Teacher Guide Sample (Prepublication Pages—for Review Purposes Only)

Experience Chemistry

TEACHER GUIDE

SAVVAS

Experience Chemistry

Experience It!

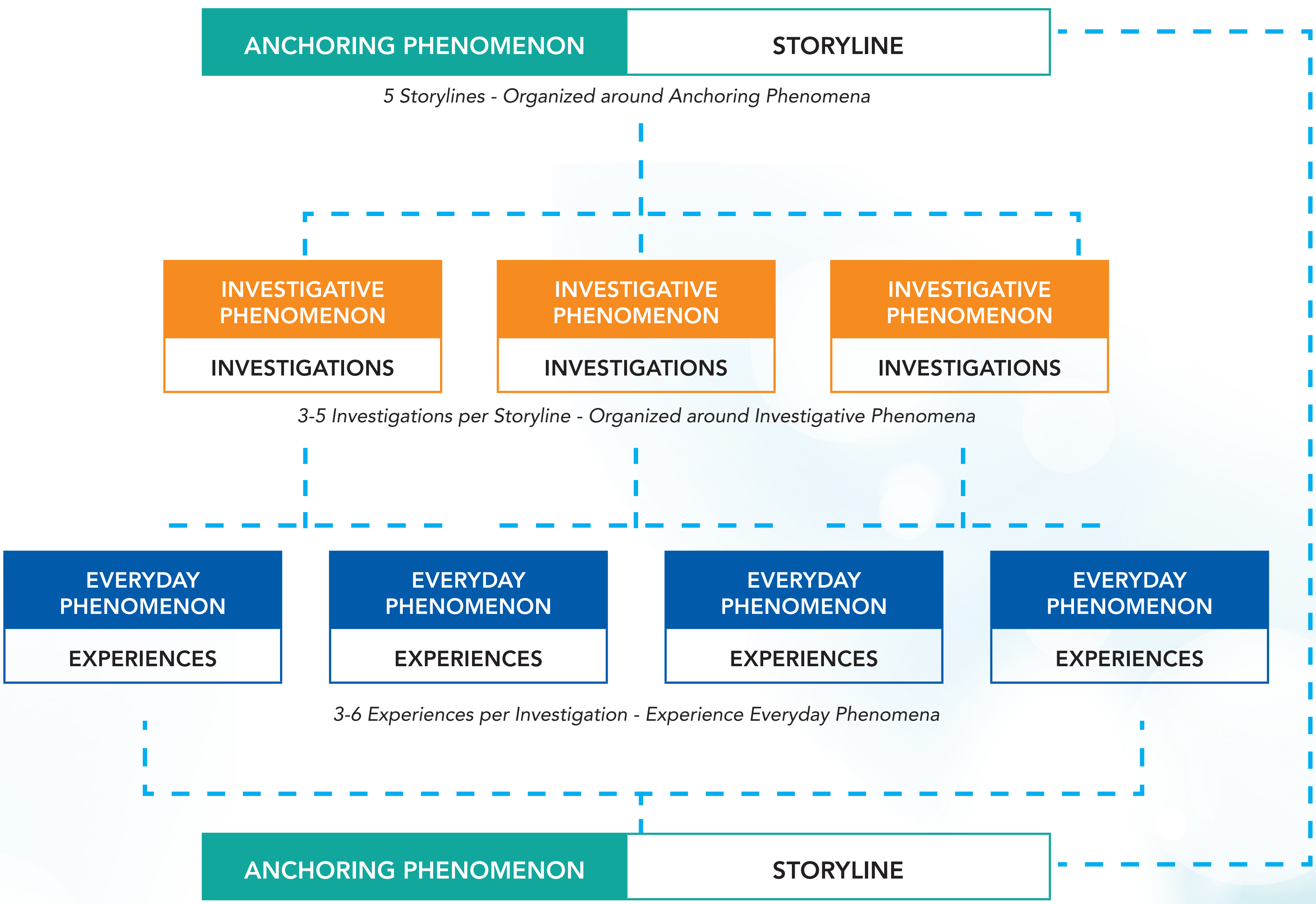
IT'S THE SCIENCE OF DOING!

Welcome to "phenomenal" science! Check out this sample of the Teacher Guide to see all the tools we provide so you can facilitate an active learning classroom.

See more at **Savvas.com/ExperienceChemistry.**

Look How It's Organized

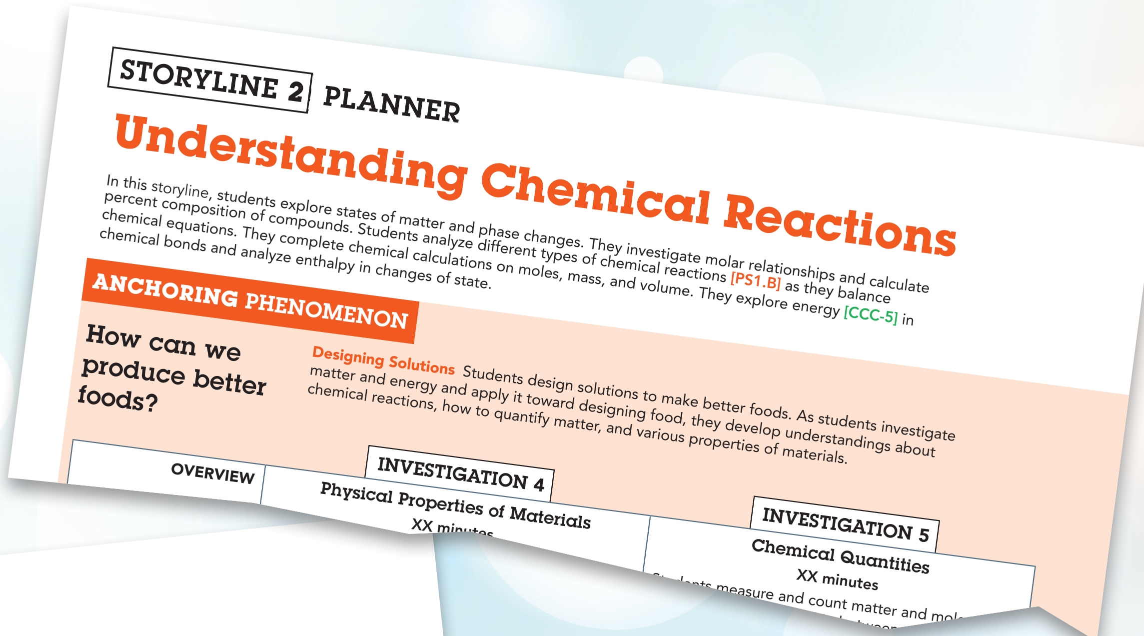
Experience Chemistry is organized around five Storylines. Each Storyline launches an overarching Anchoring Phenomena that connects the topics in the Investigations. Thought-provoking phenomena engage students in evidence-based practices where student learning is based on ***doing*** science.



Start Your Experience Here

1. Storyline Planner

This high-level overview of the Storyline puts the spotlight on phenomena. Review the Anchoring Phenomenon and see connections in the Investigative Phenomena. Easily locate instructional minutes, standards, and assessments. Feel confident in your knowledge of the upcoming content.


STORYLINE 2 PLANNER

Understanding Chemical Reactions

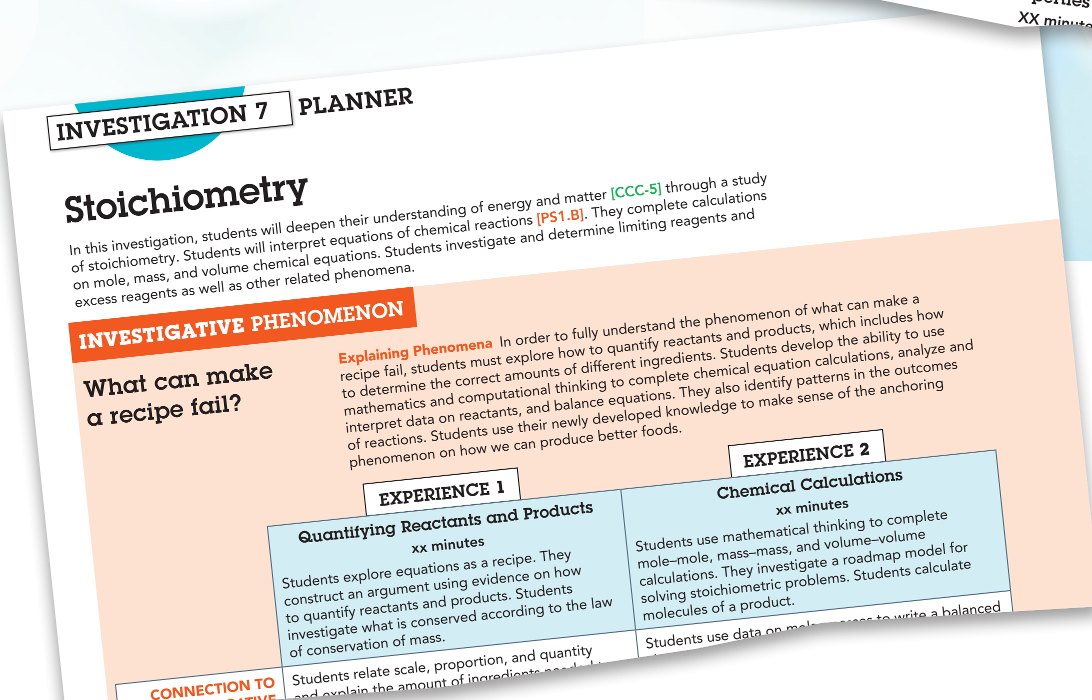
In this storyline, students explore states of matter and phase changes. They investigate molar relationships and calculate percent composition of compounds. Students analyze different types of chemical reactions [PS1.B] as they balance chemical equations. They complete chemical calculations on moles, mass, and volume. They explore energy [CCC-5] in chemical bonds and analyze enthalpy in changes of state.

ANCHORING PHENOMENON

How can we produce better foods?

Designing Solutions Students design solutions to make better foods. As students investigate matter and energy and apply it toward designing food, they develop understandings about chemical reactions, how to quantify matter, and various properties of materials.

OVERVIEW	INVESTIGATION 4	INVESTIGATION 5
	Physical Properties of Materials XX minutes	Chemical Quantities XX minutes Students measure and count matter and mol...


INVESTIGATION 7 PLANNER

Stoichiometry

In this investigation, students will deepen their understanding of energy and matter [CCC-5] through a study of stoichiometry. Students will interpret equations of chemical reactions [PS1.B]. They complete calculations on mole, mass, and volume chemical equations. Students investigate and determine limiting reagents and excess reagents as well as other related phenomena.

INVESTIGATIVE PHENOMENON

What can make a recipe fail?

Explaining Phenomena In order to fully understand the phenomenon of what can make a recipe fail, students must explore how to quantify reactants and products, which includes how to determine the correct amounts of different ingredients. Students develop the ability to use mathematics and computational thinking to complete chemical equation calculations, analyze and interpret data on reactants, and balance equations. They also identify patterns in the outcomes of reactions. Students use their newly developed knowledge to make sense of the anchoring phenomenon on how we can produce better foods.

	EXPERIENCE 1	EXPERIENCE 2
	Quantifying Reactants and Products xx minutes Students explore equations as a recipe. They construct an argument using evidence on how to quantify reactants and products. Students investigate what is conserved according to the law of conservation of mass.	Chemical Calculations xx minutes Students use mathematical thinking to complete mole–mole, mass–mass, and volume–volume calculations. They investigate a roadmap model for solving stoichiometric problems. Students calculate molecules of a product.
CONNECTION TO THE INVESTIGATIVE ...	Students relate scale, proportion, and quantity and explain the amount of ingredients needed ...	Students use data on mole... to write a balanced ...

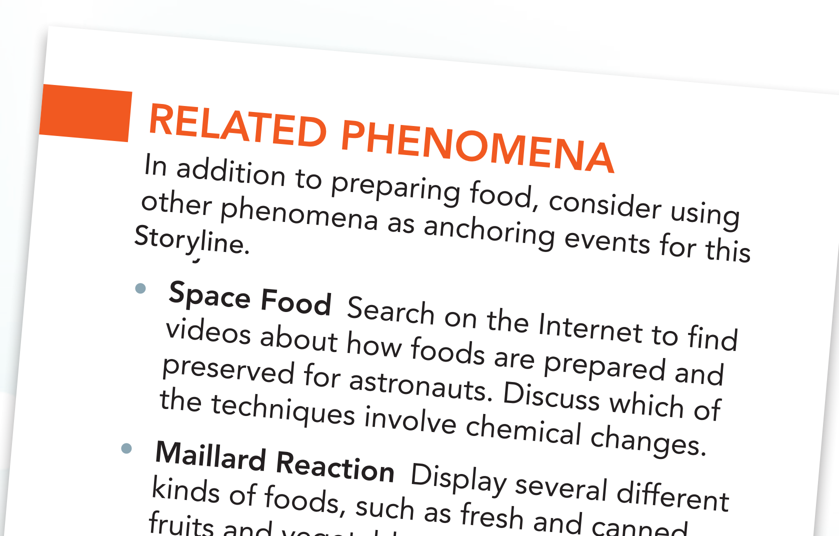
2. Investigation Planner

Dive deeper with the Investigation Planner. A clear 5E organization allows you to select which experiences best fit your schedule. Connections to the Investigative Phenomenon keep you on track.

GOT MORE TIME?

3. Got More Time?

Every activity with a green plus sign is a "Got More Time?" Experience. Personalize and enhance your instructional plan by assigning these activities, as time allows.

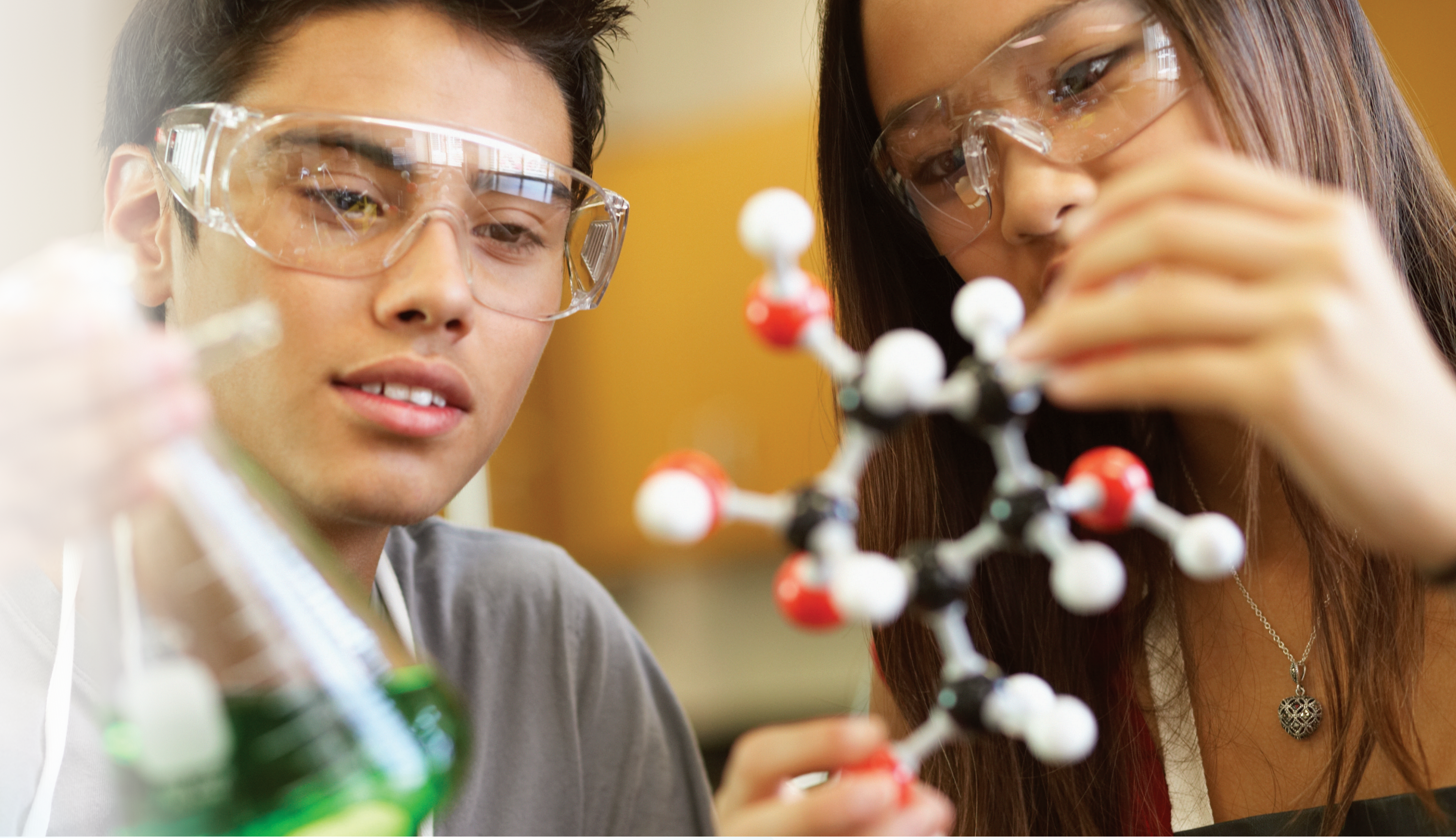

RELATED PHENOMENA

In addition to preparing food, consider using other phenomena as anchoring events for this Storyline.

- **Space Food** Search on the Internet to find videos about how foods are prepared and preserved for astronauts. Discuss which of the techniques involve chemical changes.
- **Maillard Reaction** Display several different kinds of foods, such as fresh and canned fruits and vegetables...

4. Related Phenomena

When you encounter the Anchoring and Investigative Phenomena in your planning pages, look to the margins for the Related Phenomena feature. Here you can choose from a list of suggestions to modify your course.



FLINN SCIENTIFIC

Revisit
INVESTIGATIVE PHENOMENON 15

Support Reflection Students can complete the reflection prompt, where they will unpack and make sense of the Investigative Phenomenon, based on practices and understandings that have been reinforced over the course of the experience. The Revisit Investigative Phenomenon prompt is on page 13 of the Experience Notebook and in the eText.

5. Flinn Scientific Labs

Every Flinn Scientific Inquiry Lab has 4 versions — Open-ended, Guided, Shortened, and Advanced — to give you the options you need to reach all of your students.

7. Revisit the Phenomena

Every time your students Revisit the Phenomena on their sense-making journey, turn to the Teacher Guide for tools to support their reflections.

CONNECT TO CAREERS

Purchasing Manager A purchasing manager is in charge of buying chemical reactants. Reactants are sold by weight or volume, but

ASSESS ON THE SPOT

Tell student groups that their task at the end of this experience is to come up with a question that will stump you. Divide students into small groups or use the groups that were working together on the Engineering Design Challenge. Explain that each group must come up with a question and the answer to it, and then pose their question to you. Then have groups ask their questions. You may

6. Margin Notes

Prompts such as Differentiation, Address Misconceptions, Career Connections, and Classroom Modifications provide point-of-use support where you need it most.

8. Assessment

From Assess-on-the-Spot formative prompts to Performance-Based Assessments that measure mastery of the standards, the Teacher Guide includes resources to integrate and extend these measurements of student understanding. Look for assessments by their red labeling.

