Chemistry Matters

Second Edition

Teacher Edition

Oak Meadow

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Teacher Edition Introduction

This teacher edition is designed to help you guide your student through Oak Meadow's *Chemistry Matters*, a full-year high school chemistry course.

This course introduces students to the topics, tools, terms, mathematics, and practices of the study of chemistry. The scientific method, data analysis, and powers of observation and critical thinking used to solve a problem are addressed in all aspects of the course. Students will gain practical experience through 16 labs plus dozens of hands-on activities, inquiry-based quick labs, written assignments, and creative ways to explore chemistry principles and their real-world applications. Many activities use standard household items while the more specialized tools and substances are included in the lab kits.

Many resources for this course have been compiled on the Oak Meadow website at www.oakmeadow.com/curriculum-links. It may be helpful for you to become familiar with what is available so you can provide guidance if your student struggles to find relevant information. It is also important for you to be aware of the information in the appendix regarding academic expectations, citing sources, plagiarism, and more. Students are expected to apply this knowledge in all their work.

Suggested Schedule

This course allows for 18 weeks per semester—16 weeks for the lessons, with 2 additional weeks built into each semester's schedule for extra time as needed. The lessons are designed around the chapters in the textbook. Most lessons will take 1 week. See the table below to determine which lessons will take longer.

Suggested Lesson Timetable

Lesson	Topics	Time to Complete
Semester One		
1	Chapter 1 – Introduction to Chemistry and Matter	2 weeks
2	Chapter 2 - Basic Building Materials	1 week
3	Chapter 3 – A World of Particles	2 weeks
4	Chapter 4 – Moving Electrons	1 week
5	Chapter 5 – Building with Matter	1 week
6	Chapter 6 – Speaking of Molecules	1 week
7	Chapter 7 – Building Molecules	1 week

Lesson	Topics	Time to Complete
8	Chapter 8 – Molecules in Action	1 week
9	Chapter 9 – Molecules in the Body	1 week
10	Chapter 10 – Physically Changing Matter	1 week
11	Chapter 11 – Pressing Matter	1 week
12	Chapter 12 – Concentrating Matter	1 week
	Semester One Project	2 weeks
	Total	16 weeks
Semester Two		
13	Chapter 13 – Toxic Changes	1 week
14	Chapter 14 – Measuring Toxins	2 weeks
15	Chapter 15 – Toxins in Solution	1 week
16	Chapter 16 – Acidic Toxins	1 week
17	Chapter 17 – Toxic Cleanup	1 week
18	Chapter 18 – Observing Energy	1 week
19	Chapter 19 – Measuring Energy	1 week
20	Chapter 20 – Understanding Energy	2 weeks
21	Chapter 21 – Controlling Energy	1 week
22	Chapter 22 – Radiating Energy	1 week
23	Chapter 23 – Chemical Equilibrium	1 week
24	Chapter 24 – Changing Conditions	1 week
	Semester Two Project	2 weeks
	Total	16 weeks

Assessing Student Work

In this teacher edition, answers are shown in **orange**. You will find all assignments, activities, and experiments for the course; labs are fully explained in the lab manual.

When assessing student work, if a student gives an incorrect response to a question or performs a calculation with errors, you can share the correct answer with them to clarify any misconceptions. If they answer many questions or problems incorrectly, encourage them to review the lesson material for better comprehension.

It is best not to share this teacher edition with your student, as they are expected to produce original work. Any indication of plagiarism needs to be taken seriously. Make sure your student is familiar with when and how to attribute sources. These conventions are explained fully in the appendix. Although high school students should be fully aware of the importance of academic integrity, you are encouraged to review its significance with your student at the start of the course. (Information on this is also found in the appendix.)

A Note About the Workload

Oak Meadow courses are designed to provide a variety of assignments and opportunities for further study. This allows students to find areas of interest to explore.

Students vary greatly in terms of reading speed, reading comprehension, mathematics skills, and writing ability. Some may find the reading in this course takes longer than expected; others may find the computations or writing assignments take a great deal of time. In general, students can expect to spend about five hours on each lesson (or ten hours for a two-week lesson). Students who need more time to complete the work might modify some lessons to focus on fewer assignments or opt to complete some of the written assignments orally. Modifications like these can allow students to produce work that is of a higher quality than if they were rushing to get everything done. Each lesson in this course can be customized to suit your student's needs.

Keep an eye on the workload as your student progresses through the course and make adjustments so they have time for meaningful learning experiences.

Coursebook Introduction

Welcome to *Chemistry Matters*! Did you know that chemistry has played a significant role in certain historical events? Have you ever thought about how chemistry impacts society and your daily life? Chemistry is often called the central science because it connects physical sciences and life sciences, such as biology, geology, astronomy, engineering, and medicine. The goal of this course is to provide an introduction to the major topics and mathematics of chemistry while helping you see that chemistry is all around you. We hope this course sparks your curiosity and helps you gain a better understanding of the world. Chemistry often has a bad reputation of being challenging and boring. We here at Oak Meadow say the opposite—chemistry is engaging and fascinating! Let's get started!

Course Materials

This course utilizes the following materials:

- This coursebook, which includes 24 lessons, 2 semester projects, and a full year of assignments.
- Oak Meadow's *Chemistry Matters Lab Manual*, which Includes the instructions for all the activities and lab experiments for this course. **The lab manual is necessary to complete this course.**
- The textbook *Living by Chemistry* (W. H. Freeman, 2022), which is used as the primary source for data and explanations about chemistry. It is a comprehensive text tailored to high school students, and we will cover all 24 chapters.
- *Napoleon's Buttons: How 17 Molecules Changed History* by Penny Le Couteur and Jay Burreson (Jeremy P. Tarcher/Penguin, 2003)
- Hands-On Labs Chemistry Kits (Chem 1 and Chem 2). These kits include many of the materials needed for the experiments. Some additional materials are required and are easily obtained. See the appendix of this coursebook for a full list of materials.

Students will also need the following:

- 1 box of disposable nitrile gloves for use during all inquiry and laboratory experiments
- scientific calculator
- camera

In addition, you may find that some topics benefit from additional resources for reinforcing concepts or for providing additional practice problems. The following websites are recommended when additional support is needed:

Brightstorm Chemistry

www.youtube.com/playlist?list=PL06C3C4E3F84C6A24

Khan Academy Chemistry

www.youtube.com/playlist?list=PL166048DD75B05C0D

Bozeman Science Chemistry

www.youtube.com/playlist?list=PL43285691048DAD00

How to Read Your Textbook

Take a few minutes to familiarize yourself with your textbook, *Living by Chemistry*. Scan the table of contents to get a sense of how the material is organized. Become familiar with both Appendix A and Appendix B at the back of the textbook. There is a lot of helpful information there.

When approaching a reading assignment, first look through the chapter opening, section headings, and main ideas. Then begin reading the content. Reading a chapter straight through is not always the best approach. Skip around, and go back and forth between sections, reading some parts two or three times. Skim some parts, and read other parts in depth, as needed. Pay special attention to the images and diagrams. There is a reason for the saying "A picture is worth a thousand words." It is also important to continue practicing graph and chart interpretation, as these are essential skills in many disciplines.

Whenever you are reading, take good notes! The act of writing things down with a pen and paper can improve your retention and understanding. There is a section on note-taking in the student resources section of the textbook. Another recommended method is the Cornell Notes system, which you can read about online. Find a way that works for you. After taking notes, use them! Reread them, underline key concepts, color-code them for easy reference. Taking notes is helpful in its own right, but referring to them for study will help even more.

You are encouraged to keep a list of new vocabulary terms. Looking up the bold terms in the textbook is a good start, but there will be other terms as well. Work on proper pronunciation of the terms you are learning by saying them aloud.

How the Course Is Set Up

This course is divided into 24 lessons—12 in each semester—plus 2 semester projects, 1 at the end of each semester.

For each lesson, you will complete assignments designed to gauge your understanding and critical-thinking skills. There are inquiry-based quick labs, activities, labs, and creative projects. All written responses should be in complete sentences with proper punctuation and grammar. Calculations need to show all work and include units.

Oak Meadow has partnered with Hands-On Labs (HOL) to provide you with high-quality laboratory kits to accompany this course. Note that this course includes two HOL kits (Chem 1 and Chem 2). Below is a breakdown of the labs in each kit and which lesson uses each lab. Some of the labs are optional. (See each lesson for details.) Any unfinished labs can be completed as part of the final project. Most of the labs are completed in semester 2 of this course simply because those lessons contain content that lends itself to wet lab exploration.

Chem 1 Kit (HOL SP-3005-CK-02)

Lab Name	Corresponding Lesson
Laboratory Techniques and Measurements	1 and 15
Molecular Modeling and Lewis Structures	7
Naming Chemical Compounds	13
pH of Common Materials	16
Properties of Gases	11
Stoichiometry of a Precipitation Reaction	17
The Mole Concept: Chemical Formula of a Hydrate	14
Titration for Acetic Acid in Vinegar	16

Chem 2 Kit (HOL SP-3006-CK-02)

Lab Name	Corresponding Lesson
Antacid Analysis and Titration	16
Caloric Content of Food	19
Colligative Properties and Molar Mass Determination	14
Electrochemical Cells and Cell Potentials	21
Le Chatelier's Principle	24
Quantitative Spectroscope and Visible Light	22
Reaction Order and Rate Laws	20
Using Buffers	23

This course is designed for independent learning, so hopefully you will find it easy to navigate. However, it is assumed you will have an adult supervising your work and providing support and feedback. If you have a question about your work, please ask for help!

When you begin each lesson, scan the entire lesson first. Take a quick look at the number of assignments and amount of reading. Having a sense of the whole lesson before you begin will help you manage your time effectively.

Academic Expectations

You are expected to meet your work with integrity and engagement. Your work should be original and give an authentic sense of your thoughts and opinions, rather than what you think your teacher wants to hear. When you use other sources, you are required to cite them accurately. In chemistry, as with other sciences, the general standard is to follow the American Medical Association (AMA) method. Information on AMA style and how it compares to other citation methods can be found in the appendix of this coursebook. More detailed information can be found here:

> "Citation and Style Guide Help: AMA Style"
>
> researchguides.uic.edu/styleguides/ama

Plagiarism, whether accidental or intentional, is a serious matter. Plagiarism will result in a failing grade for the lesson, and repeated plagiarism is grounds for dismissal from the school. The appendix of this coursebook includes information about academic expectations and original work guidelines. It is your responsibility to make sure you understand these expectations and abide by them.

If you are enrolled in a school and are working with a teacher, you will find a reminder at the end of every lesson that instructs you to share your work with your teacher. Continue working on the next lesson while you are waiting for your teacher to provide feedback.

Remember, chemistry is all around you. Keep looking for connections between what you observe around you and what you are learning. Stay curious!

Lesson

1

Introduction to Chemistry and Matter

Learning Objectives

In this lesson, you will:

- Become familiar with basic laboratory safety rules and the importance of the safe use of chemicals.
- Identify basic laboratory equipment.
- Distinguish between matter and non-matter.
- Convert measurements between scientific notation and standard notation.

Lesson Introduction

Chemistry is the study of matter. Matter is anything that has mass and occupies space. It is the "stuff" of the physical universe. This lesson introduces the concept of matter, standard safety procedures, and the basic calculations of chemistry.

This lesson also focuses on density, an intensive property of matter. You might recall the mathematical formula for density is D = M/V. Can you recall what each of the symbols in the equation stands for and what the relationship means? Can you recall what an intensive property is?

You have two weeks to complete this lesson.

Laboratory Safety Rules

It is essential that students read, understand, and follow the laboratory safety rules. It may be helpful to review them with your student. The HOL lab kits include safety glasses and five pairs of gloves per kit for use with specific experiments involving potentially harmful chemicals. However, it is strongly

ASSIGNMENT CHECKLIST

- ☐ Read and acknowledge the laboratory safety rules.
- ☐ Complete Before You Begin: Get to Know the Periodic Table.
- ☐ Complete one Inquiry Activity:

  Option 1: Does It Float? A Demonstration of Density

  Option 2: The Floating Egg
- ☐ Read chapter 1 and pages A-0–A-1, A-9–A-11, and A-15–A-17 of Appendix A in your textbook.
- ☐ View lesson videos.
- ☐ Complete the lesson assignments.
- ☐ Activity A: Measuring and Graphing
- ☐ Activity B: Understanding Material Safety Data Sheets (optional)
- ☐ Experiment: Laboratory Techniques and Measurements

recommended that students get into the habit of using safety glasses and gloves for every experiment and activity. For this reason, students are asked to supply their own box of gloves so they will have enough pairs for every lesson.

Read page xx in your textbook (the page before the start of Unit 1).

Throughout the course, you will conduct home experiments that involve the use of potentially harmful chemicals. These labs are designed to give you a hands-on learning experience, but they need to be done in a safe manner. As such, it is important that we begin this course with a review of safe laboratory techniques.

