Teacher's Edition

IQWST

Introduction to Chemistry

How Can I Make New Stuff from Old Stuff?

Second Edition

HOW CAN I MAKE NEW STUFF FROM OLD STUFF?

Chemical Reactions and Conservation of Matter

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Investigating and Questioning Our World through Science and Technology (IQWST)

HOW CAN I MAKE NEW STUFF FROM OLD STUFF?

Chemical Reactions and Conservation of Matter

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About the Publisher

Sangari Active Science Corporation is a mission-driven company that is passionate about STEM education. We make it easy for teachers to teach with quality, investigation-centered science curriculum, tools, and technology. For more information about what we do, please visit our website at http://www.sangariglobaled.com.

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IC2 CONTENTS

IQWST OVERVIEW

IQWST is a carefully sequenced, 12-unit middle school science curriculum, developed with support from the National Science Foundation. As designed, each academic year includes four units, one in each discipline: Physics, Chemistry, Life Science, and Earth Science. IQWST's foundation is the latest research on how students learn and how they learn science in particular. At its core, IQWST engages students in scientific practices as they experience, investigate, and explain phenomena while learning core ideas of science. Rather than memorizing facts, students build understanding by connecting ideas across disciplines and across the middle grades. The following are key components of IQWST, important whether following NGSS, the Framework, or individual state standards.

Core Ideas: Focus on a limited number of core science ideas, aiming for depth of understanding rather than the superficial coverage inherent when aiming for breadth.

Scientific Practices: Engage meaningfully in science and the work of scientists through eight practices, used singly or in combination to explore and learn core ideas *in each lesson*.

Crosscutting Concepts: Thread throughout the curriculum the seven cross-disciplinary concepts, repeatedly revisited such that students construct deep understanding of the ideas as they apply to each science discipline.

Coherence: Build understanding through a progression within each grade level and across grade levels. Learning critical concepts and practices across content areas and grades provides students with opportunities to develop, reinforce, and use their understandings on an ongoing basis throughout their middle school years.

Performance Expectations: Identify *how* students engage with a specific practice in order to learn a specific core idea and to build increasing understanding of a broader crosscutting concept.

THE IQWST UNIT SEQUENCE: BUILDING COHERENCE

Although IQWST units can be enacted in a manner that meets district needs, they are designed based on research that shows the importance of coherent curriculum, structured such that students build understanding as they revisit ideas across disciplinary strands, content, and grade levels and deepen their understanding across time. The *Framework* indicates, "Standards should be organized as progressions that support students' learning over multiple grades. They should take into account how students' command of concepts, core ideas, and practices becomes more sophisticated over time with appropriate instructional experiences" (NRC 2011).

The role of coherence in materials and instruction is well documented: Most science programs (textbooks and instruction) do not support deep, integrated student learning because they lack coherence (Kesidou & Roseman, 2002; National Research Council, 2007). Yet presenting interrelated ideas and making connections between and among them explicit (Roseman, Linn, & Koppal, 2008) was found to be the strongest predictor of student outcomes in the Trends in International Mathematics and Science Study (TIMSS) (Schmidt, Wang, & McKnight, 2005).

Curricular coherence is best accomplished through teaching the ideas in IQWST units in a recommended sequence. That sequence aligns with NGSS, which treats a core idea such as "energy," for example, as both a Crosscutting Concept and a Core Idea. In IQWST, students engage with ideas about energy in the first physical science unit of the sequence and then revisit energy concepts in life science, chemistry, and Earth science—and in later physical science units—so that as students apply energy ideas to new content and contexts, their understanding of one of the most challenging concepts in science education deepens across middle school.

The following chart illustrates the recommended sequence for optimum curriculum coherence, enabling students to build on and revise their understanding of core content and to strengthen their ability to successfully engage in scientific practices over multiple years.

IQWST MIDDLE SCHOOL CURRICULUM

Level 1	Physical Science	Introduction to Chemistry	Life Science	Earth Science
	Can I Believe My Eyes? Light Waves, Their Role in Sight, and Interaction with Matter	*How Can I Smell Things from a Distance?* Particle Nature of Matter, Phase Changes	*Where Have All the Creatures Gone?* Organisms and Ecosystems	*How Does Water Shape Our World?* Water and Rock Cycles
Level 2	Introduction to Chemistry	Physical Science	Earth Science	Life Science
	How Can I Make New Stuff from Old Stuff? Chemical Reactions, Conservation of Matter	*Why Do Some Things Stop While Others Keep Going?* Transformation and Conservation of Energy	*What Makes the Weather Change?* Atmospheric Processes in Weather and Climate	*What Is Going on Inside Me?* Body Systems and Cellular Processes
Level 3	Earth Science	Life Science	Physical Science	Introduction to Chemistry
	How Is the Earth Changing? Geological Processes, Plate Tectonics	*Why Do Organisms Look the Way They Do?* Heredity and Natural Selection	*How Will It Move?* Force and Motion	*How Does Food Provide My Body with Energy?* Chemical Reactions in Living Things

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UNIT STRUCTURE

Driving Questions

Each IQWST unit focuses on a Driving Question, which is also the unit's title. A Driving Question is a rich, open-ended question that uses everyday language to situate science content in contexts that are meaningful to middle school students. As each unit progresses, the phenomena, investigations, discussions, readings, and writing activities support students in learning content that moves them closer to being able to answer the Driving Question in a grade-appropriate manner.

Learning Sets

IQWST lessons are grouped into three to five learning sets per unit, each guided by a subquestion that addresses content essential to answer the Driving Question. This structure unifies lessons and enables students to meet larger learning goals by first addressing constituent pieces of which they are comprised.

IQWST lessons support research-based instructional routines with several components designed and structured to meet teacher needs. Each lesson comprises multiple activities (i.e., Activity 1.1, Activity 1.2) that altogether address one to four Performance Expectations (as described in NGSS). Each lesson is preceded by lesson preparation pages, Preparing the Lesson, as described in the following Lesson Structure section.

LESSON STRUCTURE

Each IQWST lesson contains common components to support teachers as they progress through the unit's activities.

Preparing the Lesson

The information on the first pages of each lesson supports the teacher in previewing and preparing for the lesson.

Teacher Background Knowledge

This section describes content to be addressed in the lesson, specifics about use of language or measurement tools, and prerequisite knowledge students are expected to have. If IQWST units are taught in the designed sequence, prerequisite knowledge is that which is expected from elementary school. If IQWST units are taught in an alternative sequence, this section alerts teachers about what students will need to understand in order to make sense of activities in a unit and to achieve its learning goals. This section also addresses content that may lie outside of teacher expertise in order to support teachers in working with content with which they are less familiar.

Sometimes, a Common Student Ideas heading describes ideas from research on misconceptions or describes other difficulties students have been shown to have with the content of a particular lesson. The section may describe prior knowledge that does not align with accepted science and that may be a stumbling block to understanding.

Setup

Setup is noted on the preparation page when the teacher needs to prepare materials ahead of time, such as mixing solutions, premeasuring materials for student groups, or setting up stations.

Safety Guidelines

A section on safety is included in the IQWST Overview. Within units, safety guidelines specific to a lesson are sometimes described separately so as to call attention to them. Examples include how chemicals should be handled and disposed of or when wafting is necessary rather than inhaling substances.

Differentiation Opportunities

Differentiation ideas highlighted prior to a lesson specify ways to either go beyond the performance expectations for the lesson or to support students who need additional help with content. Differentiation strategies that can be applied across lessons are described elsewhere in this Overview.

Building Coherence

This section briefly situates the lesson in those that precede and follow it and often references content students will have encountered in previous IQWST units, if units have been enacted in the recommended sequence.

Timeframe (Pacing)

This note estimates the number of class periods the lesson will take to complete based on widespread classroom experience. Richer discussions, more time spent on reading or writing skills, enacting demonstrations as group activities or vice versa, and other teacher-chosen adaptations require adjusting the timeframe. Most lessons require two or more class periods, as most are composed of multiple activities. Pacing is based on 50-minute class periods. Longer or shorter periods, or block schedules, require adjustment so that each class session is a coherent whole. Suggested pacing is also noted on the Unit Calendar located in the front matter.

Overview

A succinct list provides a snapshot of primary activities within a lesson, identified by activity number (i.e., Activity 1.1, Activity 1.2).

Performance Expectations

Performance Expectations describe what students should *know* and *be able to do* in a given lesson. Performance expectations describe one or more scientific practices in which students will engage in order to learn a disciplinary core idea, often also addressing a crosscutting concept, such that teachers can effectively plan, focus, and assess students' understanding.

Materials

These sections list the supplies required to carry out each activity within a lesson. They are quantified and grouped based on teacher needs, group needs, and individual needs.

Introducing the Lesson

This feature is included when activities are specifically designed to launch a lesson, often including integration of the previous reading or homework assignment.

Discussion Types

Types of discussion are described elsewhere in this Overview and are identified within each activity: Brainstorming, Synthesizing, or Pressing for Understanding. Each discussion has a stated purpose, followed by suggested prompts to guide conversation. Prompts are not intended as a script but provide teachers with alternatives they can use or from which they can shape their own questions—both factual/close ended and open ended to encourage thinking, challenging, explaining, and arguing from evidence.

Reading Follow Up and Introducing Reading

Suggestions for introducing and following up reading aid comprehension, retention, and integration of reading into science lessons. Readings are designed to be done independently, as homework, providing students with opportunities to revisit class activities, to connect science to their everyday lives, to deepen their understanding of content, and to apply their understanding to new examples and contexts. The pacing of lessons, as described, presumes that reading is not an in-class activity but is an at-home activity to extend student learning. Reading is addressed more fully elsewhere in this Overview.

Teacher Supports

Icons


Apple – Signals an "aside" to the teacher, often a strategy or a hint about student thinking likely to arise during an activity. Strategies and hints are embedded at points in the lessons that are most helpful to the teacher.


Checkmark – Signals a point at which the teacher should stop and check students' understanding before moving forward in the lesson or unit. Often, the ideas accompanied by this icon can be used as assessment opportunities.


Open Book – Signals either a reading assignment or a follow-up homework activity at the point in a lesson that it is best assigned. Typically the book icon is at the end of an activity and indicates work that is to be done in preparation for the activity that follows.

Safety – Signals precautions important to ensure safety in a lesson. Many lessons do not have specific safety precautions; instead, the lesson directs the teacher to the Overview, where general precautions, to be followed across IQWST lessons, are outlined.


Key – Signals smaller-scale learning goals that may be components of a larger disciplinary core idea. Key ideas might also include scientific principles derived from class activities, important definitions, or a new type of X to be added to a list of "types of X" students have been compiling in the unit. Key ideas might include main ideas at which students should arrive after an activity, reading, or class discussion.


Probe – Signals that technology is used in a particular lesson either for modeling (e.g., a computer simulation) or for quantitative measurement (e.g., probes and data loggers).


Pencil (only in Student Edition) – Signals places in which a written response is expected. Because questions are used as headers and are also woven throughout readings to engage students as active readers, an icon is used to indicate when a written response, rather than simply "thinking about," is required.

Projected Images (PI)

The value for students of seeing images in science cannot be overestimated. Projected Images (PI) are to be displayed for the class. Selected images may be printed for display on the Driving Question Board and perhaps laminated for reuse.

Each IQWST lesson includes projected images, charts, and graphs to expand students' understanding of science concepts. These colorful images are most effective for instruction if they are displayed in the front of the room on the white board. The images are located on the IQWST Portal in each unit folder, and all are named clearly.

The IQWST Portal

The IQWST Portal is an online resource for educators and students to access IQWST curriculum resources, including teacher editions of IQWST textbooks, student lab books, unit materials lists, assessments, and more. The IQWST Portal also provides access to digital resources including lesson-specific videos and audio files with narration of every student reading. Interactive resources and simulations like NetLogo are also located on the IQWST Portal.

The IQWST Portal is organized with each of the 12 units listed as a course. Within each course the content is divided into learning sets that are composed of multiple lessons. Within the lessons, educators can access digital versions of IQWST print materials, digital resources, and interactive resources. Each unit also contains a news section with up-to-date links to articles and research relevant to physical science, chemistry, life science, and Earth science.

DIFFERENTIATION IN IQWST

Range of Student Learners

Strategies built into IQWST lessons acknowledge students' differing capabilities, expectations, experiences, preferred learning styles, language proficiency, reading strategy use, and science background knowledge, among others. Materials address diverse needs by connecting classroom science to students' everyday, real-world interests and experiences. Each activity provides opportunities for teacher guidance, for independent work as well as small-group and whole-group interaction, for investigation, for discussion, and for reading, writing, and talking science. Opportunities for differentiation abound in each of these areas and in each lesson, so all students can work at their appropriate level of challenge.

Activity-based experiences enable students to share common experiences from which to build understanding. Students with kinesthetic preferences can use their strengths as doers and problem solvers. Those with verbal preferences can talk and write about processes and practices and can contribute ideas from readings to the discussion. Those with tactile preferences can manipulate materials. Those with visual preferences observe rather than only read about science. IQWST does not require memorizing definitions, writing paragraphs using vocabulary, or writing lab reports. Students with a range of learning preferences, language abilities, and other strengths and weak areas as learners can contribute to, engage in, and learn from each investigation—independently and collaboratively.

Specific differentiation opportunities are described in the Preparing the Lesson pages that precede each lesson. The following general strategies apply across IQWST.

General Differentiation Strategies

- Students begin each unit with an activity to generate original questions that will form the Driving Question Board (DQB) for the unit. Some of their questions will not fit into any of the categories used to organize the DQB and will not be addressed in the unit. Such questions may be assigned to students as an ongoing, individual project that they complete using various resources.

    - Such projects enable students who benefit from "going beyond" the unit to do so independently. With the teacher's discretion, projects for advanced students might come from such work, requiring use of multiple resources with varied text complexity.
    - Passionate interest has been shown to motivate students who struggle with reading to nonetheless read texts well beyond their Lexile level or presumed "ability" in a quest to learn more about something they are invested in. English Learners, students with learning disabilities, and struggling readers should thus be encouraged to investigate topics in which they are keenly interested. Some students will need support with resources (e.g., Internet search terms or suggested websites), but it is important to encourage all students to pursue areas of interest.

- Two follow-up questions that students cannot get wrong, simply by virtue of having read are (1) What did you find most interesting about last night's reading? and (2) What is one new thing you learned as you read last night's assignment? Some variation of either of these questions can be used for accountability purposes (i.e., Did the student read?) and for encouragement purposes (i.e., There are no wrong answers).

- Discussion is important to allow exchange of ideas and examination of one's own ideas. Many students, especially English-language learners, students with learning disabilities, or students with auditory processing difficulties, struggle to make sense of a question and formulate a response in time to raise their hands and articulate their ideas orally. For such students, consider a think-pair-share strategy. Pose a question and provide students with time to *think* about their response (or to write their ideas). Then, *pair* students with partners to *share* ideas. The teacher can then call on a pair, who can give a response they have had time to rehearse. This activity can be taken a step further to *square* the response by having two pairs talk together.