The Flinn Lab Experience

Experience Chemistry takes inquiry to a higher level. An exclusive partnership with Flinn Scientific, the leading classroom lab solutions provider, embeds engaging Flinn Scientific Labs into *Experience Chemistry* lessons. Experience *It!*

Hands-On Labs

Labs focus on real-world phenomena. Customize your lessons with four versions of every lab: including **Open-Ended**, **Guided**, **Shortened**, and **Advanced**.

Lab Videos

Teachers and students experience everything in a clear and effortless way. Videos provide background, demos, and summaries of key concepts and practices.

Lab Kits

Simplify lab set-up and solution preparation with time-saving lab kits aligned to the Performance-Based Assessments.

Engineering Design Challenges

Students design, test, and evaluate solutions. Focusing on defining and solving problems strengthens science and engineering skills.

Performance Tasks

Students demonstrate mastery of performance expectations by applying their understanding to a new situation in a Performance-Based Assessment at the end of every Investigation.

Virtual Reality

Immerse your students in 360° simulations that bring chemistry to life.

Meet the Authors

Christopher Moore, Ph.D., is an associate professor of physics education at the University of Nebraska Omaha. Dr. Moore has worked as a physical science teacher, a professional materials scientist, and a scholar and consultant on science education. His educational research focuses on the development of scientific reasoning and expert-like science practice abilities, with an emphasis on practices that cross disciplines. He is the author of *Creating Scientists: Teaching and Assessing Practices for NGSS* as well as *Teaching Science Thinking*.

Michael E. Wysession, Ph.D., is professor of Earth and Planetary Sciences, Washington University, St. Louis, Missouri. An author of more than 100 science publications, Dr. Wysession was awarded the prestigious National Science Foundation Presidential Faculty Fellowship and Packard Foundation Fellowship for his research in geophysics. He is an expert in geoscience literacy and serves as Chair of the Earth Science Literacy Initiative. Dr. Wysession is part of The Great Courses® video series and was a NGSS writing team leader.

Consulting Author

Bryn Lutes, Ph.D., received her doctorate in Chemistry from Washington University in St. Louis where she currently teaches General Chemistry, Advanced Inorganic Chemistry Laboratory, and Descriptive Inorganic Chemistry. She continuously works to incorporate in-class group activities and flipped-classroom instruction to facilitate student learning. She also has developed problems for, and coordinates the implementation of, a peer-led team learning (PLTL) program.

Program Contents

Student Experiences

VOLUME 1

STORYLINE 1:
Atoms, Elements, and Molecules

Investigation 1:
Atomic Structure

EXPERIENCE

1.1	The Particle Nature of Matter
1.2	Modeling Atoms
1.3	Atomic Emission Spectra and the Bohr Model
1.4	Modern Atomic Theory
1.5	Electrons in Atoms

Investigation 2:
The Periodic Table

EXPERIENCE

2.1	The Periodic Table: An Overview
2.2	The Periodic Table and Atomic Structure
2.3	Periodic Trends

Investigation 3:
Chemical Bonding

EXPERIENCE

3.1	Ionic Bonds
3.2	Metallic Bonds
3.3	Covalent Bonds
3.4	Intermolecular Attractions
3.5	Names and Formulas of Compounds

STORYLINE 2:
Understanding Chemical Reactions

Investigation 4:
Physical Properties of Materials

EXPERIENCE

4.1	States of Matter
4.2	Modeling Phase Changes
4.3	Comparing Ionic and Molecular Compounds
4.4	Comparing Metals and Nonmetals
4.5	Water and Aqueous Systems
4.6	Properties of Solutions

Investigation 5:
Chemical Quantities

EXPERIENCE

5.1	The Mole Concept
5.2	Molar Relationships
5.3	Percent Composition and Empirical Formula
5.4	Concentrations of Solutions

Investigation 6:
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EXPERIENCE

6.1	Modeling Chemical Reactions
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Investigation 7:
Stoichiometry

EXPERIENCE

7.1	Quantifying Reactants and Products
7.2	Chemical Calculations
7.3	Limiting Reagent and Percent Yield

Investigation 8:
Thermochemistry

EXPERIENCE

8.1	Energy in Chemical Bonds
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8.3	Heat in Changes of State

VOLUME 2

STORYLINE 3:
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9.1	Properties of Gases
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9.3	Ideal Gases
9.4	Gases in Earth's Atmosphere

Investigation 10: **Weather and Climate**

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- 10.1 Earth's Surface Systems
- 10.2 Water and Energy in the Atmosphere
- 10.3 Atmospheric System Feedback
- 10.4 Long-Term Climate Factors
- 10.5 Short-Term Climate Factors

Investigation 11: **Global Climate Change**

EXPERIENCE

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- 11.2 Evidence of Climate Change
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- 12.1 Rates of Reaction
- 12.2 The Progress of Chemical Reactions
- 12.3 Reversible Reactions and Equilibrium
- 12.4 Free Energy and Entropy

Investigation 13: **Acids-Base Equilibria**

EXPERIENCE

- 13.1 Acids, Bases, and Salts
- 13.2 Strong and Weak Acids and Bases
- 13.3 Reactions of Acids and Bases
- 13.4 Buffered Solutions

Investigation 14: **Ocean Acidification**

EXPERIENCE

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- 14.2 Earth's Ocean as a Carbon Sink
- 14.3 Oceans and Climate Change
- 14.4 Consequences of Ocean Acidification

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- 15.2 Modeling and Predicting Outcomes of Redox Reactions
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Investigation 16: **Organic Chemistry**

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- 16.1 Hydrocarbons
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Investigation 17: **Nuclear Processes**

EXPERIENCE

- 17.1 Radioactivity and Half-Life
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- 17.3 Nuclear Technologies

Investigation 18: **Green Chemistry**

EXPERIENCE

- 18.1 Industrial Chemicals
- 18.2 Principles of Green Chemistry
- 18.3 Designing Sustainable Processes

Understanding Chemical Reactions

In this storyline, students explore states of matter and phase changes. They investigate molar relationships and calculate percent composition of compounds. Students analyze different types of chemical reactions [PS1.B] as they balance chemical equations. They complete chemical calculations on moles, mass, and volume. They explore energy [CCC-5] in chemical bonds and analyze enthalpy in changes of state.

ANCHORING PHENOMENON

How can we produce better foods?

Designing Solutions Students design solutions to make better foods. As students investigate matter and energy and apply it toward designing food, they develop understandings about chemical reactions, how to quantify matter, and various properties of materials.

	INVESTIGATION 4	INVESTIGATION 5
OVERVIEW	**Physical Properties of Materials** **XX minutes** Students discover the structure and attractive forces of solids, liquids, and gases. They compare ionic and molecular compounds and metals and nonmetals. They investigate bonding and surface tension of water in aqueous systems.	**Chemical Quantities** **XX minutes** Students measure and count matter and moles and investigate the relationship between moles, mass, and volume. Students calculate percent composition and determine empirical and molecular formulas of compounds. They practice calculating molarity.
INVESTIGATIVE PHENOMENON	How do we design materials for a specific function?	Why do we quantify matter in different ways?
CONNECTION TO THE ANCHORING PHENOMENON	Students identify properties of different states of matter and use this to better design materials and foods.	Students use their knowledge of molar and mass relationships to explain how to quantify different types of matter and to apply these calculations to designing better foods.
EXPERIENCES*	1 **States of Matter** (XX min), pp. 200–212 2 **Modeling Phase Changes** (XX min), pp. 213–223 3 **Comparing Ionic and Molecular Compounds** (XX min), pp. 224–228 4 **Comparing Metals and Nonmetals** (XX min), pp. 229–235 5 **Water and Aqueous Systems** (XX min), pp. 236–248 6 **Properties of Solutions** (XX min), pp. 249–258	1 **The Mole Concept** (XX min), pp. 262–270 2 **Molar Relationships** (XX min), pp. 271–279 3 **Percent Composition and Empirical Formula** (XX min), pp. 280–290 4 **Concentrations of Solutions** (XX min), pp. 291–300
INVESTIGATION EVALUATION	**Performance-Based Assessment** Road Deicers **3-D Assessment** Physical Properties of Materials **Experience Notebook** Performance-Based Assessment, p. 259; **Appendix C** Problem Bank, p. XX	**Performance-Based Assessment** Chemical Quantities **3-D Assessment** Chemical Quantities **Experience Notebook** Performance-Based Assessment, p. 301; **Appendix C** Problem Bank, p. XX
NEXT GENERATION SCIENCE STANDARDS	HS-PS1-3, HS-PS2-4, HS-PS3-5	HS-PS1-7

* Pacing includes both Experience Notebook coverage and core instructional activities.

GOT MORE TIME? Personalize and enhance your instructional plan by assigning the activities with the got-more-time icon, as time allows.

Anchoring Phenomenon Video Food as Fuel

Experience Notebook Inquiry Launch, p. 196

Problem-Based Learning Experience The Chemistry of Cooking and the Properties of Baked Goods

INVESTIGATION 6	INVESTIGATION 7	INVESTIGATION 8
Chemical Reactions **XX minutes** Students explore types of chemical reactions and balance their equations. They predict the products of reactions.	**Stoichiometry** **XX minutes** Students quantify and interpret balanced equations. They complete molar calculations. They explore limiting and excess reagents and determine percent and theoretical yields.	**Thermochemistry** **XX minutes** Students explore enthalpy of a system and the need for activation energy. They apply Hess's Law while calculating enthalpy of fusion, solidification, vaporization, and condensation.
How is energy obtained from chemical reactions?	What can make a recipe fail?	Why do you get hot when you exercise?
Students explain how energy is obtained from chemical reactions using knowledge of the different types of reactions. They apply this knowledge while explaining chemical reactions in food and how to design better foods.	Students apply knowledge of limiting and excess reagents to explain why a recipe fails. They also explain limiting and excess ingredients in foods.	Students use knowledge of system enthalpy to explain why we get hot when we exercise. They further apply this to enthalpy of foods and how to change it.
1 **Modeling Chemical Reactions** (XX min), pp. 304–314 2 **Predicting Outcomes of Chemical Reactions** (XX min), pp. 315–328 3 **Reactions in Aqueous Solutions** (XX min), pp. 329–336	1 **Quantifying Reactants and Products** (XX min), pp. 340–346 2 **Chemical Calculations** (XX min), pp. 347–356 3 **Limiting Reagent and Percent Yield** (XX min), pp. 357–366	1 **Energy in Chemical Bonds** (XX min), pp. 370–378 2 **Enthalpies of Formation and Reaction** (XX min), pp. 379–386 3 **Enthalpy in Changes of State** (XX min), pp. 387–394
Performance-Based Assessment Identify Evidence of Chemical Reactions **3-D Assessment** Chemical Reactions **Experience Notebook** Performance-Based Assessment, p. 337; **Appendix C** Problem Bank, p. XX	**Performance-Based Assessment** The Stoichiometry of Filling a Balloon **3-D Assessment** Stoichiometry **Experience Notebook** Performance-Based Assessment, p. 367; **Appendix C** Problem Bank, p. XX	**Performance-Based Assessment** Enthalpy of a Neutralization Reaction **3-D Assessment** Thermochemistry **Experience Notebook** Performance-Based Assessment, p. 395; **Revisit Anchoring Phenomenon**, p. 395; **Appendix C** Problem Bank, p. XX
HS-PS1-2, HS-PS1-4, HS-PS1-5, HS-PS1-7	HS-PS1-7	HS-PS1-4, HS-PS1-5, HS-PS1-7

STORYLINE

Problem-Based Learning Experience The Chemistry of Cooking and the Properties of Baked Goods

Benchmark 3-D Assessment Storyline 2

STORYLINE 2

Understanding Chemical Reactions

Teacher Background

The properties of any kind of matter, including the food we eat, can be explained in terms of its atoms and molecules and the attractions and repulsions of electric charges within and between them. Atoms are constantly in motion, and the motion varies depending on the substance they form and its state (solid, liquid, or gas). The motion of atoms and how they interact is affected by temperature and pressure.

Many substances react chemically with other substances to form new substances with different properties. All chemical reactions involve changes in bond energies. Some chemical reactions release energy and others require an energy input. Chemical reactions and energy transfers can be explained by the collision of molecules and the rearrangement of atoms. The conservation of mass and the chemical properties of the elements involved can be used to predict chemical reactions. Chemical processes and the properties of materials are the foundation of many biological and geophysical phenomena.

Points of Integration

In this Storyline, links are made across the domains of physical science, Earth and space science, and engineering design.

Earth and Space Science As you discuss modeling phase changes in Investigation 7, use the real-world example of the phases of water on Earth [ESS2.C]. Water can be found in the atmosphere as vapor, ice crystals, or precipitation; on land as liquid; and on mountains as snow and ice. Earth and the Earth's atmosphere act as a closed system where the energy and matter [CCC-5] are conserved. Remind students that this means that the same atoms that are in the atmosphere as water vapor will someday fall to the Earth as precipitation, freeze at the top of a mountain, melt, and flow down a river to the ocean.

Engineering Design As you are discussing alloys, students take part in the engineering design process when they are asked to think about designing a bicycle frame [ETS1.A] and to evaluate rope materials to determine which material will function best [ETS1.B] at the top of mountains.

ENCOUNTER

ANCHORING PHENOMENON

How can we produce better foods?

Every food we eat is a product of chemical reactions. Chemical reactions cause seeds to germinate, all plant parts to form, animals to grow and reproduce, and eggs to form. They determine how long foods remain fresh and how safe they are. The chemical reactions that take place in our foods determine what nutrients are in different foods and how long nutrients remain available in the foods. They are responsible for how our foods taste.

Food chemistry deals with how foods change when they are cooked or preserved and how we can enhance or prevent the changes from happening. Good chefs understand the chemistry behind the techniques they use to produce their own recipes. Make chemistry more relative to students by incorporating examples from foods or cooking techniques when discussing chemical reactions.

RELATED PHENOMENA

In addition to preparing food, consider using other phenomena as anchoring events for this Storyline.

- **Space Food** Search on the Internet to find videos about how foods are prepared and preserved for astronauts. Discuss which of the techniques involve chemical changes.
- **Maillard Reaction** Display several different kinds of foods, such as fresh and canned fruits and vegetables, a slice of bread, some cooked meat, and cheese. Ask students which foods are the result of chemical reactions.

Food as Fuel

Anchoring Phenomenon Video As students watch the Anchoring Phenomenon Video, ask them to record any questions they may have. Have them turn to a partner and discuss the video.

- **Ask** What is happening to the properties of the marshmallow? (The properties are changing; the marshmallow changes from white to black.)
- **Ask** Do you think the white marshmallow and the black marshmallow are the same material with the same chemical composition? (No, they are different materials with different chemical compositions.)
- **Ask** What happened to cause this change? (A chemical reaction [combustion] is producing a new substance.)

Students will revisit this phenomenon at the end of the Storyline to demonstrate their understanding of it.

Inquiry Launch

Experience Notebook Use the classroom discussion from the Anchoring Phenomenon Video activity to discuss the photo on pages 196 and 197. Have student pairs make a two-column chart with these titles for the two column heads: Chemical Change and Physical Change. Instruct students to list in each column as many examples of food changes taking place in the photo as they can. Have student pairs share their completed lists with the class. Then lead a discussion about the advantage for a chef of having knowledge of food chemistry.

- **Ask** Do you think an understanding of chemistry would help these chefs? Why or why not?
- **Ask** What types of information might a chef need to prepare a perfect meal?
- **Ask** What questions do you think a chef would need and want answered to properly prepare a meal?

The Chemistry of Cooking and the Properties of Baked Goods

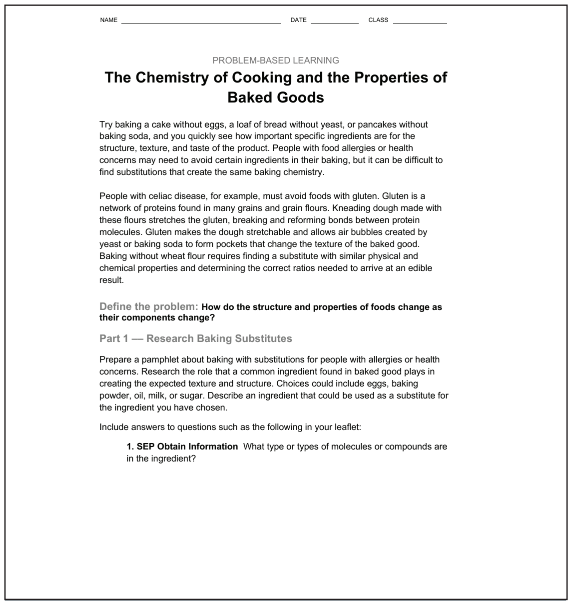
Problem-Based Learning Experience Students prepare a leaflet on baking with substitutions for people with allergies or health concerns. They choose a common ingredient found in baked goods, identify the chemical composition of the ingredient and the role the ingredient plays in the final product, and then research a possible substitute for the ingredient. In Part 2, They design and test a recipe using the substituted ingredient. In Part 3, students find the amount of kilocalories in each ingredient they used and calculate the number of kilocalories in a serving of the original recipe and their new recipe.

- **Safety** Before any food is brought into the classroom, check whether any students have allergies to any of the ingredients. Students that have food allergies should be excused from class that day. Prompt students to wear safety goggles and heat-resistant gloves when cooking food. Monitor students closely while handling objects that are hot. Remind students that they cannot eat or drink anything in the lab.
- You may wish to assign a specific ingredient to each group in Part 1 so that all ingredients are analyzed.
- Guide struggling students through the conversions and calculations in Parts 2 and 3.
- Provide students an alternative option to make their leaflet after they complete the other questions in Parts 1–3.
- After the activity, have groups present their leaflets to the class.

Anchoring Phenomenon Video

Experience Notebook, pp. 196–197

eTEXT



NAME ______ DATE ______ CLASS ______

PROBLEM-BASED LEARNING

The Chemistry of Cooking and the Properties of Baked Goods

Try baking a cake without eggs, a loaf of bread without yeast, or pancakes without baking soda, and you quickly see how important specific ingredients are for the structure, texture, and taste of the product. People with food allergies or health concerns may need to avoid certain ingredients in their baking, but it can be difficult to find substitutions that create the same baking chemistry.

People with celiac disease, for example, must avoid foods with gluten. Gluten is a network of proteins found in many grains and grain flours. Kneading dough made with these flours stretches the gluten, breaking and reforming bonds between protein molecules. Gluten makes the dough stretchable and allows air bubbles created by yeast or baking soda to form pockets that change the texture of the baked good. Baking without wheat flour requires finding a substitute with similar physical and chemical properties and determining the correct ratios needed to arrive at an edible result.

Define the problem: **How do the structure and properties of foods change as their components change?**

Part 1 — Research Baking Substitutes

Prepare a pamphlet about baking with substitutions for people with allergies or health concerns. Research the role that a common ingredient found in baked good plays in creating the expected texture and structure. Choices could include eggs, baking powder, oil, milk, or sugar. Describe an ingredient that could be used as a substitute for the ingredient you have chosen.