1. Wear closed-toe shoes when working with chemicals.
2. Keep all other nonessential lab items, such as bags, papers, food, cosmetics, lotions, etc., out of the work space.
3. Never eat, drink, or chew gum when working on labs.
4. Before every lab, read all the directions carefully. Make sure you understand the overall goal of the lab.
5. Check that all your equipment and supplies are clean and in working order before beginning.
6. Gather all equipment needed for the lab. Keep all other lab materials packaged and out of the work space.
7. Always wear safety glasses and gloves. They are provided in your lab kit.
8. Tie back long hair and loose clothing to keep them away from chemicals and flames.
9. Remove dangling jewelry.
10. Never touch, taste, or smell any chemical. To note odor, gently wave your hand over the opening of the container to direct the fumes toward your nose and smell carefully (wafting).
11. Never conduct your own experiments. Follow the directions provided and use materials only as intended.
12. Hot glassware does not appear hot. Carefully check before touching.
13. Dispose of any unused or spilled chemicals by soaking them up with a paper towel and placing it in a trash can. **Never dispose of chemicals down the sink or toilet.**
14. Clean up your work space and all equipment after each experiment. Dispose of materials as noted above or place them back in your lab kit for future use. Since you are conducting these experiments at home (and possibly in your kitchen), it is critically important that you clean up your work space before anyone else uses the area or food is prepared.
15. Wash your hands thoroughly after each experiment!

Let your teacher know that you have read and understand these rules. If at any point during this course you have questions about the laboratory directions or need assistance, stop working and contact your teacher immediately.

Before You Begin: Get to Know the Periodic Table

Central to chemistry is the periodic table of elements, which you can find on pages 46–47 in your textbook. While there is no need to memorize it, it is important to learn how to use this powerful tool. Each lesson in this course opens with a quick activity designed to help you become comfortable using the periodic table and familiar with where elements are located.

We'll begin our exploration with this question: What are the only two letters *not* used in the periodic table? Note that some versions of the periodic table show temporary chemical names (shaded gray) that are or were pending official chemical symbols and names. Temporary names don't count as part of this question.

This section appears in each lesson to help students become comfortable with using the periodic table and familiar with all the information it contains. There is a copy of the periodic table in the textbook. Students will be referring to it often.

Many Before You Begin sections include a question for students to answer. In answer to the question in this lesson, letters J and Q are the only two letters not used in the periodic table.

Bonus question: Can you name the Muppet character named after a piece of laboratory equipment?

Beaker

Chemistry in Context: Density of Crude Oil

This section, found in each lesson, provides relevant information and real-world applications related to the lesson topic. These topics can also be used for additional learning, discussion, research, and optional extra credit. Density plays an important role in environmental contamination of surface water and groundwater. Consider the Deepwater Horizon oil spill in the Gulf of Mexico in April 2010, the worst oil spill in U.S. and petroleum industry history. The Deepwater Horizon oil rig, located 42 miles off the coast of Louisiana, experienced a series of problems in the abandonment of a newly drilled well that led to an explosion and the uncontrolled release of 3.19 million barrels of oil for 87 days. Although the well was over 5,000 feet beneath the surface of the ocean water, oil spread through the water column and floated on the ocean's surface. The oil spread quickly due to winds and wave action, and it created a 22-mile-long plume of contamination. Environmental responders addressed the oil at the surface through physical (skimmers or large sponges) and chemical means (dispersants and surfactants) to remove as much oil as quickly as possible. Crude oil has a density of 870 kg/L and salt water has a density of 1,029 kg/L. Since crude oil is less dense than salt water, the majority of the oil floated on the surface of the water. Environmental cleanup of a spill of this size was difficult and took several years to complete. Recent reports still show oil continuing to impact the ecosystem in the Gulf.

If you'd like to learn more, read the following article:

> "Gulf Oil Spill"
>
> ocean.si.edu/conservation/pollution/gulf-oil-spill

Brown pelicans, covered in oil from the Deepwater Horizon oil spill, wait to be cleaned at the Fort Jackson Wildlife Care Center, Buras, Louisiana, June 3, 2010. (Image credit: International Bird Rescue Research Center)

Inquiry Activity

In each lesson, you'll find quick inquiry activities designed to introduce lesson topics. These mini-labs will help you hone your observation and prediction skills and learn to recognize connections between chemical reactions and scientific concepts. **Always take photos of your setup and results to share with your teacher.**

Complete one of the following options (read both before you decide):

- Option 1: Does It Float? A Demonstration of Density
- Option 2: The Floating Egg

These activities are designed to allow students to explore the lesson concepts experientially before reading the textbook and working more in depth with the lesson material. Some inquiry activities will have follow-up questions while others are primarily experiential.

Students should include photos of their setup and results for all activities and labs.

Option 1: Does It Float? A Demonstration of Density

Materials

- Ivory bar soap
- various other brands of bar soap
- various brands of regular and diet soda cans, unopened
- 1 orange
- 1 lemon
- 1 lime

Directions

1. Fill a large sink or a bucket with water.
2. Place an unwrapped bar of Ivory soap in the water. (Note: It must be Ivory brand.) Observe what happens. Does it float?
3. Repeat the process with other brands of bar soap and compare your results. Create a data table to record your results. (Make sure to give your data table a title.)
4. Remove the soaps. Save the Ivory bar soap for lesson 10.
5. Place various unopened soda cans in the water. Record the results.
6. Remove the soda cans. Add the unpeeled orange, lemon, and lime to the water. Record the results.
7. Peel the fruits and place them back in the water. Record the results.

Follow Up

1. Did any results surprise you? What properties allow the items to float? Examine each item closely to see if you can spot any clues or commonalities.

   Answers will vary. Students should note that the Ivory soap has bubbles whipped into it, which make it float, and diet sodas have less sugar, so they float. The citrus fruits may stump the students since the results vary. They should note that the orange floats with the peel but sinks without it. The lemon always floats, and the limes always sink. This may surprise the students, and they may or may not have a possible explanation. The pores of the orange rind are what make it float, while the actual water content of the lemon versus the lime is what determines if it floats or sinks.

   Students should include photos of their setup and results. The table they create should look similar to the one below. Look for column labels and a title on the table.

   Results of Density Demonstration Activity

Item	Floats	Sinks
Ivory soap	X	
Any other brands of soap tested		X
Regular sodas		X
Diet sodas	X	
Orange w/ peel	X	
Orange w/o peel		X
Lemon w/ peel	X	
Lemon w/o peel	X	
Lime w/ peel		X
Lime w/o peel		X

2. Explain in your own words what density means and why something floats or sinks in water based on its density.

   Answers will vary. Students should have some previous understanding of density and may state that it is how heavy something is. They should note that something less dense than water will float while denser items will sink.

Option 2: The Floating Egg

Materials

- water
- 2 drinking glasses
- 4 Tbsp salt
- 2 eggs

Directions

1. Fill both drinking glasses about two-thirds full with tap water.
2. Add 4 tablespoons of salt to one of the glasses.
3. Gently place one egg in each glass.

Follow Up

1. What did you observe? Propose a reason for your observations.
2. Explain in your own words what density means and why something would float or sink in water based on its density.

   Students will observe that the egg in the tap water sinks, but the egg in the salt water floats. This is because the addition of salt makes the density of the water greater than that of the egg. Look for students to provide photos of their results.

3. Optional extra credit: You can also float eggs in water to determine how fresh they are. Look up how to do this online and document your procedure and results. Explain what you learned.

   Fresh eggs will sink while older eggs will float. This is due to the amount of air that is released inside the egg as the egg ages, which makes it more buoyant.

Reading

Read the following in your textbook, *Living by Chemistry*:

- Chapter 1, Defining Matter (pages 1–23)
- Appendix A, pages A-0–A-1, SI Units of Measure section
- Appendix A, pages A-9–A-11, Graphing section
- Appendix A, pages A-15–A-17, Scientific Notation and Dimensional Analysis sections

Important note: Do not skip reading the appendix sections noted for each lesson as this is where the explanation for the math problems and sample calculations are located.

Viewing

Watch the following videos after reading chapter 1 in your textbook.

Note: Lesson videos are not meant to serve as an alternative to the reading. For all lessons, you are expected to complete the reading. Videos will support what you have learned from the textbook.

1. The featured demo on page 7 requires some chemicals not typically found at home. It's a great simple reaction though if you want to purchase the materials and conduct the experiment on your own. Check out this video that walks you through the reaction:

"How to Make Gold Pennies!" (Video length: 3:57)

www.youtube.com/watch?v=5fmRfsep450

2. Material Safety Data Sheets (MSDS) are written by chemical manufacturers to provide information on the safe handling of chemicals. Watch this video for a quick review of lab safety and MSDS (sometimes called Safety Data Sheets or SDS):

   "Lab Techniques & Safety: Crash Course Chemistry #21" (Video length: 9:02)

   www.youtube.com/watch?v=VRWRmIEHr3A

Videos are used to help students understand key concepts of this course and are required viewing. It's best for students to watch the videos after reading the textbook material because the videos support and build on what the students have learned.

Assignments

Throughout the course, lesson assignments will use the information provided in the textbook. If you use additional sources for your response, include a citation. When performing calculations, always show your work.

1. You should be familiar with the scientific method from previous science courses you have taken. What are the steps of the scientific method? How might a chemist working in a laboratory use the scientific method in their research?

   Students should recall that the scientific method includes making observations, conducting research, forming a hypothesis, testing, recording data, and drawing conclusions. Students may mention the importance of publication and peer-review studies. Answers will vary regarding how a chemist might use the scientific method in research but may include forming and testing hypotheses, controlling variables in experiments, conducting multiple trials, recording detailed observations, and taking accurate measurements. Students may also note that all experiments and good science are based on the scientific method.

2. Go outside and observe your surroundings. Make a list of five things that are classified as matter and five things that are not classified as matter. Briefly explain your reasonings. Provide a photo of your setting.

   Students should list various parts of their surroundings, providing a photo as evidence. Items listed as matter will include anything solid, liquid, gas, or plasma. Non-matter items may include time, sound, sunlight, gravity, heat, energy, feelings, or thoughts.

3. Why is chemistry often called the central science? Given an example to support your answer.

   Chemistry is the central science because it is the foundation for understanding all other sciences and it connects all sciences together. Students should provide a relevant example from their own lives or previous studies. For instance, chemical compounds in the form of medications connect chemistry with medicine, pharmacology, and psychiatry.

4. Imagine a large quantity of jet fuel has been released at a nearby airport. The density of jet fuel is 0.804 kg/L. The density of water is 1,000 kg/L. If the jet fuel spill migrates to the groundwater supply, would you expect to find jet fuel at the top or bottom of the aquifer?

   Jet fuel is less dense than water and would therefore settle on top of water.

5. Open your laboratory kits for this course. Pull out all the materials. (Do not open any of the chemical packets yet.) Review the package list and check your lab equipment against the video linked below.

   "Lab Equipment—Explained" (Video length: 9:39)

   www.youtube.com/watch?v=ZFe8cJ5YONM

   Identify five pieces of equipment in your kit and their proper usage in a chemistry lab.

   Answers will vary.

6. Scientists measure physical quantities such as length, width, temperature, and density. Any measurement must always include a unit that tells what was measured. There are two major unit systems in the world: the U.S. Customary System (also known as the British Imperial System), primarily used in the United States for nonscientific measurements, and the Système International (SI, also known as the metric system), which is used in nearly all other countries for both scientific and nonscientific measurements. The U.S. scientific community uses SI (metric) units.

   a. What are the common prefixes used in the metric system? Hint: review Appendix A in your textbook.

      deci-*, *centi-*, *milli-*, and *kilo-

   b. Why is the United States one of the only countries to not use the metric system for general use? Check out this video for some good background information:

      "Why Don't the U.S., Myanmar, and Liberia Use the Metric System?" (Video length: 8:04)

      www.youtube.com/watch?v=QwIkExIIxiQ

      The United States has not adopted the metric system, despite several attempts through legislation proposed by past administrations, because it would be very costly and difficult to implement.

7. Complete the problems below to review scientific and standard notation.

   Note: Correct use of superscripts and subscripts is required for this course. All handwritten and typed work must show exponents and chemical formulas with appropriate superscripts and subscripts. Points will be deducted for shortcuts or for failing to write correct formulas. A revision of work will be required when proper superscripts and subscripts are not used.

   Convert the following values to scientific notation.

   a. 5,213 = $\mathbf{5.213 \times 10^3}$

b. 73,200 = **7.32×10^4**

c. 23.21 = **2.321×10^1**

d. 21,000,000,000 = **2.1×10^{10}**

e. 4,713,000,000 = **4.713×10^9**

f. 0.02 = **2×10^{-2}**

g. 0.000314 = **3.14×10^{-4}**

h. 0.00000000043791 = **4.3791×10^{-10}**

Convert the following values to standard notation.

i. 2×10^3 = **2,000**

j. 2.331×10^5 = **233,100**

k. 9.51×10^{22} = **95,100,000,000,000,000,000,000**

l. 5×10^{-3} = **0.005**

m. 7.6278×10^{-5} = **0.000076278**

n. $10^3 + 10^5$ = **1,000 + 100,000 = 101,000**

o. $(2.51 \times 10^2) + (5.23 \times 10^4)$ = **251 + 52,300 = 52,551**

p. $10^4 - 10^2$ = **10,000 – 100 = 9,900**

q. $(2 \times 10^4) - (7 \times 10^2)$ = **20,000 – 700 =19,300**

r. $10^{12} \times 10^5$ = **$10^{(12+5)} = 10^{17}$ = 100,000,000,000,000,000**

s. $(7.2 \times 10^5) \times (2.12 \times 10^{-2})$ = **$(7.2 \times 2.12) \times 10^{(5-2)} = 15.264 \times 10^3$ = 15,264**

8. The factor label method, also called dimensional analysis, is the standard method for making conversions throughout this course. You should review Appendix A (pages A-15–A-17) in your textbook. **Answers must be shown with proper dimensional analysis.**

   Consider the following example: How many seconds are there in one week?