- Some students participate more fluently and comfortably if they are sometimes told ahead of time which question they are going to be asked to share their ideas about. Preparation time allows them to jot notes, to practice orally, or to reread a written response and be confident about sharing aloud. A teacher can prepare a sticky note such as "Be ready to talk about your answer to Question 3," and can place that note on a student's book in the course of teaching a lesson. This enables students with a range of language proficiencies, background knowledge, memory, or ability to process information time to think through their ideas and thus to be more confident and successful sharing in whole-class contexts.

Reading Differentiation Strategies

- Readings are designed based on research indicating that when students are passionate about a topic they often read well beyond their determined "reading level." Thus, IQWST readings emphasize engaging students in science. In many programs, reading level is simplified by shortening sentences and using easier vocabulary. However, doing so shortchanges students in two ways. First, shorter sentences require removal of connecting words (therefore, so, then) that actually support comprehension. Second, simplifying text by limiting multisyllabic words shortchanges students by ensuring that weaker readers remain unable to engage with texts that use the vocabulary of science. Therefore, IQWST does not differentiate with simplified materials but with strategies that support readers to learn all they can from the texts provided.

- IQWST lessons provide strategies for introducing reading, monitoring student comprehension, and following up on reading assignments. A Getting Ready section begins each reading as a research-based strategy for improving comprehension—the sections generate interest and engage students, activate prior knowledge, and provide a purpose for reading. Although these strategies support all students, struggling readers can be explicitly taught the value of each of these components as strategies successful readers use to improve comprehension. Strong readers, often unknowingly, "wonder" about what they are about to read, thus providing a purpose for reading that improves their comprehension and retention.

- Reading in science contains both main ideas and important details. Some IQWST readings employ methods for students who need to continue to work on reading strategies with built-in prereading strategies and advance organizers to help students with both text structure and content. Teachers may create additional advance organizers, as desired for particular readings.

- Encourage students to read all of the written material, as it is designed to support learning of key concepts, and to extend the application of key ideas into the real world thus to generate interest in science. However, many options enable the teacher to support struggling readers, students with learning disabilities, English Language Learners, and advanced students.

    - If students find an assignment overwhelming, let them know what to focus on as they read, perhaps indicating (or marking) two or three sections of the reading that they should read carefully. Doing so gives them freedom to read all of the material but focuses their reading so that they are more likely to experience success when they can participate in follow-up class discussion because they focused on the "right" section of the reading.
    - When a reading has multiple examples (e.g., a reading about how the eyes of three types of animals work), invite students to prepare to talk about any one of the three. Doing so does not erase the opportunity to read all but enables students to make choices and to focus their reading, providing encouragement and small steps toward success.
    - Many opportunities exist for advanced students to conduct Internet searches and read more complex texts as they either pursue areas of interest or are assigned such work by the teacher.

- Support readers by pre-identifying challenging language in the readings. On the board, write 2-3 words likely to be stumbling blocks, pronounce them, and provide connections (if possible) to everyday use of such words or to cognates for English-language learners (e.g., consulting an English/Spanish science glossary). IQWST is built on a strong research base showing that the best way to learn vocabulary is to encounter and use words in context. Use an interactive Word Wall to display words so that they may be referred to often. Pre-identifying and pronouncing words that might cause difficulty is not meant as a strategy for teaching vocabulary but only as a way to ensure that when students encounter Leonardo da Vinci's name or see "optical illusion" in print, they will not experience unfamiliar words as roadblocks.

- Readings should be previewed and followed up in class, and soon most students, even struggling readers, will attempt at least portions of the reading. Even if they do not read the entire assignment, or do not read well, students will make sense of whatever they do accomplish in ways that will help them learn. IQWST is not a textbook-driven curriculum, so using class time to read the materials does not align with a project- and inquiry-based philosophy in which students experience phenomena and then think about, write about, talk about, and read about science to learn content in meaningful ways. Encourage reluctant readers by asking follow-up questions that draw on examples from the reading, making the focus not on details, but on sense making, so that all can feel successful and encouraged to read.

Writing Differentiation Strategies

- Writing in science must be clear and accurate. For students with motor skills difficulties, provide ample writing space by using the margins, the back of the page in the student book, or additional paper. Students can also write on a computer, print, and paste the page into the student book.

- To support students with learning disabilities, who may omit words in writing, suggest that they read their own writing aloud, as they can often "hear" omissions when they do so. Alternatively, a peer or family member can read a written response aloud to allow students to self-correct as they hear errors in their writing. Another person may also scribe while students who struggle with writing provide oral responses, allowing students to express their understanding of science ideas and to communicate more successfully.

Mathematics Differentiation Strategies

- Measurements in science are precise, and measuring using science equipment can be difficult. Collaborative investigations enable students with varied strengths to work together. Although all students should learn how to use the tools of science, students who have difficulties with motor skills or vision impairments, for example, do not need to physically measure or be the person solely responsible for reading the thermometer. Instead, students work together to carry out investigations.

- Procedures in science require a sequencing of steps that can be difficult for some students if instructions are given only orally or only in print. To support all students, review written instructions orally, step-by-step, as needed. Have students reread procedures even after they have been reviewed. Demonstrate procedures for investigations that are anticipated to cause confusion or frustration. Many students are more successful if they check off steps as each is completed.

SCIENTIFIC AND ENGINEERING PRACTICES

The *Framework* and NGSS identify eight practices that build and refine scientific knowledge and thus are central to the scientific enterprise. Rather than separate content knowledge and inquiry skills, as in previous versions of national standards newer standards move toward combining core content and scientific practices in tandem. IQWST is based on the same extensive research that forms the foundation of science education for the 21st century and the basis for the *Framework* and NGSS. Thus, IQWST lessons integrate and continually reinforce practices such that students develop greater facility with and deeper understanding of these practices and of the content they address, whether NGSS, the Framework, or state standards guide learning.

Engaging in scientific practices enables students to experience how it is that scientists come to particular understandings rather than to experience science as a set of complete, discrete, isolated facts. In addition, a focus on practices, as an extension of previous approaches to inquiry, expands students' understanding of science beyond viewing it as a limited set of procedures or as a single approach typically characterized as "the scientific method."

Scientific practices require both knowledge and skill, and IQWST approaches scientific practices in that manner; they are always contextualized. Rather than a lesson about "how to construct a good scientific explanation," explanations are taught in the context of a lesson about core content using the construction of an evidence-based explanation as a way to think about, make sense of, and communicate one's understanding of phenomena. All eight practices are reflected throughout IQWST. However, each unit's learning goals emphasize particular practices, emphasizing those best taught (and practiced) in the context of a given unit's learning goals and investigative activities.

- Asking Questions and Defining Problems
- Developing and Using Models
- Planning and Carrying Out Investigations
- Analyzing and Interpreting Data
- Using Mathematics, Information and Computer Technology, and Computational Thinking
- Constructing Explanations and Designing Solutions
- Engaging in Argument from Evidence
- Obtaining, Evaluating, and Communicating Information

Each of these is addressed individually in sections that follow.

Scientific Practice 1: Asking Questions and Defining Problems

A key IQWST instructional component is each unit's Driving Question. A driving question is a rich, open-ended question that uses everyday language to situate scientific principles in contexts that are meaningful to middle school students. The discussions, investigations, science readings, and writing activities all relate to the Driving Question. IQWST involves students in constructing, evaluating, communicating, and reaching consensus on scientific explanations of how and why phenomena happen. In order to engage in this practice, students must make sense of phenomena they study and then articulate and defend their understandings to themselves, each other, the teacher, and other audiences. As each unit progresses, students learn content that moves them closer to being able to answer the Driving Question in a grade-appropriate manner. As important, each unit purposefully solicits students' original questions and provides the teacher with guidance about posting those questions on a Driving Question Board in the classroom and integrates them into the lessons. Thus science becomes "what I wonder about" rather than only "what I am told I should think about."

In addition, in the process of exploring phenomena and wondering how and why things happen, students question one another about what they observe and the conclusions they draw. They question one another about the texts they read. They learn about questioning in this manner, as well as asking testable questions that students can answer by designing, planning, and carrying out an investigation. In some IQWST units, students work together to define a problem, determine how to find a solution, and compare ideas with others in the process of solving the problem.

Driving Question Board

To organize each IQWST unit, the Driving Question is displayed on a Driving Question Board (a bulletin board or large area on a wall). The Driving Question Board (DQB) is a tool used throughout IQWST to focus students' attention, record what they have learned, and show students where they have been and the direction they are going. The DQB serves as a visual reference that remains in place throughout a unit. Lesson plans typically guide the teacher in their use. Although the teacher maintains the DQB, because it functions as a shared space to represent learning, students might also contribute regularly to the display.

Each IQWST lesson addresses a component of the unit's Driving Question, supporting students in making sense of science content and determining which part of a question they can answer and which they still need to investigate. Thus, new lessons are motivated, in part, by what questions still need to be addressed. The visual display supports teachers and students in tracking and organizing ideas along the way.

Each unit invites students to post their own original questions on the DQB to encourage active engagement in a participatory classroom culture. As they think of new questions at any time during the unit, students write those questions on sticky notes and add them to the class DQB. Across a unit, the Driving Question Board will come to include the unit-specified question and subquestions, as well as student questions, drawings, photographs, artifacts, objects, and sample student work. The DQB will serve as a focal reference helpful to all but especially important for students for whom visual representations aid in their learning, such as connecting new ideas to previous understandings. Revisit the DQB with students in each lesson. Refer to it often. Point to artifacts displayed on it as a reminder of previous activities or understandings. Post on it summaries of scientific principles, as well as artifacts students create that relate to specific questions. Any projected image used in IQWST could be printed, laminated, or inserted into a plastic sleeve and displayed on the Driving Question Board. This includes models or data tables developed as a class or any other visual representation of concepts students have studied.

Space on the Driving Question Board may be limited, but it is important that aesthetics and the neatness of the DQB do not outweigh the support provided to students when they can frequently refer to the visual representations as a reminder of activities done and content learned throughout a unit.

Scientific Practice 2: Developing and Using Models

The *Framework* describes the central role of constructing and using models to explain: "Science often involves the construction and use of a wide variety of models and simulations to help develop explanations about natural phenomena. Models make it possible to go beyond observations and imagine a world not yet seen. Models enable predictions . . . to be made in order to test hypothetical explanations." NGSS specifies that models can include "diagrams, physical replicas, mathematical representations, analogies, and computer simulations," all of which contain "approximations and assumptions" that students need to learn to recognize as a given model's limitations. In science, models are used to help people understand, describe, predict, and explain phenomena in the real world.

Scientific modeling consists of several core practices: constructing models, using models to explain or predict, evaluating models, and revising models. IQWST engages students in all of these, supporting learners as they develop models, use models to explain, use models to predict, critique one another's models, and revise models as they learn new information—engaging in modeling as real scientists do. Because modeling is often connected with other aspects of scientific practice, students' experiences with modeling are embedded in the broader context of investigating, understanding, and explaining phenomena. Students create and use models to understand and apply scientific ideas, to illustrate and defend ideas, and to evaluate interpretations.

Engaging Students in Modeling

Students need to understand the purpose of models and modeling in science in order to effectively engage in the practice of developing and using models. Initially, it may be useful to have students think about other models they know, such as models of weather phenomena that scientists use to explain and predict the path of hurricanes, tornadoes, thunderstorms, or snowstorms.

Before Students Develop Models

1. It is helpful to emphasize that the point of developing models is to try to explain the phenomenon just investigated in class. Students' models should demonstrate their best ideas about how to show how and why X happened, so that the model can be used to explain what happened to someone else.

2. Begin to develop criteria for good models, which can be posted in the classroom and used throughout IQWST as students develop their own models and critique one another's models. These ideas should come from class discussion and should be written in students' own language. Important ideas include the following:
   a. Models need to explain. Does the model show *how* and *why* the phenomena happened the way they did? Is there anything in the model that does not need to be here? Are there steps we are leaving out?
   b. Models need to fit the evidence. Does this model fit what was seen about the phenomenon?
   c. Models need to help others understand a phenomenon. Is the model easy to understand? Are there ways to clarify what it shows?
   d. As lessons lead to the need for model revision to account for a new phenomenon, address the idea that models also can be used to predict. Probe students with the following questions: What does our model predict about what will happen in situation X? Was that what actually happened? What does that mean about our model? What do we need to revise based on our new evidence?

Before Students Share Models

It is helpful to give students guidance about how they should listen to each other as they present their models. Eventually students will ask critical questions and make constructive suggestions to each other. Be sure to support that process until they understand this kind of classroom discourse. The following are ideas to address:

1. Different ideas will arise as we try to figure things out. This is our chance to put our heads together and come up with the best model we can come up with, as a group. But we need to agree on what we are looking for. As we listen to each other explain our models, remember what we created these models to try to do. Let's talk about what is important.
2. All scientific models have limitations. Not every aspect of a phenomenon can be explained using a single model. Models often simplify as they illustrate things that are too small, too large, too fast, or too slow to observe without a model as a representation. A static model cannot show movement. No model can sufficiently illustrate the number of molecules involved in a phenomenon nor the time required for others to take place.
3. More than one model can be used to explain the same phenomenon. Scientists judge how good a model is based on how well it helps to explain or predict phenomena—not by how similar it looks to the thing it aims to explain or describe. For example, a good model of gases can be used to explain all the behaviors of gases observed in the real world (e.g., what happens when air is cooled, heated, or compressed), but it will not be used to explain the behavior of solids. Different models have different advantages and disadvantages.

Constructing Models Depends on Scientific Argumentation

The practice of constructing models in IQWST draws critically on another scientific practice, Engaging in Argument from Evidence. In the practice of constructing models in IQWST, argumentation occurs when students defend their proposed models, showing how the model fits evidence and explains the phenomena. Argumentation occurs in classroom discourse when comparing and discussing competing models. IQWST lessons contain support for students to critique one another's models and ultimately to reach consensus, both critical parts of the argumentation practice.

Scientific Practice 3: Planning and Carrying Out Investigations

IQWST is an activity-based, phenomena-rich, investigative curriculum. Students plan investigations that address the Driving Question for each unit and carry out investigations in each lesson. The investigations build understanding of core ideas throughout each unit, always directed at gaining more understanding toward being able to answer the Driving Question. In addition, students' original questions not answered in the unit can be used as a springboard for additional investigation. Some investigations arise out of previous ones in a process of figuring out "what we know as a class" and "what we need to figure out next," typically in learning the how and why of a process. Any such questions can motivate further investigation. Thus, besides those opportunities provided by the curriculum itself, the teacher can require or encourage the planning and carrying out of investigations that extend student learning beyond the performance expectations of a given unit.

Carrying out a multistep procedure is an important science literacy skill; thus teachers might have students plan investigations, write procedures, and share plans and procedures with other groups to read and critique.