Include answers to questions such as the following in your leaflet:

1. **SEP Obtain Information** What type or types of molecules or compounds are in the ingredient?

PBL Experience Interactive Worksheet

INVESTIGATION 7 PLANNER

Stoichiometry

In this investigation, students will deepen their understanding of energy and matter [CCC-5] through a study of stoichiometry. Students will interpret equations of chemical reactions [PS1.B]. They complete calculations on mole, mass, and volume chemical equations. Students investigate and determine limiting reagents and excess reagents as well as other related phenomena.

INVESTIGATIVE PHENOMENON

What can make a recipe fail?

Explaining Phenomena In order to fully understand the phenomenon of what can make a recipe fail, students must explore how to quantify reactants and products, which includes how to determine the correct amounts of different ingredients. Students develop the ability to use mathematics and computational thinking to complete chemical equation calculations, analyze and interpret data on reactants, and balance equations. They also identify patterns in the outcomes of reactions. Students use their newly developed knowledge to make sense of the anchoring phenomenon on how we can produce better foods.

	EXPERIENCE 1	EXPERIENCE 2
	Quantifying Reactants and Products xx minutes Students explore equations as a recipe. They construct an argument using evidence on how to quantify reactants and products. Students investigate what is conserved according to the law of conservation of mass.	**Chemical Calculations** xx minutes Students use mathematical thinking to complete mole–mole, mass–mass, and volume–volume calculations. They investigate a roadmap model for solving stoichiometric problems. Students calculate molecules of a product.
CONNECTION TO THE INVESTIGATIVE PHENOMENON	Students relate scale, proportion, and quantity and explain the amount of ingredients needed to produce three loaves of bread and relate that to the phenomenon of what can make a recipe fail.	Students use data on molar masses to write a balanced chemical equation for making dough. They relate this to the phenomenon of what can make a recipe fail.
ENGAGE	**Teacher's Guide** Everyday Phenomenon The Equation for a Sandwich, p. 278	**Teacher's Guide** Everyday Phenomenon Counting a Year in Milliseconds, p. 285
EXPLORE	**Inquiry Lab** Identify Unknowns Through Stoichiometry **Analyzing Data** Proportional Relationships in Chemical Reactions	**Inquiry Lab** Determination of Reaction Output **Simulation** Understanding Stoichiometry
EXPLAIN	**Modeling** Put It Together **Experience Notebook,** pp. 340–346	**Modeling** Choose a Practical Unit **Animation** Stoichiometry Calculations **Experience Notebook,** pp. 347–356
ELABORATE	**Peer Review Rubric** Evaluate Put It Together **Writing About Science** Parts and the Whole	**Peer Review Rubric** Evaluate a Practical Unit **Writing About Science** A Scale That Reads Moles
EVALUATE	**Quiz** Quantifying Reactants and Products **Experience Notebook** Revisit Investigative Phenomenon, p. 346	**Quiz** Chemical Calculations **Experience Notebook** Revisit Investigative Phenomenon, p. 356

GOT MORE TIME? Personalize and enhance your instructional plan by assigning the activities with the got-more-time icon, as time allows.

Investigative Phenomenon Video When Recipes Go Wrong

Claim-Evidence-Reasoning Discuss the Investigative Phenomenon

Experience Notebook, p. 338

EXPERIENCE 3

Limiting Reagent and Percent Yield

xx minutes

Students compare limiting reagents to limiting ingredients of fish tacos. They analyze and interpret data on mass of products and reactants. They define problems and construct explanations on percent yield and then calculate percent yield.

Students identify theoretical yield of partial loaves of bread, percent yield, and they explain how much of each ingredient is remaining. They use this to refine explanations on what can make a recipe fail.

Teacher's Guide Everyday Phenomenon Stop the Burn, p. 291

Inquiry Lab Formation of Barium Iodate

Virtual Lab Limiting Reagent

Claim-Evidence-Reasoning A Measure of Success

Experience Notebook, pp. 357–366

Discussion Rubric Evaluate Error

Engineering Design Challenge Build a Film Canister Rocket

Quiz Limiting Reagent and Percent Yield

Experience Notebook Revisit Investigative Phenomenon, p. 366

Notes:

INVESTIGATION 7

Stoichiometry

Teacher Background

Investigation 7 investigates the calculation of quantities in chemical reactions. This investigation differs from others in that it is very abstract and, on the surface, may not seem to connect much to chemistry. Students often get caught up in the math of stoichiometry and lose sight of the reason it is necessary—because mass is neither created nor destroyed in a chemical reaction. Continually encourage students to think of what they are doing mathematically as accounting for mass on one side of the reaction or another. In addition, keep the Investigative Phenomenon, a recipe, in students' minds. Many of the analogies for stoichiometry involve everyday objects, which can help students grasp the math, but may not help students connect the math to chemistry.

Learning Progression

This investigation layers the concept of conservation of mass on top of many of the chemical ideas students have encountered thus far. As students progress through this investigation, they explore different factors that can make a recipe fail by applying mathematical and computational thinking [SEP-5] to consider the proportional relationships [CCC-3] between reactants and products in chemical reactions [PS1.B]. In Experience 1, students begin balancing equations as a way of conserving mass [CCC-5] in the system. In Experience 2, they begin using conversion factors to determine moles, mass, volume, and particles of a reactant or product. In Experience 3, they apply their calculations to determining limiting reactants and percent yield. In this experience, they use the concept of limiting reactant to design [ETS1.C] a rocket and determine the optimal amount of each reactant to launch it efficiently.

RELATED PHENOMENA

In addition to the use of recipes, consider using other phenomena to launch Investigation 7.

- **Hair Dye** Hair dye contains proportioned ingredients that are activated when they are mixed together. Ask students to predict what they think happens if the wrong proportions are mixed. The wrong proportions in the mixture could lead to the wrong shade.
- **Air Bag Challenge** Give students a plastic, sandwich-sized zipper bag, vinegar, and baking soda. Challenge them to inflate the bag with the maximum amount of CO_2 gas without breaking the bag. Keep the mass of the system less than 12 g.

TAKE IT LOCAL

Visit a local bakery and ask the bakers to explain the importance of proportions in baking. Note that most bakers use mass (grams) rather than volume (cups) when they bake, because it better allows for scaling the recipe and maintaining correct proportions. Discuss ingredients that have important chemical roles and that students may have worked with in the lab, such as baking soda, salt, and vinegar.

ENCOUNTER

INVESTIGATIVE PHENOMENON

What can make a recipe fail?

Introduce this investigation with the phenomenon of a recipe. For a recipe to be successful, ingredients must be added in the correct proportions to each other. If you know how much of one ingredient you have, you can determine how much you need of others using conversion factors (Experience 1). A balanced chemical equation is a type of recipe, and the act of balancing reactants and products accounts for conservation of mass. A balanced equation tells us how to calculate the amount of reactant needed or to predict the amount of product, using unit conversions and mole ratios (Experience 2). If the proportions of products are not exact, one reactant will run out before the other, thereby limiting the amount of product formed (Experience 3). In addition, all reactions in the real world involve error, which will usually result in a yield of less than 100%.

When Recipes Go Wrong

Investigative Phenomenon Video This short video helps show baking as a set of chemical reactions. For those reactions to produce a successful baked good, they must be added in correct proportion to each other. The same is true of any chemical reaction: reactants will react only in specific proportions to each other, and produce a product in proportion to the amount of reactants.

- Before students watch the video, ask them to describe times they have baked things using a recipe. **Ask:**
  a. What did the recipe look like? What kinds of measurements did it use?
  b. What do you think would have happened if you had added more or less of one of the ingredients?
  c. Have you ever baked something and forgotten one of the ingredients? What happened?
- After students view the video, **Ask:**
  a. When making cookies, what factors could lead to a bad batch of cookies?
  b. How do you think baking with a recipe is similar to a chemical reaction?
  c. Suppose a chemist must produce chemical C using this reaction: $A + B \rightarrow C$. What are some factors that might prevent the chemist from making as much chemical C as possible? Think on a molecular level.

Discuss the Phenomenon

Claim-Evidence-Reasoning Have students review the video to help in their understanding of the phenomenon they observed. To help build understanding of the phenomenon, brainstorm a list of questions about the observed phenomenon. Have students complete question 1 of the CER worksheet and start thinking about the evidence they need to answer their question.

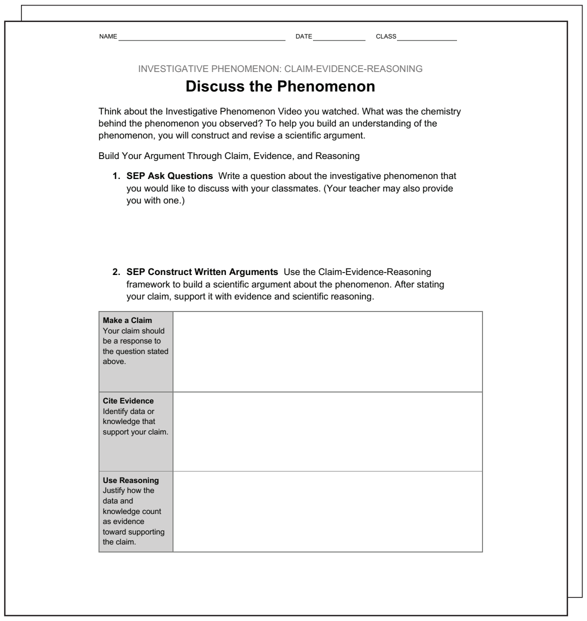
Remind students that their understanding of the phenomenon will be incomplete at this stage, but that they will revisit this activity as they learn more. Make sure to provide students with an opportunity to revisit their CER arguments throughout the investigation as well as at the end of the investigation for further revision and peer review.

Reflect on the Phenomenon

Experience Notebook To get students thinking more deeply about proportions in chemical reactions, write the formulas for sucrose and steviol on the board ($C_{12}H_{22}O_{11}$; $C_{20}H_{30}O_3$). As a class, compare the number of each type of atom in the two compounds. Then tell students to assume that in the process of producing carbon dioxide, the sucrose or steviol is broken down. **Ask** If you break down one of each molecule, do you have the same number of carbon and oxygen atoms to make the carbon dioxide?

When Recipes Go Wrong

Investigative Phenomenon Video: When Recipes Go Wrong



NAME ______ DATE ______ CLASS ______

INVESTIGATIVE PHENOMENON: CLAIM-EVIDENCE-REASONING

Discuss the Phenomenon

Think about the Investigative Phenomenon Video you watched. What was the chemistry behind the phenomenon you observed? To help you build an understanding of the phenomenon, you will construct and revise a scientific argument.

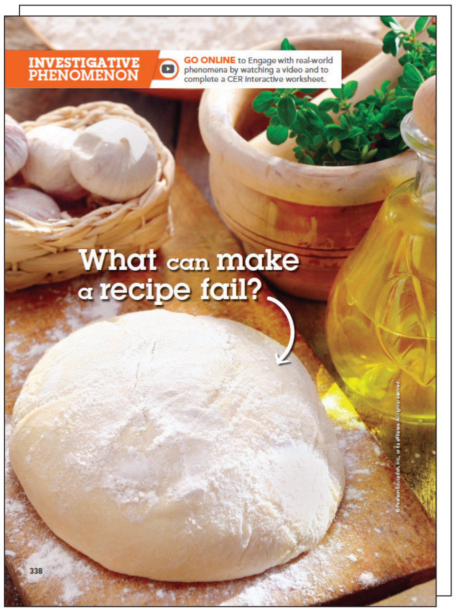
Build Your Argument Through Claim, Evidence, and Reasoning

1. **SEP Ask Questions** Write a question about the investigative phenomenon that you would like to discuss with your classmates. (Your teacher may also provide you with one.)

2. **SEP Construct Written Arguments** Use the Claim-Evidence-Reasoning framework to build a scientific argument about the phenomenon. After stating your claim, support it with evidence and scientific reasoning.

Make a Claim Your claim should be a response to the question stated above.	
Cite Evidence Identify data or knowledge that support your claim.	
Use Reasoning Justify how the data and knowledge count as evidence toward supporting the claim.	

CER Interactive Worksheet



Experience Notebook, pp. 338–339

eTEXT

EXPERIENCE 1

Quantifying Reactants and Products

Teacher Background

In Experience 1, students are introduced to the basic mathematics of chemistry by looking at chemical equations as a representation of the conversion of mass. You may wish to explain to students that, although stoichiometry may seem more like math than chemistry, it is the underlying "language" of how chemistry works. It is vital for being able to carry out chemical reactions with an understanding of how much reactant is needed and how much product will be produced. Some students may initially be intimidated by the math involved. Give special attention to these students and use hands-on models and real-world examples to help them feel more comfortable with the concepts. Once they have grasped a conservation of mass in a real-life situation or with a model, transition to the more abstract idea of the chemical equation and its coefficients.

Objectives

- **Analyze data on proportionality of reactants and products to predict their stoichiometric ratios in the corresponding chemical equation.**
- **Develop a model that demonstrates conservation of mass in a chemical equation.**
- **Apply mathematical concepts to interpret a chemical equation.**

ENGAGE

EVERYDAY PHENOMENON

Is there math in my sandwich?

Use the teacher demo to prompt discussion about proportionality in chemical reactions and the conservation of mass. Encourage students to take notes and add them to their observations during the Inquiry Lab.

The Equation for a Sandwich

Engage students with this demonstration of making sandwiches to introduce the concept of stoichiometry and proportionality in chemical equations.

Materials 6 slices of bread, 9 slices of sandwich meat, 3 slices of cheese, 3 small plates, 1 large plate, scale

1. Place the slices of bread, meat, and cheese on separate plates where students can see them.
2. Ask a volunteer to keep track and add together the masses of the sandwich ingredients. Note to students that each sandwich requires 2 slices of bread, 3 slices of sandwich meat, and 1 slice of cheese.
3. Separately find the mass of each ingredient and tell the volunteer to record the information. Instruct the volunteer to add up the masses of the ingredients and to write the total in a place where students can see it.
4. Ask students to guide you in writing an equation for the sandwich, noting the meaning of coefficients on each ingredient.
5. Ask students to predict the mass of the entire sandwich and to explain their predictions. Guide the discussion to address conservation of mass.
6. Find the mass of the whole sandwich to demonstrate that mass is conserved.

RELATED PHENOMENA

In addition to the teacher demo, The Equation for a Sandwich, consider using other phenomena to launch this experience.

- **Spotless Pennies** Place old and dirty pennies in a table salt and vinegar solution. See how long it takes before the pennies are clean. Have students quantify the chemical equation of the reaction ($CH_3COOH + NaCl \rightarrow CH_3COONa + HCl$) with a partner in any way they want (atoms, molecules, mass, etc.).
- **Crushed Candy** Show a video of someone crushing candy (such as peppermint candy canes). Have students discuss how the law of conservation of mass is seen in the video.
- **Decomposition of Baking Soda** Have students heat a sample of baking soda in a crucible and examine the mass before and after heating. Ask students to use stoichiometry to prove which chemical reaction occurred:

  $NaHCO_3(s) \rightarrow NaOH(s) + CO_2(g)$

  $2NaHCO_3(s) \rightarrow Na_2CO_3(s) + CO_2(g) + H_2O(g)$

  $2NaHCO_3(s) \rightarrow Na_2O(s) + 2CO_2(g) + H_2O(g)$

  $NaHCO_3(s) \rightarrow NaH(s) + CO(g) + O_2(g)$

  ($2NaHCO_3(s) \rightarrow Na_2CO_3(s) + CO_2(g) + H_2O(g)$ is the correct equation.)

7. Write the equation $2H_2 + O_2 \rightarrow 2H_2O$ on the board. Invite students to describe how this equation is similar to the equation for the sandwich. **Ask:**
   a. How many of each type of atom do we start with?
   b. How many of each type of atom do we end with?
   c. What would you predict to be the mass of the "ingredients" versus the final product?
   d. What does this tell you about conservation of mass in a chemical (or sandwich-making) reaction?

   Use this discussion to transition to the Inquiry Lab. Tell students to keep the concept of conservation of mass in mind as they are doing the lab.

EXPLORE

Identify Unknowns Through Stoichiometry

25

Inquiry Lab Students investigate the identity of an unknown Group 1 metal carbonate through gas evolution and titration. This will give them insight into how scientists can learn the identity of unknown substances.

Lab Demo Video Watch the Lab Demo Video for advice on materials and preparation.

Choose Your Version Open-ended (O), Guided (G), Shortened (S), Advanced (A)

Materials 2 mL 0.04% bromocresol green indicator solution, 60 mL 0.1 M hydrochloric acid solution, 20 mL 2 M hydrochloric acid solution, Unknown A, Unknown B, 500 mL distilled or deionized water, balance, 50-mL beaker, beaker tongs or heat-resistant gloves, 50-mL buret, buret clamp, 500-mL Erlenmeyer flask, 3 125-mL Erlenmeyer flasks, 25-mL graduated cylinder, 50-mL graduated cylinder, 500-mL graduated cylinder, hot plate, ice bath, magnetic stirrer with stir bar, ring stand, white paper, 2 weighing dishes

Safety Hydrochloric acid solution is toxic and corrosive to eyes and skin tissue. Potassium carbonate is a body tissue irritant. Make sure that students avoid contact of all chemicals with eyes and skin. They should wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Tell students to wash their hands thoroughly with soap and warm water before leaving the laboratory.

Expected Outcome The mass lost when CO_2 is released will allow students to determine the molar mass of their assigned Group 1 metal carbonate in Part 1. In Part 2, carbonate acts as a weak base in solution and is neutralized by HCl. The indicator will turn from blue-green to yellow-green when the reaction is complete. The amount of acid used will vary between the metal carbonates.

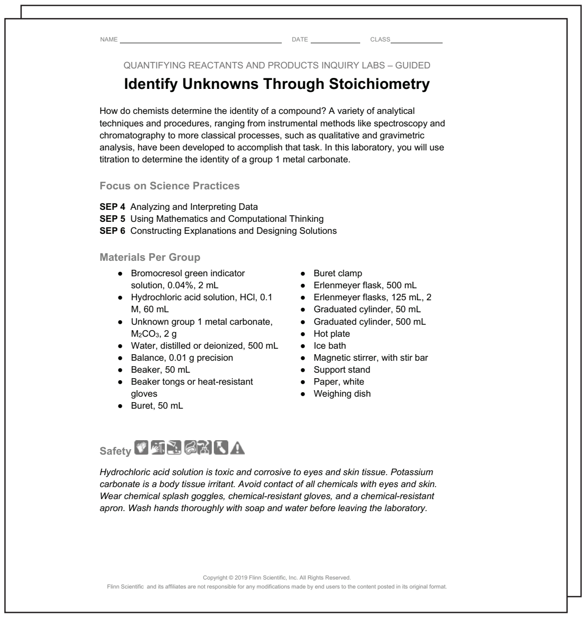
Lab Summary Video Watch the Lab Summary Video for support on connecting the lab investigation to the Investigative Phenomenon.

ASSESS ON THE SPOT

Tell student groups to discuss the main concepts they have learned in this lab. Then have students write individually in their science notebooks about what they learned and one question they have about the lab. Collect their responses and use them to gauge understanding.