   Solution:

   $$1\text{ week} \times \frac{7\text{ days}}{1\text{ week}} \times \frac{24\text{ hours}}{1\text{ day}} \times \frac{60\text{ minutes}}{1\text{ hour}} \times \frac{60\text{ seconds}}{1\text{ minute}} = 604{,}800\text{ seconds}$$

   Notice the following:

   - The beginning of the problem is the amount given in the problem (1 week).
   - The beginning unit (week) means that the next conversion factor should have that unit (week) in the denominator so that unit can cancel out.

- Since days is the numerator unit of the first factor, days must be the unit in the denominator of the next factor.
- This method carries on until the unit in the numerator of the final conversion is the unit you are solving for.
- Each factor must be a true statement.

Convert the following and show your work using correct dimensional analysis. Calculator error can be common when doing these types of problems so pay close attention to parentheses and the order of operations when using your calculator.

Include units in your answer. For a and b, express your answer in standard notation and scientific notation.

a. 1.5 years to seconds

$1.5 \text{ years} \times \left(\frac{365 \text{ days}}{1 \text{ year}}\right)\left(\frac{24 \text{ hours}}{1 \text{ day}}\right)\left(\frac{60 \text{ minutes}}{1 \text{ hour}}\right)\left(\frac{60 \text{ seconds}}{1 \text{ minute}}\right) = 47{,}304{,}000 \text{ sec or } 4.7304 \times 10^7 \text{ sec}$

b. 4,600 Euros to U.S. dollars (exchange rates vary daily, but assume 1 USD = 0.88 Euro). As a second step, convert to the number of U.S. dimes.

$4{,}600 \text{ Euro} \left(\frac{1 \text{ dollar}}{0.88 \text{ Euro}}\right) = 5{,}227 \text{ USD or } 5.227 \times 10^3 \text{ USD}$

$4{,}600 \text{ Euro} \left(\frac{1 \text{ dollar}}{0.88 \text{ Euro}}\right)\left(\frac{10 \text{ dimes}}{1 \text{ dollar}}\right) = 52{,}272 \text{ dimes or } 5.2272 \times 10^4 \text{ dimes}$

c. 33 mL to dL

$33 \text{ mL} \times \left(\frac{1 \text{ dL}}{100 \text{ mL}}\right) = 0.33 \text{ dL}$

d. 950 g to kg

$950 \text{ g} \times \left(\frac{1 \text{ kg}}{1{,}000 \text{ g}}\right) = 0.950 \text{ kg}$

e. 275 mm to cm

$275 \text{ mm} \times \left(\frac{1 \text{ cm}}{10 \text{ mm}}\right) = 27.5 \text{ cm}$

f. 1,000 L to kL

$1{,}000 \text{ L} \times \left(\frac{1 \text{ kL}}{1{,}000 \text{ L}}\right) = 1 \text{ kL}$

g. 4,500 mg to g

$4{,}500 \text{ mg} \times \left(\frac{1 \text{ g}}{1{,}000 \text{ mg}}\right) = 4.5 \text{ g}$

9. Answer questions 2, 4, 6, 8, and 10 on pages 22–23 in your textbook.

2. Matter is anything that has mass and takes up space.

4. 7.2 g/cm^3. The density of one penny is the same as the density of two pennies.

6. 2,500 g

8. Approximately 15% of salt

10. Yogurt cups, milk cartons, and egg cartons will be found floating on seawater as they are all less dense than seawater.

10. Explain why density is an intensive property while the properties used to calculate it (mass and volume) are both extensive properties.

    Mass and volume are extensive properties as they both depend on the amount of substance. As the size of a sample changes, so do the mass and volume. However, density does not change based on the amount of a substance. So, regardless of the mass or volume, the density of a substance remains the same. Therefore, density is an intensive property.

Activities

Complete Activity A. Activity B is optional and can be done for extra credit.

- Activity A: Measuring and Graphing
- Activity B: Understanding Material Safety Data Sheets

(All activities are found in Oak Meadow's *Chemistry Matters Lab Manual*.)

See the student lab manual for complete details on the activities. Answers to the activity questions are below. Students should include photos of their setup and results for all activities and labs.

Before You Begin

1. Write one paragraph explaining the following. Properly cite any references you use.
   - Describe how to create a meaningful line graph. What titles, labels, and notations would you include?
   - What is the general equation for a line? Define all variables.
   - What is the equation for determining the slope of a line?
   - Optional extra credit: Define and explain interpolation and extrapolation as it relates to the slope of a line.

Look for the following to be stated in paragraph form:

A meaningful line graph accurately reflects data with evenly spaced intervals and a title that describes the data presented. Both axes should be labeled with units.

The general equation for a line is $y = mx + b$ where m is the slope and b is the y-intercept. The variables y and x represent values on the respective axes.

Slope is determined by taking two coordinates and solving for rise over run: $\frac{(y_2 - y_1)}{(x_2 - x_1)}$.

Optional extra credit: Interpolation is the determination of a value on the line of best fit from within the measured data range. Extrapolation is the determination of a value on the line of best fit from outside the range of measured data.

Data Table: Measurement of Shapes

Shape	Length (RN) (cm)	Length (SN) (cm)	Width (RN) (cm)	Width (SN) (cm)	Area (RN) (cm^2)	Area (SN) (cm^2)	Mass (g)
A							
B							
C							
D							
E							

Data table values will vary. Students should provide photos of their shapes with their completed data table. Look for correct conversions and accurate measurements.

Analysis

1. Using your graph, calculate the slope of your line of best fit. Show your work.

   Answers will vary. Check the calculations and graph for accuracy. The graph should take up a full page, include a title and labels, and show an accurate line of best fit.

2. Using the constructed graph, determine the area of the irregular shape E. Include the correct units in your answer.

   a. Area of shape E = ______________

   Answers will vary. Point E should be plotted (and labeled) on the graph.

   b. Was this task completed through interpolation or extrapolation? Explain.

   Answers will vary depending on the overall size of their irregular shape relative to the knowns they made using the four squares A–D. Interpolation means that E plotted within the line of best fit data points; extrapolation means that E plotted beyond their data set.

3. How was this graph useful when obtaining information? Was it more accurate than trying to make direct measurements? Explain.

   Students may report that this was a lot of work, but they should be able to recognize the value of creating a standard curve to quickly estimate measurements for unknowns, which is common in the sciences.

Activity B: Understanding Material Safety Data Sheets

1. What does MSDS stand for?

   Material Safety Data Sheet

2. What is the name of your chemical?

   Acetic acid

3. What is its formula?

   $C_2H_4O_2$ or CH_3COOH
   Look for students to use appropriate subscripts in the formula. This will be important throughout the course.

4. Identify three important types of information found on an MSDS and provide that information for this compound.

   Answers may include information on health hazards, fire hazards, what should be done in case of spills or leaks, special precautions, first aid, and what conditions should be avoided.

Experiments

Complete the following lab experiment, which is found in Oak Meadow's *Chemistry Matters Lab Manual*.

- Laboratory Techniques and Measurements

The materials for this experiment are found in the HOL Chem 1 Kit.

Note: You will be completing Exercise 1: Length, Temperature, and Mass and Exercise 2: Volume and Density in this lesson. Exercise 3: Concentration, Solution, and Dilution will be covered in lesson 15.

Include photos of your lab setup and results. Complete all the required lab questions. You will generate data tables to be included with your lab.

Laboratory Techniques and Measurements

Learning Objectives

- Perform measurements with a graduated cylinder, volumetric flask, graduated pipet, ruler, digital scale, and thermometer.
- Perform the water displacement method for measuring the volume of an irregularly shaped object.
- Calculate experimental error.
- Practice basic math and graphing skills.

See the student lab manual for complete details on the experiments. Answers to the experiment questions are below. Students should include photographs of their lab setup and results for each experiment.

Since data from observations and measurements can vary, data table answers throughout this teacher edition may differ from the student's answers. However, the general data range and patterns should be similar.

Exercise 1: Length, Temperature, and Mass

Data Table 1: Length Measurements

Sample measurements are below. The student's data may be different.

	Length (cm)	Length (mm)	Length (m)
CD or DVD	12.00	120.0	0.120
Key	5.23	52.3	0.0523
Spoon	15.00	150.0	0.1500
Fork	20.20	202.0	0.2020

Data Table 2: Temperature Measurements

Sample measurements are below. The student's data may be different.

	Temperature (°C)	Temperature (°F)	Temperature (K)
Hot from Tap	35.0	95.0	308.2
Boiling	94.0	201.2	367.2
Boiling for 5 minutes	95.5	203.9	368.7
Cold from Tap	19.5	67.1	292.7
Ice Water, 1 minute	5.0	41.0	278.2
Ice Water, 5 minutes	4.0	39.2	277.2

Data Table 3: Mass Measurements

Sample measurements are below. The student's data may be different.

	Estimated Mass (g)	Actual Mass (g)	Actual Mass (kg)
Pen or Pencil	3.0	4.5	0.0045
3 Pennies	12.3	7.6	0.0076
1 Quarter	5.1	5.8	0.0058
2 Quarters, 3 Dimes	15.0	18.2	0.0182
4 Dimes, 5 Pennies	22.5	21.6	0.0216
3 Quarters, 1 Dime, 5 Pennies	35.3	32.0	0.0320
Key	15.0	12.6	0.0126
Key, 1 Quarter, 4 Pennies	22.2	28.2	0.0282

Exercise 1 Questions

1. Water boils at 100°C at sea level. If the water in this experiment did not boil at 100°C, what could be the reason?

   If the water did not boil at 100°C, it is the result of a higher elevation. The higher the elevation (from sea level), the lower the atmospheric pressure and the lower the boiling point. This experiment was conducted at Hands-On Laboratories at approximately 5,280 feet above sea level, where the boiling point was determined to be 93.8°C.

2. While heating two different samples of water at sea level, one boils at 102°C and one boils at 99.2°C. Calculate the percent error for each sample from the theoretical 100.0°C.

$$\frac{|102°C - 100°C|}{100°C} \times 100 = 2\%$$

$$\frac{|99.2°C - 100°C|}{100°C} \times 100 = 0.8\%$$

Exercise 2: Volume and Density

Data Table 4: Liquid Measurements

	Water	Isopropyl Alcohol
Mass A: Graduated Cylinder (g)	**19.9**	**19.9**
Volume (mL)	**5.0**	**5.0**
Mass B: Graduated Cylinder with Liquid (g)	**24.7**	**23.7**
Mass B – A: Liquid (g)	**4.8**	**3.8**
Density (g/mL)	**0.97**	**0.76**
Percent Error (%)	**3.5**	**3.3**

Data Table 5: Magnet—Direct Measurement Method

	Magnet
Mass (g)	**4.3**
Length (cm)	**2.56**
Width (cm)	**0.59**
Height (cm)	**0.59**
Volume (cm^3)	**0.89**
Density (g/cm^3)	**4.8**

Data Table 6: Water Displacement Method

	Magnet	Metal Bolt
Mass (g)	**4.3**	**8.0**
Initial Volume of Graduated Cylinder (mL)	**7.1**	**6.5**
Final Volume of Graduated Cylinder (mL)	**8.0**	**7.5**
Object Volume (mL)	**0.9**	**1.0**
Density (g/mL)	**5**	**8.0**

Exercise 2 Questions

1. An unknown, rectangular substance measures 3.60 cm high, 4.21 cm long, and 1.17 cm wide. If the mass is 21.3 g, what is this substance's density (in g/mL)? Remember to always show your work.

$$\textbf{Volume} = 3.60 \text{ cm} \times 4.21 \text{ cm} \times 1.17 \text{ cm} = 17.7 \text{ cm}^3$$

$$\textbf{Mass} = 21.3 \text{ g}$$

$$\textbf{Density} = \frac{21.3 \text{ g}}{17.7 \text{ cm}^3} \times \frac{1 \text{ cm}^3}{1 \text{ mL}} = 1.20 \text{ g/mL}$$

2. A sample of gold (Au) has a mass of 26.15 g. Given that the theoretical density is 19.30 g/mL, what is the volume of the gold sample?

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

$$\frac{19.30 \text{ g}}{\text{mL}} = \frac{26.15 \text{ g}}{x}$$

$$19.30 \text{ g } (x) = 26.15 \text{ g (mL)}$$

$$x = 1.355 \text{ mL}$$

3. A student was given an unknown metal. The student determined that the mass of the metal was 30.2 g. The student placed the metal in a graduated cylinder filled with 20.0 mL of water. The metal increased the volume of water to 22.9 mL. Calculate the density of the metal and determine the identity of the metal using the table below.

   The calculated density of the unknown metal is 10.4 g/mL. The closest density is 10.5 g/ml, which makes the unknown silver.

   ### Table 1: Density of Metals

Metal	Density (g/mL)
Lead	11.3
Silver	10.5
Nickel	9.90
Zinc	7.14

Further Study

This section provides additional ways for students to explore the lesson topic. These activities are optional and can be used as extra credit or to replace other lesson assignments (with teacher approval).

The following activities are optional.

Chemistry is the foundation of many careers. Create a poster, presentation, or report on one of the careers listed below. Check the U.S. Department of Labor for information. Include the following:

- Description of the career with detailed information about what the job entails and how it relates to chemistry.
- Typical educational requirements (education level, college major/minor, and job training)
- Salary range (entry level, mid-level, and senior level)
- Related careers (Identify other professionals who would collaborate with those in this career.)
- Future outlook for this career (competition, growth, and employment change expected)

Cite your sources in AMA format.