Scientific Practice 4: Analyzing and Interpreting Data

IQWST units engage students in observation, data collection and organization, interpretation, and using data to make sense of phenomena they investigate. All lessons regularly use the language of "observation," "data," and "evidence." Teachers are encouraged to ask students to support their ideas with evidence (e.g., Why do you think that? How could that happen? What if . . . ? What evidence do you/we have for that?), requiring students to consider their data carefully. Teachers encourage students to question data provided by others. This creates a situation in which using data as evidence to defend a claim makes sense—students need evidence because they will be questioned about their data in discussion.

Students analyze both qualitative and quantitative data in IQWST. They learn that both are important and while observation with the unaided eye enables them to make some significant claims, instrumentation and scientific tools enable them to be much more precise. Students analyze data they have collected themselves as well as data collected by others (e.g., changes in a population over time, melting points of substances they are unable to investigate in the classroom). Charts and graphs require understanding of independent and dependent variables, and investigations require understanding of what it means to control variables. Throughout the units, IQWST provides students with multiple opportunities to analyze and interpret data through classroom discourse as a whole class, in small groups, in pairs, and independently, providing practice in multiple contexts that reinforce the development of this scientific practice.

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Scientific Practice 5: Using Mathematics, Information and Technology, and Computational Thinking

NGSS specifies within this practice ideas such as "using digital tools," for example, "to analyze very large data sets for patterns and trends" and "to test and compare solutions to an engineering design problem." In addition, this practice specifies a need for students to "measure and compare quantitative attributes of different objects and display the data using simple graphs." Therefore, IQWST units include lessons that include probes, sensors, data loggers, and a sensor interface as digital tools that enable quantitative measurement and graphic display in a manner in which real scientists do their work.

IQWST uses the language of *probes*, *sensors*, *data loggers,* and *sensor interface* for illustrative purposes, given rapid changes and advancements in technology and the attempt to use generic terms where possible. IQWST materials show photographs of and reference Pasco brand probes for several activities, as Pasco makes high-quality equipment for middle school use. If your school uses another brand of technology, adjustments may be required in the instructions to students. If your school does not have probeware, and you elect not to purchase such equipment, then more significant adjustment to activities will be necessary, especially where measurements may not be made quantitatively without similar devices. It is recommended, in keeping with the NGSS call for the types of scientific practices considered integral to science education, that probeware be used as recommended in IQWST. More specific guidelines and instructions specific to brands of probeware may be found on the Teacher Portal with updates available to teachers in a timely manner.

Mathematics is used throughout the IQWST program as students take measurements using the tools of science, collect data, plot data on graphs or create data tables, and come to understand and work with dependent and independent variables. Students use scientific probes to calculate in the manner of scientists. Computers are used for simulations of models of phenomena, such as predator/prey relationships, or for observing a phenomenon in slow motion so that it can be more carefully examined.

Scientific Practice 6: Constructing Explanations and Designing Solutions

The *Framework* defines explanations as "accounts that link scientific theory with scientific observations or phenomena" and identifies the related engineering practice of designing solutions, in which students construct and defend solutions to problems that draw on scientific ideas. In IQWST, these two aspects of the practice are combined as constructing, evaluating, and defending evidence-based scientific explanations. The scientific practice of explanation goes beyond asking students to describe what they know about a particular idea. Instead, students develop a chain of reasoning that shows why the phenomenon occurs as it does.

For example, rather than asking students simply to "explain the process of cellular respiration," an IQWST Life Science Unit asks students to "explain why the air a human breathes out contains less oxygen than the air breathed in." Students not only describe the process of respiration but also construct a causal chain that fits the evidence. Drawing on prior ideas from chemistry and physical science, such a chain should specify where glucose goes in the body, what materials can get into and out of cells, and conclude that a chemical reaction requiring both glucose and oxygen must be taking place in cells to convert energy to a form the organism can use.

What Does It Mean to Construct an Explanation?

In the practice of constructing explanations in IQWST, students make claims, use data as evidence to support their claims, and engage in reasoning that draws on scientific principles, or the "what we know" in science, to explain the "how" and "why" of phenomena they investigate in the classroom. Teachers pose questions that push students to think more deeply about what they have observed, read, and experienced, modeling this practice so that students learn to question one another. IQWST lessons support students in critiquing one another's explanations, providing students with opportunities to talk, to write, to discuss, to give and receive feedback, and to revise the explanations they have constructed. Many literacy standards are addressed as students cite evidence from sources; integrate information from observations and from text; write arguments that use a claim, use data as evidence, and use logical reasoning in an explanatory text; and engage in revision focused on writing clearly and coherently for a specific purpose and audience.

Supports are designed around a framework that divides scientific explanations into three smaller, manageable, and teachable components for middle school students: claim, evidence, and reasoning (referred to as the C,E,R framework). IQWST identifies these components in order to support students as they learn to write in a new way.

Claim

A claim is a statement of one's understanding about a phenomenon or about the results of an investigation. The claim is a testable statement about what happened. The claim expresses what the author is trying to help the audience understand and believe.

Claims may be made about data that students have been given or they have gathered themselves. If an investigation has independent and dependent variables, the claim describes the relationship between them.

In practice, teachers have found it useful to teach that a claim must be a complete sentence, cannot begin with "yes" or "no," and is typically the first sentence of an explanation. Although it is not necessary that a claim be the first sentence, experience has shown that freedom to vary the guidelines is best managed *after* the guidelines and their purpose have been learned.

The claim is often the part of an explanation that students find easiest to include and to identify as they critique others' explanations. One of the purposes of focusing on evidence-based scientific explanations is to help students include more than a claim (or "simple" answer to a question) in their writing.

Evidence

The evidence consists of the data used to support the claim. The evidence tells the audience the support the author has collected that makes the claim convincing.

An explanation must contain accurate and sufficient evidence in support of the claim. Evidence makes claims understandable and convincing. While "data" can refer to all the observations that students have collected or analyzed, data become "evidence" when used to support a claim. The evidence for explanations can come from investigations students conduct, from observations they make, or from reports of empirical research others have done. Where possible, explanations incorporate more than one piece of data as evidence.

A goal in IQWST is to help students understand that data must be marshaled as evidence in support of a particular claim. In complex situations, more than one claim might be made about a single data set. It might also be that more data are available than are necessary to support a particular claim. Students must determine which are the appropriate data to use in support of a claim they have made and what are sufficient data to support that claim. The idea that multiple claims might be made using the same data develops across the curriculum as the inquiry activities become more complex, and students' options for research questions (and resulting claims and evidence) become increasingly open ended.

Reasoning

Students learn that the accepted scientific understanding or principles that underlie the explanation must be made explicit in a process IQWST calls reasoning. The reasoning presents the logic that leads from the evidence to the claim and, if possible, connects it with a scientific principle. The reasoning says why the claim makes sense, given what is understood so far about the phenomena. Reasoning ties in the scientific knowledge or theory that justifies the claim and helps determine the appropriate evidence. The reasoning may include a scientific principle that reflects the consensus students have developed so far about the phenomena they are investigating. It may also require a logical chain that shows how the principle and evidence work together to support the claim. For example, the reasoning for the effects of a competitor X on population Y may refer to a series of connected steps that start with the increase in population size of the competing species X, decrease of available food sources needed by both X and Y, and then drop in population size of Y due to lack of food.

The reasoning connects to the general knowledge of the scientific community and a chain of logic to explain how particular data support a claim, given what scientists know about the world. Reasoning is the most difficult aspect of explanation writing for students to understand and is the most difficult aspect for teachers to teach. Reasoning requires relating general scientific principles—what is already known in science—to the specific question being investigated and requires students to make explicit the steps of their thinking.

Scientific Practice 7: Engaging in Argument from Evidence

The *Framework* defines the central role of scientific argumentation in building scientific knowledge as "a process of reasoning that requires a scientist to make a justified claim about the world. In response, other scientists attempt to identify the claim's weaknesses and limitations." In the practice of constructing explanations in IQWST, argumentation occurs when students defend their explanations both in written form, by providing supporting evidence and reasoning, and in classroom discourse, when comparing and discussing competing explanations. IQWST lessons contain support for students to critique one another's explanations and to reach consensus, both critical parts of argumentation. Students learn about criteria for critiquing explanations that also apply to arguments: both must fit the evidence, be logically coherent, fit what is known in science, and include important steps in reasoning.

Argumentation is key in IQWST thus significant attention is paid to evidence-based explanation and argumentation, and students engage in this practice in every IQWST unit.

Scientific Practice 8: Obtaining, Evaluating, and Communicating Information

Student readings provide additional information to support students' in-class investigations. Readings are designed to be integrated into each lesson such that students obtain, evaluate, and communicate information from multiple sources—their own work, others' work, and the science they read about—in all that they do. In addition, opportunities abound for additional research using the Internet, for example, so that students can pursue areas of individual interest that go beyond the performance expectations and grade-level standards. That is, a student who reads about solar sails, described in an IQWST reading as an example of the use of solar power, might wish to learn more about what solar sails are and how they work. Such reading might also trigger interest in alternative forms of energy and their advantages and disadvantages and lead to a written project as situated in the context of the science being studied. This can enable a student to apply his or her understanding to global concerns or to issues in the local community. Such projects, models, and written products that result can interest and motivate students, deepen content understanding, encourage engagement in scientific practices and literacy practices related to science, and provide application and extension opportunities beyond the classroom. In addition, deeper understanding will likely be fostered as the student encounters new ideas in science that fit with the knowledge gleaned from such a project as the core of learning—connecting new understandings with prior knowledge—is strengthened. IQWST does not require research paper types of projects; however, opportunities for teachers to collaborate across content areas such that students might explore science topics as a way to meet literacy learning goals is an option, given that students are likely to encounter many topics they wish to explore further as they investigate phenomenon and read, write, and talk science in every lesson.

INSTRUCTIONAL SUPPORT FOR SCIENTIFIC PRACTICES

The following strategies support students in developing experience with scientific practices.

Use Data to Build Understanding

As designed, earlier IQWST units help students become familiar with observation and data collection and with using data to make sense of phenomena. Teachers are encouraged to ask students to support ideas with evidence (e.g., Why do you think that? How could that happen? What if . . . ? What evidence do you/we have for that?). Teachers allow students to question evidence provided by others. This creates a situation in which using data as evidence to defend a claim makes sense—students need evidence because they will be questioned about it in discussion.

Model the Practice

The teacher uses a think-aloud process to make thinking visible to students. This highlights the underlying aspects of scientific practices, making them explicit as the teacher "talks through" his or her thinking, modeling how good writers, modelers, thinkers, observers, or questioners think as they engage in the practice.

Identify the Audience

All written tasks should be constructed with an audience in mind. This helps students shape their writing, so that the audience can make sense of a written explanation, a model, or a representation of data. In IQWST, students may be asked to think about convincing someone from another class of the validity of the claim in an explanation, to share with someone at home and get feedback, or to explain to an absentee student, someone new the school, or an elementary student.

Motivate the Practice

As teachers incorporate explanation construction and modeling into lessons, they must help students move back and forth between the components of the practice (e.g., claim, evidence, reasoning) and the overall purpose of the practice. Otherwise, focusing on the components becomes formulaic, and students lose sight of the purpose of explanations and modeling in science. To help students see a need for this work, they are placed in situations in which they must engage in argumentation as a way to "convince" someone that their conclusions make sense and can be supported with data.

Generate Criteria

When students are asked to convince one another and to determine whether they are convinced by someone's claim, they need criteria on which to base decisions. Although teachers begin with criteria in mind (described in each unit), they guide students to develop criteria in their own words. The framework can be given to students at the outset; however, students have a deeper understanding of the components and more buy-in when they work cooperatively as a class to generate criteria or the framework for an explanation.

Critique Examples

Students are accustomed to process writing in ELA, but they tend to think that once something is written in other content areas it is finished. Whole-class, teacher-led, and small-group critique of explanations and models helps students see that explanations can be revisited, rethought, and revised. A teacher can create sample explanations for critique purposes. Once students have written explanations, their work can be used anonymously for whole-class critique. Teacher-guided critique, in which the teacher asks probing questions in a discussion, is a useful next step. Once students have practiced in teacher-led sessions, they are ready to critique one another's work. In any critique, strengths and weaknesses should be highlighted and suggestions for improvement offered. It is small-group or paired sharing, in which students compare ideas and justify their use of evidence, that IQWST emphasizes. It is in those comparison and justification activities that deep conceptual understanding takes place, and it is these activities that motivate the use of explanations and models in science.

LITERACY IN THE IQWST CLASSROOM

IQWST supports literacy for diverse learners as students transition from *learning to read and write* in elementary school to *reading and writing to learn* in middle school. Lessons draw on the most recent research in literacy learning, with emphasis on reading comprehension and on the role that reading and writing—in tandem—play in learning. In IQWST, students learn by engaging with the tools, materials, ideas, and principles of science and by thinking, reading, writing, and talking science.

Literacy practices are integrated into every IQWST lesson. The curriculum encourages students to be reflective and critical thinkers, to ask questions of the teacher and each other, to share in small- and whole-group discussion, to read texts that connect science to their everyday lives and prior knowledge, to write responses to embedded questions, to construct models and written explanations and to revise them, to engage in argumentation to defend their ideas and to challenge one another's thinking.

Student books are consumable, functioning as portfolios; the lab activity pages, models and diagrams students draw, readings, and all writing are in one place. Books can be used to teach additional skills by a specialist, support person, or teacher who chooses to teach annotation or highlighting, for example, as students write directly in their books.

Reading in Science

IQWST materials are designed to meet expectations for reading and include strategies to guide teachers in addressing literacy requirements with additional depth or to differentiate for diverse students.

LITERACY GOALS	AS ADDRESSED IN IQWST
Cite specific textual evidence to support analysis of science and technical texts.	Discussion prompts and strategies for teachers and responses to questions embedded in readings ask students to refer to text for evidence.
Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.	Summarizing or referencing central ideas from text in discussion is often done in the "Reading Follow Up" section that begins most lessons.
Follow precisely a multistep procedure when carrying out an experiment taking measurements or performing technical tasks.	Activity sheets that accompany investigations and homework activities provide extensive practice in reading and following procedures.
Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to Grades 6–8 texts and topics.	The language of science is key to science learning. Thus readings address vocabulary in a manner that is context rich, and use of an interactive Word Wall reinforces the reading and the use of science language.

Analyze the structure an author uses to organize a text, including how the major sections contribute to the whole and to an understanding of the topic.	Readings provide opportunities for teacher-led analysis of structure.
Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text.	Readings provide an opportunity for teacher-led analysis of purpose.
Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).	Readings support students in moving back and forth between text and visual information (e.g., "notice the shaded area in the diagram"), and some readings suggest that teachers reinforce this practice when previewing or reviewing readings.
Distinguish among facts, reasoned judgment based on research findings and speculation in a text.	This is best accomplished through suggested projects in which students pursue individual interests or go into more depth studying a topic related to class.
Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.	Questions such as "How does what you read help you think about yesterday's investigation?" support students in integrating multiple sources of information. Videos and simulations, as well, are interwoven with reading and with hands-on investigations.