PROFESSIONAL DEVELOPMENT

Background Notes Some students may find it challenging to shift from concrete examples of stoichiometry to the calculations required in the lab, and they may be more focused on balancing numbers than on conservation of mass. Review a similar reaction with them (perhaps one that includes a Group 1 metal carbonate that is not being used), guiding them through thinking about why proportions are important in conserving the total number of atoms, and therefore mass, involved in the reaction.



NAME ______ DATE ______ CLASS ______

QUANTIFYING REACTANTS AND PRODUCTS INQUIRY LABS – GUIDED

Identify Unknowns Through Stoichiometry

How do chemists determine the identity of a compound? A variety of analytical techniques and procedures, ranging from instrumental methods like spectroscopy and chromatography to more classical processes, such as qualitative and gravimetric analysis, have been developed to accomplish that task. In this laboratory, you will use titration to determine the identity of a group 1 metal carbonate.

Focus on Science Practices

SEP 4 Analyzing and Interpreting Data
SEP 5 Using Mathematics and Computational Thinking
SEP 6 Constructing Explanations and Designing Solutions

Materials Per Group

- Bromocresol green indicator solution, 0.04%, 2 mL
- Hydrochloric acid solution, HCl, 0.1 M, 60 mL
- Unknown group 1 metal carbonate, M_2CO_3, 2 g
- Water, distilled or deionized, 500 mL
- Balance, 0.01 g precision
- Beaker, 50 mL
- Beaker tongs or heat-resistant gloves
- Buret, 50 mL
- Buret clamp
- Erlenmeyer flask, 500 mL
- Erlenmeyer flasks, 125 mL, 2
- Graduated cylinder, 50 mL
- Graduated cylinder, 500 mL
- Hot plate
- Ice bath
- Magnetic stirrer, with stir bar
- Support stand
- Paper, white
- Weighing dish

Safety

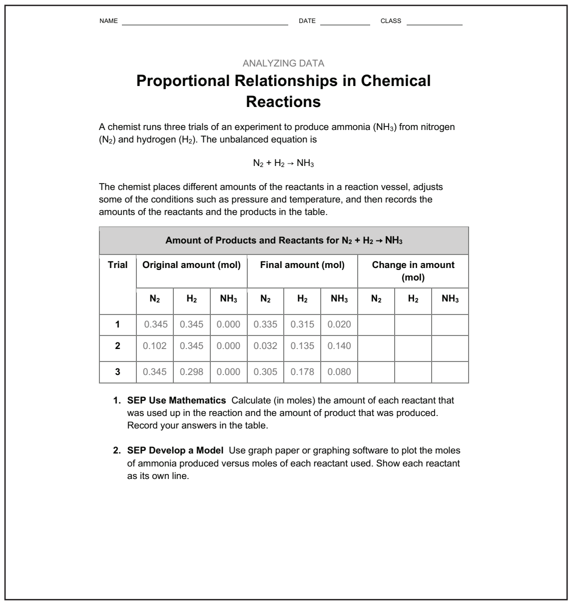
Hydrochloric acid solution is toxic and corrosive to eyes and skin tissue. Potassium carbonate is a body tissue irritant. Avoid contact of all chemicals with eyes and skin. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Wash hands thoroughly with soap and water before leaving the laboratory.

O/G/S/A Lab Interactive Worksheets

CLASSROOM MODIFICATIONS

Based on your students' abilities and your schedule, you may choose the Inquiry Lab to be more advanced or more guided.

- **Advanced Inquiry Lab** Students investigate the identity of an unknown Group 1 metal carbonate through gas evolution and titration.
- **Guided Inquiry Lab** Students investigate the identity of an unknown Group 1 metal carbonate through titration.



NAME ______________ DATE ________ CLASS ________

ANALYZING DATA

Proportional Relationships in Chemical Reactions

A chemist runs three trials of an experiment to produce ammonia (NH_3) from nitrogen (N_2) and hydrogen (H_2). The unbalanced equation is

$$N_2 + H_2 \rightarrow NH_3$$

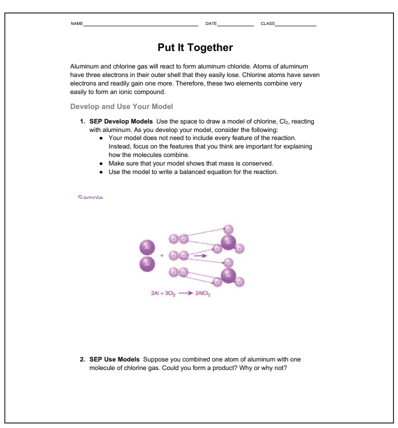
The chemist places different amounts of the reactants in a reaction vessel, adjusts some of the conditions such as pressure and temperature, and then records the amounts of the reactants and the products in the table.

Amount of Products and Reactants for $N_2 + H_2 \rightarrow NH_3$									
Trial	Original amount (mol)			Final amount (mol)			Change in amount (mol)		
	N_2	H_2	NH_3	N_2	H_2	NH_3	N_2	H_2	NH_3
1	0.345	0.345	0.000	0.335	0.315	0.020			
2	0.102	0.345	0.000	0.032	0.135	0.140			
3	0.345	0.298	0.000	0.305	0.178	0.080			

1. **SEP Use Mathematics** Calculate (in moles) the amount of each reactant that was used up in the reaction and the amount of product that was produced. Record your answers in the table.

2. **SEP Develop a Model** Use graph paper or graphing software to plot the moles of ammonia produced versus moles of each reactant used. Show each reactant as its own line.

Analyzing Data Interactive Worksheet



NAME ______________ DATE ________ CLASS ________

Put It Together

Aluminum and chlorine gas will react to form aluminum chloride. Atoms of aluminum have three electrons in their outer shell that they easily lose. Chlorine atoms have seven electrons and readily gain one more. Therefore, these two elements combine very easily to form an ionic compound.

Develop and Use Your Model

1. **SEP Develop Models** Use the space to draw a model of chlorine, Cl_2, reacting with aluminum. As you develop your model, consider the following:
   - Your model does not need to include every feature of the reaction. Instead, focus on the features that you think are important for explaining how the molecules combine.
   - Make sure that your model shows that mass is conserved.
   - Use the model to write a balanced equation for the reaction.

Sample

2. **SEP Use Models** Suppose you combined one atom of aluminum with one molecule of chlorine gas. Could you form a product? Why or why not?

Modeling Interactive Worksheet

ELD SUPPORT

Listening Actively Students listen and process information and explanations about classmates' models in the Put It Together modeling activity.

- **Emerging** After each classmate presents their model, have students state one fact they learned about the model.
- **Expanding** Have students complete the Emerging activity. Then have students ask at least one question about each model and have their classmates' respond to the question.
- **Bridging** Lead an oral discussion on the ways in which classmates could improve their models. Students should also include an explanation about how they could improve their own models.

Proportional Relationships in Chemical Reactions

Analyzing Data In this activity, students analyze data [SEP-4] they are given from separate trials of an experiment used to produce ammonia from nitrogen and hydrogen. They calculate [SEP-5] the number of moles used in the reaction [PS1.B] and the moles of product that were produced in each trial. Then they make a graph that models [SEP-2] the relationships between the moles of reactant used to the moles of product produced.

- Review with students the role of stoichiometry and proportions in the equation: $2H_2 + O_2 \rightarrow 2H_2O$. **Ask** If you carried out this reaction, what ratio would you expect to find between reactants and products?
- Pair students and tell them to complete the activity together. Then tell the pairs to find another pair to discuss their responses with. As a class, review the balanced equation and discuss how the data reflects the conservation of mass.

DIFFERENTIATED INSTRUCTION

- **Support Special Needs Students** Allow students who are easily distracted to work on their own, providing guidance when needed. When these students are finished, bring them together to compare the ratios they calculated and to discuss their responses to question 5.
- **Support Struggling Students** Guide students through setting up and plotting their graphs.
- **Support Advanced Students** Combine this activity with the modeling activity, inviting students to make a drawn or hands-on model of the production of ammonia. Have students complete a gallery walk of any models students made (including models for the modeling activity), and allow peers to circulate and ask each other questions about the models.

EXPLAIN

Put It Together

Modeling In this activity, students model [SEP-2] the reaction [PS1.B] between aluminum and chlorine, and use their models to write a balanced equation for the reaction. They also identify the limitations of their models and consider ways that those limitations could be addressed.

Choose from these suggested strategies to guide students in developing and using their models.

- Pair students to work on their models and to answer question 2. Remind students that they should each have their own unique model but use their partner for guidance. Tell them to also make a model that shows the reasoning behind their answers to question 2. Then have students find another partner to discuss the limitations of their models and ideas for revisions.
- You may wish to have students work individually to make their models, write the balanced equation, and answer question 2. Circulate among students and provide guidance as necessary. Then pair students to discuss the limitations of their models and make suggested revisions.
- If students prefer, allow them to make a hands-on model. Invite other students to engage with the hands-on models and offer thoughts on limitations and revisions of the models.

Quantifying Reactants and Products

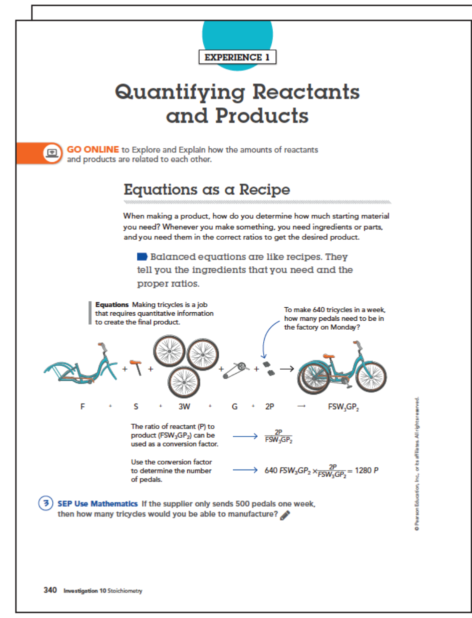
Experience Notebook Assign this section of the Experience Notebook or Realize Reader before having students work on any of the activities in the Elaborate portion of this experience. The background knowledge found here is vital for understanding those assignments.

Use the strategies below to help students better understand the content on the indicated pages.

- **Equations as a Recipe** (pp. 340–341) Bring students back to the opening demonstration of sandwich making, and discuss how the sandwich equation is similar to the tricycle equation. Guide students through the Sample Problem. Then pair students and tell them to set up and solve equations [SEP-5] for questions 3 and 4. Call on pairs to share their equations and solutions with the class.
- **Interpreting Chemical Equations** (p. 342) Review with students the differences between atoms, molecules, moles, mass, volume, and molar mass. Then write and number four simple equations (you may wish to choose some from the online practice problems). Direct students to count off in 4's. Tell students to work with the equation that matches their number, making a model [SEP-2] similar to the chart on page 342, and to show conservation of mass as demonstrated on page 344. Tell students to find a partner with the same number and discuss their work. As a class, discuss any questions students have.
- **What is Conserved?** (p. 344) Again, remind students of the sandwich demonstration. **Ask:**
  a. How did the mass of the ingredients compare to the mass of the sandwich?
  b. How is the sandwich similar to a chemical reaction?
  c. How much CO_2 would be produced (in moles and grams) by burning 36 g of charcoal?
- **Proportionality of Reactants and Products** (p. 345) Pair students to discuss the graphs on page 345. Ask students to describe instances in which they would use the graphs. Call on pairs to share their answers, and as a class describe how the two graphs are different.

ASSESS ON THE SPOT

Place students in groups of four, and tell them to count off from 1 to 4 within the group. Together, the group should answer this question: Why is the number of grams of reactant equal to the grams of product, but the number of moles may change? Randomly choose a number between 1 and 4, and the student with that number in their group has to share their answer.



Experience Notebook, pp. 340–346

eTEXT

SAMPLE PROBLEM SUPPORT

For the problem on page 341:

- Review the use of coefficients and subscripts with students. **Ask** Why are numbers that were coefficients on the left side subscripts on the right?
- If students are overwhelmed by the number of variables, simplify the problem to $F + 2P + 3W = FP_2W_3$.
- Remind students that the two conversions represent the same ratio. For example, $\frac{3}{4}$ and $\frac{4}{3}$ both represent a 3 of one thing and 4 of another, although the two fractions have different values.

For the problem on page 343:

- Review the importance of setting up equations with units that cancel.
- Review how to find molar mass using the periodic table.
- Call on students to explain how: *a.* relates to the first shaded box, and *b.* relates to the second shaded box, and how the calculations above the bottom shaded box show that mass is conserved.

NAME ________________ DATE ________ CLASS ________

PEER REVIEW RUBRIC

Evaluate Put It Together

Use this rubric to help you assess your classmates' models and explanations of the reaction between chlorine and aluminum.

	EXEMPLARY Score the work 3 if:	ACCOMPLISHED Score the work 2 if:	DEVELOPING Score the work 1 if:	Explain Your Score
Components of the Model Score: ______	The model shows the correct ratio of molecules for the reaction and explains their movement. The correctly balanced equation is provided.	The model shows the same ratio of molecules as the equation, which may or may not be balanced correctly, and shows that no atoms have been created or destroyed (same number of atoms on both sides of the equation).	An attempt is made to balance the equation, but the model may not show the same ratio of molecules.	
Relationships Score: ______	The model accurately depicts the 2:3 ratio needed for the reaction to take place.	The model describes the correct ratio but does not accurately explain why the relative amounts of reactants are needed.	The model attempts to describe a relationship between the amounts of reactants and products of the reaction.	
Connections Score: ______	The model makes sense and can be adapted to represent equations of other reactions.	The model makes sense but is more specific to this reaction and may not be applied to understand other reactions.	The model is unclear and would not be effectively applied to understand other reactions.	
Limitations of the Model Score: ______	Limitations of this model are described, including that it only represents a limited number of molecules.	The explanation acknowledges that this model has limitations, though they are not clearly and specifically identified or described.	There is no acknowledgment that this model has limitations.	

Peer Review Rubric Interactive Worksheet

CONNECT TO CAREERS

Purchasing Manager A purchasing manager is in charge of buying chemical reactants. Reactants are sold by weight or volume, but reactions occur in moles. The purchasing manager must be able to consider purchases in moles as well as conventional units of sale. Tell students to look into the training required for purchasing managers.

ELABORATE

Evaluate Put It Together

20

Peer Review Rubric In this activity, students use the rubric as a scoring guide to evaluate [SEP-8] their classmates' models and explanations of the reaction [PS1.B] between chlorine and aluminum.

- Make a copy of each student's model (include a photo if the student made a physical model rather than a drawing), replacing the students' names with numbers.
- Organize the class into groups of three, give each group a set of three models to critique, and provide each student three blank rubrics. Students should use a separate rubric sheet to evaluate each model. Remind students that the model should reflect conservation of mass [CCC-5] and the proportional relationship [CCC-3] between reactants and products in the reaction, and to consider that in their scoring. Remind them that their participation in the peer review will be assessed on the accuracy and fairness of their evaluations.
- Collect the rubrics. Return students' models, along with the peer review rubrics. Suggest that students make revisions to their models based on the peer reviews. Allow time for students to ask for clarifications from their reviewers.

PROFESSIONAL DEVELOPMENT

Science and Engineering Notebooks Have students use their science notebooks to model and explain an additional reaction between magnesium and chlorine. Students should write the correct ratio of molecules for the reaction and provide a correctly balanced equation. Have students share their notebooks with a partner so they can critique each other.

DIFFERENTIATED INSTRUCTION

- **Support Less Proficient Readers** For less proficient readers, read aloud the rubric as they follow along. Clarify and/or restate the expectations of the models at the Exemplary, Accomplished, and Developing stages after all of each stage's components are read.
- **Support Special Needs Students** Some students may benefit from completing this activity over multiple days. Alternatively, providing special needs students with a structured amount of time to complete each step could help keep students focused on the task at hand.

Parts and the Whole

Writing About Science In this activity, students use dimensional analysis to determine the lowest cost option for a one-month supply of ingredients for a company that produces handmade soap. First, students research the role of oil, lye, and water in soap making. They construct an explanation [SEP-6] of how the properties of soap change if too little oil or too little lye is used. Then, students use mathematical thinking [SEP-5] to calculate how much a soap company will spend on ingredients for 20 kg of soap. They connect how calculating ratios for prices for the soap recipe is similar to doing stoichiometric calculations.

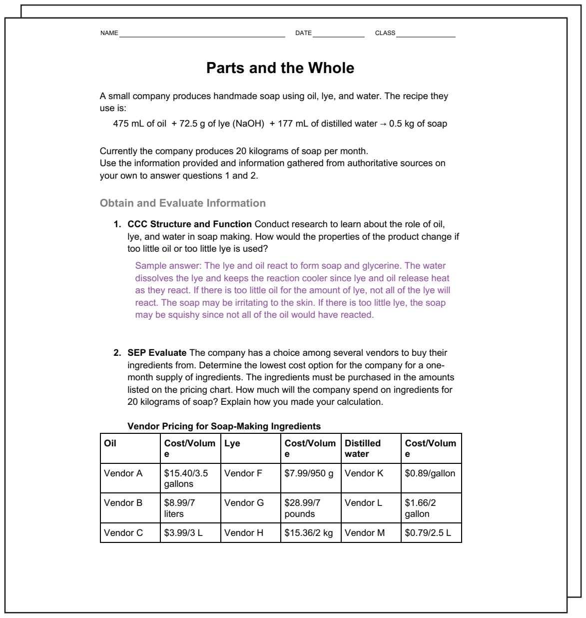
- Make sure students research how the sodium hydroxide (lye) is an alkali base and fatty acids make up the oil.
- It may be helpful to define useful terms students can use in their research, such as *saponifcation*, which is the chemical reaction of soap, and *superfatting*, which includes extra fats in the soap mixture.
- To provide additional support for question 2, lead a class discussion about how to determine how much the company will spend on ingredients for 20 kg of soap. Point out that students first need to determine the minimum amount of each ingredient needed. Next, students should convert the units to determine how many containers of each product are needed from each vendor and then multiply the number of containers by the price per container to find the cost per vendor. Have students analyze their data to determine which vendor provides the lowest price for ingredients.
- After students complete the worksheet, have them work with a partner and review their answers. Then, as a class, have pairs share their answers to check for accuracy.

DIFFERENTIATED INSTRUCTION

- **Support Struggling Students** Some students may have difficultly visualizing the vendor pricing for the soap-making ingredients. Set out physical representations of a gallon, liter, and pound so students can understand the cost/volume better for the prices. For students struggling with conversion factors, remind them that conversion factors should always be oriented so that like units cancel, leaving the desired unit in the numerator. Explain to students that planning the steps of the solution can make the task simpler.
- **Support Advanced Students** Have advanced students conduct the writing task with the addition of the scenario that the small soap company wants to add fragrance and/or coloring to the soap. Students should research other companies and see the amount that is added to a typical bar of soap and the cost.

ASSESS ON THE SPOT

Have students summarize in a paragraph the importance of quantifying reactants and products in soap making. Then have students share their summaries with a partner. Make sure students emphasize that, depending on the amount of soap being produced and the size of the bars, quantities of the ingredients or reactants are quantified in different ways.