Chemistry-related careers include the following:

Agricultural chemist
Anesthesiologist
Atmospheric chemist
Biochemist
Biomedical engineer
Botanist
Coroner
Crime lab analyst
Environmental chemist
Environmental engineer
Food and flavor chemistry
Forensic chemist
Geochemist
Hair colorist
Hazardous waste management
Hematologist
Hydrogeologist
Industrial hygienist
Inorganic chemist
Limnologist
Materials scientist
Mechanic
Medical technologist
Metallurgy
Military systems
Nuclear engineer
Oceanographer
Oncologist
Optometrist
Organic chemist
Patent lawyer
Petroleum engineer
Pharmacist
Phlebotomist
Physical chemist
Physician
Physicist
Plumber
Protein chemist
Radiologist
Soil scientist
Textile chemist
Toxicologist
Veterinarian
Water/wastewater plant manager

For this optional project, encourage creativity and in-depth research. Students should include source citations in AMA format, which is the commonly used format in science. (See the appendix for details on AMA format.)

SHARE YOUR WORK

When you have completed this lesson, share the following work with your teacher:

- Acknowledgment of lab safety rules
- Answers to Before You Begin: Get to Know the Periodic Table
- Inquiry Activity:
  - Option 1: Does It Float? A Demonstration of Density
  - Option 2: The Floating Egg
- Answers to lesson assignments
- Activity A: Measuring and Graphing
- Experiment: Laboratory Techniques and Measurements
- Optional extra credit:
  - Activity B: Understanding Material Safety Data Sheets
  - Further Study

If you have any questions about the lesson assignments or how to share your work, let your teacher know.

Students are advised to share their work with their teacher at the end of each lesson. This will help them receive timely feedback on their coursework and give the teacher the opportunity to identify and correct misconceptions quickly. If you (or a teacher the student is working with) prefer a different submission schedule, make sure your student understands when and how to submit work and when to expect feedback.

Lesson

2

Basic Building Materials

Learning Objectives

In this lesson, you will:

- Define chemical and physical properties.
- Make observations of chemical and physical properties.
- Distinguish between an element and a compound.
- Apply the law of conservation of mass to chemical equations.
- Name the major groups and describe the basic trends of the periodic table.

Lesson Introduction

Chemistry often feels like learning a new language. Numbers have scientific meaning and are presented in a way that is new for most students. Chemical and physical changes that you observe in the lab and in your daily life are clues to what is occurring on a molecular level. Those changes can be quantified and described by the language and mathematics of chemistry.

You are likely already familiar with the periodic table, but you may not realize that it is a powerful tool that beautifully, almost miraculously, organizes essential information regarding each element. Once you understand how the periodic table is arranged, you can use this information to solve problems and predict chemical reactions.

You have one week to complete this lesson.

ASSIGNMENT CHECKLIST

- ☐ Complete Before You Begin: Get to Know the Periodic Table.
- ☐ Complete one Inquiry Activity:

  Option 1: Removing Color with Bleach: A Demonstration in Chemical Change

  Option 2: Oobleck: A Demonstration of the States of Matter
- ☐ Read chapter 2 in your textbook.
- ☐ View lesson videos.
- ☐ Complete the lesson assignments.
- ☐ Activity: Color Coding the Periodic Table

Before You Begin: Get to Know the Periodic Table

Take another look at the periodic table. Can you figure out which elements were named after celestial bodies?

Helium (He) is named after the sun.

Mercury (Hg) is named after Mercury.*

Selenium (Se) is named after the moon.

Tellurium (Te) is named after Earth.

Cerium (Ce) is named after Ceres (dwarf planet).

Palladium (Pd) is named after Pallas (asteroid).

Uranium (U) is named after Uranus.

Neptunium (Np) is named after Neptune.

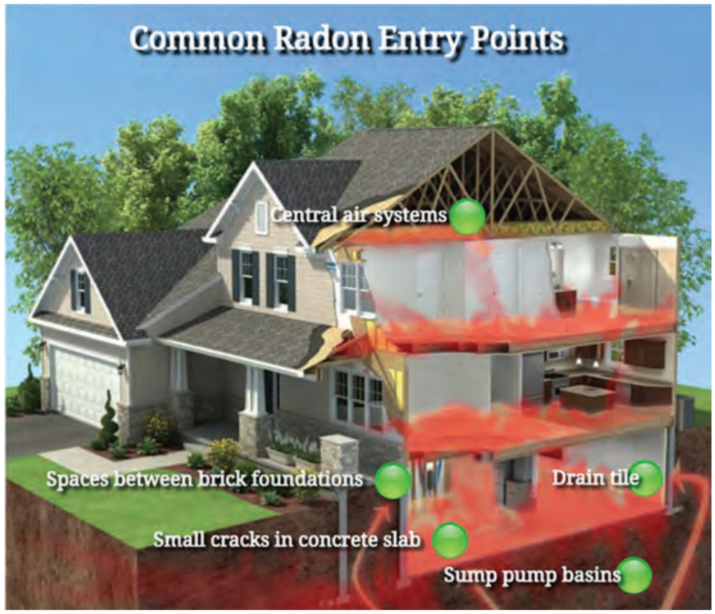
Plutonium (Pt) is named after Pluto (dwarf planet).

***Note that mercury is not necessarily named after the planet, though most students will likely list it. Both the planet and element are named after the god, Mercury (also known as Hermes), the fastest of the gods. The planet Mercury is the fastest to revolve around the sun. The element mercury is named from the Greek word, *hydrargrum* (hence the Hg symbol), which means liquid silver or quicksilver, for its mobility.**

Chemistry in Context: Radon Pollution

Elements and compounds are all around you. They are in your body, your home, your food, and literally everything you come into contact with every day. However, some elements are extremely harmful, and their placement on the periodic table predicts their behavior. Some elements are helpful, but there are some you can't see or smell that are harmful to your long-term health.

Take radon, for example, which is a heavy radioactive gas located in Group 18 (noble gases). Radon is colorless and has a density of 9.73 kg/L. The density of air is 1.23 kg/L, which means that radon will settle below air. Radon naturally occurs from the breakdown of uranium in the ground. In some areas, radon occurs at higher levels. In these areas, radon can enter through the foundations of homes and buildings and settle in the basements or lowest levels of the structures since it is a dense gas. Over time, exposure to radon gas can lead to lung cancer. When purchasing a home, often the home inspection period will include testing for radon gas with a test kit, which is available at nearly all home improvement stores. The presence of radon gas above the EPA action level of 4 pCi/L (picocuries per liter of air) requires a radon mitigation system to be installed to reduce radon levels in the breathing zone of the structure and thus reduce the risk of developing lung cancer.



(Image credit: radonmitigationspokane.com)

Inquiry Activity

Select one of the two following mini-labs:

- Option 1: Removing Color with Bleach: A Demonstration in Chemical Change
- Option 2: Oobleck: A Demonstration of the States of Matter

Option 1: Removing Color with Bleach: A Demonstration in Chemical Change

Safety alert: Perform this activity in a well-ventilated area, and wear gloves and safety glasses. Working with bleach will discolor clothing, so use caution.

Read the entire activity before you begin. Create a data table to record your observations.

Materials

- clear plastic cups
- water
- food coloring
- bleach
- dropper or small spoon

Directions

1. Put on safety glasses and gloves. Make sure you are in a well-ventilated area.
2. Add water to each cup until it is about half full.
3. Add two to three drops of food coloring to each cup. Mix the water with the food coloring.

4. Add one drop of bleach to each cup. Observe and write down what happens.
5. Add more drops, one at a time, to each cup. Note what happens and how many drops are added.
6. Test other colors and strengths of food coloring. Are there any colors that the bleach does not remove?
7. Take photos of your setup and results to share with your teacher.

Analysis

1. Look up the chemical formula of bleach. What do you think happened to the color? What do you think is reacting in this case?

   Bleach is sodium hypochlorite (NaOCl). Students should report that the bleach quickly removes all the food coloring. Students should have a general understanding that bleach releases chlorine. The chlorine combines with hydrogen in the water and releases oxygen. The oxygen combines with the color to form a colorless compound.

   Students should include photos of their setup and results for all activities and labs.

Option 2: Oobleck: A Demonstration of the States of Matter

Materials

- cornstarch
- water
- small bowl
- spoon

Directions

1. Add three heaping spoonfuls of cornstarch to the bowl and then add an equal amount of water.
2. Using the spoon, gently mix the cornstarch in the water.
3. Experiment with the material by gently pushing your hand into it and then quickly punching the mixture with your fist.
4. Take a handful of the mixture and roll it into a ball. Squeeze the mixture and release it several times.
3. Take photos of your oobleck and how it reacts to different treatment. (You might need someone to help you with this.)

Analysis

1. What happened when you played with the material?
2. Is this material a solid or a liquid? What factors seem to determine how the mixture behaves?

   Oobleck is a non-Newtonian fluid, meaning that it does not follow Newton's law of viscosity. If the cornstarch and water mixture is pressed (stressed), it behaves as a solid, but without any pressure, it will flow like a liquid.

Reading

Read chapter 2, Basic Building Materials (pages 26–54) in your textbook.

Viewing

Watch the following videos after reading chapter 2:

"The Copper Cycle—Acid, Deadly Gas and Blue Blood!" (Video length: 3:54)

www.youtube.com/watch?v=dyoVw-bjsU8

"The Law of Conservation of Mass—Todd Ramsey" (Video length: 4:36)

www.youtube.com/watch?v=2S6e11NBwiw&list=PLqOO1COTFHBtV_jPHcG_6ys0yN-_eANLJ&index=33&t=0s

"The Genius of Mendeleev's Periodic Table—Lou Serico" (Video length: 4:24)

www.youtube.com/watch?v=fPnwBITSmgU

Assignments

1. Describe the difference between an element and a compound.

   An element is a substance that cannot be broken down into simpler parts. A compound is a combination of elements in specific ratios.

2. Explain the law of conservation of mass. What does this mean for the mass of the reactants and the mass of the products in a chemical reaction?

   The law of conservation of mass states that mass cannot be gained or lost in a chemical reaction. Students might also say that mass cannot be created or destroyed. This means that the mass of the reactants must always equal the mass of the products in a chemical reaction.

3. Matter cannot be created or destroyed. Explain two long-term environmental impacts of this concept.

   Answers will vary. Possible answers include oxygen, carbon dioxide, water, and other important resources that cycle through the environment. Dangerous waste products that cannot be broken down into safer substances will always be present in the environment. The resources that are currently available on the planet are the only resources that will ever be available.

4. Would you expect carbon to be more similar to nitrogen, oxygen, or silicon? Explain your reasoning.

   Carbon is most similar to silicon because they are in the same column. So, although silicon is a metalloid and carbon is a nonmetal, they both form four bonds, which means they will behave most similar to each other over nitrogen or oxygen.

5. Look at the chart on page 35 in your textbook. Notice that some gases are composed of two atoms of the same element (for example, H_2). This is referred to as diatomic. Research the seven diatomic elements. Create a mnemonic (a phrase, song, poem, etc.) for remembering these elements. Feel free to illustrate your mnemonic as well.

   Students should create a unique mnemonic device that includes hydrogen (H), bromine (Br), oxygen (O), nitrogen (N), chlorine (Cl), iodine (I), and fluorine (F).

6. The formula for chlorine gas is not Cl, but Cl_2. What does this mean? Is NO a compound or an element? Is Cl_2 a compound or an element?

   The 2 on the Cl means that 2 chlorine atoms are bonded together. NO is a compound. Cl_2 is a diatomic element.

7. Research Antoine Lavoisier, Dmitri Mendeleev, Lothar Meyer, and Henry Mosley. Briefly explain how each scientist contributed to the development of the periodic table.

   Antoine Lavoisier (1743–1794) determined the composition of many compounds in his experiments to show how chemical compounds form. As more and more compounds were identified, he recognized that it was difficult to memorize all this information and began working to develop a systematic method for naming chemical compounds. Dmitri Mendeleev, in 1869, published the first periodic table of the elements. The same year, Lothar Meyer published a nearly identical table, but Mendeleev was given more credit since his was published first. Mendeleev was also able to predict elements not yet discovered based on his periodic table. Since protons were still unknown to science, this periodic table was arranged in order of increasing atomic mass. In 1913, Henry Moseley determined the atomic number for each discovered element and rearranged the periodic table according to increasing atomic number.

   Research sources should be provided.

8. Take a look at the periodic table on page 50 in your textbook.

   a. For metals, how does reactivity change as you move down a group of the periodic table? How does it change as you move across a period from left to right?

      For metals, reactivity increases down a group and decreases across the period. Francium would be the most reactive.

   b. For nonmetals, how does reactivity change as you move down a group of the periodic table? How does it change as you move across a period from left to right?

      For nonmetals, reactivity decreases down a group and increases across the period. Fluorine would be the most reactive.

9. Classify each of the following observations as chemical or physical and explain how you know.

   a. When sodium metal is dropped into water, a flame appears and the substance NaOH (sodium hydroxide) is formed.

      This is an example of a chemical change due to the release of heat.

b. When snow melts, a majority of the snow goes directly from the solid phase to the vapor phase in a process called sublimation.

This is an example of a physical change since only the state of the snow from solid to liquid form is changing.

c. The compound NOCl, which is a poisonous gas, decomposes into nitrogen monoxide (NO) and chlorine gas (Cl_2) at certain temperatures.

This is a chemical change since the arrangement of the atoms is changing to form new compounds.

10. Optional extra credit: Answer questions 10–14 on page 54.

Answers will vary slightly. Sample answers are provided.

10. a. The office supply items (tacks, rubber bands, etc.) have similar uses; they all hold things together.

b. Food items would be found together in a kitchen, office supplies might be in a desk, and other items found in a garage or shed.

c. The nail, washer, and paper clip are all made of metal. Rice, pea, and beans are natural grains.

d. The rubber band and Cheerio might be similar in color, as might the nail and washer.

