Chemistry Matters

Teacher Manual

Oak Meadow

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Introduction

This teacher manual 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.

Course Materials

This course utilizes the following materials:

- Oak Meadow's *Chemistry Matters* 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, 2018), 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 the student coursebook for a full list of materials.

A complete materials list for this course is found in the appendix of the student coursebook. In addition, students will need to provide the following:

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

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 of the student coursebook 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
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

Lesson	Topics	Time to Complete
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 manual, answers are seen in **orange**. You will find all assignments, activities, and experiments listed, but the student coursebook and lab manual contain the full instructions and additional information. For the full content of the course, please refer to the student coursebook and 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 manual 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 of the student coursebook. 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 coursebook 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.

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.

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 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 pages xx–xxi in your textbook (the two pages 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.

ASSIGNMENT SUMMARY

- ☐ 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-8–A-11, and A-14–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

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 42–43 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. See the student coursebook for details. These topics can also be used for additional learning, discussion, research, and optional extra credit.

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

See the student coursebook for the materials list and directions for each inquiry activity. 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

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

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 2–19)
- Appendix A, pages A-0–A-1, SI Units of Measure section
- Appendix A, pages A-8–A-11, Graphing section
- Appendix A, pages A-14–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 6 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 = **5.213×103**

   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. $2 \times 10^3 =$ **2,000**

j. $2.331 \times 10^5 =$ **233,100**

k. $9.51 \times 10^{22} =$ **95,100,000,000,000,000,000,000**

l. $5 \times 10^{-3} =$ **0.005**

m. $7.6278 \times 10^{-5} =$ **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 can review examples of this in Appendix A in your textbook.

   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, and 6 on page 21 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

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.

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.

Activity A: Measuring and Graphing

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*.

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 manual 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.

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

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

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

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?

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

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

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

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

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 of the student coursebook 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.

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),**

ASSIGNMENT SUMMARY

- ☐ 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

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.

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.

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

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 22–49) 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 32 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 46 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.

Activities

Complete the following activity.

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.

Before You Begin: Get to Know the Periodic Table

Take another look at your periodic table. Can you figure out which five elements were named for places in the United States?

Americium: America

Berkelium: University of California at Berkeley

Californium: California and University of California

Livermorium: Lawrence Livermore National Lab

Tennessine: Tennessee

ASSIGNMENT SUMMARY

- ☐ 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

Inquiry Activity

Practice Wafting

This is an important skill for students to practice.

Reading

Read chapter 6, Speaking of Molecules (pages 146–183) 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)

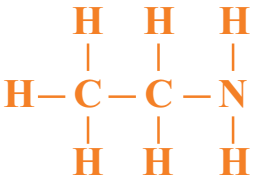
www.youtube.com/watch?v=Sk7W2VgbhOg

"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.



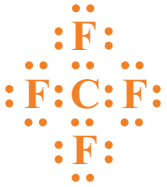
   b. What rule did you use to determine how to draw the structural formula? How does it help you?

      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.

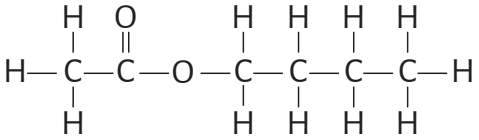
2. Draw the Lewis dot diagram for CF_4.



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.

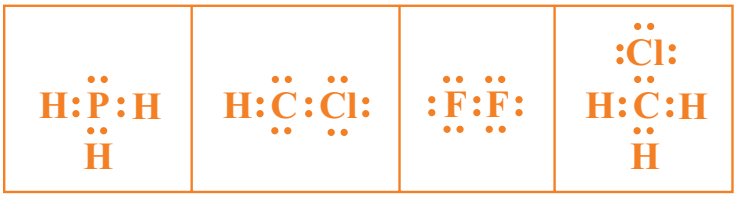
(All activities are found in Oak Meadow's *Chemistry Matters Lab Manual*.)

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.