NAME ____________ DATE ________ CLASS ________

Parts and the Whole

A small company produces handmade soap using oil, lye, and water. The recipe they use is:

475 mL of oil + 72.5 g of lye (NaOH) + 177 mL of distilled water → 0.5 kg of soap

Currently the company produces 20 kilograms of soap per month.
Use the information provided and information gathered from authoritative sources on your own to answer questions 1 and 2.

Obtain and Evaluate Information

1. **CCC Structure and Function** Conduct research to learn about the role of oil, lye, and water in soap making. How would the properties of the product change if too little oil or too little lye is used?

   Sample answer: The lye and oil react to form soap and glycerine. The water dissolves the lye and keeps the reaction cooler since lye and oil release heat as they react. If there is too little oil for the amount of lye, not all of the lye will react. The soap may be irritating to the skin. If there is too little lye, the soap may be squishy since not all of the oil would have reacted.

2. **SEP Evaluate** The company has a choice among several vendors to buy their ingredients from. Determine the lowest cost option for the company for a one-month supply of ingredients. The ingredients must be purchased in the amounts listed on the pricing chart. How much will the company spend on ingredients for 20 kilograms of soap? Explain how you made your calculation.

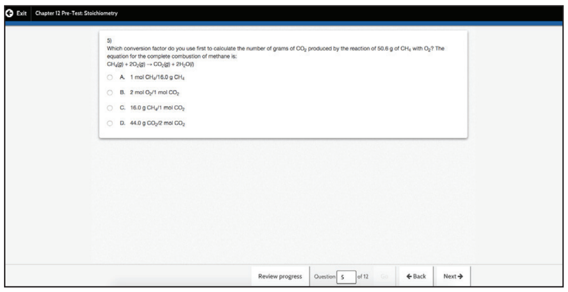
Vendor Pricing for Soap-Making Ingredients

Oil	Cost/Volume	Lye	Cost/Volume	Distilled water	Cost/Volume
Vendor A	$15.40/3.5 gallons	Vendor F	$7.99/950 g	Vendor K	$0.89/gallon
Vendor B	$8.99/7 liters	Vendor G	$28.99/7 pounds	Vendor L	$1.66/2 gallon
Vendor C	$3.99/3 L	Vendor H	$15.36/2 kg	Vendor M	$0.79/2.5 L

Writing About Science Interactive Worksheet

INTEGRATE THE THREE DIMENSIONS

In the Writing About Science activity, Parts and the Whole, students quantify the chemical reaction [PS1.B] of soap. They complete calculations [SEP-5] on vendor pricing for the ingredients of the soap making. Students relate how making the calculations for the proportions and then converting the units of the ingredients is similar to doing stoichiometric calculations of matter [CCC-5].



Interactive Online Quiz

Quiz Interactive Worksheet

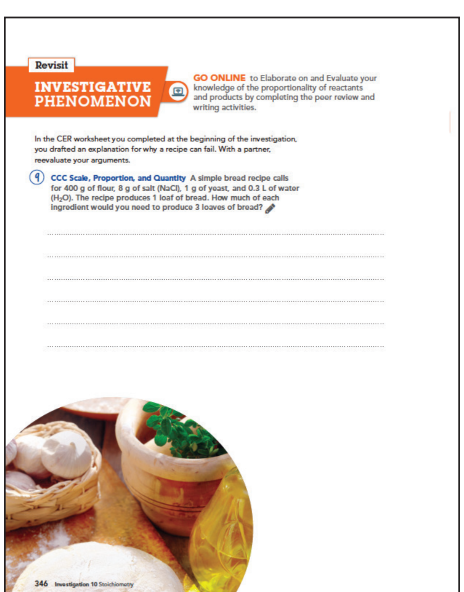
EVALUATE

Quantifying Reactants and Products

Quiz Assign the quiz in online technology-enhanced, auto-graded format or as an editable quiz worksheet. Use the scoring notes and remediation strategies found online to assess students' responses and to provide targeted feedback for each item to remediate well before assigning the summative 3-D Assessment.

REMEDIATION SUGGESTIONS

- **If** students are having difficulty converting from grams to moles and moles to grams, **then** lead a class discussion about how to do the calculations using a periodic table.
- **If** students are struggling with the concept of proportionality and chemical equations as a recipe, **then** prompt them to review the Modeling activity, Put It Together. Students can also review the tricycle diagram on page 340 and the Sample Problem on page 341 of the Experience Notebook for additional support.
- **If** students are struggling with the relationship between balanced equations and conservation of mass, **then** have them review the Analyzing Data activity, Proportional Relationships in Chemical Reactions. Students may also want to review the Sample Problem on page 343.
- **If** students are having difficulty understanding how parts can be combined as reactants to make a product, **then** have them return to the writing activity, Parts and the Whole.



Revisit
INVESTIGATIVE PHENOMENON

GO ONLINE to Elaborate on and Evaluate your knowledge of the proportionality of reactants and products by completing the peer review and writing activities.

In the CER worksheet you completed at the beginning of the investigation, you drafted an explanation for why a recipe can fail. With a partner, reevaluate your arguments.

9 **CCC Scale, Proportion, and Quantity** A simple bread recipe calls for 400 g of flour, 8 g of salt (NaCl), 1 g of yeast, and 0.3 L of water (H_2O). The recipe produces 1 loaf of bread. How much of each ingredient would you need to produce 3 loaves of bread?

346 Investigation 10 Stoichiometry

Experience Notebook, p. 346

eTEXT

Revisit INVESTIGATIVE PHENOMENON

Support Reflection Students can complete the reflection prompt, where they will unpack and make sense of the Investigative Phenomenon, based on practices and understandings that have been reinforced over the course of the experience.

- Tell students to write out an equation for the loaf of bread. For guidance, they can look at the equation for a tricycle on page 341 of the Experience Notebook. Call on students to share their equations.
- As a class, discuss the ingredients required for three loaves of bread. Further discuss how these particular ingredients are crucial for a bread recipe and how using alternatives that do not have similar properties would make the recipe fail.
- **Ask** Why don't we need to convert the recipe into moles to determine how much we would need? (Because we are multiplying all of the reactants by the same number. The proportions between them don't change; therefore, we can triple all of them and the proportions will remain the same.)

Develop a Draft CER Argument Have students answer question 2 in the CER worksheet and develop a draft of a CER argument to address the Investigative Phenomenon. Have students add any evidence they have collected from the activities so far in this investigation. Evidence may include the proportional nature of chemical reactions and conservation of mass.

EXPERIENCE 2

Chemical Calculations

Teacher Background

Experience 2 brings the concept of mole ratio to the application of unit conversions in predicting the amount of product in a reaction. Therefore, this experience is largely focused on math in a chemistry context. Students begin with a lab that requires them to calculate the mass of reactants required to produce a given amount of product. They explore the use of units for mass, volume, and moles in an online simulation and a modeling activity. Finally, they hypothesize about the usefulness of a scale that can measure substances in moles. Becoming adept at unit conversions is necessary for mastering chemistry, so it is important to provide students with a variety of entry points, such as hands-on models, math manipulatives, and opportunities to draw and annotate their own models.

Objectives

- **Use dimensional analysis to determine the mass of reactant required to obtain a given amount of product.**
- **Use the mole ratio in a chemical reaction to relate amounts of participating substances.**
- **Develop and use a model of different units of measurement.**
- **Calculate and communicate data on different units of measurement.**

ENGAGE

EVERYDAY PHENOMENON

Why do we use different types of measurements?

Use the teacher demo to prompt discussion about why we use a variety of types of measurements to describe the world around us.

Counting a Year in Milliseconds 15

Engage students with this demonstration of an everyday phenomenon to introduce the concept of converting from one unit of measurement to another.

Materials colored pens

1. Explain to students that in chemistry, as in other areas of life, different units of measurement are used in different situations. Emphasize that being able to convert and relate units to each other is an important aspect of chemistry.
2. Tell students that to demonstrate how to convert units, they will help you convert a year into milliseconds. Write *1 year* on the board. Solicit suggestions about how to start the conversion. Ask students to identify a unit of measurement we divide a year into.
3. If one of the students responds with "days," write *1 year × 365 days/1 year*. Use the same color for numbers with year units and a new color for *365 days*. Note for students that the years cancel, and the multiplication gives an answer in days. (A similar equation can be set up if a student responds with "months.")
4. Continue the problem, having students guide you through writing "1 year × 365 days/1 year × 24 hours/1 day × 60 minutes/1 hour × 60 seconds/1 minute × 1000 milliseconds/1 second," being sure to keep numbers with matching units in the same color.

RELATED PHENOMENA

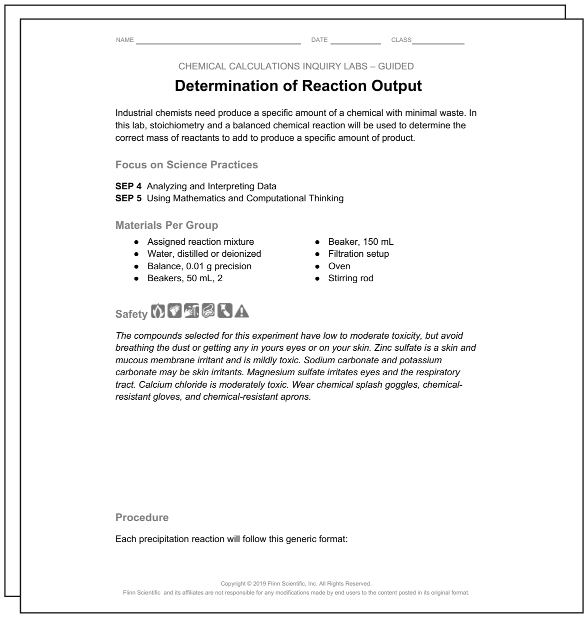
In addition to the Counting a Year in Milliseconds teacher demo, consider using other phenomena to launch this experience.

- **Ideal Omelette** Have students imagine an ideal omelette that they would want to eat or make for someone else. Ask them to discuss the ratio of ingredients used to make the omelette. Have them further discuss why ratios are important here.
- **Let's Make Salt** Show a video of the production of NaCl from sodium metal reacting with chlorine gas. **Ask** Is this how table salt is really made? Why not? Could we make NaCl this way? How would we do it? What ingredients would we need to start with? Work with the students to formulate the equation and write it on the board. Then ask them to balance the equation.

  $$(2Na(s) + Cl_2(g) \rightarrow 2NaCl(s))$$

  Explain that although the balanced equation tells us that 2 particles of Na react with 1 particle of Cl_2, in reality chemical reactions occur with huge numbers of particles. The word *mole* represents a huge number of particles. Chemists can say 2 moles of Na react with 1 mole of Cl_2 in this reaction.

  Ask If we started with 5.00 grams of Na metal, how many grams of Cl_2 gas should be used to have a "perfect reaction"? In other words, we don't want any leftover Na particles or Cl_2 particles after the reaction is complete. Allow students to brainstorm this problem. Some students may suggest 2.5 grams of Cl_2 as the answer. From this preconception, discuss the different sizes of the particles. Remind students that particles have different sizes and masses. A 2:1 mass ratio does not give us a 2:1 particle ratio. Provide support to help students use a mole-to-mole ratio rather than a gram ratio. Go through the stoichiometric calculation together as a class.


NAME ____________ DATE ______ CLASS ______

CHEMICAL CALCULATIONS INQUIRY LABS – GUIDED

Determination of Reaction Output

Industrial chemists need produce a specific amount of a chemical with minimal waste. In this lab, stoichiometry and a balanced chemical reaction will be used to determine the correct mass of reactants to add to produce a specific amount of product.

Focus on Science Practices

SEP 4 Analyzing and Interpreting Data
SEP 5 Using Mathematics and Computational Thinking

Materials Per Group

- Assigned reaction mixture
- Water, distilled or deionized
- Balance, 0.01 g precision
- Beakers, 50 mL, 2
- Beaker, 150 mL
- Filtration setup
- Oven
- Stirring rod

Safety

The compounds selected for this experiment have low to moderate toxicity, but avoid breathing the dust or getting any in yours eyes or on your skin. Zinc sulfate is a skin and mucous membrane irritant and is mildly toxic. Sodium carbonate and potassium carbonate may be skin irritants. Magnesium sulfate irritates eyes and the respiratory tract. Calcium chloride is moderately toxic. Wear chemical splash goggles, chemical-resistant gloves, and chemical-resistant aprons.

Procedure

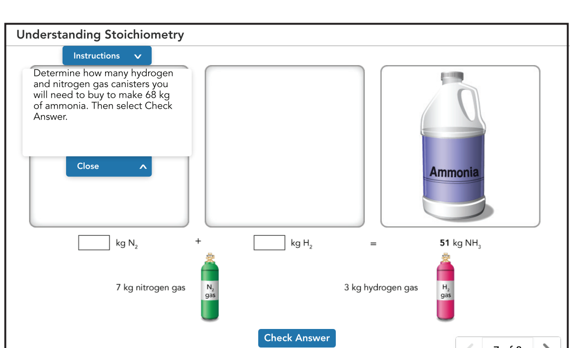
Each precipitation reaction will follow this generic format:

O/G/S/A Lab Interactive Worksheets

ELD SUPPORT

Exchanging Information/Ideas In small groups, students discuss how they designed and carried out the precipitate reaction in the Inquiry Lab.

- **Emerging** Tell students to use phrases and short sentences to describe simple actions they took, such as "measured 2 grams of reactant."
- **Expanding** Tell students to take turns asking and answering questions about the Inquiry Lab.
- **Bridging** Have students complete the Expanding activity, using well-articulated comments.



Simulation: Understanding Stoichiometry

5. When you reach the answer, **ask** Why don't we just use milliseconds or hours to count all of our time?
6. Explain that chemistry has similar units that are more appropriate at certain times. Ask students to describe when they measure in moles and when in grams. How do they covert from one to the other?
7. Tell students that in this experience they will investigate ways to use units in chemistry, particularly in calculations. Transition the conversation to introduce the Inquiry Lab.

EXPLORE

Determination of Reaction Output

Inquiry Lab Students use stoichiometry calculations [SEP-5] to predict the mass of product in a reaction of sodium bicarbonate with heat. They then investigate [SEP-3] the reaction to assess the accuracy of their calculations.

Lab Demo Video Watch the Lab Demo Video for advice on materials and preparation.

Choose Your Version Open-ended (O), Guided (G), Shortened (S), Advanced (A)

Materials assigned reaction mixture, distilled or deionized water, balance, 2 50-mL beakers, 150-mL beaker, Büchner funnel, 250-mL filter flask, filter paper, oven, stirring rod

Safety The chemicals in this lab can be moderately toxic and an irritant to the eyes, skin, and respiratory tract. Make sure students wear chemical splash goggles, chemical-resistant gloves, and chemical-resistant aprons and wash their hands thoroughly with soap and warm water after the lab.

Expected Outcome As long as the calculations are accurate and students have good lab technique, their theoretical yield should be very close to their actual yield.

Lab Summary Video Watch the Lab Summary Video for support on connecting the lab investigation to the Investigative Phenomenon.

ASSESS ON THE SPOT

Give students a selection of graphic organizers to choose from, or allow them to make their own. Tell them to devise a concept map that shows how their initial calculations are related to the reaction they carried out in the Inquiry Lab and their actual yield. Invite some students to share their concept maps with the class. Collect students' concept maps and assess gaps in understanding.

PROFESSIONAL DEVELOPMENT

Develop Classroom Collaboration Many students may see the Inquiry Lab (and stoichiometry in general) as a set of math problems, rather than a demonstration of a chemical phenomenon. Keep the chemistry on their radar by emphasizing that stoichiometry is necessary to reflect that matter is conserved in a chemical reaction [PS1.B]. During the Inquiry Lab, encourage groups to track where each type of atom appears in both reactants and products and to compare amounts of and ratios between types of atoms as they balance equations and predict amounts of product.

Understanding Stoichiometry

Simulation In this simulation, students use a model [SEP-2] to produce industrial-scale measures of ammonia. They are presented with a few different scenarios, and they choose the appropriate units from a selection provided, considering the scale and proportion [CCC-3] involved.

- Pair students and prompt them to review the first part of the simulation (about tricycle stoichiometry), making notes and sketches, and recording any questions they have. Tell them to discuss any questions with each other or with another pair. Students should move on to the next section only when they have answered their questions.
- For the second part of the simulation, tell pairs to have one person complete the first scenario and make choices, while the other person observes and provides hints. Then have students switch roles for the second scenario. They can continue alternating until they have completed all the questions.

EXPLAIN

Choose a Practical Unit

Modeling In this activity, students calculate [SEP-5] the mass and volume of a mole of propane and predict how much carbon dioxide is produced during 20 hours of grilling. They make a flowchart model [SEP-2] to analyze the relationships between units of moles, mass, and volume, using an amount of propane gas, and then describe the advantages and disadvantages of using each unit (grams, liters, moles) by itself.

Choose from these strategies to guide students through the activity:

- Students can work in groups of four. Offer them colored pens and poster board or butcher paper, and instruct them to create visual models large enough to share with another group. Tell students to take turns presenting their models to the group. After the presentations, students should note any revisions they would like to make to their models.
- Hang the models around the room and let students peruse them. Then, as a class, discuss strengths of different models. Remind students to make notes of any additional revisions they would make to their models.

Stoichiometry Calculations

Animation In this animation, students are guided through the steps of converting between mass and moles to determine the mass or moles of product produced in a reaction [PS1.B].

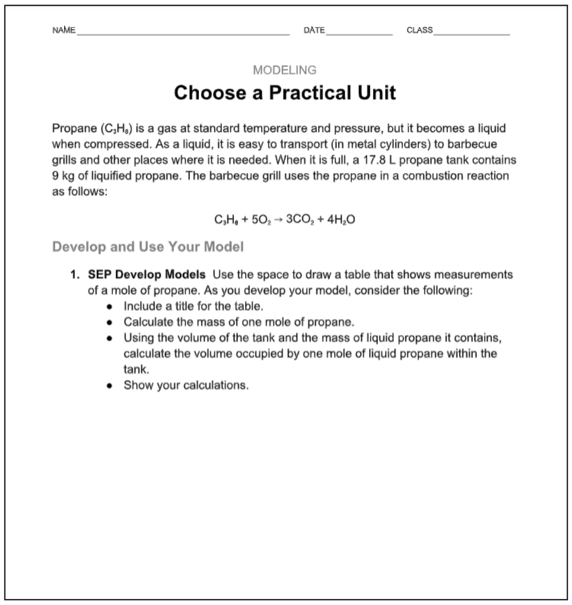
- Before students view the animation, prepare five problems for students to solve (e.g., "A reacts with B to form C. If you start with 20 g of A, how much C will you get?" Tell them to balance the equation if necessary).
- Watch the animation as a class and make a list of steps for converting from one unit to another.
- Pair students and give the class the first problem to solve. Remind students to follow the conversion steps. Replay the animation for additional support.
- Ask a pair of volunteers to write their solution on the board, and invite classmates to ask questions. Do the same with the four remaining problems.

INTEGRATE MATH

Conversion Ask students to describe how they would calculate the number of students in 8 classes. Explain that they are converting from what they know (the number of classes) to what they do not know (the total number of students). Prompt students to make this familiar conversion by considering proportions and cancelling units:

$$\frac{32 \text{ students}}{1 \text{ class}} \times 8 \text{ classes} = 256 \text{ students}$$

As a class, discuss other everyday examples, and note how they are similar to converting from grams to moles.