11. Tack, rice, screw, rubber band, pea, Cheerio, waster, paper clip, black bean, macaroni, nail, binder clip, lima bean, noodle

12. Answers will vary. Possible answers include sorting items by weight or into categories such as beans/grains, processed food, metals, and office supplies.

13. Typical Weight of Household Items (in grams)

tack 0.21			rice 0.34
screw 0.45	rubber band 0.50	pea 0.61	Cheerio 0.74
washer 0.94	paper clip 1.09	black bean 1.52	macaroni 1.83
nail 2.31	binder clip 2.94	lima bean 3.24	noodle 3.88

14. Answers will vary. Students should add two additional household items to their chart from #13.

Activities

Complete the following activity.

- Activity: Color Coding the Periodic Table

(All activities are found in Oak Meadow's *Chemistry Matters Lab Manual*.)

Activity: Color Coding the Periodic Table

2. Fill in the blanks in the following sentences.
   a. Rows of elements in the periodic table are called **periods**.
   b. Columns of elements in the periodic table are called **groups** or **families**.
   c. Using page 44 of the textbook, identify the name of the following groups:
      - Group 1 (1A) **alkali metals**
      - Group 2 (2A) **alkaline earth metals**
      - Groups 3–12 (1B–8B) **transition metals**
      - Group 17 (7A) **halogens**
      - Group 18 (8A) **noble gases**

Further Study

(All Further Study activities are optional.)

Select any element of the periodic table. Research the element name and symbol, and provide a description. List the uses of the element. Describe how the element is mined or obtained. Create a poster, slide presentation, drawing, or painting about your element that summarizes this information. Creativity is encouraged! Cite your sources in AMA format.

Answers will vary. Review the student's information for accuracy and check the cited sources.

SHARE YOUR WORK

When you have completed this lesson, share the following work with your teacher:

- Answers to Before You Begin: Get to Know the Periodic Table
- Inquiry Activity:
  - Option 1: Removing Color with Bleach: A Demonstration in Chemical Change
  - Option 2: Oobleck: A Demonstration of the States of Matter
- Answers to lesson assignments
- Activity: Color Coding the Periodic Table
- Optional extra credit: Further Study

If you have any questions about the lesson assignments or how to share your work, let your teacher know.

Lesson 6

Speaking of Molecules

Learning Objectives

In this lesson, you will:

- Describe the meaning behind molecular formulas.
- Relate molecular structure to smell.
- Predict molecular structure based on bonding patterns in covalent compounds.
- Identify functional groups.
- Draw Lewis dot structures of molecules.
- Explain how single, double, or triple bonds form and compare their relative strengths.

Lesson Introduction

What does chemistry have to do with smell? Well, everything! Molecular structure is predictable and will result in a pattern that can be related to how certain things smell. Chemistry is all around you, even right under your nose!

You have one week to complete this lesson.

ASSIGNMENT CHECKLIST

- ☐ Complete Before You Begin: Get to Know the Periodic Table.
- ☐ Inquiry Activity: Practice Wafting
- ☐ Read chapter 6 in your textbook.
- ☐ View lesson videos.
- ☐ Complete the lesson assignments.
- ☐ Activity A: Single, Double, and Triple Bond Experiment for Kids
- ☐ Activity B: Connect the Dots: Lewis Dot Structure Tetris

Before You Begin: Get to Know the Periodic Table

Take another look at your periodic table. Can you identify the four elements named after locations within the United States?

Berkelium: University of California at Berkeley

Californium: California and University of California

Livermorium: Lawrence Livermore National Lab

Tennessine: Tennessee

Chemistry in Context: Natural Gas Additive

In this chapter, we will examine the smells of various molecules and how smells relate to chemical structure. Untreated natural gas is odorless and colorless. It took a major disaster to realize that using odor to detect leaks of natural gas is a quick and easy first line of defense.

On March 18, 1937, a natural gas leak at the London School in New London, Texas, went undetected and resulted in the deaths of over 295 students and teachers. The immediate response to the disaster was to mandate the addition of thiols (also known as mercaptan)—a strong-smelling class of chemicals with various odors ranging from garlic to rotten eggs—to natural gas to make leaks easily detectible. This practice was quickly adopted worldwide. Today, the most common smell additive is t-butyl-mercaptan, $(CH_3)_3CSH$.

Inquiry Activity

Practice Wafting

In this chapter, we will learn about how chemical structure is associated with smells.

Recall from your lab safety rules that it is never safe to smell chemicals or solutions directly. Instead, you use your hand to pull odor toward you while keeping chemicals at a safe distance, a method called wafting. Check out this funny video on how to take a sniff (and other lab safety rules):

> "Lab Rules—Dua Lipa 'New Rules' Parody" (Video length: 2:00)
>
> www.youtube.com/watch?v=BRDApYgvDqQ

Materials

Look for chemicals around your house that you know have strong or distinct odors. You will need four. Possibilities include:

- garlic
- essential oils
- detergents
- nail polish remover (acetone)
- mineral spirits
- motor oil

Procedure

1. Choose four different things with strong smells.
2. Make a chart to record the substances and describe the smells. Does the substance smell sweet, minty, earthy, fishy, etc.? Then look up the chemical formula of what you smelled, and add it to your chart.
3. Keep this chart handy as you read the chapter and see if your observations match what you learn.

This is an important skill for students to practice.

Reading

Read chapter 6, Speaking of Molecules (pages 154–191) in your textbook.

Viewing

Watch the following videos after reading chapter 6:

“Chemistry of Fragrances: Lessons in Chemistry” (Video length: 2:54)

www.youtube.com/watch?v=ndG-1kGD8k0

“Smells Lesson 3 Tutorial—HONC 1234 Rule” (Video length: 4:03)

www.youtube.com/watch?v=zdZAAM-uqEg

“Lewis Dot Structures” (Video length: 4:40)

www.youtube.com/watch?v=Sk7W2VgbhOg

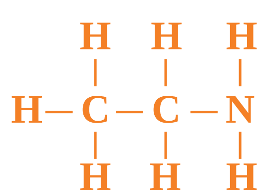
“How Do We Smell?—Rose Eveleth” (Video length: 4:19)

www.youtube.com/watch?v=snJnO6OpjCs

Assignments

1. For the molecule C_2H_7N:

   a. Draw the structural formula.



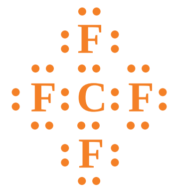
b. What rule did you use to determine how to draw the structural formula? How does it help you?

The HONC 1234 rule tells you how many bonds each atom forms.

c. Determine the functional group in the molecule. What smell do you predict for the molecule? Explain your reasoning.

The molecule smells fishy because it contains an amine functional group.

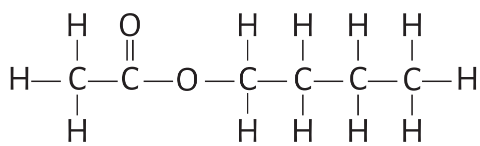
2. Draw the Lewis dot diagram for CF_4.



3. How can two molecules that have the same molecular formula have different smells?

The smell depends on how the atoms in the molecule are arranged. Atoms that have the same molecular formula could have different functional groups.

4. Identify the functional group in this molecule by name and predict the type of smell it will have.



Functional group: **ester**

Smell: **sweet**

Activities

Complete both of the following activities.

- Activity A: Single, Double, and Triple Bond Experiment for Kids
- Activity B: Connect the Dots: Lewis Dot Structure Tetris

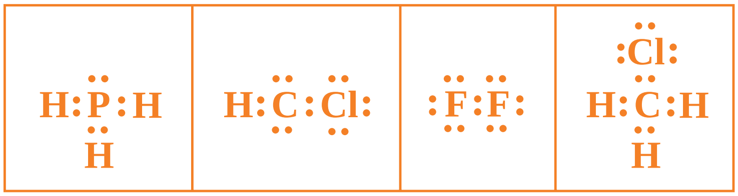
(All activities are found in Oak Meadow's *Chemistry Matters Lab Manual*.)

Activity A: Single, Double, and Triple Bond Experiment for Kids

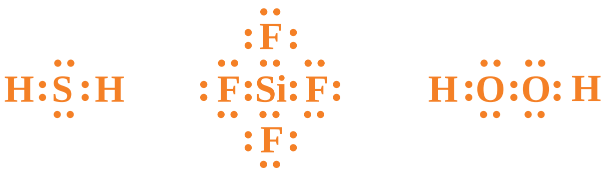
Students should provide a creative experimental design for elementary students that is age appropriate and includes information learned in this lesson.

Activity B: Connect the Dots: Lewis Dot Structure Tetris

1. PH_3 $HOCl$ F_2 CH_3Cl

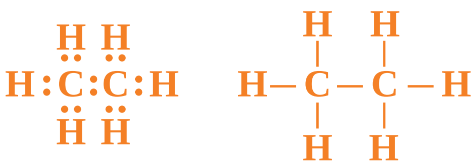


2.

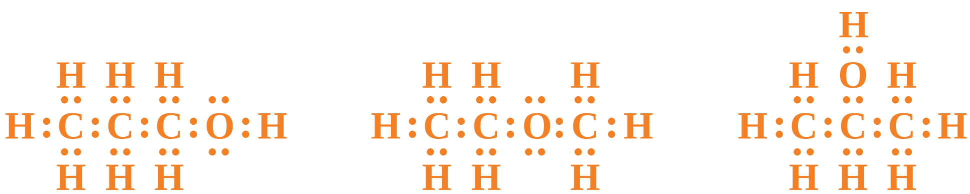


H_2S SIF_4 H_2O_2

3.



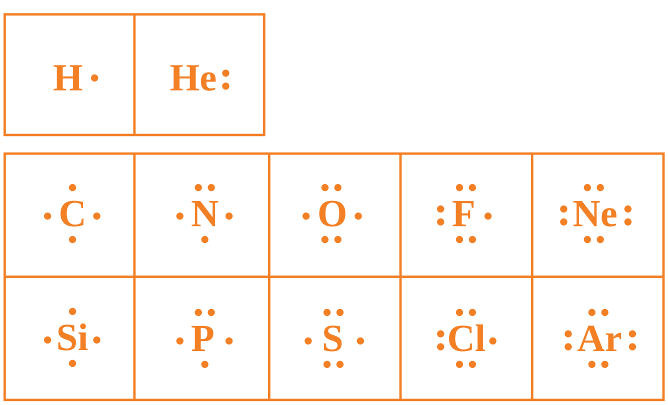
4.



The three isomers do not follow the HONC 1234 rule.

5. Answers will vary. Note that students may have trouble with puzzle pieces overlapping each other. This is to be expected sometimes since molecules are three-dimensional structures.

6.



7. The Lewis dot symbols in the two rows match. The number of valence electrons goes up from four to eight across each row while the number of bonds goes from four to zero and the number of unpaired electrons decreases.

8. **HONC 1234 is an easy way to remember that hydrogen, oxygen, nitrogen, and carbon atoms have one, two, three, and four valence electrons, respectively, that are capable of being shared with other atoms.**

9.

Further Study

Research the 1984 Bhopal disaster. Discuss the chemistry of the disaster, specifically how the putrid-smelling methyl isocyanate leak led to this major industrial disaster. Write a one-page essay or create a slide presentation. Cite your sources in AMA format.

SHARE YOUR WORK

When you have completed this lesson, share the following work with your teacher:

- Answers to Before You Begin: Get to Know the Periodic Table
- Inquiry Activity: Practice Wafting
- Answers to lesson assignments
- Activity A: Single, Double, and Triple Bond Experiment for Kids
- Activity B: Connect the Dots: Lewis Dot Structure Tetris
- Optional extra credit: Further Study

If you have any questions about the lesson assignments or how to share your work, let your teacher know.

Lesson 17

Toxic Cleanup

Learning Objectives

In this lesson, you will:

- Predict the solubility of the products of chemical reactions.
- Write complete and net ionic equations.
- Perform stoichiometry calculations based on balanced chemical equations.
- Apply mole ratios in stoichiometry calculations.
- Determine limiting and excess reactant.
- Determine percent and theoretical yield.

ASSIGNMENT CHECKLIST

- ☐ Complete Before You Begin: Get to Know the Periodic Table.
- ☐ Inquiry Activity: Exploding Sandwich Bag
- ☐ Read chapter 17, pages A-11–A-14 of Appendix A, and pages B-16–B-21 of Appendix B in your textbook.
- ☐ View lesson videos.
- ☐ Complete the lesson assignments.
- ☐ Experiment: Stoichiometry of a Precipitation Reaction

Lesson Introduction

As we wrap up Unit 4 in your textbook, our study of toxins concludes by combining solubility, reactions, molar mass, and mole conversions. In chemistry, calculations that deal with the amounts of substances in chemical reactions is referred to as stoichiometry. The word *stoichiometry* is derived from two Greek words: *stoicheion*, meaning "element," and *metron*, meaning "measure." In this lesson, you will determine the amount (mass, moles, and volume) of reactants and products in a chemical reaction.

You have one week to complete this lesson.

Before You Begin: Get to Know the Periodic Table

This week, we will examine the element silver. View these videos:

"Silver—Periodic Table of Videos" (Video length: 9:23)

www.youtube.com/watch?v=pPd5qAb4J50

"Silver Halides—Periodic Table of Videos" (Video length: 7:05)

www.youtube.com/watch?v=-ksJDdN7YQQ

Briefly comment on what you liked and/or learned from these videos on silver.