RANGE OF READING IN IQWST

As students transition from learning-to-read to reading-to-learn, IQWST supports them with built-in strategies for students and teachers. IQWST does not provide texts at multiple Lexile levels, based on research that indicates (1) that students who are interested in a topic will choose to read well beyond their test-determined reading level, and (2) that reducing word length and shortening sentences (key strategies for decreasing reading level) can impair comprehension.	Rather than confine students who read below level to reading lesser content, materials suggest strategies for teachers to differentiate instruction so all students have opportunities to use the materials to develop as readers capable of using a range of written materials. Suggestions for students at the top of the grade level reading band encourage independent reading of texts beyond curriculum requirements, so no ceiling suppresses what IQWST students can achieve as readers and critical thinkers.

IQWST readings are integral to students' understanding of science concepts and enable teachers to simultaneously address reading- and writing-related concepts.

Readings

- Extend classroom learning by providing additional examples of principles and concepts encountered in class
- Review in-class activities to help students understand and retain main ideas and to support absent students with content they missed
- Elicit students' prior knowledge and draw on it in engaging ways
- Provide real-world connections that illustrate the value of science outside the classroom
- Use examples with which middle school students are likely to have personal experience or at least be familiar
- Embed questions, to which students write responses, supporting integration of reading and writing in the service of learning, as well as support students' active engagement as readers

Given that the ability to "read and comprehend complex informational texts independently and proficiently" is a lifelong literacy skill, IQWST materials are designed such that readings are intended to be done independently, outside of class time. The few exceptions, in which class time is specifically devoted to addressing some portion of a reading assignment, are clearly indicated in the materials.

Introducing Reading sections in the teacher materials often suggest that the teacher review the Getting Ready section of the student materials as a whole-class, oral activity, thus eliciting whole-class prior knowledge, engaging students in brief discussion, and setting a purpose for the homework reading. Reading setup could take as few as 2 to 3 minutes of class time, or as much as 10, depending on the teacher's purpose, students' abilities, and the nature of the individual activity, but in general, teachers should plan on three to five minutes to introduce the reading.

The Student Edition

Annotated versions of the student pages—in the Teacher Resource Book—provide the teacher with likely student responses or expected responses (including correct answers, where appropriate) as well as ideas for using those responses as formative or summative assessments.

Driving Question Notes and Scientific Principles Pages

The first few pages of every student edition are provided as note-taking space in which students can record both their own individual ideas that connect with the Driving Question, and those big ideas generated by the class. Students should record their own original questions and can add information about those as they progress through the unit. Scientific principles are big ideas that the entire class "arrives at" by the end of many lessons and that students record for ongoing reference. The teacher materials often suggest ideas to be recorded on these pages, but they can be used to record any information the teacher or students deem appropriate. Tracking of scientific principles is a way to ensure that the class articulates "what we know so far" as students progress through the unit; it has common language to draw on when constructing explanations or arguments that draw on these big ideas.

Activity Sheets

IQWST students experience phenomena in a problem-based, investigative context, typically guided by activity sheets for each lesson. These pages support students as they plan and carry out investigations, follow procedures, make predictions and compare them with what happened, organize and analyze data, and make sense of science. Activity sheets often include an opportunity for students to explain the *how* or *why* of a phenomenon, deepening students' understanding as they engage in scientific practices.

Having a student read the "What will we do?" section aloud is one strategy to provide students with an overview of activities in which they are about to engage. Read through the procedure with students, demonstrate it, highlight key components, or summarize briefly so that students conceptualize the big picture of what they are going to do. For example, tell students "You are going to observe two materials separately, and then observe them again after you put them together. It is important that you describe your observations in the table on your activity sheet. Then, you will write some questions about what you observed." Such review frames the activity for all students but is especially important for students who need to hear and not just read the procedure or who need to understand the big picture before making sense of the individual steps.

Homework

Some take-home assignments are designed as extension activities, typically requiring students to apply what they have learned to new contexts. These assignments reinforce in-class activities, providing independent practice focused on key ideas in each unit.

Using IQWST Readings Effectively

The Teacher Edition provides two primary ways of supporting students as readers in science by taking a brief amount of time to introduce the readings and consistently following up on readings in class discussion, as bell work at the beginning of class, or in a quiz-type format.

Introducing Reading

The best way to introduce readings is for the teacher to take the first few minutes of class time to generate interest. Materials typically include an Introducing Reading section with ideas. While spending a few minutes can have tremendous payoff for students, sometimes the teacher will be pressed to do something quick. Most important is that something is done to introduce the reading in order to engage interest, elicit prior knowledge, and set a purpose for reading.

Reading Follow Up

It is important to follow up the readings or other homework. Use the embedded assessments for grades or points or use them to generate follow-up discussion to begin a class period. Students held accountable for reading either through assessments or through in-class questions that require having read the materials in order to participate in discussion are more likely to read as homework. As they enter class, a simple way to do this is to have on the board an opening question that draws on what they read.

Writing in Science

LITERACY GOALS	AS ADDRESSED IN IQWST
Write arguments focused on discipline-specific content. (a) Introduce claims, distinguish from opposing claims, and organize reasons and evidence logically. (b) Support claims with logical reasoning and relevant, accurate data, and evidence. (c) Clarify relationships among claims, counterclaims, reasons, and evidence. (d) Maintain a formal style. (e) Provide a concluding statement that supports the argument.	One pervasive opportunity in IQWST is for students to construct evidence-based explanations of phenomena they investigate and to analyze and give feedback on the written explanations of their peers. In some units, this is taken a step further into argumentation, with written and oral defense of arguments: a key scientific practice supported when the unit content is conducive to argumentation. Reading and discussing writing can help students deepen their own understanding, hone their critical thinking skills, and support consensus-building or argumentation skills in a group.
Write informative/explanatory texts, including scientific procedures/experiments. (a) Introduce the topic clearly and organize ideas, concepts, and information as appropriate to achieving purpose. (b) Develop the topic with relevant facts, details, or other information. (c) Clarify the relationships among ideas and concepts. (d) Use precise language and domain-specific vocabulary to explain the topic. (e) Maintain a formal style and objective tone. (f) Provide a concluding statement that supports the explanation presented.	In addition to the information in the previous box, students write explanations in response to questions embedded in their reading materials and on activity sheets to conclude and make sense of investigations. Additional opportunities to write explanatory texts are often provided in the Differentiation Opportunities sections that precede each lesson.
Narrative skills—for example, write precise enough descriptions of step-by-step procedures they use in investigations that others can replicate them and (possibly) reach the same results.	Students write step-by-step procedures when they design investigations, engaging in an important scientific practice.
Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.	All explanations and arguments in IQWST are designed for a specific purpose and audience, and many other writing tasks define a purpose and audience so that students learn to write for different purposes.
With some guidance and support from peers and adults, students develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on how well purpose and audience have been addressed.	Process writing, as learned in ELA, is used throughout IQWST as students compose evidence-based scientific explanations and arguments, share them with peers, give and receive feedback, and revise.

Use technology, including the Internet, to produce and publish writing and present the relationships between information and ideas clearly and efficiently.	Opportunities to use the Internet to search for information and to inform writing are provided as Differentiation Opportunities to enable students to pursue curriculum-related topics in which they are keenly interested or for the teacher to assign topics to advanced students so that they might "go beyond" the curriculum's learning goals.
Conduct short research projects to answer a question (including a self-generation question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.	Self-generated questions are at the core of IQWST, generated in the initial lesson in each unit, and then questions are continually encouraged throughout. Students write their questions on sticky notes, post them on a Driving Question Board, and are advised (or can be required) to investigate them independently.
Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation.	In order to engage in the previously mentioned activity, students draw on multiple resources, including in-class activities and readings and Internet searches for other resources.
Draw evidence from informational texts to support analysis, reflection, and research.	Students draw on multiple resources including in-class activities and readings and Internet searches for other resources.

Summarizing is another valuable way to use writing. Summarizing requires determining and restating main ideas and findings. To support students in summarizing key ideas, provide practice for them to verbalize their thinking before writing or time to write about their ideas before sharing orally. For instance, before writing a summary of a reading, students could be asked the following: *How would you summarize this reading for students who were absent yesterday? What did they miss that they need to know?* After discussing, students will be better prepared to write summaries. Writing before sharing orally enables students to think and to process what they have learned before they are called upon to share ideas in class. These and other strategies support students as readers, writers, speakers, and listeners in the context of the science classroom.

In addition to the multiple opportunities provided for students to write to learn in IQWST lessons, activity sheets, readings, and home assignments, teachers can provide additional opportunities to meet the needs of individual students, many of which are suggested in the Differentiation Opportunities section that precedes each lesson.

Speaking and Listening

LITERACY GOALS	AS ADDRESSED IN IQWST
Engage effectively in a range of collaborative discussions (one-on-one, in-group, and teacher-led) with diverse partners . . . building on others' ideas and expressing their own clearly, (a) come to discussions prepared, having read required material, (b) follow rules for collegial discussions, (c) pose and respond to questions with elaboration and detail . . . connect the ideas of several speakers and respond to others' questions and comments with relevant evidence, observations, and ideas; and (d) acknowledge new information expressed by others and, when warranted, qualify, justify, or modify their own views in light of the evidence presented.	These behaviors are addressed in daily discussion, often as a follow-up to reading, to make sense of science during and after investigations and as a precursor to writing. Students given opportunities to talk about their ideas and those of others; to use talk as a way to think more deeply; and to critique claims, evidence, and reasoning orally are then better positioned to be able to write convincingly about their ideas. In addition, talking through ideas in this manner enables students to make sense of reading they have done or can set up reading as students read purposefully to determine whether their ideas were right, wrong, or somewhere in between.
Interpret and analyze information, main ideas, and supporting details presented in diverse media and formats (e.g., visually, quantitatively, orally) and explain how the ideas clarify a topic, text, or issue.	As students engage with phenomena during investigations, their work requires interpreting and analyzing information that is visual/observational, verbal as expressed in both oral and written texts, and both qualitative and quantitative, requiring students to synthesize information from multiple sources.
Delineate a speaker's argument and specific claims, evaluating the soundness of the reasoning and the relevance and sufficiency of the evidence.	Activities throughout IQWST that call for explanation or argumentation also call for students to share and to critique one another's ideas.
Present claims and findings, sequencing ideas logically and emphasizing salient points in a focused, coherent manner; use appropriate eye contact, adequate volume, and clear pronunciation.	Activities throughout IQWST that call for explanation or argumentation, as well as modeling, also call for students to present their ideas to a partner, a small group, or to the whole class.
Include multimedia components and visual displays in presentations to clarify claims and findings and emphasize salient points.	Visual displays, especially models that accompany explanations and arguments, are constructed and shared in every IQWST unit.
Adapt speech to a variety of contexts and tasks, demonstrating command of formal English when indicated or appropriate.	The primary manner of speaking and listening in IQWST is presenting ideas for comparison with others' ideas and both giving and receiving oral feedback.

Classroom Culture

Establishing a culture in which students actively participate in "talking science" is at the core of IQWST, but it is challenging for both teachers and students. By the time students have reached the middle grades, they know a great deal about what it means to "do school." They raise their hands, do so only when they think they have the right answer, and respond to teacher-posed questions rather than to peers' ideas. In an IQWST classroom, students ask questions that arise out of individual interests or concepts about which they are confused. They ask questions of other students, as well as the teacher. Science discussions promote active engagement in science learning such that everybody expresses their understanding and learns from each other. The goal is for students to develop as thinkers and problem solvers through participating in thoughtful talk about core content.

Sharing ideas openly, asking questions of one another, defending one's ideas, and not having right answers challenges many students, as well. Students who are successful when reading and answering questions may not be comfortable discussing and exploring alternative ways to explore concepts. Students may be uncomfortable participating in discussions if they are unsure of the correct answer or may be uncomfortable with the idea that multiple responses may be considered correct at a given time in the process of learning. Students who are successful doing activities and discussing their reasoning may struggle when they are required to write about their ideas. Students who have looked to the teacher for answers and guidance may find it unusual that they need to question another student or provide rationale for their responses.

Establishing a classroom culture wherein students feel comfortable sharing and discussing with each other and feel confident about participating actively begins on the first day of class. Since IQWST may introduce a new manner of discussion for students, the teacher will need to model sharing, listening, and learning with students by demonstrating the value of contributions, not just correct answers. The primary goal of oral discourse is for students to articulate their own understanding and to listen and respond to each other. This goal is assisted when the following occurs:

- All students are provided opportunities to participate.
- All students are encouraged to participate.
- Students are encouraged to think together, rather than only speak, if they think they have the correct answer.
- Students see the value in wrong answers for figuring things out.
- Students are provided opportunities to write their responses before sharing aloud.
- Students use information in readings as a springboard for discussion.
- Students listen carefully to others and respond to others' ideas.

Small-group discussions are an integral part of the inquiry process in IQWST. They provide the best opportunity for students to learn from each other and interact with their peers as well as with the teacher. It is important that all students have an opportunity to participate, express their ideas, listen to one another, and respect others' ideas. Developing a classroom culture in which this is the norm may take time, especially if this is not what students are accustomed to in other classroom settings.

Teacher Supports

IQWST lessons support teachers by providing scaffolding to help facilitate conversation. Teacher supports include a list of possible questions or prompts a teacher may use or adapt, as needed, possible student responses, information about what student responses might suggest about their understanding, and ideas about how to address those ideas. The lessons support the teacher in creating a culture of science discourse by providing question stems such as these:

- What can you add to make this idea clearer?
- How does this idea compare to the idea of the previous speaker?
- What can you add to expand on what was just said?
- How can you summarize our conclusions?

Three Types of Discussion

IQWST lessons identify discussions by type to assist teachers in recognizing the structure of the discussion and conducting the discussion according to the guidelines for each.

In IQWST, brainstorming is any discussion with the purpose of generating and sharing ideas without evaluating their validity. Prompts provided for all brainstorming discussions are suggestions meant to encourage students to express their ideas. It may be useful to record ideas on the board, on a computer, or on a transparency so that students can see what has been said and can build on others' ideas. A photograph of notes recorded on the board, a printout, or a transparency can be attached to the Driving Question Board as a reminder of the activity.

1. Discussion: Brainstorming
   Purpose: To articulate and share ideas without evaluating their validity.
   - All ideas are accepted in brainstorming.
   - Ideas are captured and recorded as they are generated.
   - Brainstorming prompts include the following:
     - o What have you observed or experienced?
     - o What do you think about when you hear the word . . . ?
     - o What do you know about . . . ?
     - o Who has a different way of thinking about this topic?
   - Follow-up can include, as appropriate, such questions as the following: Where does that idea come from? How do you know? Where have you heard/seen/experienced that before?
2. Discussion: Synthesizing
   Purpose: To put ideas together or assemble them from multiple activities into a coherent whole.
   - Discussions may include making connections to personal experiences, to the Driving Question, and to other lessons or content areas.
   - Synthesizing prompts include the following ones:
     - o How does this connect to . . . ?

- o How does this support the Driving Question?
- o How does this help us think about the activity we did yesterday?
- o What do we know about this topic so far?