NAME ______ DATE ______ CLASS ______

MODELING

Choose a Practical Unit

Propane (C_3H_8) is a gas at standard temperature and pressure, but it becomes a liquid when compressed. As a liquid, it is easy to transport (in metal cylinders) to barbecue grills and other places where it is needed. When it is full, a 17.8 L propane tank contains 9 kg of liquified propane. The barbecue grill uses the propane in a combustion reaction as follows:

$$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$$

Develop and Use Your Model

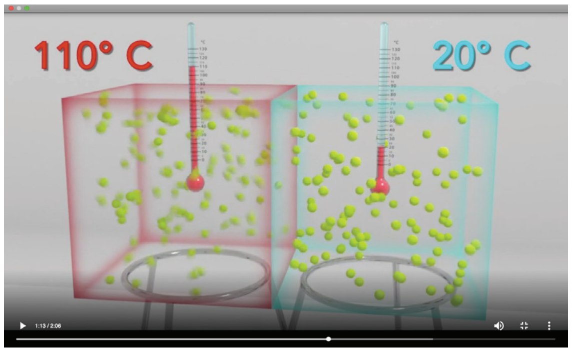
1. **SEP Develop Models** Use the space to draw a table that shows measurements of a mole of propane. As you develop your model, consider the following:
   - Include a title for the table.
   - Calculate the mass of one mole of propane.
   - Using the volume of the tank and the mass of liquid propane it contains, calculate the volume occupied by one mole of liquid propane within the tank.
   - Show your calculations.

Modeling Activity Interactive Worksheet

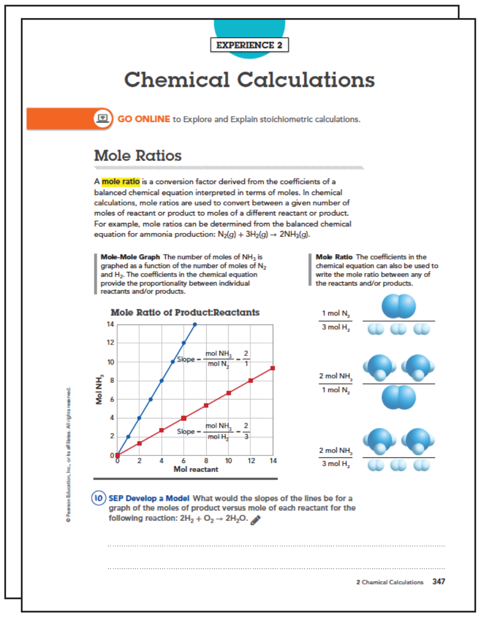
CLASSROOM MODIFICATIONS

Based on your students' abilities and your schedule, you may wish to edit the Choose a Practical Unit worksheet to make it more open ended or more guided.

- **More Open Ended** Allow students to choose from a variety of hydrocarbon fuels. Tell them to research the density of that fuel as a liquid and determine an appropriate-size tank for 20 L of fuel.
- **More Guided** Provide students with a skeletal outline for the flowchart and include areas to place calculations.



Animation: Stoichiometry Calculations



Experience Notebook, pp. 347–355

eTEXT

SAMPLE PROBLEM SUPPORT

Help students with calculating moles of a product by walking through question 12, part b, on page 349 in the Experience Notebook. The amount of Al_2O_3 is given as 3.7 mol, so that is what you start with. The mole ratio can be found from the balanced equation.

$$3.7 \text{ mol } Al_2O_3 \times \frac{4 \text{ mol Al}}{2 \text{ mol } Al_2O_3} = 7.4 \text{ mol Al}$$

Assist students with calculating the mass of a product by walking through question 14 on page 351. Start with 5.00 g CaC_2 (given). Find how many grams of C_2H_2 and CaC_2 equal a mole by looking at the atomic mass on the periodic table.

$$5.00 \text{ g } CaC_2 \times \frac{1 \text{ mol } CaC_2}{64.1 \text{ g } CaC_2} \times \frac{1 \text{ mol } C_2H_2}{1 \text{ mol } CaC_2} \times \frac{26.0 \text{ g } C_2H_2}{1 \text{ mol } C_2H_2} = 2.03 \text{ g } C_2H_2$$

Help students with calculating the volume of a product by walking through question 16 on page 353. Start with 3.86 L CO (given). Make sure students use the conversion factor: 1 mol = 22.4 L.

$$3.86 \text{ L CO} \times \frac{1 \text{ mol CO}}{22.4 \text{ L CO}} \times \frac{1 \text{ mol } O_2}{2 \text{ mol CO}} \times \frac{22.4 \text{ L } O_2}{1 \text{ mol } O_2} = 1.93 \text{ L } O_2$$

Assist students with calculating the molecules of a product by walking through question 18 on page 355. Start with 6.54 g $KClO_3$ (given). Make sure students use the conversion factor, 1 mol = 6.02×10^{23} molecules.

$$6.54 \text{ g } KClO_3 \times \frac{1 \text{ mol } KClO_3}{122.55 \text{ g } KClO_3} \times \frac{3 \text{ mol } O_2}{2 \text{ mol } KClO_3} \times \frac{6.02 \times 10^{23} \text{ molecules}}{1 \text{ mol } O_2} = 4.82 \times 10^{22} \text{ molecules}$$

Chemical Calculations

Experience Notebook Assign this section of the Experience Notebook or Realize Reader before having students work on any of the activities in the Elaborate portion of this experience. The background knowledge found here is vital for understanding those assignments.

Use the strategies below to help students better understand the content on the indicated pages.

- **Mole Ratios** (p. 347) Return to the sandwich-making demonstration that opened Experience 1. On the board, write the equation for the sandwich (2 slices of bread + 3 slices of meat + 1 slice of cheese = 1 sandwich). Have students make a graph similar to the one on page 347, using the ratios of sandwich ingredients. Pair students and tell them to write a sentence about what the information in the graph on page 347 tells them, and invite pairs to share with the class.
- **Mole–Mole Calculations** (pp. 348–349) Ask students to explain why, when given an amount of a substance, the moles of the wanted substance must be in the numerator. Then pair students and direct them to write a mole conversion problem for each of the two equations on page 349. Tell them to swap problems with a neighboring pair, solve them, and then gather as a group of four to discuss.
- **Mass–Mass Calculations** (pp. 350–351) Have students write problems using the ammonium and acetylene reactions. Offer one or two sample problems to be sure students know what the problem should include. Have students swap problems with a neighboring peer to solve. Encourage students to share with the class how they solved the problems.
- **Volume–Volume Calculations** (pp. 352–353) As a class, discuss and list the ways in which volume–volume calculations differ from and are similar to the previous two types of calculations. Remind students how to use a graph to determine the slope of a line. Then pair students and tell them to determine the slopes of the lines of product versus reactant for the formation of nitrogen monoxide on page 353. Call on two different pairs to share their results with the class.
- **A Roadmap for Solving Stoichiometric Problems** (pp. 354–355) Tell students to work individually to make a visual guide or flowchart to explain how to do unit conversions. Tell them the chart must include moles, molecules, volume, and mass. Group students in threes to share their visuals with each other. Tell students to make whatever revisions they would like to their visual. Then have them use their flowchart to work on some of the sample problems online.

DIFFERENTIATED INSTRUCTION

- **Support Less Proficient Readers** Encourage students to review the more graphical parts of each Experience Notebook page first and then take in the text at the top of the page. Tell them to circle words or phrases they do not understand, and then identify explanations in the graphical portions. When reading captions, tell students to match the wording in the caption to what they see in the images on the page.
- **Support Struggling Students** Tell students to review each page and write a two- or three-sentence summary of the information in their own words. Tell them to write annotations for graphs, describing what information the graph is conveying and how it relates to the chemical reaction it is describing. Offer models or manipulatives to any students who are finding the math confusing.

ASSESS ON THE SPOT

- Before students leave class, have them complete an exit card and use what they have learned about stoichiometric calculations to explain the following statement: Stoichiometric calculations are not possible without a balanced equation. (Students should explain that a chemical reaction's mole ratios are derived from the relationships between coefficients in a balanced chemical equation.)

ELABORATE

Evaluate a Practical Unit

Peer Review Rubric Students use the rubric as a scoring guide to evaluate [SEP-8] their classmates' explanations of propane units and how to convert between the different units.

- Group students in sets of three. Give each group an envelope and a set of three rubrics. Tell groups to come up with a team name, write it on their envelope, and then put each group member's model inside.
- Have groups exchange envelopes. Tell each group to use a sticky note to assign a number to each model. Have group members collaborate on evaluating the models, using a new, appropriately numbered rubric sheet for each one. When groups are done, tell them to return the models and evaluations to the appropriate team.
- Before students look at their evaluations, ask each team to highlight something they thought was notable about at least one of the models they evaluated. Then tell students to look at their evaluations and make any revisions necessary to their models.

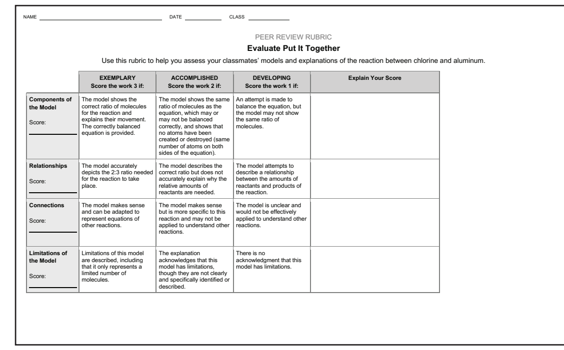
ASSESS ON THE SPOT

Divide the class into groups of three. Give students the reaction for the combustion of propane: $C_3H_8 + 5O_2 \rightarrow 4H_2O + 3CO_2$. Have students discuss what mass of carbon dioxide will be produced if 66 g of propane are used in the reactants. Tell groups to choose one student to write the first step in solving the equation and draw a line under what they have written, without input from group members. Tell a second student to write the second step and draw a line under that. They should not consider what the first student wrote, but only write their assigned step. The third student does the same with the third step. Once all three steps have been written, allow group members to confer until they think they have the correct answer. As a class, discuss the process of solving the problem, and address any questions students have.

A Scale That Reads Moles

Writing About Science In this activity, students conduct research and write about a potential new invention, a scale that can measure moles of a substance. In this scale, the number of moles refers to the number of particles under consideration. For example, if we place 18 g of water on the scale, the reading could be either 1 mole (of water molecules) or 3 moles (total number of H and O atoms).

- Allow students to work either individually or in pairs. Tell them to make notes about ideas that come to mind when they first consider the questions. Then encourage them to review the material they covered in Experiences 1 and 2, keeping the questions in mind and making notes that relate to the questions as they are gathering information. Suggest that they draft their responses from what they can find in the material they are reviewing. If a student feels they need to consult another source, help them formulate the question they are trying to answer.
- When students have finished writing, organize the class into small groups to discuss their responses. Invite groups to make a drawing, design document, or mock advertisement of their "mole scale" to show the class.



NAME ______ DATE ______ CLASS ______

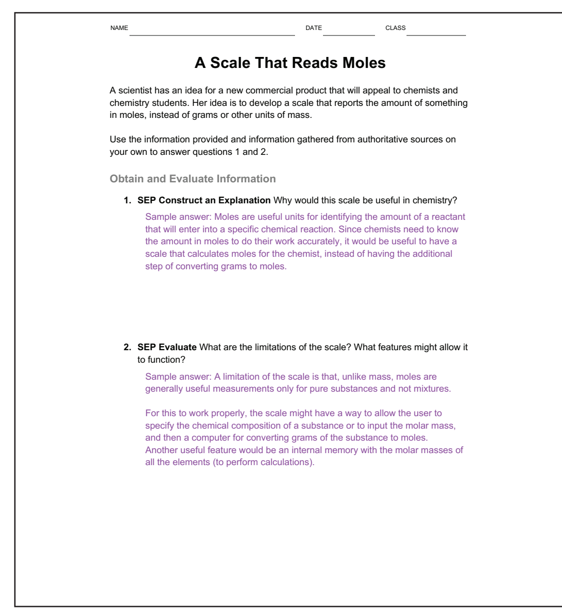
PEER REVIEW RUBRIC

Evaluate Put It Together

Use this rubric to help you assess your classmates' models and explanations of the reaction between chlorine and aluminum.

	EXEMPLARY Score the work 3 if:	ACCOMPLISHED Score the work 2 if:	DEVELOPING Score the work 1 if:	Explain Your Score
Components of the Model Score: ____	The model shows the correct ratio of molecules for the reaction and explains their movement. The correctly balanced equation is provided.	The model shows the same ratio of molecules as the equation, which may or may not be balanced correctly, and shows that no atoms have been created or destroyed (same number of atoms on both sides of the equation).	An attempt is made to balance the equation, but the model may not show the same ratio of molecules.	
Relationships Score: ____	The model accurately depicts the 2:3 ratio needed for the reaction to take place.	The model describes the correct ratio but does not accurately explain why the relative amounts of reactants are needed.	The model attempts to describe a relationship between the amounts of reactants and products of the reaction.	
Connections Score: ____	The model makes sense and can be adapted to represent equations of other reactions.	The model makes sense but is more specific to this reaction and may not be applied to understand other reactions.	The model is unclear and would not be effectively applied to understand other reactions.	
Limitations of the Model Score: ____	Limitations of this model are described, including that it only represents a limited number of molecules.	The explanation acknowledges that this model has limitations, though they are not clearly and specifically identified or described.	There is no acknowledgment that this model has limitations.	

Peer Review Rubric Interactive Worksheet



NAME ______ DATE ______ CLASS ______

A Scale That Reads Moles

A scientist has an idea for a new commercial product that will appeal to chemists and chemistry students. Her idea is to develop a scale that reports the amount of something in moles, instead of grams or other units of mass.

Use the information provided and information gathered from authoritative sources on your own to answer questions 1 and 2.

Obtain and Evaluate Information

1. **SEP Construct an Explanation** Why would this scale be useful in chemistry?

   Sample answer: Moles are useful units for identifying the amount of a reactant that will enter into a specific chemical reaction. Since chemists need to know the amount in moles to do their work accurately, it would be useful to have a scale that calculates moles for the chemist, instead of having the additional step of converting grams to moles.

2. **SEP Evaluate** What are the limitations of the scale? What features might allow it to function?

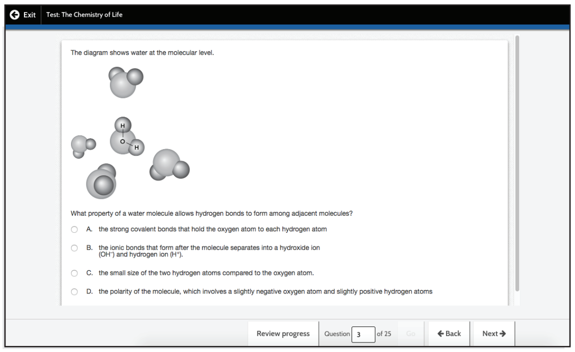
   Sample answer: A limitation of the scale is that, unlike mass, moles are generally useful measurements only for pure substances and not mixtures.

   For this to work properly, the scale might have a way to allow the user to specify the chemical composition of a substance or to input the molar mass, and then a computer for converting grams of the substance to moles. Another useful feature would be an internal memory with the molar masses of all the elements (to perform calculations).

Writing About Science Interactive Worksheet

INTEGRATE THE THREE DIMENSIONS

In the Writing About Science activity, students use computational thinking [SEP-5] to explain why a scale [CCC-3] that reports the amount of something in moles would be useful in chemistry. Students should consider how this scale could be used to describe and predict specific chemical reactions [PS1.B]. Students evaluate [SEP-8] the limitations of the scale and then describe what features might allow it to function.



Interactive Online Quiz

Quiz Interactive Worksheet

EVALUATE

Chemical Calculations

15

Quiz Assign the quiz in online technology-enhanced, auto-graded format or as an editable quiz worksheet. Use the scoring notes and remediation strategies found online to assess students' responses and to provide targeted feedback for each item to remediate well before assigning the summative 3-D Assessment.

REMEDIATION SUGGESTIONS

- **If** students are struggling to describe mole ratios, **then** have them review the first part of the simulation, Understanding Stoichiometry, in which they build a bicycle and compare the process to making a molecule.
- **If** students are struggling with the process of unit conversion, **then** have them review the second part of the simulation, Understanding Stoichiometry. Students may also work with a partner and discuss the steps that are confusing when they convert units.
- **If** students are having trouble interpreting the graphs in the Experience Notebook, **then** suggest they make a chart to record *x* and *y* coordinates of the lines at various points to see the mathematical relationship between the two lines.
- **If** students feel overwhelmed by the math and Sample Problems in the Experience Notebook, **then** have them focus on one type of conversion at a time, beginning with moles of a product, and practice problems until they feel confident enough to move on.

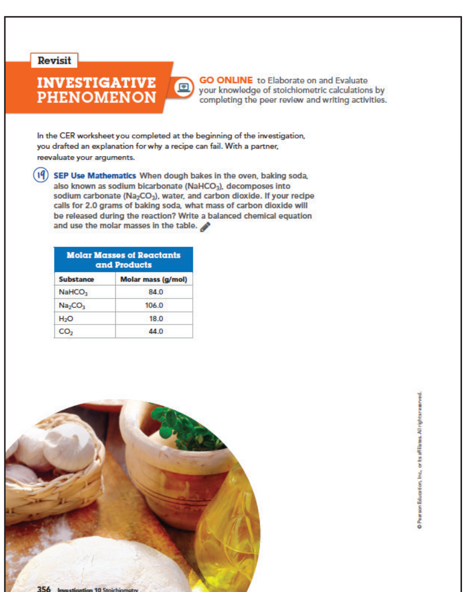
Revisit INVESTIGATIVE PHENOMENON

10

Support Reflection Students can complete the reflection prompt, where they will unpack and make sense of the Investigative Phenomenon, based on practices and understandings that have been reinforced over the course of the experience.

- Ask students if they are comfortable completing various chemical calculations that involve moles, volume, and mass.
- Have students work with a partner and summarize how chemical calculations are important in making sure recipes do not fail.

Further Develop Your CER Argument Have students add any evidence they have collected in this experience. Evidence may include the concept that substituting one mass or volume of an ingredient for another may not take into account molar mass and mole ratios of ingredients.


Revisit
INVESTIGATIVE PHENOMENON

GO ONLINE to Elaborate on and Evaluate your knowledge of stoichiometric calculations by completing the peer review and writing activities.

In the CER worksheet you completed at the beginning of the investigation, you drafted an explanation for why a recipe can fail. With a partner, reevaluate your arguments.

19 **SEP Use Mathematics** When dough bakes in the oven, baking soda, also known as sodium bicarbonate ($NaHCO_3$), decomposes into sodium carbonate (Na_2CO_3), water, and carbon dioxide. If your recipe calls for 2.0 grams of baking soda, what mass of carbon dioxide will be released during the reaction? Write a balanced chemical equation and use the molar masses in the table.