Chemistry in Context: Chelation Therapy

Since the lethal dose of heavy metals is often very low, accidental ingestion of iron, mercury, arsenic, and lead can be treated through chelation therapy. Chelation therapy works by introducing a chelator (binding agent), such as ethylenediaminetetraacetic acid (EDTA), dimercaptosuccinic acid, and dimercaprol, into the bloodstream. These compounds circulate in the blood and act as sponges to bind to metals that are then filtered through the kidneys and released in urine.

Inquiry Activity

Exploding Sandwich Bag

In this lesson, we will explore how one compound can limit the overall reaction and the amount of products that can form. This simple visual demonstration will help you understand this concept.

Materials

- safety glasses
- vinegar
- baking soda
- measuring cup
- warm water
- tissue
- ziplock sandwich bag

Procedure

Note: This is best done outside. If you can't go outside, do this in a large sink or bathtub as it will be messy!

1. Put on safety glasses.
2. Put about $\frac{1}{4}$ cup of warm water in the bag, and then add about $\frac{1}{2}$ cup of white vinegar.
3. Place 3 teaspoons of baking soda in the middle of the tissue and wrap it up so it is completely enclosed.

4. Working quickly, partially close the bag, leaving enough space to drop in the tissue with the baking soda. Put the tissue in the bag and quickly seal.
5. Quickly put the bag down and observe what happens.
6. Photograph or video your setup and results.

Analysis

1. Can you change the amount of baking soda to optimize the reaction and produce the best pop? Try it.

   Students should comment that adding more baking soda will make the reaction better. The optimal ratio is 12:1 baking soda to vinegar.

2. Keeping the amount of baking soda the same, change the amount of vinegar in the bag. Does this impact the reaction? Which seems to be limiting the amount of pop you produce, the vinegar or the baking soda?

   It depends on the setup. When there is an abundance of baking soda, the vinegar is limiting. When there is a lot of vinegar, the baking soda is limiting. Most students will likely suggest the vinegar is limiting.

3. Optional challenge: Scale the reaction up and do this with a larger bag. You may need to get a lot of supplies, but it would make for a memorable demonstration!

Reading

Read the following in your textbook:

- Chapter 17, Toxic Cleanup (pages 473–494)
- Appendix A: Ratios and Proportions (pages A-11–A-14)
- Appendix B: More Stoichiometry Practice (pages B-16–B-21)

The U.S. Environmental Protection Agency oversees hazardous waste cleanup. (Image credit: U.S. EPA)

Viewing

Watch the following videos after reading chapter 17:

"Stoichiometry—Chemistry for Massive Creatures: Crash Course Chemistry #6" (Video length: 12:46)

www.youtube.com/watch?v=UL1jmJaUkaQ

"Limiting Reagents and Percent Yield" (Video length: 4:34)

www.youtube.com/watch?v=dodsvTfqWNc

"Solution Chemistry and Net Ionic Equations" (Video length: 4:35)

www.youtube.com/watch?v=dvupBubB-HQ

"Mole Ratio Practice Problems" (Video length: 21:00)

www.youtube.com/watch?v=S6UQX7ZdkTg

Assignments

Use the solubility chart on page 475 in your textbook to answer the following questions. It may be helpful to review the mole road map in lesson 12 of this coursebook.

1. Predict the products of the following reaction and balance the equation.

   $TiCl_3(aq) + LiOH(aq) \rightarrow ?$

   $TiCl_3(aq) + 3LiOH(aq) \rightarrow Ti(OH)_3(s) + 3LiCl(aq)$

2. You combine a solution of potassium sulfate (K_2SO_4) with a solution of lead (II) nitrate ($Pb(NO_3)_2$) and observe that one of the products is a solid. Write the formula for the solid that is formed.

   $PbSO_4$

3. Write a balanced chemical equation describing what happens when you mix sodium phosphate and calcium nitrate. Include phases in your equation.

   $2Na_3PO_4(aq) + 3Ca(NO_3)_2(aq) \rightarrow Ca_3(PO_4)_2(s) + 6NaNO_3(aq)$

4. How many grams of magnesium do you need to produce 285 g of magnesium chloride? Show your work.

   $Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$

   molar mass $MgCl_2$ = 24.31 g + 2(35.45 g) = 95.2 g

   $$285\text{ g }MgCl_2 \times \frac{1\text{ mol}}{95.2\text{ g }MgCl_2} \times \frac{1\text{ mol Mg}}{1\text{ mol }MgCl_2} \times \frac{24.31\text{ g Mg}}{1\text{ mol}} = 72.8\text{ g Mg}$$

   Note that the middle conversion step is the mole ratio and uses the coefficients from the balanced chemical equation. In this case, it is a 1:1 ratio.

5. If you have 84.0 g N_2 and 12.0 g H_2 for the reaction below, what is the limiting reactant? Show your work.

   $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

   molar mass N_2 = 2(14.01) = 28.02 g

   molar mass H_2 = 2(1.008) = 2.016 g

   Using the mass of each compound given, predict how much of the other reactant could form:

$$84.0\text{ g }N_2 \times \frac{1\text{ mol}}{28.02\text{ g }N_2} \times \frac{3\text{ mol }H_2}{1\text{ mol }N_2} \times \frac{2.016\text{ g }H_2}{1\text{ mol}} = 18.1\text{ g }H_2$$

$$12.0\text{ g }H_2 \times \frac{1\text{ mol}}{2.016\text{ g }N_2} \times \frac{1\text{ mol }N_2}{3\text{ mol }H_2} \times \frac{28.02\text{ g }N_2}{1\text{ mol}} = 55.6\text{ g }N_2$$

   This means that 18.1 g of hydrogen would be required for 84 g of nitrogen. However, only 12.0 g of hydrogen is available based on what is given in the problem. Therefore, there will not be enough hydrogen, and hydrogen is the limiting reactant. You can check that by looking at the results for nitrogen. Starting with 12 g of hydrogen would require 55.6 grams of nitrogen and there are 84 grams available. This means there is enough nitrogen and nitrogen is therefore the excess reactant.

6. Lead ions can be removed from a water supply by adding sodium chloride. Balance the chemical equation for this reaction:

   $Pb(NO_3)_2(aq) + NaCl(aq) \rightarrow PbCl_2(s) + NaNO_3(aq)$

   $Pb(NO_3)_2(aq) + 2NaCl(aq) \rightarrow PbCl_2(s) + 2NaNO_3(aq)$

   a. How many moles of NaCl do you need for every mole of $Pb(NO_3)_2$ in the water?

      2 mol NaCl

   b. Describe how to determine whether 324 g of NaCl is enough to remove 662 g of dissolved $Pb(NO_3)_2$ from a water supply.

      Based on the equation, 2 mol NaCl are needed for every mole of $Pb(NO_2)_2$. Convert grams to moles (234 g of NaCl is equal to 4 mol and 662 g of $Pb(NO_3)_2$ is equal to 2 mol). Based on the equation, there is enough sodium chloride to react with all the lead(II) nitrate.

Experiments

Complete the following lab experiment.

- Stoichiometry of a Precipitation Reaction

The materials for this experiment are found in the HOL Chem 1 Kit.

Answer all questions. Provide data tables. Provide photos of your setup and results.

(All lab experiments are found in Oak Meadow's *Chemistry Matters Lab Manual*.)

Stoichiometry of a Precipitation Reaction

Learning Objectives

- Calculate the theoretical maximum amount of product produced in a precipitation reaction using stoichiometry.
- Perform a precipitation reaction and measure the precipitate to calculate percent yield.
- Explain differences between theoretical and actual yield in a controlled experiment.

Exercise 1: Stoichiometry of a Precipitation Reaction

Data Table 1: Stoichiometry Values

	Value
Initial: $CaCl_2 \cdot 2H_2O$ (g)	**1.50**
Initial: $CaCl_2 \cdot 2H_2O$ (mol)	**0.0102**
Initial: $CaCl_2$ (mol)	**0.0102**
Initial: Na_2CO_3 (mol)	**0.0103**
Initial: Na_2CO_3 (g)	**1.09**
Theoretical: $CaCO_3$ (g)	**1.02**
Mass of Filter Paper (g)	**1.09**
Mass of Filter Paper + $CaCO_3$ (g)	**2.12**
Actual: $CaCO_3$ (g)	**1.03**
% Yield:	**101%**

Exercise 1 Questions

1. A perfect percent yield would be 100%. Based on your results, describe your success in recovery of the calcium carbonate and suggest possible sources of error.

   The answers to the question of percent yield will differ by student. The answer obtained during testing at HOL was 88.2%. However, the suggested possible sources of error are the same, whether or not the yield was above or below 100%. Possible sources of error in calculating the percent yield include scale inaccuracies, salt sticking to the filter paper, incorrect math calculations, impurities in the chemicals, etc. However, students should note that the calcium chloride dihydrate may contain more water than it suggests in the empirical formula (as a result of humidity, for instance) and thus the 1.00 g of the calcium chloride dihydrate may contain a higher percentage of water than suggested, lowering the amount of pure calcium chloride in the 1.00 g.

2. What impact would adding twice as much Na_2CO_3 than required for stoichiometric quantities have on the quantity of product produced?

   As long as the minimum amount of Na_2CO_3 required to reach stoichiometric quantities is added to the reaction, the addition of more Na_2CO_3 would not impact the quantity of product produced. The $CaCl_2$ is the limiting reactant; thus, in this experiment, it is the addition of the calcium chloride that determines the quantity of precipitated product produced.

3. Determine the quantity (g) of pure $CaCl_2$ in 7.5 g of $CaCl_2 \cdot 9H_2O$. Show your work.

   $$\frac{x\text{ g}}{110.98\text{ g/mol }CaCl_2} = \frac{7.5\text{ g}}{273.12\text{ g/mol }CaCl_2} \cdot 9H_2O$$

   $x = 3.0$ **g** $CaCl_2$

   There are 3.0 g of pure $CaCl_2$ in 7.5 g of $CaCl_2 \cdot 9H_2O$.

4. Determine the quantity (g) of pure $MgSO_4$ in 2.4 g of $MgSO_4 \cdot 7H_2O$. Show your work.

   $$\frac{x\text{ g}}{120.37\text{ g/mol }MgSO_4} = \frac{2.4\text{ g}}{246.48\text{ g/mol }MgSO_4} \cdot 7H_2O$$

   $x = 1.2$ **g** $MgSO_4$

   There are 1.2 g of pure $MgSO_4$ in 2.4 g of $MgSO_4 \cdot 7H_2O$.

5. Conservation of mass was discussed in the Exploration section. Describe how conservation of mass (actual, not theoretical) could be checked in the experiment performed.

   To check the conservation of mass in the reaction performed in the exercise, the mass of sodium chloride produced from the reaction would need to be isolated from solution, measured, and added to the mass of precipitate formed. Next, the mass of the NaCl and $CaCO_3$ would be compared to the combined starting mass of $CaCl_2$ and Na_2CO_3.

Further Study

For extra credit, complete the Unit 4 review test on pages 496–498 in your textbook. This is especially recommended for those who need extra review of the material and those who plan to pursue a degree in science or medicine.

1. C	**5. C**	**9. A**	**13. D**	**17. C**
2. C	**6. C**	**10. A**	**14. D**	**18. B**
3. A	**7. B**	**11. C**	**15. A**	**19. B**
4. B	**8. B**	**12. B**	**16. B**	**20. A**

SHARE YOUR WORK

When you have completed this lesson, share the following work with your teacher:

- Answers to Before You Begin: Get to Know the Periodic Table
- Inquiry Activity: Exploding Sandwich Bag
- Answers to lesson assignments
- Experiment: Stoichiometry of a Precipitation Reaction
- Optional extra credit: Further Study (Unit 4 test)

If you have any questions about the lesson assignments or how to share your work, let your teacher know.

Lesson 23 Chemical Equilibrium

Learning Objectives

In this lesson, you will:

- Describe the mathematical relationship between reactants and products in an equilibrium mixture.
- Explain reversible and irreversible reactions and what happens in a chemical system at equilibrium.

Lesson Introduction

In the final unit for this semester, we will examine how chemical reactions can spontaneously reverse the formation of the products and maintain balance (equilibrium) with the reactants. Not all reactions are reversible; those reactions are said to go to completion, meaning that the end products are fully formed, and the reaction cannot reverse. An example of this is baking cookies: all the ingredients (reactants) go into making the cookies (product), and you can't separate back out the flour, sugar, butter, etc., once the reaction (mixing and baking) is completed. However, some reactions can be at equilibrium when the reactants become products at the same time that the products are turned back into reactants. The reaction goes forward and backward. When the amount of forward reaction matches the amount of backward reaction, the reaction is at equilibrium. This requires the system to be closed, meaning that no additional changes are taking place. (That will be explored in the next lesson.) Equilibrium reactions are occurring all around you every day and may be more common than you think. Let's explore!

You have one week to complete this lesson.

ASSIGNMENT CHECKLIST

- ☐ Complete Before You Begin: Get to Know the Periodic Table.
- ☐ Inquiry Activity

  Option 1: Humpty Dumpty (Reversible or Irreversible Change)

  Option 2: Cabbage Juice Indicator
- ☐ Read chapter 23 in your textbook.
- ☐ View lesson videos.
- ☐ Complete the lesson assignments.
- ☐ Experiment: Using Buffers

Before You Begin: Get to Know the Periodic Table

This week, we will examine the element plutonium. View these videos:

"Plutonium—Periodic Table of Videos" (Video length: 3:58)

www.youtube.com/watch?v=XLufmakbiU0&ab_channel=PeriodicVideos

"How to Make Plutonium—Periodic Table of Videos" (Video length: 11:53)

www.youtube.com/watch?v=-sh5XZo5wRE

Briefly comment on what you liked and/or learned from this video on plutonium.

