INVESTIGATION 7 PLANNER

# Stoichiometry

In this investigation, students deepen their understanding of energy and matter [CCC-5] through a study of stoichiometry. Students interpret equations of chemical reactions [PS1.B]. They complete calculations of mole, mass, and volume for 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.

| | EXPERIENCE 1<br>**Quantifying Reactants and Products**<br>**2 days** | EXPERIENCE 2<br>**Chemical Calculations**<br>**2.5 days** |
|---|---|---|
| | Students explore equations as a recipe. They construct an argument using evidence of how to quantify reactants and products. Students investigate what is conserved according to the law of conservation of mass. | 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. 210 | **Teacher's Guide** Everyday Phenomenon Counting a Year in Milliseconds, p. 217 |
| **EXPLORE** | **Inquiry Lab** Identify Unknowns Through Stoichiometry<br>**Analyzing Data** Proportional Relationships in Chemical Reactions ⊕ | **Inquiry Lab** Determination of Reaction Output<br>**Interactivity** Understanding Stoichiometry ⊕ |
| **EXPLAIN** | **Modeling** Put It Together<br>**Experience Notebook,** pp. 252–257 | **Modeling** Choose a Practical Unit<br>**Animation** Stoichiometry Calculations ⊕<br>**Experience Notebook,** pp. 259–267 |
| **ELABORATE** | **Peer Review Rubric** Evaluate Put It Together<br>**Writing About Science** Parts and the Whole ⊕ | **Peer Review Rubric** Evaluate a Practical Unit<br>**Writing About Science** A Scale That Reads Moles ⊕ |
| **EVALUATE** | **Quiz** Quantifying Reactants and Products<br>**Experience Notebook** Revisit Investigative Phenomenon, p. 258 | **Quiz** Chemical Calculations<br>**Experience Notebook** Revisit Investigative Phenomenon, p. 268 |

*Pacing for Encounter Investigative Phenomenon core instruction is a half-day.

†Pacing for core Investigation Assessment is approximately 1 day.

**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*

**Virtual Reality Experience**

**Experience Notebook,** p. 250*

## EXPERIENCE 3

### Limiting Reagent and Percent Yield

**2 days**

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 the theoretical yield of partial loaves of bread, calculate percent yield, and 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. 223

**Inquiry Lab** Formation of Barium Iodate

**Virtual Lab** Limiting Reagent

**Claim-Evidence-Reasoning** A Measure of Success

**Experience Notebook,** pp. 269–277

**Discussion Rubric** Evaluate Error

**Engineering Design Challenge** Build a Film Canister Rocket

**Quiz** Limiting Reagent and Percent Yield

**Experience Notebook** Revisit Investigative Phenomenon, p. 278

## INVESTIGATION ASSESSMENT

**Performance-Based Assessment** The Stoichiometry of Filling a Balloon†

**3-D Assessment** Stoichiometry†

**Experience Notebook** Performance-Based Assessment, p. 279; Revisit Anchoring Phenomenon, p. 279†; **Appendix C** Problem Bank, pp. R17–R19

# 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

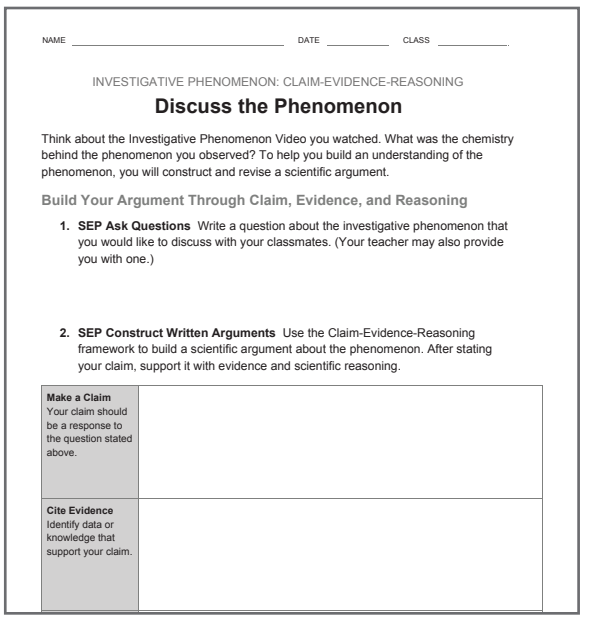
**Claim-Evidence-Reasoning** Have students review the video to help in their understanding of the phenomenon they observed. To help build understanding of the phenomenon, brainstorm a list of questions about the observed phenomenon. Have students complete Question 1 of the CER worksheet and start thinking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

**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. | |

**CER Interactive Worksheet**


**Experience Notebook,** pp. 250–251

**eTEXT**