Molar Masses of Reactants and Products

Substance	Molar mass (g/mol)
$NaHCO_3$	84.0
Na_2CO_3	106.0
H_2O	18.0
CO_2	44.0

356 Investigation 10 Stoichiometry

Experience Notebook, p. 356

eTEXT

EXPERIENCE 3

Limiting Reagent and Percent Yield

Teacher Background

In Experience 3, students apply their stoichiometric skills to determine the limiting reactant in a reaction, after which they calculate and explain the percent yield. They begin with a hands-on Inquiry Lab followed by a Virtual Lab, both of which explore how the amount of product increases and then flattens out, as one reagent is first limiting and then in excess. The experience continues to review these concepts from a variety of angles, prompting students to complete problems and explain the answers. Finally, students apply the concept of a limiting reactant to the design of a rocket that will be launched using a reaction between baking soda and vinegar. Along the way, be sure that students continue to see the larger picture of the math describing and quantifying a phenomenon that occurs during chemical reactions.

Objectives

- **Explain the concept of limiting reactant and how it affects the amount of product produced in a reaction.**
- **Explain theoretical and actual yield and why the former is usually larger than the latter.**
- **Use computational thinking to predict the grams of product given the grams of reactant.**

ENGAGE

EVERYDAY PHENOMENON

What is the limiting reagent?

Use the teacher demo to prompt discussion about limiting reagents for the reaction that occurs when a candle burns.

Stop the Burn

Engage students with this demonstration of a burning candle in a bell jar to introduce the concept of limiting reactants.

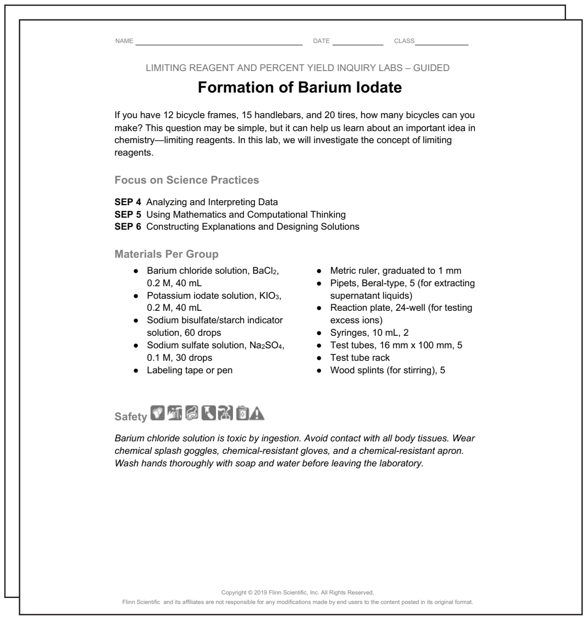
Materials candle, nonflammable surface, bell jar, match

1. Invite a volunteer to write on the board the balanced combustion equation that occurs when a candle burns: $2\ C_{18}H_{38} + 55\ O_2 \rightarrow 36\ CO_2 + 38\ H_2O$.
2. Place the candle on the nonflammable surface and light it. Allow it to burn for a minute or two to demonstrate that it continues to burn.
3. Place the bell jar over the burning candle. Have students observe the candle until the flame goes out.
4. Point to the combustion equation on the board and ask what two reactants must be available for the candle to burn. Explain that when the bell jar was placed over the candle, the amount of oxygen became limited. Not enough oxygen was available to react with all of the candle wax. Explain that oxygen was a limiting reagent and that students will learn more about limiting reagents in the Inquiry Lab.
5. Ask students what they think the result would be if a cake batter had an insufficient amount of an ingredient.

RELATED PHENOMENA

In addition to Stop the Burn teacher demo, consider using other phenomena to launch this experience.

- **Cakes with More or Less** Write this reaction that occurs in cake batter: baking soda + cream of tartar + water → carbon dioxide. Tell students that this reaction is what causes cake to rise: the CO_2 produces bubbles in the batter. Discuss how using more or less of baking soda or cream of tartar that is called for in the recipe would affect the resulting cake.
- **Tickets to a Show** Present this scenario: You want to buy as many tickets as you can to an upcoming show. The tickets are $15 and you have $50. **Ask** How many tickets can you buy? Explain that the money is the limiting reactant, even though you will have some left over. If the show were sold out except for two tickets, the tickets would be limiting.


NAME ______ DATE ______ CLASS ______

LIMITING REAGENT AND PERCENT YIELD INQUIRY LABS – GUIDED

Formation of Barium Iodate

If you have 12 bicycle frames, 15 handlebars, and 20 tires, how many bicycles can you make? This question may be simple, but it can help us learn about an important idea in chemistry—limiting reagents. In this lab, we will investigate the concept of limiting reagents.

Focus on Science Practices

SEP 4 Analyzing and Interpreting Data
SEP 5 Using Mathematics and Computational Thinking
SEP 6 Constructing Explanations and Designing Solutions

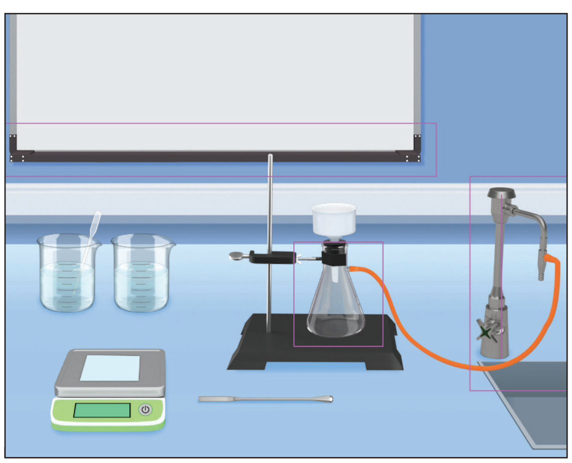
Materials Per Group

- Barium chloride solution, $BaCl_2$, 0.2 M, 40 mL
- Potassium iodate solution, KIO_3, 0.2 M, 40 mL
- Sodium bisulfate/starch indicator solution, 60 drops
- Sodium sulfate solution, Na_2SO_4, 0.1 M, 30 drops
- Labeling tape or pen
- Metric ruler, graduated to 1 mm
- Pipets, Beral-type, 5 (for extracting supernatant liquids)
- Reaction plate, 24-well (for testing excess ions)
- Syringes, 10 mL, 2
- Test tubes, 16 mm x 100 mm, 5
- Test tube rack
- Wood splints (for stirring), 5

Safety

Barium chloride solution is toxic by ingestion. Avoid contact with all body tissues. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Wash hands thoroughly with soap and water before leaving the laboratory.

O/G/S/A Lab Interactive Worksheets



Virtual Lab

CLASSROOM MODIFICATIONS

Based on your students' abilities and your schedule, you may wish to edit the Virtual Lab to be more open ended or more guided.

- **More Open Ended** Instead of providing a procedure for determining how adding different amounts of magnesium sulfate to sodium carbonate affects the mass of solid magnesium carbonate that formed, have students determine that on their own.
- **More Guided** Provide students with a data table with the data filled in for $MgSO_4$ added (mL) and $MgCO_3$ produced (g). Define the relationship between the two and discuss it with students.

EXPLORE

Formation of Barium Iodate

Inquiry Lab In this lab, students vary the amounts of either Ba^{2+} or IO_3^- to evaluate limiting reagents and how the mole ratio [SEP-5] between the reactants [PS1.B] plays a role.

Lab Demo Video Watch the Lab Demo Video for advice on materials and preparation.

Choose Your Version Open-ended (O), Guided (G), Shortened (S), Advanced (A)

Materials 40 mL 0.2 M barium chloride solution, 40 mL 0.2 M potassium iodate solution, 60 drops sodium bisulfate/starch indicator solution, 30 drops 0.1 M sodium sulfate solution, labeling tape or pen, metric ruler, 5 Beral-type pipets (for extracting supernatant liquids), 24-well reaction plate (for testing excess ions), 2 10-mL syringes, 5 16 × 100 mm test tubes, test tube rack, 5 wood splints (for stirring)

Safety Tell students that barium chloride solution is toxic by ingestion, and that they should avoid contact with all body tissues. Students should wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Remind students to wash their hands thoroughly with soap and warm water before leaving the laboratory.

Expected Outcome In Stage 1, when the volume of barium exceeds that of the iodate, the barium will be in excess and the height of the precipitate will be greater. In Stage 2, students will need to conclude to hold the volume of barium constant. The barium will remain in excess until the volume of iodate is twice that of barium.

Lab Summary Video Watch the Lab Summary Video for support on connecting the lab investigation to the Investigative Phenomenon.

Limiting Reagent

Virtual Lab In this Virtual Lab, students investigate [SEP-3] the concept of gold in the ocean and whether dissolved gold can be changed into solid gold. They explore the reaction [PS1.B] between magnesium sulfate and sodium carbonate by analyzing data [SEP-4] on a graph generated by the choices they make in the lab.

- Using a projector, demonstrate the lab to students, asking them to draw parallels between this Virtual Lab and the Inquiry Lab they carried out earlier. Then tell students to work on their own to complete the lab, making notes in their science notebooks.
- When students have finished, pair them to discuss their results and conclusions. Tell pairs to compose a paragraph that summarizes the key points in this lab and relates this lab to the previous one.

ASSESS ON THE SPOT

Tell students to write a short journal entry in their science notebooks that explains what they did and learned in the Inquiry and Virtual Labs. Collect the notebooks entries and review them to gauge understanding.

INTEGRATE MATH

Unit Conversions As students are working their way through the Virtual Lab, tell them to calculate the number of moles of each reactant being used at each point and the mass of product produced. Have them make a graph of moles of Na versus moles of NaCl produced. Tell them to determine the point in the lab at which moles of reactant have reached the proper ratio so that all of the reactant is used up. Remind them to make notes and do these calculations in their science notebooks.

EXPLAIN

A Measure of Success

Claim-Evidence-Reasoning In this activity, students construct an explanation [SEP-6] about the percent yield of a decomposition reaction [PS1.B] of potassium chlorate ($KCLO_3$). Students should support their claims with observed evidence and scientific reasoning.

- Review the concepts of theoretical, actual, and percent yield from the Inquiry and Virtual Labs. Give everyday examples, such as a cookie recipe that claimed to yield 30 cookies but only produced 28.
- Emphasize to students that their CERs should include calculations and explanations of how error arises. Remind them that experimental error is different from human error.
- You may wish to select some peers in the class to answer questions for students who are stuck or intimidated by the math. You could allow these peers to help their classmates one-on-one, or consult with them in small groups where students can ask questions and hear responses to their peers' questions as well.

PROFESSIONAL DEVELOPMENT

Science and Engineering Notebooks Throughout this experience, encourage students to use their science notebooks to record problem-solving techniques, make sketches, and use writing to connect concepts. Prompt students to consider how the concepts of mole ratio and theoretical yield are connected. Remind students that this experience involves many types of calculations. Tell them to make a chart or table to keep track of the types of calculations and examples of each. Point out that this type of chart will be very useful for them when solving problems.

Limiting Reagent and Percent Yield

Experience Notebook Assign this section of the Experience Notebook or Realize Reader before having students work on any of the activities in the Elaborate portion of this experience. The background knowledge found here is vital for understanding those assignments.

Use the strategies below to help students better understand the content on the indicated pages.

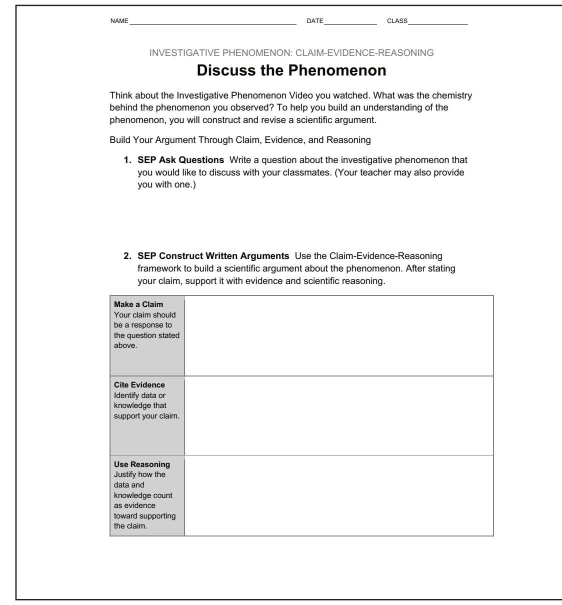
- **Limiting Ingredients** (p. 357) Prompt students to think about limiting factors by applying them to scenarios they have already encountered in this investigation—tricycles, recipes, and any demonstrations you have done. Then shift to chemical equations. Provide students with a few reactions with 1:1 molar ratios. Ask students to tell you the limiting reactant and explain why it is limiting.
- **Limiting and Excess Reagents** (p. 358) Review the bicycle model. Then pair students and tell them to refer to the diagram for the production of ammonia to determine the limiting and excess reactant, and how much excess reactant there is in these two scenarios:

  a. start with 10 moles of N_2 and 10 moles of H_2

  b. start with 6 moles of N_2 and 5 moles of H_2
- **Mass of Products and Reactants** (p. 359) As a class, review mole–mass conversions. Explain to students that they can apply these calculations to scenarios such as the ones they were given for the previous page. Have students work in pairs to determine the limiting and excess reactants in these scenarios:

  a. start with 14 g of N_2 and 14 g of H_2

  b. start with 42 g of N_2 and 8 g of H_2



NAME ____ DATE ____ CLASS ____

INVESTIGATIVE PHENOMENON: CLAIM-EVIDENCE-REASONING

Discuss the Phenomenon

Think about the Investigative Phenomenon Video you watched. What was the chemistry behind the phenomenon you observed? To help you build an understanding of the phenomenon, you will construct and revise a scientific argument.

Build Your Argument Through Claim, Evidence, and Reasoning

1. **SEP Ask Questions** Write a question about the investigative phenomenon that you would like to discuss with your classmates. (Your teacher may also provide you with one.)
2. **SEP Construct Written Arguments** Use the Claim-Evidence-Reasoning framework to build a scientific argument about the phenomenon. After stating your claim, support it with evidence and scientific reasoning.

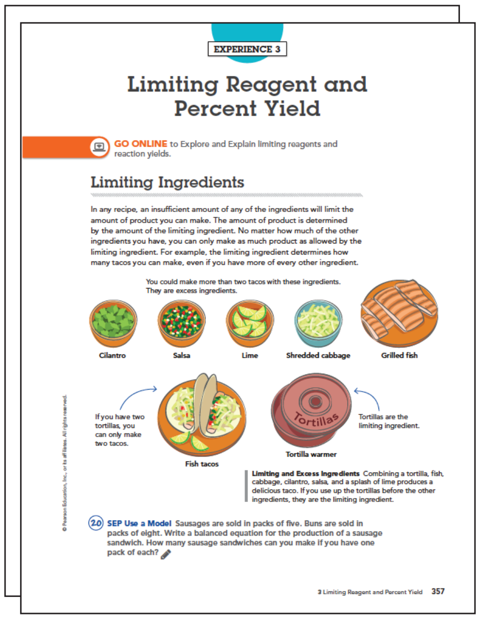
Make a Claim Your claim should be a response to the question stated above.	
Cite Evidence Identify data or knowledge that support your claim.	
Use Reasoning Justify how the data and knowledge count as evidence toward supporting the claim.	

CER Interactive Worksheet

ELD SUPPORT

Selecting Language Resources In pairs, students provide written responses affirming their general understanding about the percent yield of a reaction in the CER activity.

- **Emerging** Have students make a list of words and phrases that are specific to the concepts in the CER activity. Tell them to discuss meanings of these words and phrases, using context and word cognates to help them with vocabulary they are uncertain about.
- **Expanding** Have students make a list of words and phrases they know that relate to the percent yield of a reaction. Tell them to review meanings of each phrase and discuss how they might use it to support their CER.
- **Bridging** Challenge students to use scientific and academic language by giving them a word limit for sections on their CER. Encourage them to use concise phrasings that convey complex ideas to support their CER.


EXPERIENCE 3

Limiting Reagent and Percent Yield

GO ONLINE to Explore and Explain limiting reagents and reaction yields.

Limiting Ingredients

In any recipe, an insufficient amount of any of the ingredients will limit the amount of product you can make. The amount of product is determined by the amount of the limiting ingredient. No matter how much of the other ingredients you have, you can only make as much product as allowed by the limiting ingredient. For example, the limiting ingredient determines how many tacos you can make, even if you have more of every other ingredient.

Limiting and Excess Ingredients Combining a tortilla, fish, cabbage, cilantro, salsa, and a splash of lime produces a delicious taco. If you use up the tortillas before the other ingredients, they are the limiting ingredient.

20 **SEP Use a Model** Sausages are sold in packs of five. Buns are sold in packs of eight. Write a balanced equation for the production of a sausage sandwich. How many sausage sandwiches can you make if you have one pack of each?

Experience Notebook, pp. 357–367

eTEXT

SAMPLE PROBLEM SUPPORT

When taking students through the Sample Problems in the Experience Notebook, introduce each with a real-life example. Work the computation visually, using tricycles, and then introduce the chemical reaction. With each new calculation, refer to the previous problem(s) to show how each new problem builds on what was done in the previous one.

Make a visual model of the reaction and use circles and arrows to show how parts of the equation are related to the atoms and molecules in the reaction. Color-code the model if possible.

CONNECT TO CAREERS

Food Chemist Food chemists are professionals who specialize in developing recipes by considering quantities and proportions of chemicals. Explain that many of the packaged foods students may eat every day—frozen pizza, cake mixes, even snack chips—contain flavor mixtures and chemicals that affect how the food looks and tastes. A food chemist will often test many different proportions of ingredients to see how changes in the chemistry affect the food product. Tell students to choose one processed food and do research to determine what kind of knowledge a chemist developing that food would need.

- **Sample Problem Support** (pp. 361–364) If students have difficulty with part b of question 24 on page 361, walk them through it. Explain that they should start with 2.7 moles of C_2H_4 (given) and multiply that by the ratio of moles of H_2O over moles of C_2H_4 from the balanced equation (2/1).

  $$2.7 \text{ mol } C_2H_4 \times \frac{2 \text{ mol } H_2O}{1 \text{ mol } C_2H_4} = 5.4 \text{ mol } H_2O$$

  If students have trouble with calculating theoretical yield on page 364, walk them through question 27. Begin with 84.8 g Fe_2O_3 (given). Find how many grams of Fe_2O_3 and Fe equal a mole by using the atomic mass on the periodic table.

  $$84.8 \text{ g } Fe_2O_3 \times \frac{1 \text{ mol } Fe_2O_3}{159.7 \text{ g } Fe_2O_3} \times \frac{2 \text{ mol Fe}}{1 \text{ mol } Fe_2O_3} \times \frac{55.8 \text{ g Fe}}{1 \text{ mol Fe}} = 59.3 \text{ g Fe}$$

- **Percent Yield** (pp. 362–363) Return to the bicycle model. Have students describe the theoretical yield if you have 12 frames, 24 pedals, and 36 wheels. Then have them describe what the actual yield would be if a friend comes along and takes two of the pedals for a project of his or her own. Pair students and tell them to review the Sample Problem on page 364, and explain how they would calculate and explain the percent yield of tricycles. Ask pairs for their answers and discuss any questions students have.