In IQWST, the purpose of a Pressing for Understanding discussion is to get students to think more deeply and to make sense of their experiences. Some questions can lead to a simple answer, others to a deeper, more thoughtful answer. Learning through inquiry encourages students to think more deeply but only if their thinking is scaffolded until they learn to think in terms of how and why, to make connections, to analyze, and to synthesize. Probing questions such as *Why do you say that?, What makes you think that?,* and *How do you think that works?* invite students to think more deeply and, over time, establish a culture in which doing so is the norm in science class.

3. Discussion: Pressing for Understanding

   Purpose: To figure things out or make sense of readings or activities while going deeper and beyond surface answers.

   - Discussions may involve respectful challenge, debate, or arguments in which students justify their ideas.
   - When pressed, students may revise their previous ideas as they learn new information that shows the limitations of their previous understandings.
   - Pressing for Understanding prompts include the following:
     - o How do you know? What evidence supports that idea?
     - o Why does our old model not work to explain this new phenomenon?
     - o How could we figure this out?
     - o How does . . . compare to . . . ?
     - o What new questions do you have?

THE LANGUAGE OF SCIENCE: VOCABULARY

New Meanings, Familiar Words

Science as a discipline is known for its challenging vocabulary; thus IQWST lessons contain supports to help students develop deeper understanding of science concepts, including how, when, and why particular language is used. Students are engaged in thinking about the language of science in multiple ways.

IQWST takes a research-based, contextual approach to science language, stressing the repeated, ongoing, pervasive use of new words in oral and written discourse, acknowledging that language and conceptual understanding develop hand-in-hand. Science words are taught as they are needed. Typically, after a concept has been encountered, it is then given a label (the vocabulary word). A primary support for students occurs when teachers use science vocabulary frequently and appropriately and guide students to do so as well.

One of the hallmarks of successful readers is their ability to understand word meanings as they occur in varied contexts. When the teacher uses science vocabulary in context and calls attention to similarities and distinctions between words, all students are supported in building their science vocabularies. Students' everyday understanding can help or hinder their understanding of the uses of many words in science. Words like *absorb* and *reflect* have everyday uses that are consistent with their meanings in science, so linking the everyday to the scientific is likely to be helpful. However, words like *volume* and *mass* or words that name scientific practices such as *modeling* or *explanation,* have everyday meanings that may not help students understand the meaning in science. In those cases, making differences explicit supports students in learning multiple uses of words, including specific uses in science.

Simple routines used before students read new text can help students recognize and use science language as they read, write, and discuss their developing understandings.

Prereading

Before asking students to read independently, the teacher can identify words that will be difficult for the class. Words the teacher anticipates will be difficult can be rehearsed by displaying them (on the board or on a Word Wall), pronouncing them, and providing a snapshot definitions aimed only to help students recognize the words when they encounter them in the context of written text. This scaffolding helps students move words from listening and speaking vocabulary to their reading and writing vocabulary.

Building Vocabulary

Many science words have common prefixes, suffixes, or root words. Building a list of words with similar word parts allows students to see, define, and make connections between words such as *biology* and *ecology*, especially when connected to biosphere, ecosystem, eco-friendly, biochemical, and biography, among others.

For teachers required to do more intense vocabulary study at the middle school level, strategies should support students in developing deeper understanding of science concepts, rather than simply memorizing textbook-style definitions. Although writing vocabulary words in sentences is common school practice, it has not been shown to promote science vocabulary learning. Thus time is better spent engaged in tasks that use science vocabulary: constructing oral and written explanations and arguments, composing brief summaries, and answering questions that require both critical thinking and the use of appropriate vocabulary.

Interactive Word Wall

Keeping a space in the classroom to post new science language, as new words are encountered, provides students with multiple exposures to new words and allows them to refer to the Word Wall when communicating ideas, formulating questions, or writing (and learning to spell science vocabulary). Having words posted allows the teacher to gesture to the Word Wall during discussion to support students in using science language in their talk. Words written on sentence strips can easily be moved to increase opportunities for connecting words in various ways, grouping them or creating concept maps. Word Walls may be enhanced by short definitions or by visual representations, as well. Students with artistic ability or who like to draw, or who learn by the act of creating representations may create visuals to post on the Word Wall along with new words. Most important is that the classroom is language rich, providing students with ongoing exposure to discipline-specific vocabulary, which supports them as readers, writers, and critical thinkers in science.

ASSESSMENTS

Embedded/Formative Assessments

Formative assessment opportunities are embedded within IQWST lessons. They occur during discussions, activities, and readings and can be used to gauge students' understandings and developing science ideas in the moment. Formative assessments used regularly during the learning process enable the teacher to determine whether concepts need to be revisited, whether an optional activity would be beneficial for student learning, whether discussion should be extended or guided differently in order to support student learning, or whether some or all students would benefit from additional support. Formative assessments also enable teachers to provide explicit feedback to students on their ideas, so students can know in what ways they are on track toward meeting learning goals. Formative assessments also enable teachers to differentiate instruction in response to students' current understandings. Questions embedded in readings and as suggested prompts for discussion include possible student responses and, where appropriate, correct answers. When using embedded assessments to gauge students' understanding, analyze responses by listening for students'

- the ability to connect previous ideas with new content;
- the ability to summarize ideas accurately;
- current content understanding, as it will lead to meeting learning goals; and
- developing use of appropriate science language.

Summative Assessments

Many of the embedded assessments, while designed for formative use, may be assigned points or letter grades. Any written response in the student books may be seen as a summative opportunity. An option is to invite students to submit their one "best response" to questions in a lesson or their best evidence-based explanation or other revised response for a grade. This practice acknowledges that motivation, interest, and understanding vary from day to day and recognizes that assessing one's best work helps students be more aware of their own performance and what constitutes "good work" in science. IQWST also provides a bank of questions, available electronically, and in Word format, that teachers may draw from to customize quizzes and tests. Questions may be used as they are or adapted to best match instruction or to meet students' needs (i.e., differentiation).

SAFETY PRACTICES

Laboratory investigations excite students about the practice of science and lead to reflective discussions about investigation design and the real work of scientists. With investigations comes the need to teach laboratory safety and practice safety precautions with middle school students who may be new to lab experiences.

Science teachers are expected to take all possible actions to avoid accidents in the laboratory setting and to monitor labs for hazardous chemicals or flammable materials. This includes standard safety practices that include housekeeping to keep the laboratory areas clear of clutter and prohibiting unsupervised access to areas where electricity, chemicals, or heat sources are used.

Teachers should provide information about, and practice, laboratory evacuation drills. Gas and electricity should be shut off during any drills or whenever the class is leaving the lab. All exits must be kept free from obstructions, and no materials should be stored outside of the lab storage room. Safety rules should be posted in the room and reviewed with students prior to lab work. If the teacher, school, or district has specific science rules, those should be posted.

IQWST lessons contain specific safety information at the start of each lesson and throughout the lessons for easy reference for teacher and student. MSDS sheets should be consulted for appropriate use of all chemicals.

Science Lab Rules

There are many science rules to ensure safety in the laboratory. IQWST lessons have specific science cautions through each lesson to guide teachers and students, but middle school students, because of their inexperience with science labs, may need to be aware of certain safety procedures that include the following:

1. Clothing and Hair—Loose or baggy clothing, dangling jewelry, and long hair are safety hazards in the laboratory.
2. Cold and Heat Protection—Cold or hot materials should only be touched with hands protected by items such as safety tongs, safety mittens, or rubber gloves. In some instances, only the teacher should handle materials at extreme temperatures (e.g., dry ice).
3. Food—No eating, drinking, or use of cosmetics should occur during lab time. Even familiar substances used in activities (e.g., marshmallows for molecules) should not be consumed, as they may be contaminated in the lab setting.
4. Glass Caution—Glass should be used cautiously, and students should report any chipped, cracked, or scratched glassware should such occur during a lab activity.
5. Housekeeping—Work areas should be kept clean at all times, with backpacks, books, purses, and jackets placed away from lab tables.
6. Washup—Hands should be washed with soap and water before and after laboratory work. Students should not touch their faces or hair with either bare or gloved hands that have handled lab materials.

7. Safety Equipment—Personal protective equipment such as goggles, gloves, and aprons should be used as appropriate for the activity.
8. Allergies—All allergies should be noted for students and a plan put in place if peanuts, peanut oil, latex, or other known allergenic items are used in the lab. For example, although gloves and goggles provided in IQWST materials are latex-free, some units use balloons, which students with latex allergies should not handle.
9. Sniffing—When directed to "sniff" in the lab, students should be taught to follow the teacher's directions for "wafting" odor to the nose.

These rules are general and should always be followed in a lab situation. IQWST provides a letter to parents that discusses science safety rules. If a school or district has another science letter, and/or additional safety rules, teachers should use the district letter and follow all school or district guidelines for safety in the science lab. For additional safety information, consult the NSTA safety portal at http://www.nsta.org/portals/safety.aspx.

SAFETY LETTER

Dear Students, Parents, and Guardians:

Middle school science consists of engaging topics for students to investigate in a lab setting. However, any science activity may have potential safety issues if not conducted properly. Safety in the science classroom is an important part of the scientific process. To ensure a safe learning environment, a list of rules has been developed and discussed with all students because science rules must be followed at all times. Additional safety instructions will be given for each activity. Please discuss the safety rules with your child and return the bottom of this letter.

No science student will be allowed to participate in science activities until the student and a parent or guardian have acknowledged their understanding of these safety rules by signing this document.

Science Safety Rules

1. Conduct yourself in a responsible manner at all times in the science room.
2. Follow instructions carefully. Ask questions if you do not understand the instructions.
3. Use equipment (e.g., scissors and sharp items) only as directed by the teacher.
4. Perform only approved experiments.
5. Never eat, drink, chew gum, or taste anything in the science lab.
6. Keep hands away from face, eyes, and mouth while using science materials. Wash your hands with soap and water after the activity.
7. Wear safety goggles when instructed. Never remove safety goggles during an experiment. There are no exceptions to this rule!
8. Clean all work areas and equipment, and dispose properly of any waste materials.
9. Report any accident (spill, breakage, and so on), injury, or broken equipment to the teacher immediately.
10. If you have allergies, it is important that your teacher knows about them and that you avoid handling materials that could cause problems. For example, if you are allergic to latex, you can participate in activities that use balloons, but you should not be the one to handle the balloons.

SAFETY AGREEMENT

Dear Students, Parents, and Guardians:

We are providing the Science Safety Rules to keep you informed of the school's effort to create and maintain a safe science classroom/laboratory environment for all students.

Your signature on this letter indicates that you have read the Science Safety Rules, have reviewed them with your child, and are aware of the measures taken to ensure the safety of your son/daughter in the science classroom.

Parent/Guardian Signature: ____

Student Signature: ____

Date: ____

Important question – Does your child have any health issues or allergies? If yes, please list them here.

Unit Overview

How Can I Make New Stuff from Old Stuff?

How Can I Make New Stuff from Old Stuff is a 6–8-week project-based introduction-to-chemistry unit. This unit builds on core science concepts such as the particle nature of matter, and substances and their properties (IQWST IC1). The unit continues to support students' engagement with scientific practices such as asking questions, developing and using models to explain phenomena, planning and carrying out investigations, and analyzing and interpreting data such that students can construct explanations and engage in argumentation from evidence.

In order to contextualize chemistry concepts and scientific inquiry in real-world student experiences, the unit focuses on making new substances from old substances—specifically making soap from fat and sodium hydroxide. The core science concepts explored in the unit, especially those related to matter and its interactions, and to energy, and more specifically to chemical reactions and to conservation, are instrumental to understanding and answering the Driving Question and are foundational for future science learning.

DRIVING QUESTION: HOW CAN I MAKE NEW STUFF FROM OLD STUFF?

The Driving Question, How Can I Make New Stuff from Old Stuff? organizes and structures the unit's activities. Students complete a number of investigations of other substances, as well as of soap and fat, each time cycling back to soap and fat, as a variety of substances are needed to eventually make their own soap. Students are motivated, in part, by the notion that a caustic substance used in drain cleaners (sodium hydroxide) can be combined with something used for cooking (lard, vegetable shortening, or another fat), and through a chemical reaction can become a new substance used for washing their bodies! Each cycle of investigation supports students in delving deeper into the science content to understand substances, then properties, then the fact that substances can interact to form new substances with new properties (i.e., chemical reactions), and finally the concept of conservation of mass. Each cycle includes exploration of the macroscopic phenomena and the use of molecular models to explain the phenomena.

Three learning sets and 14 lessons compose the unit's instructional sequence.

LEARNING SET 1

The primary learning goal of the first learning set is to deepen students' understanding of substances and their properties, which they may have been introduced to in previous science classes (e.g., IQWST IC1). Initially, students explore two unknowns (soap and a fat) to review what they know about substances and their properties. Students come to understand that a substance is made of only one material all the way through (which differentiates substances from mixtures), and that properties are characteristics of substances that can be used to describe substances, to help identify substances, and to distinguish substances from one another. To further develop understanding of properties and what it means for them to be *characteristic* of a substance, students investigate the solubility, melting point, and density of soap and fat.

After exploring phenomena at the macroscopic scale, students apply and further refine their understanding of models and modeling as a scientific practice by developing and using models to explain phenomena at the microscopic scale. Students use molecular models to explore what it means to describe a substance as being made of the same type of atom or molecule all the way through. Models are used to explain what it means to say that properties are characteristic of a substance—that it does not matter where a sample of a substance is drawn from a larger portion, or how large the sample is, the properties of the substance will always be the same. Students also review the scientific practices of constructing explanations and constructing arguments from evidence, which they have previously encountered (IQWST LS1). Throughout the unit, students write about, talk about, and revise explanations and arguments about how they can determine whether two substances (fat and soap) are the same or different.

LEARNING SET 2

The second learning set builds conceptual understanding of substances and properties as it introduces chemical reactions. Students first explore macroscopic phenomena by planning and carrying out a number of investigations of chemical reactions. Through their investigations, students learn that a chemical reaction is a process in which old substances (reactants) interact to form new substances (products) with new properties. Students use models to further develop their understanding of the particulate nature of matter in the context of these chemical reactions, learning that new substances are the result of atoms in the old substances rearranging to form new molecules. It is the atoms and molecules—the type, number, and arrangement (thus rearrangement)—that give substances their properties. Although this concept is introduced in previous units students may have studied (especially IQWST IC1), the core concepts are now revisited and applied to new contexts to deepen understanding of the unseen molecular world.

After exploring chemical reactions, students examine both phase changes and mixtures (addressing common conceptions that these processes result in new substances) to determine whether new substances form during these processes and how scientists would determine the answer. Students use molecular models to explore what is happening to the atoms and molecules in phase changes and mixtures. At the end of the learning set, students make soap from fat, experiencing another chemical reaction firsthand, with their own bar of soap as each group's product.

LEARNING SET 3

Students conduct experiments in both open and closed systems, observing that no matter how substances interact, the total mass of the system does not change. Students use molecular models to explain what happens to the atoms and molecules so that the total mass of a system stays the same.

