Weighing)

   D. Pour the water into a 100 ml beaker and dissolve the 1 g of NaCl into it. Use a stirring rod to help dissolve the NaCl.

   E. What is the percent concentration of the solution? Remember that the percent concentration is the mass of solute (NaCl) divided by the mass of the solution (NaCl and H2O) x 100 percent.

   F. How would you prepare twice the volume of the same percent concentration solution of NaCl and water?



1A

1B

1C

1D

2. Water & Salt (Part 2)

   A. Measure out 16 ml of water and pour it into a 100 ml beaker.

   B. Measure out 4 g of NaCl and dissolve it into the 16 ml of water.

   C. What is the percent concentration of NaCl in your solution?

3. How would you prepare 85 ml of a 15 percent sucrose (table sugar) solution? Prepare this solution.

4. Determine the solubility of NaCl in water.
   Solubility is defined as the maximum amount of a solute that can dissolve into a given volume of solvent.

   A. Measure out 100 ml of water using a graduated cylinder and pour it into a 250 ml beaker.

   B. Fill a weigh boat approximately half full with NaCl and record the mass.

   C. Gradually add the NaCl to the 100 ml of water while stirring until no more will dissolve.

      You may need to refill the weigh boat with additional NaCl to be added to the water. If you do, keep track of the mass of the additional NaCl used.

   D. Determine the maximum number of grams of NaCl that will dissolve in 100 ml of water.

Calculate the percent concentration of NaCl as

$$\frac{\text{the number of grams of NaCl}}{(\text{grams of NaCl} + \text{water})} \times 100\%$$

For example, if you dissolve 23 g of NaCl into 100 ml of water and no more dissolves, the **solubility** is

$$\frac{23 \text{ g NaCl}}{100 \text{ ml } H_2O}$$

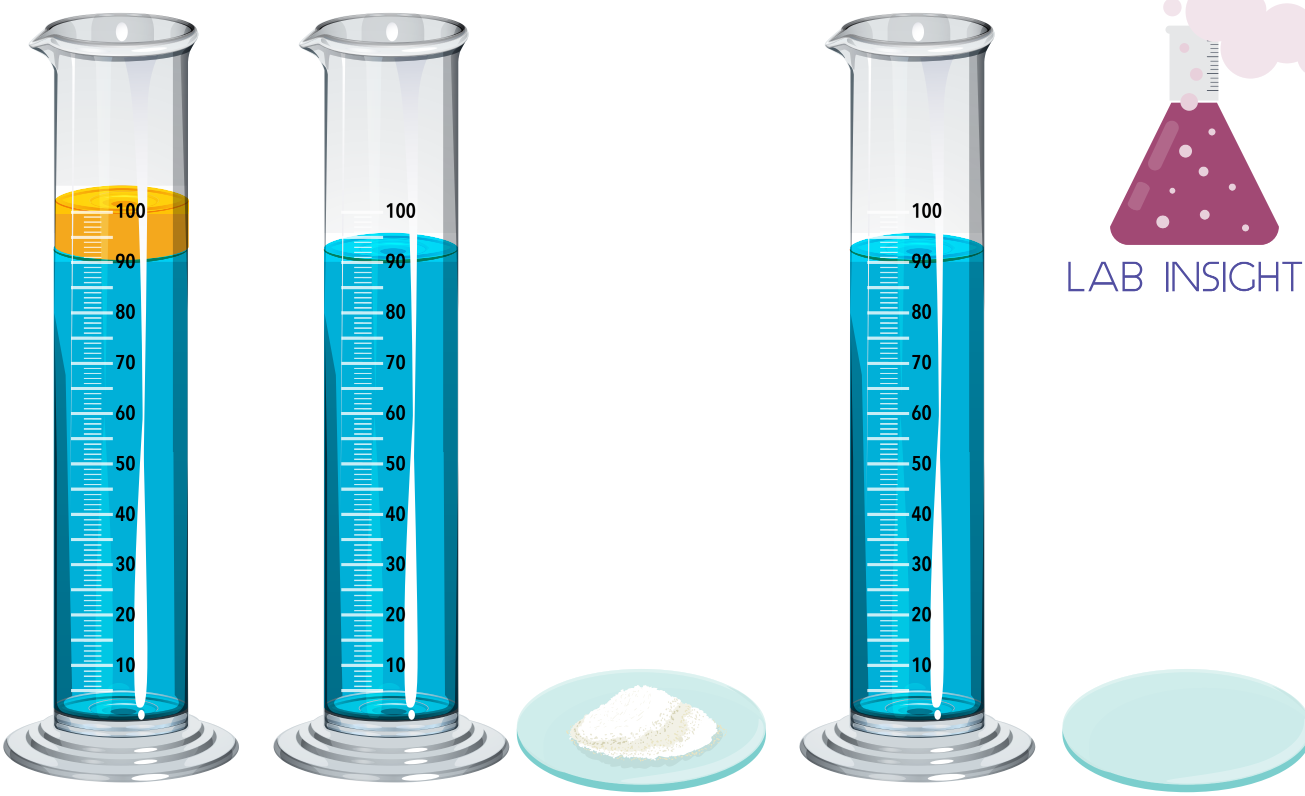
The **percent concentration** is

$$\frac{23 \text{ g NaCl}}{(23 \text{ g NaCl} + 100 \text{ g } H_2O)} \times 100\% = \left(\frac{23}{123}\right) \times 100\% = 19\%$$

The lab report should include a description of all your procedures and the answers to your calculations. Be sure to always show your work. This way it is evident that you have a grasp of the concepts even if you made an arithmetic error somewhere.

NON-SOLUBLE VS SOLUBLE

LAB INSIGHTS



The oil is 10 percent of the total liquid in the graduated cylinder, and the oil is not soluble in the water.

The NaCl on the plate is 10 percent of the total solution.

When the NaCl is poured into the water, it dissolves because it is soluble in water.