DIFFERENTIATED INSTRUCTION

- **Support Special Needs Students** To help students integrate the mathematical concepts, have them work through a practice problem in pairs, using colored pens or pencils. Practice problem: A reaction with a calculated yield of 9.23 g produced 7.89 g of product. What is the percent yield of the reaction? (85.5%)
- **Support Less Proficient Readers** Encourage students to first focus on the graphic on page 358 of the Experience Notebook. Tell them to write or say aloud an explanation of what the graphic is showing. Then tell them to look through the text for phrases that describe the graphic, using the image to support their understanding.
- **Support Advanced Students** Invite students to choose one of the online problems and make a 3-D model of it, which they can then present to classmates or use as a peer tutor to support students who are more challenged by the material.

ASSESS ON THE SPOT

As students are work on practice problems, take a quick survey using hand signals to gauge understanding.
Thumbs up = I've got this.
Thumbs down = I'm frustrated and confused.
Hand flat, palm down = I'm ok, but have questions.
Work with frustrated students while having those who gave thumbs up answer questions for others.

ELABORATE

Evaluate Error

Discussion Rubric In this activity, students discuss [SEP-8] why percent yield is different from theoretical yield. Then they use the rubric as a scoring guide to assess their evaluation of theoretical yield compared to actual yield.

- Allow students time to revise their CER in light of what they have learned since they first filled it out. Remind them to use clear evidence and reasoning and to communicate as clearly as they can. Point out that they can include explanations of:
  a. Why percent yield is usually less than theoretical yield
  b. What might cause percent yield to be higher than theoretical yield
  c. Why experimental error and uncertainties always occur in scientific experiments
  d. The difference between human and experimental error
- In small groups, have students share their revised CERs. After group discussion, tell students to use the rubric to evaluate their understanding and communication, keeping in mind that they will be assessed on the accuracy of their self-evaluation.

Build a Film Canister Rocket

Engineering Design Challenge In this activity, students apply their knowledge of chemical reactions [PS1.B], stoichiometry, and conservation of mass [CCC-5] to design [ETS1.C] and launch a film canister rocket 1 m high using a specific ratio of reactants as fuel.

Materials and Advance Preparation 5 g sodium bicarbonate, 15 mL vinegar per trial, balance, film canister with cap, manila folder, meterstick, scissors, spatula, tape or glue, timer, large tray, weighing dish or paper, colored markers (optional), paper clips (optional), tissue paper (optional)

Expected Outcome The highest_launching rockets will have a large ratio between the rocket's weight and the mass of baking soda.

Safety Sodium bicarbonate may be harmful if swallowed. Instruct students to wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Make sure students wash their hands thoroughly with soap and warm water before leaving the laboratory.

Use the following strategies to guide students as they complete steps in the Engineering Design Challenge.

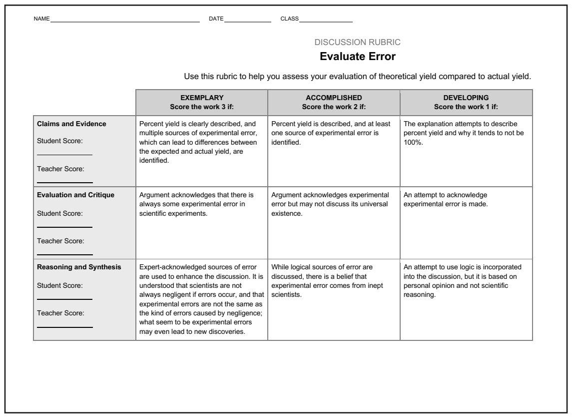
Step 1 When defining the problem, encourage students to include all of the information they must discern. For example, how much will the rocket weigh? How much fuel is needed to launch that weight of rocket? Their definition of the problem may include more than one step or problem to solve.

Step 3 Remind students to use authoritative sources and to keep a record of all of their sources.

Step 4 Remind uncertain students that they should do their best to get their design correct but should also expect to have to make adjustments and do several trials. They do not have to get the perfect design on their first try.

ASSESS ON THE SPOT

Tell student groups that their task at the end of this experience is to come up with a question that will stump you. Divide students into small groups or use the groups that were working together on the Engineering Design Challenge. Explain that each group must come up with a question and the answer to it, and then pose their question to you. Then have groups ask their questions. You may wish to introduce this activity at the end of the previous class period or at the beginning of this one, to help students start thinking of questions to pose.



NAME ______ DATE ______ CLASS ______

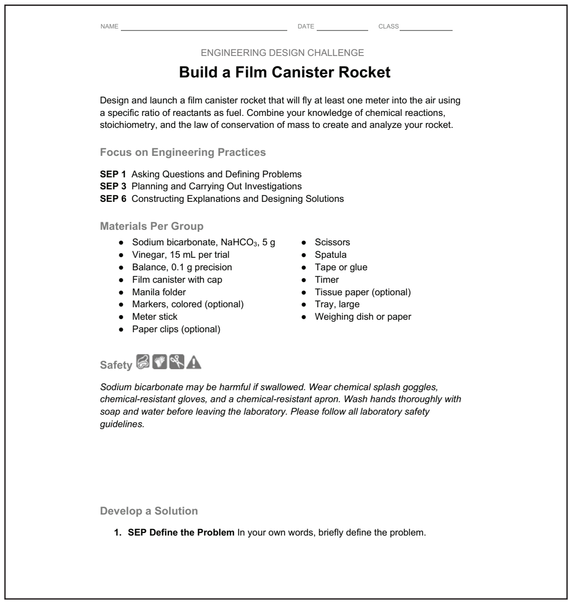
DISCUSSION RUBRIC

Evaluate Error

Use this rubric to help you assess your evaluation of theoretical yield compared to actual yield.

	EXEMPLARY Score the work 3 if:	ACCOMPLISHED Score the work 2 if:	DEVELOPING Score the work 1 if:
Claims and Evidence Student Score: ______ Teacher Score: ______	Percent yield is clearly described, and multiple sources of experimental error, which can lead to differences between the expected and actual yield, are identified.	Percent yield is described, and at least one source of experimental error is identified.	The explanation attempts to describe percent yield and why it tends to not be 100%.
Evaluation and Critique Student Score: ______ Teacher Score: ______	Argument acknowledges that there is always some experimental error in scientific experiments.	Argument acknowledges experimental error but may not discuss its universal existence.	An attempt to acknowledge experimental error is made.
Reasoning and Synthesis Student Score: ______ Teacher Score: ______	Expert-acknowledged sources of error are used to enhance the discussion. It is understood that scientists are not always negligent if errors occur, and that experimental errors are not the same as the kind of errors caused by negligence; what seem to be experimental errors may even lead to new discoveries.	While logical sources of error are discussed, there is a belief that experimental error comes from inept scientists.	An attempt to use logic is incorporated into the discussion, but it is based on personal opinion and not scientific reasoning.

Discussion Rubric Interactive Worksheet



NAME ______ DATE ______ CLASS ______

ENGINEERING DESIGN CHALLENGE

Build a Film Canister Rocket

Design and launch a film canister rocket that will fly at least one meter into the air using a specific ratio of reactants as fuel. Combine your knowledge of chemical reactions, stoichiometry, and the law of conservation of mass to create and analyze your rocket.

Focus on Engineering Practices

SEP 1 Asking Questions and Defining Problems
SEP 3 Planning and Carrying Out Investigations
SEP 6 Constructing Explanations and Designing Solutions

Materials Per Group

- Sodium bicarbonate, $NaHCO_3$, 5 g
- Vinegar, 15 mL per trial
- Balance, 0.1 g precision
- Film canister with cap
- Manila folder
- Markers, colored (optional)
- Meter stick
- Paper clips (optional)
- Scissors
- Spatula
- Tape or glue
- Timer
- Tissue paper (optional)
- Tray, large
- Weighing dish or paper

Safety

Sodium bicarbonate may be harmful if swallowed. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Wash hands thoroughly with soap and water before leaving the laboratory. Please follow all laboratory safety guidelines.

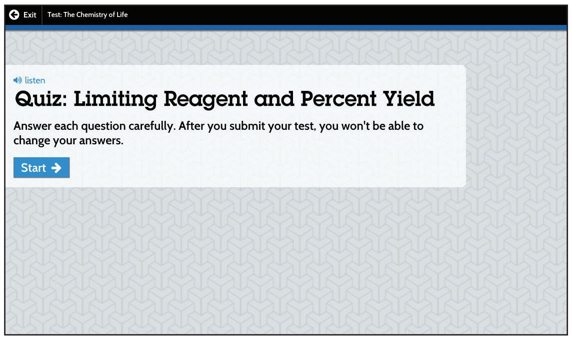
Develop a Solution

1. **SEP Define the Problem** In your own words, briefly define the problem.

Engineering Design Challenge Interactive Worksheet

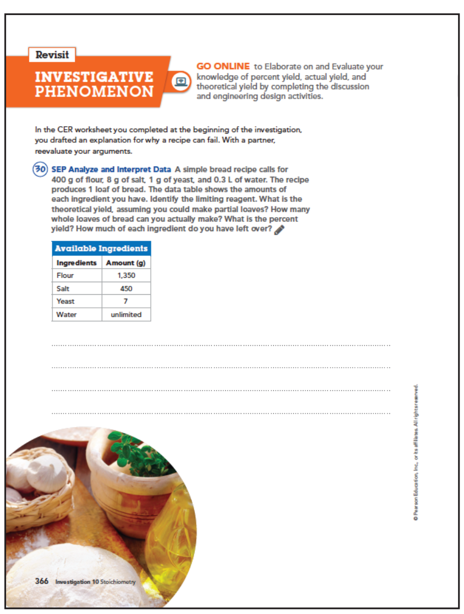
INTEGRATE THE THREE DIMENSIONS

In the Engineering Design Challenge, students conduct an investigation [SEP-3] to determine the correct ratio [CCC-3] of ingredients to design [ETS1.C] and launch a film canister rocket 1 m high. Students consider the proportional nature of chemical reactions [PS1.B] and how it governs the amount of product produced, and therefore, the amount of fuel that will be required to launch the rocket.



Interactive Online Quiz

Quiz Interactive Worksheet


Revisit

INVESTIGATIVE PHENOMENON

GO ONLINE to Elaborate on and Evaluate your knowledge of percent yield, actual yield, and theoretical yield by completing the discussion and engineering design activities.

In the CER worksheet you completed at the beginning of the investigation, you drafted an explanation for why a recipe can fail. With a partner, reevaluate your arguments.

30 **SEP Analyze and Interpret Data** A simple bread recipe calls for 400 g of flour, 8 g of salt, 1 g of yeast, and 0.3 L of water. The recipe produces 1 loaf of bread. The data table shows the amounts of each ingredient you have. Identify the limiting reagent. What is the theoretical yield, assuming you could make partial loaves? How many whole loaves of bread can you actually make? What is the percent yield? How much of each ingredient do you have left over?

Available Ingredients

Ingredients	Amount (g)
Flour	1,350
Salt	450
Yeast	7
Water	unlimited

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EVALUATE

Limiting Reagent and Percent Yield

15

Quiz Assign the quiz in online technology-enhanced, auto-graded format or as an editable quiz worksheet. Use the scoring notes and remediation strategies found online to assess students' responses and to provide targeted feedback for each item to remediate well before assigning the summative 3-D Assessment.

REMEDIATION SUGGESTIONS

- **If** students are struggling to revise their explanations about the percent yield of a reaction, **then** tell them to review their Experience Notebooks and labs for additional support.
- **If** students are struggling with the concepts of limiting reactant in the Experience Notebook, **then** tell them to review the Inquiry and Virtual Labs to connect their reactions with the graphs that they made.
- **If** students are challenged by the CER and discussion rubric, **then** tell them to review the Sample Problems and page 363 in the Experience Notebook.
- **If** students are struggling to design a rocket that will fly a meter in the Engineering Design Challenge, **then** refer them to the Experience Notebook to consider the effect of having vinegar as the limiting reactant versus baking soda.

Revisit INVESTIGATIVE PHENOMENON

10

Support Reflection Students can complete the reflection prompt, where they will unpack and make sense of the Investigative Phenomenon, based on practices and understandings that have been reinforced over the course of the experience.

- Ask students how comfortable they are determining limiting reagents. On the board, work through a few more examples solving for the unknown limiting reagent. Ask students to tie in how limiting reagents are determined in recipes.
- Have students summarize differences between calculating theoretical and percent yield. Make sure students have a complete grasp of the two different yields.

Evaluate and Revise Your CER Argument Have students answer questions 3 and 4 in the CER activity and re-evaluate the claim they made. Students should add any additional evidence they have collected in this investigation and revise their CER. Evidence may include a limiting reactant shift in the recipe as the result of the change, or errors in measurement that result in less of the product than expected.

EVALUATE

Stoichiometry

3-D Assessment For a summative assessment of Investigation 7, assign the 3-D Assessment, which is available online as an ExamView bank or as an editable worksheet.

The Stoichiometry of Filling a Balloon

Performance-Based Assessment Use this Performance-Based Assessment to assess students' mastery of the standards. In this activity, students determine the amount of sodium bicarbonate to add to acetic acid to produce a specific amount of carbon dioxide gas. Students use mathematical and computational thinking [SEP-5] to calculate the mass of sodium carbonate needed to produce certain moles of carbon dioxide gas and to calculate moles of acetic acid used in their experiment. They identify patterns [CCC-1] and interpret their data [SEP-4]. They use the results to determine which reactant is the limiting reagent and which is in excess in the reaction [PS1.B]. They design a solution [SEP-6] for how to measure the amount of carbon dioxide produced in the reaction to determine whether the reaction went to completion. They construct an explanation on how the experiment would be changed if it were carried out with a different substance instead.

Safety Acetic acid is a skin and eye irritant, make sure students avoid contact with eyes and skin. Students should wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Remind students to wash hands thoroughly with soap and warm water before leaving the laboratory.

Expected Outcome The balloon size should increase fairly uniformly for flasks 1–4 and then stay constant. It may be hard to tell the difference between flasks 3, 4, 5, and 6. The limiting reagent is sodium bicarbonate for the first three flasks and acetic acid for the remaining three.

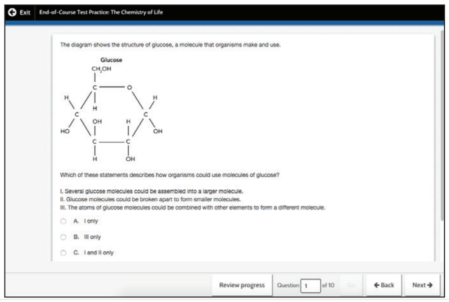
Experience Notebook (p. 367) After students complete the Performance-Based Assessment, have them complete the reflection prompt in the Experience Notebook.

DIFFERENTIATED INSTRUCTION

- **Support Struggling Students** Struggling students may have difficulty completing the stoichiometry math involved in the Performance-Based Assessment. Have an advanced student help them with the parts they are having difficulty on.
- **Support Advanced Students** Have advanced students add an additional flask (flask 7) to their lab. This flask should be greater than flask 6, which has 0.036 theoretical moles of carbon dioxide produced. Alternatively, advanced students can expand upon the design the solution by listing criteria and constraints.

How can we produce better foods?

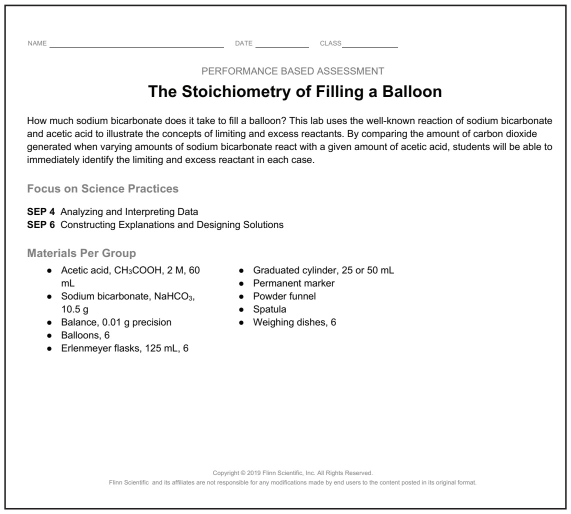
Revisit Anchoring Phenomenon At the end of Investigation 7, have students revisit the Anchoring Phenomenon question about how to produce better foods. Lead a class discussion about limiting ingredients (reagents) of food dishes. Prompt students to relate those responses to explain how foods can be produced better.



Interactive Online 3-D Assessment

Interactive ExamView 3-D Assessment

3-D Assessment Interactive Worksheet



NAME ______ DATE ______ CLASS ______

PERFORMANCE BASED ASSESSMENT

The Stoichiometry of Filling a Balloon

How much sodium bicarbonate does it take to fill a balloon? This lab uses the well-known reaction of sodium bicarbonate and acetic acid to illustrate the concepts of limiting and excess reactants. By comparing the amount of carbon dioxide generated when varying amounts of sodium bicarbonate react with a given amount of acetic acid, students will be able to immediately identify the limiting and excess reactant in each case.

Focus on Science Practices

SEP 4 Analyzing and Interpreting Data
SEP 6 Constructing Explanations and Designing Solutions

Materials Per Group

- Acetic acid, CH_3COOH, 2 M, 60 mL
- Sodium bicarbonate, $NaHCO_3$, 10.5 g
- Balance, 0.01 g precision
- Balloons, 6
- Erlenmeyer flasks, 125 mL, 6
- Graduated cylinder, 25 or 50 mL
- Permanent marker
- Powder funnel
- Spatula
- Weighing dishes, 6

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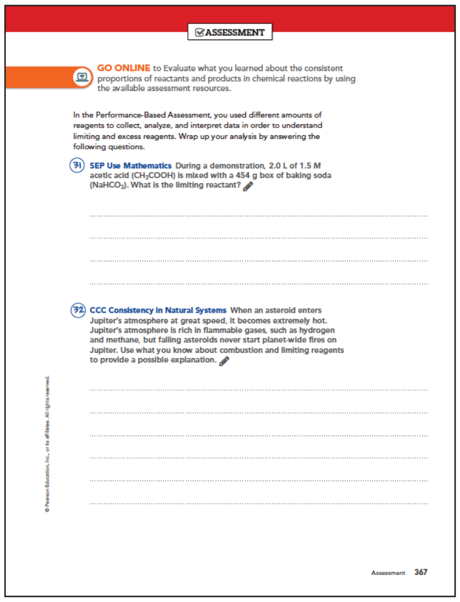
Performance-Based Assessment Interactive Worksheet



ASSESSMENT

GO ONLINE to Evaluate what you learned about the consistent proportions of reactants and products in chemical reactions by using the available assessment resources.

In the Performance-Based Assessment, you used different amounts of reagents to collect, analyze, and interpret data in order to understand limiting and excess reagents. Wrap up your analysis by answering the following questions.

31 **SEP Use Mathematics** During a demonstration, 2.0 L of 1.5 *M* acetic acid (CH_3COOH) is mixed with a 454 g box of baking soda ($NaHCO_3$). What is the limiting reactant?

32 **CCC Consistency in Natural Systems** When an asteroid enters Jupiter's atmosphere at great speed, it becomes extremely hot. Jupiter's atmosphere is rich in flammable gases, such as hydrogen and methane, but falling asteroids never start planet-wide fires on Jupiter. Use what you know about combustion and limiting reagents to provide a possible explanation.

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