The unit ends with students testing the properties of their homemade soap to determine whether it qualifies as a new substance and why. They examine molecular models of the soap-making process to determine that the fat and sodium hydroxide interact, and their atoms combine in new ways to form a new substance—soap. The final project involves the planning and carrying out of one of two investigations—either to determine whether their homemade soap is better than commercial soap, or to test a new recipe for better homemade soap than they made in their first effort.

IQWST CHEMISTRY SAFETY GUIDELINES

Students experiencing phenomena and engaging in scientific investigation are central to IQWST and to science in general. Inherent in "doing science" is using a vast array of materials and in chemistry, especially, safe, responsible laboratory procedures are imperative. It is important to inform students of safety precautions associated with doing investigations, review guidelines for every investigation, and reinforce and monitor students as they engage in experimentation. Each lesson in IQWST includes safety guidelines. The best way to have a safe science classroom is to be aware of possible risks and hazards to remind students that safety is paramount. A number of safety guidelines, for teachers and students, will create a safe and engaging science laboratory experience for all.

Teachers

- Read the chemical safety information on all chemicals you receive, in terms of using and disposing of chemicals.
- Carefully read the safety guidelines that are included in each of the lessons. Although IQWST labs are designed to be safe, some investigations use chemicals that could be dangerous if not used as directed. Be familiar with possible hazards for each investigation.
- Wear safety goggles at all times to model safe and appropriate laboratory procedures. If students share goggles, they should be cleaned and disinfected after each use.
- Have a first-aid kit and eye wash station available in the classroom. Portable eye wash stations are available for purchase.
- Caution students to never look directly into a test tube, flask, or beaker that contains compounds or solutions. If the material in the flask, beaker, or test tube is hot, it could boil/splash out.
- In some IQWST labs, students are directed to smell or *waft* the odor from a solution or compound. In these situations it is safe to do so, but in general, no one should deeply inhale chemicals.
- Dispose of chemicals as directed or as described in the lesson. Never casually dispose of chemicals down a drain. IQWST lessons tell if chemicals should not be placed down the drain or if chemicals can be washed down the drain after diluting with water. Never put solids directly in the sink.
- When preparing solutions, always add the compound to water. Never add a small amount of water to a solid. Some chemicals generate heat when they dissolve, and by adding small amounts of water to the chemicals splattering could occur. Always pour acid into water and never water into a concentrated acid.
- Do not use mercury thermometers. Instead, use alcohol thermometers or electronic thermometers.
- Use plastic lab equipment such as beakers and flasks instead of glass lab equipment when possible. If glassware does break, do not have students clean it up. The teacher or custodian should pick up glass and dispose of it in a container marked "broken glass."
- Provide sufficient time to complete an investigation; accidents may occur when students rush.
- Cords from hot plates, loose sleeves, hair hanging down, backpacks, and other materials on the floor or on desks are hazards to be addressed in

addition to the handling of chemicals and glassware.

Students

- Do not wear loose or flowing clothing, and roll up sleeves when doing an investigation. Tie back long hair.
- Wear safety goggles as directed; do not remove them during lab.
- Do not eat or drink when performing an investigation.
- Never taste any chemicals used in the investigations. Never use any glass or plastic laboratory equipment as a drinking glass. Objects you know are edible, for example, might be contaminated by other substances or equipment they have touched.
- Report to the teacher any injuries that occur, no matter how minor they seem.
- Read the labels on all chemicals carefully.
- Read lab procedures carefully. Doing steps in the correct order and measuring precise amounts are very important in science.
- Never mix chemicals just to see what will happen. Some combinations of chemicals can generate a great deal of heat or fumes, even to very dangerous levels.

The best way to have a safe science classroom is to be preventive. Teachers and students need to be knowledgeable of the potential hazards and how to avoid them.

PREREQUISITE CONTENT KNOWLEDGE

Three areas are presumed to be prerequisite knowledge for this unit: familiarity with phase changes, the particulate nature of matter (atoms, molecules, and elements), and mass. These concepts are presented in IQWST IC1 and IQWST ES1 in an introductory manner to be further explored and built on in this unit. The major prerequisite content knowledge is depicted in the graphic figure following this section.

PHASE CHANGES

Students should know that matter commonly occurs in three states—solid, liquid, and gas. Students should be able to identify a solid turning into a liquid (melting) and a liquid turning into a gas (evaporating, boiling). They should be able to articulate that phase changes occur when substances are heated or cooled. When the atoms or molecules in a substance speed up and move farther apart, the temperature of the substance increases. When the atoms or molecules slow down and move closer together, the temperature decreases. Student understanding of phase changes, especially at the microlevel, is enriched through their investigations in this unit.

PARTICLE NATURE OF MATTER

Students should know that matter is made up of atoms and molecules, and that an atom is the smallest part of an element. Students should define a molecule as two or more atoms that stick together. (They do not need to understand chemical bonding.) Reviewing common examples of elements, atoms, and molecules will likely be helpful (e.g., hydrogen, oxygen, and water).

MASS AND VOLUME

Students should know that all matter—by definition—has both mass and volume. Mass is the measure of the amount of a substance. Volume is the amount of space a substance takes up. Students should recognize that a substance has mass and volume whether in the solid, liquid, or gaseous state.

UNIT CALENDAR

Unit Driving Question – How Can I Make New Stuff from Old Stuff?

Learning Set 1: How Is Stuff the Same and Different?	
3 Class Periods	**Lesson 1 – How Is This Stuff the Same and Different?**
	Activity 1.1: Can I Make New Stuff from Old Stuff?
	Activity 1.2: How Is This Stuff the Same and Different?
	Reading 1.1: What Is Important about the Stuff I Use?
	Activity 1.3: Demonstration and Review of Substance, Mixture, and Property
	Reading 1.2: What Makes a Substance a Special Kind of Stuff?
1 Class Period	**Lesson 2 – Do Fat and Soap Dissolve in the Same Liquid?**
	Activity 2.1: Teacher Demonstration: Investigating Solubility
	Activity 2.2: Investigating Solubility of Soap and Fat
	Reading 2.1: Why Can I Easily Wash Soap off My Hands with Water?
2–3 Class Periods	**Lesson 3 – Do Fat and Soap Melt at Different Temperatures?**
	Activity 3.1: Teacher Demonstration of Melting Point
	Reading 3.1: Melting Points
	Activity 3.2: Does the Size of Something Affect Its Properties?
	Reading 3.2: Which Properties Can I Use When?
2 Class Periods	**Lesson 4 – What Other Properties Can Distinguish Soap from Fat?**
	Activity 4.1: Exploring the Relationship between Mass and Volume
	Reading 4.1: How Can Two Objects that Are the Same Size Have Different Masses?
	Activity 4.2: Do Fat and Soap Have the Same Density?
1 Class Period	**Lesson 5 – How Are Fat and Soap Different?**
	Activity 5.1: Are Fat and Soap the Same or Different Substances?
	Reading 5.1: What Evidence Would I Use to Tell if the Stones in a Ring Are the Same or Different?
Learning Set 2: How Can I Make New Substances?	
2 Class Periods	**Lesson 6 – What Happens to Properties When I Combine Substances?**
	Activity 6.1: Teacher Demonstration of Investigation Procedure
	Reading 6.1: Could Someone Change Straw into Gold?
	Reading 6.2: What Is a Chemical Reaction?
1 Class Period	**Lesson 7 – Is Burning a Chemical Reaction?**
	Activity 7.1: Is Burning a Chemical Reaction?
	Reading 7.1: Is Burning a Chemical Reaction?
2–3 Class Periods	**Lesson 8 – Does Acid Rain Make New Substances?**
	Activity 8.1: How Can I Investigate Acid Rain in My Classroom?
	Reading 8.1: Why Is the Statue of Liberty Green?
	Activity 8.2: Does Acid Rain Make New Substances?

	Reading 8.2: Does Acid Rain Make New Substances?
	Activity 8.3: Representing Chemical Reactions in Words and Symbols
	Reading 8.3: What Are the Many Ways of Representing Any Chemical Reaction?
2 Class Periods	**Lesson 9 – Is This a New Substance?**
	Activity 9.1: Does Electrolysis of Water Make New Substances?
	Reading 9.1: What Is the Same and Different about Boiling Water and Electrolysis?
2–3 Class Periods	**Lesson 10 – How Is a Mixture Different from a Chemical Reaction?**
	Activity 10.1: Do I Always Make New Substances When I Put Substances Together?
	Reading 10.1: What Happens to Atoms and Molecules When I See Different Processes?
2 Class Periods	**Lesson 11 – How Can I Make Soap from Fat?**
	Activity 11.1: How Can I Make Soap from Fat?
	Reading 11.1: Do People Really Make Soap from Fat?
	Activity 11.2: Testing the Properties of Soap
Learning Set 3: Do New Substances Always Come from Old Substances?	
2 Class Periods	**Lesson 12 – Does Mass Change in a Chemical Reaction?**
	Activity 12.A: Making Gloop (Optional)
	Activity 12.1: Does Mass Change When Seltzer Tablets React?
	Reading 12.1: What Happens to Mass During a Chemical Reaction in an Open System?
	Activity 12.2: Does Mass Really Change When Seltzer Tablets React?
	Reading 12.2: What Happens to Mass during a Chemical Reaction in a Closed System?
2 Class Periods	**Lesson 13 – Is My Soap a New Substance?**
	Activity 13.1: Is My Soap a New Substance?
	Reading 13.1: How Does My Soap Compare with Colonial Soap and Modern Soap?
3 Class Periods	**Lesson 14 – How Does My Soap Compare or How Can I Improve My Soap?**
	Activity 14.1: How Does My Soap Compare with Commercial Brand Soap?
	Reading 14.1: The Science behind *Rumpelstiltskin*
	Activity 14.2: How Can I Improve My Soap?

IC2 SCIENTIFIC PRINCIPLES

1. Properties are unique characteristics that help identify a substance and distinguish one substance from another.
2. A substance is made of only one type of material (atoms or molecules) all the way through.
3. A mixture is made of more than one substance (or more than one type of atom or molecule).
4. Solubility is the capacity of one substance to dissolve in another substance.
5. Hardness and melting point are both properties of substances. Melting point is the temperature at which a solid substance starts to become a liquid.
6. Properties of a given substance are the same regardless of the amount of the substance.
7. Density is the mass in a set volume of a substance. It is calculated mathematically by determining the ratio of the mass of a sample to the volume it occupies.
8. A chemical reaction happens when two or more substances combine in ways that make new substances form that have different properties from the beginning materials.
9. Burning is a chemical reaction in which a substance reacts with oxygen to form water and carbon dioxide.
10. A reactant is a starting substance in a chemical reaction. A product is the substance made by a chemical reaction.
11. A chemical reaction occurs when substances interact and their atoms combine in new ways to form new substances. The new substances and the old substances are made of the same atoms, but those atoms are arranged in new ways. As a result, the new substances have different properties from the original materials.
12. A chemical reaction is the process of one substance breaking down or two or more substances interacting and their atoms combine in new ways to form new substances with different properties from the old substances.
13. Phase changes and mixing do not make new substances.
14. Atoms do not combine in new ways during a phase change or mixing.

15 Atoms cannot be created or destroyed. In a chemical reaction, the number of atoms stays the same; therefore matter and mass are always conserved.

Lesson 1

How Is This Stuff the Same and Different?

PREPARATION

Teacher Background Knowledge

Scientific Observation

Thorough, careful, and accurate observation is imperative in science, thus the unit begins by stressing observation. Students will encounter "ways to describe" objects or materials, some of which are properties and some are not, and the distinction is important and builds over time. Students often assume that the challenge is to be correct in guessing what something *is* rather than in describing it carefully. Therefore, determining "this is soap" and "this is fat" circumvents describing the odor of the one material as sweet, fresh, or clean. Encourage students to use descriptive words and vision, hearing, and touch, when appropriate. Taste will never be appropriate in chemistry lab activities.

Substances and Mixtures

Properties are characteristics of a substance that are independent of the amount of the sample (e.g., color, hardness, density, solubility, melting point). Other ways to describe are not properties because they change with the amount of a substance (e.g., mass, volume, size, shape). Several activities help to solidify this understanding for students, but it is not uncommon for mass to continue to confuse students as not a property. Expect to continue to have to support students with probing questions and examples (e.g., holding objects up for them to see during discussion) to help them.

Properties change when two substances are mixed together to create a mixture. All samples of 24-karat gold (regardless of size/mass) have the same properties because 24-karat gold is pure gold throughout. It is not mixed with any other metal. A future reading discusses 14-karat gold or 18-karat gold mixtures of gold and other metals (e.g., silver, copper). Four samples of 14-karat gold could all have different properties because although the same amount of gold is in the sample, which other metals it is mixed with can vary. Therefore, properties can be used to distinguish substances, but not necessarily to distinguish mixtures. In the next lesson, students will begin to make the distinction between ways to describe that are properties and those that are not. Students will continue to refine their understanding of properties and nonproperties throughout the first learning set.

Use of Chalk

Chalk is used as an example of something that is "the same all the way through" because chalk has a relatively simple molecular formula ($CaCO_3$), is familiar, and can be broken into pieces as an easy illustration for students that nothing changes except the size of the piece (its mass and its volume). Chalk is calcium carbonate—$CaCO_3$. There is no reason to introduce the chemical formula unless students ask or are familiar with chemical formulas.

Properties at Different Scales

In fact, properties of substances do change at the nanoscale, but the nanoscale is beyond the scope of this unit and beyond middle school standards. Information provided here is only to help you understand some of the careful wording necessary in this unit, as well as to support your students who have questions that go beyond those this unit will address.

Properties are generally defined as characteristics that determine the nature of a material. They are the source of a material's functionality—how it appears, how it behaves, how it interacts with and reacts to the environment, and for what applications it might be useful. Many properties are constant on a given scale (macro or molecular), but the properties of matter can change across scales. In particular, as the size of a sample decreases and approaches the nanoscale, materials exhibit different properties than those they exhibit in a sample collected and studied in the classroom. For example, macroscopic spheres of gold with diameters of 1m, 1cm, and 1mm will be shiny and gold colored, and they will exhibit metallic properties such as malleability and conductivity. On the macro scale, all of these properties remain the same. However, when spheres of gold become very small, approaching the nanoscale, those properties change. On the nanoscale, the color of gold particles becomes very sensitive to size. Gold spheres with a diameter of 13nm suspended in a solution (a colloidal solution) appear red. At sizes less than 10nm, gold loses its metallic properties and is no longer able to conduct electricity.

The source of the unique properties observed on the nanoscale may be either surface- or bulk-related. Surface-dominated behaviors are governed primarily by changes to the surface-area-to-volume ratio that occur from changes in size or shape. The surface-area-to-volume ratio increases as particles become smaller. As a result, the fraction of the atoms that are on the surface increases, and surface-related properties become more important as a particle's size approaches the nanoscale. Bulk-dominated behaviors are related directly to the size or shape of the object or material. Unique shapes and structures occur at the nanoscale, leading to unique properties.

In this unit, when referring to properties independent of the sample, we are referring to an easily observed sample size (macro- and/or molecular scale)—an amount that can be observed with students' senses, or with simple techniques (for example, a light microscope) accessible in the classroom. Because properties of a substance depend on scale, but the nanoscale is not addressed in middle school standards, students study properties of a substance as always the same regardless of the size of the sample they can use in the classroom.