Chemistry in Context: Soil pH versus Flower Color

For some plants, the pH of the soil determines the color of the flowers. Hydrangeas, a small flowering shrub with large, round, clustered blooms, are one such example. The most common species (*Hydrangea macrophylla*, or French hydrangea) will grow in a variety of soil pH, but the pH of the soil is what determines what color the blooms will be. This species will bloom blue flowers in soil with a pH below 6 (acidic) or pink flowers in soil with a pH above 7. But it's not the pH itself that results in the change; rather the pH impacts the equilibrium of aluminum from the soil to the plant. The more acidic the soil, the more aluminum can move, which results in the blue blooms. Conversely, the more neutral or alkaline, the less aluminum is available to move to the plant, and the flowers become pink. So, the next time you see those beautiful hydrangea blossoms in someone's yard, you know a little something about the soil pH!

Hydrangea (Image credit: Marc Ryckaert)

Inquiry Activity

Select one of the following options.

- Option 1: Humpty Dumpty (Reversible or Irreversible Change)
- Option 2: Cabbage Juice Indicator

Option 1: Humpty Dumpty (Reversible or Irreversible Change)

One concept we will explore in this lesson is that of the reversible reaction. Let's begin exploring that concept by taking a look at reversible changes.

Read pages 614–615 in your textbook. Consider the classic children's rhyme about Humpty Dumpty, who is always pictured as an egg.

> Humpty Dumpty sat on a wall.
>
> Humpty Dumpty had a great fall.
>
> All the king's horses and all the king's men
>
> Couldn't put Humpty together again.

Put your own spin on this verse by incorporating your understanding of reversible versus irreversible reactions or processes. Write and illustrate your own version of the story of Humpty Dumpty as told through the eyes of a chemist.

Answers will vary. In this creative assignment, students will illustrate their existing knowledge on reversible versus irreversible changes. In the illustration of Humpty Dumpty as a reversible reaction, Humpty would actually be put back together. In the illustration of Humpty Dumpty as an irreversible reaction, students should show Humpty as changed to a scrambled egg or something else that cannot be reversed back to the original state.

Option 2: Cabbage Juice Indicator

In previous science courses, you may have used red cabbage for pH experiments. This chapter begins with the discussion of the chemical compound in red cabbage that results in it being a useful pH indicator. So let's revisit a classic kitchen chemistry experiment!

Materials

- goggles
- 1 head of red cabbage
- knife
- cutting board
- blender or food processor
- hot water
- stainless steel pot
- strainer or cheesecloth
- glass bowl
- 10 or more small clear bowls, cups, glasses, jars, or test tubes or beakers (ideally about the same size)

- common household liquids or solutions to test such as vinegar, baking soda, juice, cream of tartar, washing powder, soaps, bleach, ammonia, limescale remover, etc.
- something to stir with (ideally stainless steel or glass)

Procedure

1. Cut up the head of red cabbage into small pieces and measure about 2 cups of red cabbage pieces into the food processor.
2. Add approximately 1 cup of hot water to the food processor and blend.
3. Stain the mixture over a bowl. The solution in the bowl is now your red cabbage extract and your pH indicator.
4. Wearing your eye goggles, place a small amount of the red cabbage indicator into each of your small bowls and add a small amount of your various household liquids or solutions. Test as many items as you can to try and create an array of colors that go from dark red, to blue, to light green.
5. Arrange your results in order of color. Create a chart to organize your results. Enrolled students provide photographs of your results.

Analysis:

Cabbage juice can be used as a pH indicator. The H*In* molecules are red and the In^- ions are blue.

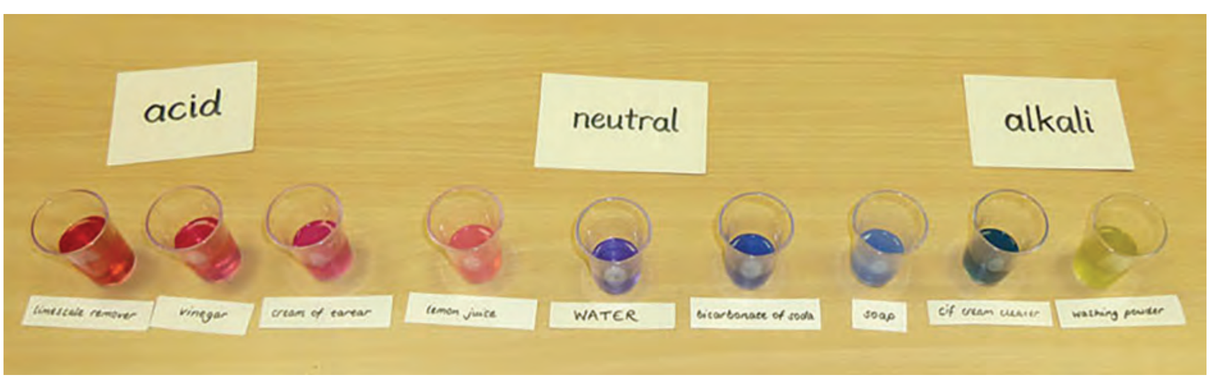
1. Complete the equation below to show what happens when H^+ is added slowly to a blue solution of the cabbage juice indicator, In^-.

   H + (aq) + In^-(aq) → **HIn(aq)**

2. Predict the color changes that you will observe as the reaction proceeds.

   Answers will vary. Most students have likely done a pH experiment like this in previous science courses; however, they will expand on this concept in the reading for this chapter so it's good to revisit.

   Students should be able to produce a spectrum of pH colors using the red cabbage juice and various items from around the house. Results should be in the range of red to blue to green. Here are some example results:



Reading

Read chapter 23, Chemical Equilibrium (pages 626–656) in your textbook.

Viewing

Watch the following videos after reading chapter 23:

"What Is Chemical Equilibrium?—George Zaidan and Charles Morton" (Video length: 3:24)

www.youtube.com/watch?v=dUMmoPdwBy4

"Equilibrium: Crash Course Chemistry #28" (Video length: 10:56)

www.youtube.com/watch?v=g5wNg_dKsYY

"Equilibrium" (Video length: 12:23)

www.youtube.com/watch?v=cHAjhM3y3ds

Assignments

1. Answer questions 1 and 2 on page 634 in your textbook.

   1. Dynamic equilibrium means that the rate of forward process and the rate of its reverse process are equal.

   2. Salt dissolves until the rate of the forward process of dissolving is equal to the rate of the reverse process of precipitation.

2. Write the general form of the equilibrium constant equation for a monoprotic weak acid (HA).

   $HA(aq) \leftrightharpoons H^+(aq) + A^-(aq)$

   $K = \frac{[H^+][A^-]}{[HA]}$

   $[H+] = \sqrt{K[HA]}$

3. Write the equilibrium constant for the decomposition of HCl(g) to H_2(g) and Cl_2(g). Hint: write the balanced chemical equation first.

   $2HCl(g) \leftrightharpoons H_2(g) + Cl_2(g)$

   $K = \frac{[H_2][Cl_2]}{[HCl]^2}$

4. Answer questions 2 and 4 on pages 654–655 in your textbook.

   2. a. The ammonium ion, NH_4^+, is a weak acid. The pH is below 7, but it is greater than 1. (pH = 1 is expected for a 0.10 M solution of a strong acid.)

   b. $NH_4^+(aq)$, $H^+(aq)$, $NH_3(aq)$, H_2O

c. **Adding ammonia to an acidic solution raises the pH due to the ammonia removing a hydrogen ion from solution to form the ammonium ion (NH_4^+).**

Alternatively, some students may also mention that ammonia reacts with the water to produce ammonium and hydroxide (a base).

$NH_3(aq) + H_2O(l) \rightarrow NH_4^+(aq) + OH^-(aq)$

4. a. **Since the K value given is quite small (1.0×10^{-4}), this would indicate that the reactants are favored.**

   b. **There will be less NO formed at a mountaintop since there is less oxygen at higher elevations and therefore oxygen would be limiting the amount of product that can be produced.**

   c. **No. Again, since the K value is very small and less than 1, the reactants are favored and therefore little NO would be expected to be formed.**

   d. **You would expect that a small K value would be associated with an endothermic reaction since the reaction is shifting to the right and favoring the reactants.**

Experiments

Complete the following experiment.

- Using Buffers

The materials for this experiment are found in the HOL Chem 2 Kit.

This lab builds on your understanding of pH from lesson 16. Review lesson 16 if you need a refresher before you begin.

(All lab experiments are found in Oak Meadow's *Chemistry Matters Lab Manual*.)

Using Buffers

Learning Objectives

- Create an acetic acid/sodium acetate buffer solution.
- Test a buffer solution by the addition of acids and bases.
- Evaluate buffering capacity in response to additions of concentrated and dilute acids and bases.

Exercise 1: Using Buffers

Data Table 1: Adding 0.1 M HCL from D1 to A1

Number of Drops	pH of Solution
0	5
2	5
4	5
6	5
8	5
10	5
12	5
14	5
16	5

Data Table 2: Adding 0.1 M NaOH from D6 to A6

Number of Drops	pH of Solution
0	5
2	5
4	5
6	5
8	5
10	5
12	5
14	5
16	5

Data Table 3: Adding 6 M HCl from Pipet into B1

Number of Drops	pH of Solution
0	5
2	5
4	4
6	1
8	1
10	1

Data Table 4: Adding 6 M NaOH from Pipet into B6

Number of Drops	pH of Solution
0	5
2	5
4	5
6	5
8	8
10	12

Part 3: Adding Dilute Concentrations of Acid and Base to Distilled Water

Data Table 5: Adding 0.1 M HCl from D1 to C1

Number of Drops	pH of Solution
0	7
2	5
4	4
6	3
8	3
10	2

Data Table 6: Adding 0.1 M NaOH from D6 to C6

Number of Drops	pH of Solution
0	7
2	8
4	10
6	12
8	12
10	12

Exercise 1 Questions

1. Describe the purpose of a buffer.

   The purpose of a buffer is to minimize the change in pH when an acid or a base is added to the solution.

2. Write the chemical equations for the neutralization reactions that occurred when HCl and NaOH were added to the buffer solution.

   $CH_3COO^-(aq) + H_3O^+(l) \rightarrow CH_3COOH(aq) + H_2O(l)$

   $CH_3COOH(aq) + OH^-(aq) \rightarrow CH_3COO^-(aq) + H_2O(l)$

3. How do the results in Data Tables 1 and 2 support the role of a buffer?

   Buffers are solutions that resist pH changes when small quantities of an acid or base are added to them. The fact that the pH of the solution did not change when either a dilute acid or dilute base were added support the idea that the acetic acid/acetate system behaves as a buffer.

4. Describe the buffer capacity of the acetic acid buffer solution in relation to the addition of both concentrated and dilute acids and bases. Reference the results in Data Tables 1–4 in your answer.

   The buffer capacity of the solution was effective for large additions of dilute acids and bases but was quickly exceeded when concentrated acids and bases were added. The acetic acid buffer solution was able to maintain pH with the addition of 16 drops of dilute acid and base, as recorded in Data Tables 1 and 2. However, adding concentrated acid and base exceeded the buffering capacity of the solution after only 2 drops, as recorded in Data Tables 3 and 4.

5. Did distilled water act as a buffer in this experiment? Use your data to support your answer.

   The data in Tables 5 and 6 clearly show that water does not behave as a buffer. Small additions of both dilute acids and bases resulted in a pH change in the solution.

6. An acetic acid buffer solution is required to have a pH of 5.27. You have a solution that contains 0.01 mol of acetic acid. What molarity of sodium acetate will you need to add to the solution? The pK_a of acetic acid is 4.74. Show calculations in your answer.

   $pH = pKa + \log \frac{[A^-]}{[HA]}$

   $5.27 = 4.74 + \log\left(\frac{x}{0.01}\right)$

   $\log\left(\frac{x}{0.01}\right) = 0.53$

   $\frac{x}{0.01} = 3.39$

   x = 0.03 mol of sodium acetate required

Further Study

Research the equilibrium of carbon dioxide in the oceans. How has this balance changed in recent years, and why? Does the change in carbon dioxide make the water more acidic or more basic? Provide the equation for the dissociation of calcium carbonate in water. Provide the K (equilibrium expression) for the reaction. How does increasing the acidity of the ocean affect the concentration of carbonate? Which oceanic ecosystems are highly sensitive to these changes? Create a poster, report, or slide presentation. Cite your sources in AMA format.

SHARE YOUR WORK

When you have completed this lesson, share the following work with your teacher:

- Answers to Before You Begin: Get to Know the Periodic Table
- Inquiry Activity: Option 1: Humpty Dumpty (Reversible or Irreversible Change) or Option 2: Cabbage Juice Indicator
- Answers to lesson assignments
- Experiment: Using Buffers
- Optional extra credit: Further Study

If you have any questions about the lesson assignments or how to share your work, let your teacher know.

Appendix

Materials List

The following materials are required to complete the activities and experiments in this course (although some activities and experiments are optional) and will need to be provided by the student. In most cases, these are common household items. Please plan in advance so you have these materials on hand when they are needed.

Inquiry Activities are found in the *Chemistry Matters* coursebook.

Activities and Experiments are found in the *Chemistry Matters Lab Manual*.

Students should supply gloves for each activity.