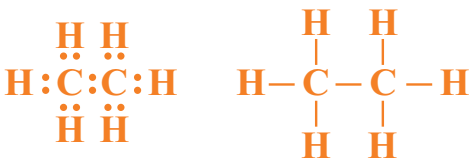
Activity B: Connect the Dots: Lewis Dot Structure Tetris

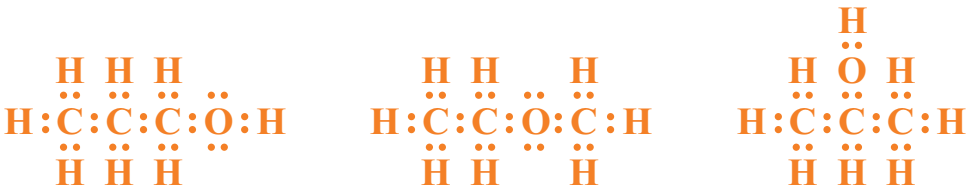
1. PH_3 $HOCl$ F_2 CH_3Cl



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.

H·	He:

·C·	·N·	·O·	:F·	:Ne:
·Si·	·P·	·S·	:Cl·	:Ar:

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.

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.

ASSIGNMENT SUMMARY

- ☐ 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-17–B-22 of Appendix B in your textbook.
- ☐ View lesson videos.
- ☐ Complete the lesson assignments.
- ☐ Experiment: Stoichiometry of a Precipitation Reaction

Inquiry Activity

Exploding Sandwich Bag

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 428–476)
- Appendix A: Ratios and Proportions (pages A-11–A-14)
- Appendix B: More Stoichiometry Practice (pages B-17–B-22)

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 459 in your textbook to answer the following questions.

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

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

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

2. You combine a solution of K_2SO_4 with a solution of $Pb(NO_3)_2$ and observe that a solid is formed. Write the formula of the solid.

   $PbSO_4$

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.

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

   1 mol $MgCl_2$ = 24.31 g + 2(35.45g) = 95.2 g

   Moles of $MgCl_2 = \frac{285\ g}{95.2\ g/mol} = 2.99$ mol

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.

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

   1 mol N_2 = 28.02 g

   1 mol H_2 = 2.016 g

   Moles of $N_2 = \frac{84.0\ g}{28.02\ g/mol} = 3.00$ mol

   Moles of $H_2 = \frac{12.0\ g}{2.016\ g/mol} = 5.95$ mol

   The mole ratio of N_2 to H_2 is 1:3, so there will be N_2 left over after all the H_2 is used up. The limiting reactant is H_2.

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.

Experiment

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.

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

   $$x = 3.0\text{ g } CaCl_2$$

   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.

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

   $$x = 1.2\text{ g } MgSO_4$$

   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 477–480 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.

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.

Inquiry Activity

Humpty Dumpty (Reversible or Irreversible Change)

Write and illustrate your own version of the story of Humpty Dumpty as told through the eyes of a chemist.

ASSIGNMENT SUMMARY

- ☐ Complete Before You Begin: Get to Know the Periodic Table.
- ☐ Inquiry Activity: Humpty Dumpty (Reversible or Irreversible Change)
- ☐ Read chapter 23 in your textbook.
- ☐ View lesson videos.
- ☐ Complete the lesson assignments.
- ☐ Experiment: Using Buffers

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.

Reading

Read chapter 23, Chemical Equilibrium (pages 609–638) 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 624 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.

   $2HCl(g) \leftrightharpoons H_1(g) + Cl_1(g)$

   $K = \frac{[H_1][Cl_1]}{[HCl]^2}$

4. Answer questions 2 and 4 on pages 637–638 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. $K = \frac{[H^+][NH_3]}{[NH_4^+]} = 1.8 \times 10^{25}$

   d. 2.5

   e. Because, in solution, NH_3 combines with H^+ to make more NH_4^+. When you add ammonia, NH_3, the hydrogen ion concentration decreases because NH_3 combines with H^+ to make NH_4.

   4. a. $K = \frac{[NH_3]^2}{[N_2][H_2]^3}$

   b. K = 12.5

   c. both

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.

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

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

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.

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

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

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

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

   $$x = 0.03 \text{ mol of sodium acetate required}$$

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.

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