Stevens, S.Y., Sutherland, L.M. & Krajcik, J.S. (2009). *The Big Ideas of Nanoscale Science and Engineering*, Arlington, VA: NSTA Press

Classroom Culture

One way to encourage students to listen and respond to one another is to have them share questions for the Driving Question Board in a structured manner. Ask a student to post the first question, and then require all future sharing to be done only when students can connect their question with one that came before it and can describe the connection for the class. For example, if the first student posts a question, "What is the brown liquid?" a second student could say, "My question connects with [name of student] because mine is also about the brown liquid—What made the blue liquid turn brown?" Another student might say, "My question connects to [name of student] because mine is also about color—How did the color change?" Another student might say, "Mine is not about color, but it is about a different change that happened—What happened to the foil?" This strategy makes the sharing session more engaging as students need to pay attention to what has been said and need to actively engage in making connections. This activity can be used to help students learn sharing strategies you want them to develop for all IQWST discussions. IQWST aims to have students engage with one another in sense making and, eventually, in arguing from evidence. To do so, students need to listen to one another and to respond to one another. (See Front Matter for more on IQWST discussion strategies.) This activity can begin to develop a classroom culture, in the first days of class, in which student-to-student conversation is a norm.

Common Student Ideas

Some students will likely continue to struggle with mass and volume as "not properties" of substances. Prepare to continue to address this over time so that students come to understand conceptually rather than simply learn the definitions and say the correct words, without truly understanding why mass and volume are important measures in science, and are typically measurements used in every investigation, but are not properties of substances. Two substances that have the same mass or volume could be very different substances, or they could be the same, but the common mass and volume do not help to determine whether they are the same or different substances.

Setup

Materials – Activity 1.1

For the Teacher

- (1) 500mL beaker for mixing solution (increase the size of the beaker if you have more than eight groups)
- 40g copper chloride (for eight groups; increase by 5g for every additional group)
- 400mL of water* (for eight groups; increase by 50mL for every additional group)

*This item is not included in the kit.

For Each Group

- (1) 150mL beaker containing 50mL copper chloride solution (prepared by teacher in advance)
- 0.5g aluminum foil (prepared by teacher in advance)
- (1) stirring spoon or rod
- (1) thermometer

For Each Student

- Activity Sheet 1.1

Materials – Activity 1.2

For Each Group

- vegetable shortening or lard (about the size of an egg)
- (1) small piece of white soap that looks similar to the shortening or lard (Scrape the brand name off the bar of soap.)

For Each Student

- Activity Sheet 1.2
- Reading 1.2

Safety Guidelines

- Instruct students never to taste anything in the science lab. Even if a substance is familiar and edible, the science equipment (beakers) and surfaces (tables) may be contaminated.
- When smelling substances, remind students to waft the aroma towards their noses.
- Do not put more than 8g of copper chloride and 0.5g of aluminum foil in the water; otherwise it may overheat and have the ability to scald.
- Copper chloride is toxic if inhaled. The teacher must prepare the solution of copper chloride, rather than have students make the solution.
- Students need to wear safety goggles and gloves (and aprons when available) during Activity 1.1.

Differentiation Opportunities

1. Before students proceed, review the laboratory procedures with them. For many students, a brief demonstration of what they will be doing, using language to describe each step, enables them to better follow a procedure. Let them see the equipment, see what it means to pour slowly or make a loose ball of foil or stir gently. Having an overall picture of what they are going to do is especially important for students with learning disabilities or organizational difficulties who need to hear and not just read the procedure, or who need to understand the big picture before making sense of the individual steps. This will also be especially helpful for students for whom English is not their first language, and the specific language of science and its procedures could interfere with their ability to understand the more important concepts.
2. All laboratory activities in this unit may be done as teacher demonstrations, but most are designed as group activities so that all students are able to experience scientific phenomena firsthand, up close, and actively. A variety of ways to assign groups exist, based on different philosophies of classroom management or of learning principles, but be certain that all students are able to (and some need to be encouraged to) participate in the "doing" and not simply the observing of investigations. For a variety of reasons, some students choose to remain on the sidelines, and these are often students who would learn better by active engagement. Encourage and prompt participation by all students in laboratory activities, in making observations, and in ongoing discussions in pairs, in small groups, and as a whole class.

LESSON 1

How Is This Stuff the Same and Different?

TEACHING THE LESSON

Performance Expectations

Students will

- generate original questions as they observe a chemical reaction.
- carry out an investigation to set a foundation for learning about the properties of matter as unique characteristics that help identify a substance and distinguish one substance from another macroscopically.

Building Coherence

This lesson introduces the Driving Question through two investigations that invite students to generate questions that will motivate the activities of the unit. The unit builds on scientific practices and content introduced elsewhere in IQWST, including constructing explanations and arguing from evidence (IQWST LS1) and the particle nature of matter (IQWST IC1).

Timeframe

3 Class Periods

Overview

Activity 1.1
Observe two materials before and after they are combined, and generate questions.

Activity 1.2
Explore two unknowns and consider the value of different ways to describe materials.

Activity 1.3
Use chalk to explore what it means for a substance to be "the same all the way through."

Safety

- Instruct students never to taste anything in the science lab.
- When smelling substances, remind students to waft the aroma towards their noses.
- See Preparation Section regarding copper chloride and aluminum foil.
- Instruct students to wear safety goggles and gloves during Activity 1.1.

Introducing the Lesson

Discussion – Brainstorming

Purpose

Elicit prior knowledge of matter, our everyday use of the word *stuff*, and the fact that stuff is made up of other stuff.

Suggested Prompts

- What does the word *stuff* mean when you use it?
- What are some examples of *stuff*? *(Students will likely name objects that are solids.)*
- The *stuff* you are naming sounds like stuff that could be called *matter* in science. What do you know about matter? *(3 states are solid, liquid, and gas; phase changes happen when you heat or cool something; all matter has mass and volume [takes up space])*
- What if someone said, "My little brother spilled stuff all over my homework" if he had knocked over juice, soda, or milk (*a liquid*). Is that *stuff* also matter?
- What if someone said, "This stuff smells weird" about an odor in the air (*a gas*). Is that *stuff* matter?
- Hold up a glass item and ask: "What is this made of?" *(glass)* "What is glass made of?" *(sand)* "How does sand become glass?"

This unit is about how old *stuff* like sand—the stuff a scientist might start with—becomes new *stuff* like glass. What other examples of old stuff being made into new stuff can students think of?

Materials – Activity 1.1

For Each Group
- (1) 150mL beaker containing 50mL copper chloride solution
- 0.5g aluminum foil
- (1) stirring spoon or rod
- (1) thermometer

For Each Student
- Activity Sheet 1.1

Activity 1.1 – Can I Make New Stuff from Old Stuff?

Students observe two materials, before and after putting them together, to think about old and new stuff. Before students proceed, have one student read aloud the What Will We Do? section. Then, review the procedure on Activity Sheet 1.1 and have each group proceed with carrying out the investigation. As they do, check that their observations are thorough, that they use as many senses as possible for the particular investigation, and that they record their observations.

You might create a class chart/table to review students' observations before they put the foil in the beaker, stressing thoroughness of descriptions.

Before (or as) students complete the conclusion section ask: What does it mean to compare? Be sure students understand that "comparing" means to articulate both similarities and differences.

Use students' responses to the last question on the activity sheet and their questions in the table to build the Driving Question Board (DQB). Introduce the Driving Question for this unit, if it is not already up for students to see: How can I make new stuff from old stuff?

In order to answer the Driving Question, the unit divides learning into three subquestions:

1. How is this stuff the same and different?
2. How can I make a new substance?
3. Do new substances always come from old substances?

In groups, students think about the questions they asked during the activity, or any new ones that come to mind as they talk. Have each group decide on some group questions that they would like to share with the class. Have each group choose two questions; have each member of the class ask one question or use some other strategy for limiting or expanding the number of questions students pose. Students should write each question on a separate sticky note.

To build the DQB, have students post their sticky notes on the question to which it seems most related (see Preparation Section for a strategy for doing this). Create a parking lot section of the DQB for questions that do not seem to fit the subquestions. Discuss questions so students can decide where they fit as a class, or let students put their questions where they think makes sense for now.

Framing the Unit

Discussion – Brainstorming

Purpose

Elicit prior knowledge and experiences; set the stage for learning core concepts in the unit.

Suggested Prompts

- Why might scientists be interested in making new stuff?
- What new stuff can you think of that scientists have made?
- How do you think scientists make new stuff from old stuff?

Students probably will not know that scientists make new substances through chemical reactions. They will study this process in Learning Set 2. For now, the question is designed to invite students to draw on prior knowledge and experience. They may think scientists mix things with chemicals, or they get things hot (or cook them) until they turn into something new. If students offer ideas, ask them for examples, or ask why they think their idea could be true. The point is to highlight their thinking processes and to bring to the forefront the experiences and understandings that inform their thinking.

Talk with students about the following. Although details are provided, ask students questions about what they may have learned previously to reinforce their understanding and to call it to mind as prior knowledge on which they will build in this unit.

- Some scientists, called chemists, are interested in learning more about matter because if they can learn about the materials something is made of they may be able to change it and make something new. By changing stuff in particular ways, scientists can make new (or better) stuff.
- This is a chemistry unit. In it, students will begin to investigate stuff by looking closely at two unknowns to determine, scientifically, whether they are the same or different materials. Scientists use the word *unknown* to label materials when they do not know what a material is. In class, however, the teacher always knows what the unknowns are—for safety reasons.

In the next activity, students observe two substances and decide whether they are the same or different.

Materials – Activity 1.2

For Each Group
- vegetable shortening or lard
- (1) small piece of white soap

For Each Student
- Activity Sheet 1.2
- Reading 1.1

Activity 1.2 – How Is This Stuff the Same and Different?

A simple activity helps students think about precise descriptions before they engage in describing the two unknowns. Tell students, "I am thinking of something round," and ask them to generate ideas of what you could be describing. Then describe: "I am thinking of something round and orange." Ask students to offer ideas. Continue to add details: "I am thinking of something round and orange, with a seed." Again ask for more students' ideas. Finally say, "I am thinking of something round, orange, with one seed, and fuzzy on the outside." *(a peach)*

Have students discuss what was most helpful to them in the previous activity so they see that the quality and precision of the descriptive words make a difference. *("A fruit that is fuzzy" would likely have sparked the idea of peach more quickly. "Round" or "fruit" are open to many more possibilities.)*

Students work in groups to complete Activity Sheet 1.2. Instruct students not to mix the pieces together, especially if you wish to use them for other classes. Remind students of appropriate lab safety.

Create a whole-class table for recording students' descriptions of the unknowns and have them copy the table onto their activity sheets. Group descriptions under column headings according to the Ways to Describe *that they report*, such as color, shape, smell, and so on. Have students look at their lists and engage in a classifying activity, deciding on ways to sort or group. Ways to Describe might include color, texture, odor, malleability (how easy it is to bend a material), length, height, shape, or mass.

	Ways to Describe				
	Color	Shape	Hardness	Smell	Texture
Unknown 1 (soap)	white	square	harder	fresh	smooth
Unknown 2 (fat)	yellowish / white	irregular	softer	sweet	greasy

Remind students of previous data collection experiences in which they learned about qualitative and quantitative data. Ask: "Which kind of data did we collect here?" *(qualitative—observable by their senses, no measurements, no instrumentation)*

Discussion – Connecting

Purpose

Address the importance of making careful observations.

Suggested Prompts

- How did careful observations of these unknowns help you get closer to figuring out what they were? *(Identify one as soap and the other as a fat—either lard or vegetable shortening.)*
- Why do scientists make careful observations of unknown objects?
- Why do scientists make careful observations of known materials, like soap and fat?
- Why would a scientist want to know what matter is made of?

Hold up a piece of fat. Ask: "Do you think this fat could be made into anything new?" Explain your ideas. Next, hold up the sodium hydroxide so that students can see (or you can read the warnings) that it is dangerous, and ask "What could this stuff make if it were mixed with fat? Would they want to rub it on their bodies like this piece of soap? Do they think fat and this chemical could somehow be made into soap?" Share ideas.

After discussing responses, show students the packaging for vegetable shortening or lard and soap. Discuss uses of both, such as cleaning, cooking, and as an ingredient in lotions and cosmetics.

In the next few weeks, students will explore those questions as they think about "old stuff" that they could start with to make "new stuff" that they would end up with. Call attention to the first subquestion on the DQB: How is stuff the same and different? This question will be explored throughout the first learning set.

Introducing Reading 1.1 – What Is Important about the Stuff I Use?

Reading 1.1 introduces the Driving Question and helps students to think about why it is important. Students might think that the Driving Question refers to recycling or to craft projects in which something old is made into something new. The reading will clarify that neither is the topic of the unit, but that *old* and *new* refer to substances before and after a process. To introduce the reading, ask: "What do you think your toothbrush bristles are made of? What do you think toothbrushes were made of before plastic was invented?" Press students to explain their ideas. If students suggest that toothbrushes were probably made of wood, ask them why that might make sense. (*Wood is plentiful; wood can be carved into different shapes.)* What do they think the bristles might have been made of? Their ideas are less important than that they are thinking about the rationale for their ideas. What prior knowledge and experience are they drawing on to answer questions and make predictions in science class? Making prior knowledge explicit—whether it is right, wrong, or somewhere in between—is central to all learning and key to IQWST discussions and students' sense making. Always introduce reading to engage interest and generate a purpose for reading, both keys to reading comprehension. And, always follow up readings not only for purposes of accountability, but to build students' understanding of core concepts, scientific practices, and crosscutting themes addressed in the readings.

Materials – Activity 1.3

For the Teacher

- (1) piece of white chalk (Coloring agents make colored chalk a mixture rather than a substance.)
- (1) bottle of sodium hydroxide (You will use sodium hydroxide later in the unit. For now, you will only show it to probe students' thinking in the second activity.)

For Each Student

- Activity Sheet 1.3
- Reading 1.2

Activity 1.3 – Demonstration and Review of Substance, Mixture, and Property

Reading Follow Up

- Why do you think plastic containers were first created? Why do you think polar fleece was created?
- Why do scientists need to compare the new stuff they create to the old stuff they started with?
- Why do people use fat?
- Why do people use soap?
- What is different about soap and fat so that people use them in such different ways?

Discussion – Connecting

Purpose

Review substance, mixture, and property.

Hold up a large piece of white chalk. Discuss the fact that each piece is the same all the way through. Break it into several pieces. Ask students if they think the piece of chalk is a substance or a mixture of substances. *(Chalk is a substance because it is made of the same material throughout.)*

Review substances, using water as an example. It is made of water molecules all the way through. *(A substance is made of only one type of particle [atom, molecule] all the way through.)*

Review mixtures, using air is an example. It is made of different types of gases and in different amounts. *(A mixture is made of more than one substance, or more than one type of atom, molecule, or particle.)*

Show another large piece of chalk. Ask students to describe observable characteristics as in the last activity. *(color, shape, hardness, brittleness, size, height, malleability, and odor)* Break the chalk into two pieces, one small and one large. Ask: "Which of the descriptions we just gave are the same for both pieces?" *(color, hardness)* "Which are different?" *(size, shape, weight, mass, length)* Break the chalk into smaller pieces and ask the same questions.