Lesson	Project	Materials
1	Inquiry Activity Option 1: Does It Float? A Demonstration of Density	Ivory bar soap various other brands of bar soap various brands of regular and diet soda cans, unopened 1 orange 1 lemon 1 lime
1	Inquiry Activity Option 2: The Floating Egg	water 2 drinking glasses 4 Tbsp salt 2 eggs
1	Activity A: Measuring and Graphing	scale (HOL kit) scientific calculator graph paper (included in the lab manual appendix) ruler pencil cardboard or stock paper scissors
1	Experiment: Laboratory Techniques and Measurements	aluminum pie pan matches or lighter CD or DVD 4 dimes fork key pen or pencil 5 pennies plastic or glass cup 3 quarters metric ruler ice cubes water spoon gloves distilled water isopropyl (rubbing) alcohol

Lesson	Project	Materials
2	Inquiry Activity Option 1: Removing Color with Bleach: A Demonstration in Chemical Change	clear plastic cups water food coloring bleach dropper or small spoon
2	Inquiry Activity Option 2: Oobleck: A Demonstration of the States of Matter	cornstarch water small bowl spoon
2	Activity: Color Coding the Periodic Table	blank periodic table (included in the lab manual appendix) colored pencils
3	Inquiry Activity: Paper Atoms	white paper scissors
3	Activity A: Red Licorice Decay	red licorice graph paper (included in the lab manual appendix) plastic knife ruler cutting board or paper plate paper towels
3	Activity B: Atomic Theory Time Line	white paper colored pencils
4	Inquiry Activity: Metallic Cereal	fortified cereal (such as Total) ziplock bag water strong magnet
4	Activity: Formulas and Oxidations Numbers	scissors glue or tape ion models (included in the lab manual appendix)
5	Inquiry Activity: Make a Conductivity Tester	plastic fork 9 V battery tape wire stripper single strand wire small light bulb (not LED) various household solutions and objects
6	Inquiry Activity: Practice Wafting	4 household objects with strong smells, such as garlic, essential oils, detergents, nail polish remover (acetone), mineral spirits, or motor oil
6	Activity B: Connect the Dots: Lewis Dot Structure Tetris	scissors glue or tape white paper Lewis dot puzzle pieces (included in the lab manual appendix)

Lesson	Project	Materials
7	Inquiry Activity: Build Your Own Superball! (optional)	20 mL sodium silicate paper towels gloves safety glasses food coloring (optional) graduated cylinder cup 10 mL ethanol wooden splint or stir bar
7	Activity A: Candy Molecules (optional)	toothpicks gumdrops or similar candies
7	Activity B: Two's Company (optional)	toothpicks gumdrops or similar candies ruler
7	Experiment: Molecular Modeling and Lewis Structures	camera pen or pencil white paper
8	Inquiry Activity: Magic Wand and Water	sink with running water small plastic object or balloon
9	Inquiry Activity: Mirror, Mirror on the Wall: Creating Mirror Images	small pocket or tabletop mirror
9	Activity A: Mirror Image Molecules	If not using molecular model kit in lab kit, then you will need: colored Styrofoam balls or other objects toothpicks
9	Activity B: Receptor Site Model	various building materials such as clay, plaster, sand, Play-Doh, candies, etc.
10	Inquiry Activity: Big Soapy Puffs	Ivory bar soap microwave microwavable bowl or large plate knife
10	Activity A: Measuring Local Rainfall	rain gauge or clean containers of various sizes thermometer
11	Inquiry Activity Option 1: Cloud in a Bottle	clean, dry 2-liter plastic soda bottle with the label removed matches warm water
11	Inquiry Activity Option 2: Balloon Volume and Temperature Changes	balloon freezer
11	Activity A: Boyle's Law	50 mL plastic syringe with cap bathroom scale graph paper (included in the lab manual appendix)

Lesson	Project	Materials
11	Activity B: Air Pressure Demonstrations	**Demo 1: Submerged Paper** white paper 2 cups (1 small and 1 large) water **Demo 2: Balloon in a Bottle** large bottle with a narrow neck deflated balloon **Demo 3: Crushing Soda Cans** empty soda can boiling water oven mitt or gloves apron **Demo 4: Suctioned Paper** cup water index card
11	Experiment: Properties of Gases (optional)	aluminum pie pan matches or lighter toothpicks hydrogen peroxide paper towels water baking soda dish soap metal spoon scissors permanent marker white paper 20 mL white vinegar
12	Inquiry Activity: Make Avogadro's Mole	stretchy fabric felt needle and thread straight pins glue material for stuffing scissors mole pattern (included in the appendix) decorations of your choosing
12	Activity B: Determine Volume of Air in One Breath	2-liter plastic soda bottle with cap sink or large container water 3 ft of flexible tubing drinking straw pen or marker 250 mL or 500 mL graduated cylinder (HOL kit)

Lesson	Project	Materials
13	Inquiry Activity: Stepping Through Paper	index card ruler scissors
14	Inquiry Activity: Sugared Up!	various sodas, sports drinks, or other beverages that contain sugar scale (HOL kit) small dishes spoon sugar
14	Activity: Weighing as a Means of Counting	spoon scale (HOL kit) samples of water, salt, and sugar
14	Experiment: The Mole Concept: Chemical Formula of a Hydrate	aluminum pie pan matches
14	Experiment: Colligative Properties and Molar Mass Determination	distilled water glass bowl 2 oz light corn syrup paper towels 2 small rubber bands scissors measuring spoon, $\frac{1}{2}$ tsp plastic cup crushed ice water stopwatch or timer table salt
15	Inquiry Activity: Making Solutions	6 clear cups water food coloring measuring spoons and cups
15	Activity: Molarity of Sweet Tea	water powdered ice tea mix (or powdered lemonade mix) pipette scale (HOL kit) spoon tape graduated cylinder 4 small glass jars or cups
15	Experiment: Laboratory Techniques and Measurements (optional)	distilled water scissors plastic or glass cup white paper white granulated sugar gloves

Lesson	Project	Materials
16	Inquiry Activity: Acidic Foods	various fruits and vegetables knife plate or cutting board baking soda
16	Experiment: Titration for Acetic Acid in Vinegar	distilled water dish soap scissors paper towels white paper tap water 5–6 heavy books 20 mL distilled white vinegar
16	Experiment: Antacid Analysis and Titration (optional)	distilled water dish soap metal spoon scissors paper towels white paper tap water 5–6 heavy books
16	Experiment: pH of Common Materials (optional)	cutting board heat-safe bowl measuring cup microwave or teakettle oven mitt scissors plate or tray red cabbage, 1 cup ruler sharp knife water spoon distilled water dish 9 liquid household items (e.g., cleaning products, coffee, lemon juice, milk, orange juice, rainwater, shampoo, soda, soap, vinegar) scissors paper towels
17	Inquiry Activity: Exploding Sandwich Bag	safety glasses vinegar baking soda measuring cup warm water tissue ziplock sandwich bag

Lesson	Project	Materials
17	Experiment: Stoichiometry of a Precipitation Reaction	distilled water dish soap scissors paper towels white paper tap water
18	Inquiry Activity: Burning Rubber	rubber band
18	Experiment: Heat versus Temperature	cup or bowl ice thermometer
18	Experiment: Specific Heat of Aluminum	safety glasses (HOL kit) thermometer measuring cup Styrofoam cup pot water aluminum foil metal tongs electronic balance (HOL kit)
19	Inquiry Activity Option 1: Candle Trick	small candle matches or lighter
19	Inquiry Activity Option 2: Burning Money	safety glasses $1 bill rubbing alcohol plate metal tongs matches
19	Experiment: Caloric Content of Food	aluminum foil aluminum pie pan distilled water dish soap lighter (or matches and a candle) marshmallow, jumbo-size paper towels soda can, empty tap water tortilla chip walnut (or other nut if allergic to handling)
20	Inquiry Activity Option 1: Chemical Energy Explosion	safety glasses clear film canister with a plastic cap Alka-Seltzer tablet tap water hot glue gun

Lesson	Project	Materials
20	Inquiry Activity Option 2: Taco Sauce Penny Cleaner	several old, tarnished pennies nonmetal bowl or plate taco sauce vinegar salt paper towels
20	Experiment: Reaction Order and Rate Laws (optional)	distilled water dish soap permanent marker white paper tap water stopwatch or timer
21	Inquiry Activity: Making a Lemon Battery	lemon or other citrus fruit(s) penny or copper wire galvanized nail or paper clip alligator clips multimeter (HOL kit) small light or buzzer
21	Experiment: Electrochemical Cells and Cell Potentials	camera scissors paper towels
22	Inquiry Activity: Light Energy	flashlight white paper flour colored and colorless transparent plastic (such as storage lids) prism (optional)
22	Experiment: Quantitative Spectroscope and Visible Light	box cutter fluorescent light scissors pencil ruler clear tape or masking tape duct tape or electrical tape spectroscope grid template (included in the lab manual appendix) car headlight incandescent light streetlight colored pencils

Lesson	Project	Materials
23	Inquiry Activity Option 2: Cabbage Juice Indicator	safety glasses 1 head of red cabbage knife cutting board blender or food processor hot water stainless steel pot strainer or cheesecloth glass bowl 10 or more small clear containers of the same size common household liquids or solutions stirrer, stainless steel or glass
23	Experiment: Using Buffers	distilled water toothpicks dish soap scissors permanent marker paper towels tap water 120 mL white vinegar
24	Inquiry Activity Option 1: Temperature and Reaction Rates	tape 4 cups hot and cold water ice 4 Alka-Seltzer tablets stopwatch or timer
24	Inquiry Activity Option 2: Equilibrium Demonstration	2 large bowls or buckets marker water 2 large cups stopwatch or timer
24	Experiment: Le Chatelier's Principle	dish soap ice water 2 cups scissors paper towels tape

Lesson	Project	Materials
Semester 2 Project Options	Experiment 1: Elephant Toothpaste	plastic soda bottle, 1 liter hydrogen peroxide (12% solution, labeled 40-volume) dish soap food coloring dry yeast measuring spoons funnel construction paper markers
	Experiment 2: Density Column	large glass vase or jar honey corn syrup maple syrup whole milk dish soap water vegetable oil rubbing alcohol lamp oil 9 clear cups, glass or plastic baster food coloring bolt popcorn kernel die cherry tomato beads soda bottle cap Ping-Pong ball
	Experiment 3: FriXion Secret Message	FriXion pen regular ink pen white paper lighter or matches
	Experiment 4: Mentos and Soda Eruption!	Mentos 2-liter bottle of diet soda white paper baking soda
	Experiment 5: Freezing Point Depression	milk cream ice rock salt table salt

Alphabetical List of Materials

Alka-Seltzer tablets

alligator clips

aluminum foil

aluminum pie pans

apron

Baking soda

balloons

bar soaps

baster

bathroom scale

battery, AA

beads

bleach

bolt

books, heavy

bottle with a narrow neck

bowl or plate, nonmetal

bowl, small

box cutter

building materials such as clay, plaster, sand, Play-Doh, candies, etc.

Camera

candle

car headlight

cardboard or stock paper

CD or DVD

cherry tomato

clear cups, glass or plastic

clear film canister with a plastic cap

colored Styrofoam balls or other objects

colored and colorless transparent plastic (such as storage lids)

colored pencils

construction paper

corn syrup

cornstarch

cream

crushed ice

cutting board

Die

diet soda, 2-liter bottle

dimes

dish soap

dishes, small

distilled water

distilled white vinegar

drinking straw

dropper or small spoon

dry yeast

duct tape or electrical tape

Eggs

ethanol

Fabric, stretchy
felt
flashlight
flexible tubing
flour
fluorescent light
food coloring
fork
fortified cereal (such as Total)
FriXion pen
fruits and vegetables
funnel

Galvanized nail or paper clip
glass bowl
glass jars or cups
glass vase or jar
gloves
glue
graduated cylinder
gumdrops or similar candies

Heat-safe bowl
honey
hot glue gun
hydrogen peroxide (12% solution, labeled 40-volume)

Ice cubes
incandescent light
index cards
Ivory bar soap

Key
knife

Lamp oil
lemon or other citrus fruit(s)
light bulb, small
light corn syrup (Karo or similar brand)
lighter
lime

Magnet, strong
maple syrup
markers
marshmallow, jumbo-size
masking tape
matches
material for stuffing
measuring spoons and cups
Mentos
metal spoon
metal tongs
microwavable bowl or large plate
microwave or teakettle
milk
mirror, small pocket or tabletop

Needle and thread

Orange
oven mitt

Paper towels
pen or pencil

pennies, tarnished

penny or copper wire

permanent markers

Ping-Pong ball

pipette

plastic cup

plastic fork

plastic knife

plastic soda bottle, 1 liter

plastic soda bottle with cap, 2 liter

plastic syringe with cap

plate or tray

popcorn kernel

pot

powdered ice tea mix (or powdered lemonade mix)

prism

Quarters

Rain gauge or clean containers of various sizes

red cabbage

red licorice

rock salt

rubber bands

rubbing alcohol

ruler

Safety glasses

salt

scientific calculator

scissors

single strand wire

sink or large container

soda bottle cap

soda cans, empty

soda cans, unopened

sodas, sports drinks, or other beverages that contain sugar

sodium silicate

spoon

stopwatch or timer

straight pins

streetlight

Styrofoam cup

sugar

Taco sauce

tape

thermometer

tissue

toothpicks

tortilla chip

Vegetable oil

vinegar

Walnut (or other nut if allergic to handling)

white paper

white vinegar

wire stripper

wooden splint or stir bar

Ziplock bags