The substance is the same. It was chalk at the beginning, and it was chalk as it was broken into smaller pieces. The color stayed the same. The hardness stayed the same. Color and hardness are properties of the substance chalk. Whether you have a tiny piece or a whole, unbroken stick, it is always chalk all the way through. Chalk is a substance, and color and hardness are properties of that substance. The size is not always the same. The shape and mass are not always the same. The substance is chalk, no matter what size piece you have. Size, shape, and mass are not properties of the chalk.

Properties are characteristics scientists use to describe substances, to help identify substances, and to distinguish substances from each other. Properties are independent of the size of the sample. Properties include color, hardness, malleability, and melting point. By the end of this lesson, the following should be on the class list and in front of students' notebooks on their Scientific Principles list. You may have others from this review lesson, as well.

- Properties are unique characteristics that help identify a substance and distinguish one substance from another.
- A substance is made of only one type of material (atoms or molecules) all the way through.
- A mixture is made of more than one substance (or more than one type of atom or molecule).

Introducing Reading 1.2 – What Makes a Substance a Special Kind of Stuff?

Ask: "Do you think gold (or diamond) is a substance or a mixture?" If you are wearing a ring or other jewelry that is either gold or silver, or has a diamond or other gemstone, show it as a reference, and ask the appropriate question about it. Have students explain their ideas. Ask: "How could we test it to know for sure?" The reading addresses this question and the importance of properties. Students should come to the next class period ready to talk about your piece of jewelry given the ideas in the reading.

Introducing reading with this kind of discussion is important and enables literacy to be integrated into science rather than reading, for example, as a separate task done only to satisfy requirements that students read in science. Always follow up, however, to establish a culture in which the reading matters and can be drawn upon to help students learn the science content.

LESSON 2

Do Fat and Soap Dissolve in the Same Liquid?

PREPARATION

Teacher Background Knowledge

Solubility

Solubility is the capacity of one substance to dissolve in another substance. Solubility is a property of a substance, meaning that a substance is or is not always soluble in another substance. Solubility is stated as "X is soluble in Y"; never "X is soluble." As students will see, "X" might be soluble in "Y," but not in "Z"; therefore, its solubility in Y and Z is a property of substance X.

The substance that dissolves (or not), usually a solid, is called the solute. The medium in which the solute is dissolved, usually a liquid, is the solvent.

When a solid solute dissolves in a liquid solvent, the particles of the solid are attracted (by intermolecular or ionic forces) and held in combination with the particles of the liquid. Both the solid particles and liquid particles still exist. Although the solid is no longer visible, it does not disappear; instead, it is distributed uniformly throughout the liquid.

The amount of any solute that will dissolve in a given amount of solvent is limited. This is the solubility. This limit, or threshold, usually increases as the temperature of the liquid increases. Conversely, the amount of solute that can mix into a solvent decreases as the temperature decreases. Therefore, to maximize the chances that the solids in this activity will dissolve (or not), use small quantities of the solids and warm the liquid solvents.

Lesson 2: Specific Solubility

- Butter is soluble in oil. Butter should dissolve completely in oil, so that it is no longer visible. Butter is not soluble in water; butter should remain visible in water.
- Baking soda and road salt are soluble in water. Both should dissolve completely in the water, so that the white solids are no longer visible. Baking soda and road salt are not soluble in oil. The white solids should be visible in the oil.
- Baking soda and road salt will be used again in Lesson 6. Be sure students record solubility data on these solids, so they can use those data in Lesson 6 and not need to remeasure solubility.
- When judging the results of a solubility test, a useful heuristic is to examine the solid and compare the resulting liquid to the standard liquid with nothing added to it. If the chunk of solid is still visible in the liquid, and the liquid looks exactly like the standard liquid, the solid is not soluble. If the solid is no longer visible in the liquid, the solid is soluble.
- Commercial soap is concentrated, so it is likely that the amount of soap

added to the water will exceed the limit that can dissolve in the water. Follow this guideline: If the soap is in smaller pieces, they are dispersed in the water and the water looks very different from standard water (cloudy rather than clear), then the soap is slightly soluble.

Planning and Carrying out Investigations

In each IQWST unit, scientific practices are the means by which the core ideas and the crosscutting concepts are addressed. Although various practices are highlighted in different lessons, scientific practices as described in NGSS are often used in tandem or are broken down into smaller steps. For example, part of planning an investigation is writing a procedure that clearly communicates what someone will do. In this lesson, students write the same procedure for measuring solubility in their own investigation as the teacher used in his or her demonstration. Later, students use this skill as a component of designing an investigation, in which planning and carrying out are more autonomous. Students develop facility with scientific practices by using them repeatedly but applying them to new situations and contexts, or as part of designing solutions.

Common Student Ideas

Dissolving

Many students have a complex understanding of the word *dissolve*. It is scientifically accurate that solubility involves dissolving. Students' responses may exhibit some of the following scientific inaccuracies about dissolving: the solid becomes liquid; the solid melts into the liquid; the solid vanishes, disappears, or goes away; or the solid and liquid react chemically with each other.

The unit is sequenced to address these common ideas, so you do not have to address them all at once. Students who had IQWST IC1 have addressed melting as a phase change, but this unit provides an opportunity to build deeper understanding and to distinguish dissolving from melting. Dissolving occurs when one substance (solute) can mix into another substance (solvent), whereas melting involves a change in phase of a single substance. Lesson 11 addresses differences between mixtures and chemical reactions. When two substances are combined, dissolving results in a mixture of those substances. In contrast, a chemical reaction results in one or more new substances. In Lesson 11, students also explore particle models of mixtures. In mixtures (a solute mixing into a solvent), the particles (atoms or molecules) of the solute have not disappeared but still exist distributed throughout the solvent.

Describing Solubility

Students initially tend to focus only on the solid (solute) and not the liquid (solvent) in which it is measured.

For example, students might say salt is soluble. Students need to qualify this statement with an appropriate solvent—Salt is soluble in water. Press students to use precise language as they describe a substance's solubility. This issue is also addressed in the reading for today's lesson.

Setup

In general, solutes dissolve more readily in solvents when the solvents are warm. Students can obtain warm tap water from a faucet. However, if the water is too warm, the fat will melt. Heat enough oil for all groups and for the demonstration using a hot plate set on low. The oil should be warm (not hot) to the touch—comfortable enough to leave your finger in it.

The solubility testing works best using small quantities of fat and soap. Prepare sufficient quantities for each group before class and then dispense them. One pea-sized piece of fat and a few tiny chips of soap per group are sufficient. The freezing and cutting technique recommended in Activity 4.2 (Setup, Lesson 4) will also be useful here.

⚠ Safety Guidelines

Refer to IQWST Overview.

Differentiation Opportunities

1. Illustrate mixtures by showing trail mix (or a similar mixture) and having all agree that it is a mixture. Then pour "samples" of it into a number of snack or sandwich bags. Visually, students can see that the smaller bags still contain a mixture that can be thought of as samples of the original. If students count the number of peanuts, candies, and raisins in their bags, they can see that the amount of each is different in each sample, and the arrangement of each is different (judged by looking at where the pieces are in the bags). Students will study this at the microlevel, but for now, this exercise may help those who especially need a visual representation or help with the language of substances, mixtures, properties, etc. to have a better understanding of why it does not make sense to talk about properties of a mixture. A mixture is not the same all the way through, thus each sample can contain different amount of the original substances. Fasten one bag onto the DQB as a visual aid that can be referenced throughout the unit.

2. You might have some students go beyond this activity to collect quantitative measurements of solubility. Each of the solids in this activity could be placed in a metal, mesh tea strainer ball (not provided), and the liquids poured into beakers. Students could determine the mass of the tea strainer and substance before and after placing them in the liquids. They could then follow the procedures (or could develop their own) to collect quantitative data.

Suggested Prompts
- What if it looked like you now had less butter/road salt/baking soda than what you started with, but you still had some in the tea strainer?
- How could you measure the amount left in the tea strainer?
- Why would you determine the mass of the tea strainers and solids before placing them into the liquids?

The mass before and after is additional quantitative data students can use to support their claims about solubility—the more soluble, the larger mass that dissolves in the liquid. These data could be added to the data chart for the entire class, or this could be an additional investigation that only some students undertake and report on individually.

If students do this quantitative measuring only for the soap and fat investigation, comparing the mass of the soap before and after in water should lead to the conclusion that soap is slightly soluble in water. Comparing the mass of the fat before and after in water should help students come to the conclusion that fat is not soluble in water. These data can help support the whole-class activity, even if only some students engage in the quantitative portion and can contribute their results to the whole class data table.

Lesson 2

Do Fat and Soap Dissolve in the Same Liquid?

TEACHING THE LESSON

Performance Expectations

Students will

- plan and carry out an investigation of solubility in order to expand their conception of substances and their properties.
- analyze and interpret data about properties of substances to identify how the substances are the same or different.

Overview

Activity 2.1
Make observations as the teacher carries out (models) an investigation of solubility.

Activity 2.2
Plan and carry out an investigation of solubility of fat and soap in oil and water.

Building Coherence

This lesson introduces *solubility*, building upon students' understanding of properties as providing evidence as to whether substances are the same or different. Students may have studied odor, color, boiling point, or melting point as properties of substances (IQWST IC1). This lesson extends the Lesson 1 investigation to include measurable (quantitative) properties; others will be investigated in following lessons.

Timeframe

1 Class Period

Safety

- Students should not taste any of the materials.
- Students should wear safety goggles because of the possibility of broken glass.

Reading Follow Up

Review the products that students examined at home and whether those products are substances or mixtures. You might tally responses across the class (for example, How many found a substance? How many found a mixture?) or across multiple classes throughout the day. Then ask, "Based on the evidence we collected, do you think there are more mixtures or more substances in our everyday lives?"

Discuss the question, "Why can we talk about the properties of a substance, but it would be impossible to talk about the properties of a mixture?" This question requires that students use the ideas from the reading, but then to go beyond what they read to make far deeper sense of the concepts of properties, substances, and mixtures. *(A mixture does not always contain exactly the same proportion of the substances of which it is made, whereas a substance is always the same type of material all the way through.)*

Introducing the Lesson

Review yesterday's activities by asking the following:

- What makes something like hardness [color, malleability] a property of a substance?
- Why is shape [weight, mass, size] not a property?

Describing a substance is different from describing an object. Objects may be made of more than one type of matter, or type of substance. Aluminum is a substance. Aluminum can be in the shape of a strip, foil, soda can, baking pan, sheet, or others. Shape, size, mass, and volume do not help us tell whether these items are made of tin, nickel, aluminum, or another metal. But, knowing that an object is made of aluminum means we can know its color, its hardness, and its malleability because they are properties of aluminum. They do not change regardless of what object the aluminum has been made into.

This can be confusing when we talk about gold or chalk, because the object has the same name as the substance it is made of. In this unit, a *substance* means what something is made of. Gold is made of gold atoms. Aluminum is made of aluminum atoms. A gold ring is made of the substance gold, which is made of gold atoms. An aluminum can or foil is made of the substance aluminum, which is made of aluminum atoms.

Refer to the DQB and the subquestion: How is stuff the same and different? Ask: "If I wanted to make the claim that fat and soap are different substances, what evidence would I need to support my argument so that someone else would believe my claim?" *(properties we can measure, such as color, odor, and hardness)* To identify unknown matter, scientists use more than one property. Two substances might have the same color or the same hardness and still be different. Students will now gather information about another property of substances by measuring the solubility of soap and fat.

Materials

For the Teacher
- 1tsp real butter*
- 1tbsp baking soda
- 1tbsp road salt
- 150mL warm tap water*
- 150mL warm vegetable oil*
- (6) 150mL beakers
- (6) glass stirring rods
- (1) craft stick or small spatula
- (1) label or tape*

For Each Group
- 1tsp fat
- white soap (tiny broken-off chips)
- warm water*
- warm vegetable oil*
- (2) plastic containers with snap caps
- (1) craft stick or small spatula
- (1) label or tape*

For Each Student
- Activity Sheet 2.1
- Reading 2.1

*This item is not included in the kit.

Activity 2.1 – Teacher Demonstration: Investigating Solubility

Discussion – Brainstorming

Purpose

Elicit prior knowledge of solubility.

Suggested Prompts

- What do you think soluble or solubility means? *(If we mix a solid in a liquid and can no longer see the solid, then the solid is soluble in the liquid.)*
- Do you know any solids that are soluble in water? *(sugar, salt)*
- Do you know any solids that are not soluble in water? *(sand)* If sand were soluble in water, what would happen? *(There would be no beaches.)*
- If you did not already know about salt, sugar, or sand, how could you determine whether they are soluble in water?
- Could substances be soluble in another substance other than water? What examples can you think of?

Build on students' responses to define solubility as the capacity of one substance to dissolve in another substance. Add concept to Scientific Principles list now or by the end of this lesson.

Solubility of solid substances is usually tested by immersing them in liquids. The solubility of a solid substance depends on the type of liquid used for testing. For example, sugar is soluble in water but not in oil. Ask: "Does sugar dissolve faster in hot or cold tea? If a smaller amount of sugar is soluble in water, would you expect a smaller amount of sugar to also be soluble in water? Explain your ideas." *(Given that solubility is a property, different amounts might dissolve more quickly or slowly, but sugar is always soluble in water.)*

This unit does not require that students learn the terms *solute* and *solvent* to understand the concept of solubility. The teacher may decide whether to introduce these terms.

Demonstration of Procedures for Measuring Solubility

Show students how to find the solubility of butter, baking soda, and road salt in both oil and water.

Procedure:

1. Place half of a pea-sized piece of butter into a beaker, using a craft stick or small spatula, and add 50mL water. Place the other half in a second beaker and add 50 mL vegetable oil. Label these beakers "butter in water" and "butter in oil," respectively.
2. Place 1/2tbsp of road salt into a beaker with 50mL water. Place the other 1/2tbsp of road salt into another beaker with 50mL vegetable oil. Label these beakers "road salt in water" and "road salt in oil," respectively.
3. Place 1/2tbsp of baking soda in a beaker with 50mL of water. Place the other 1/2tbsp of baking soda in another beaker with 50mL vegetable oil. Label these beakers "baking soda in water" and "baking soda in oil," respectively.

4. Using a different glass stirring rod for each beaker, stir the liquids and substances for approximately one minute.
5. Look for solubility qualitatively.

Discussion – Pressing for Understanding

Purpose

Analyze data to understand the solubility as a property of substances.

Suggested Prompts

- Is the butter still visible in the oil? (*no*) water? (*yes*)
- Is butter soluble in oil? *(yes)* water? *(no)*
- Is the baking soda still visible in the oil? *(yes)* water? (no)
- Is baking soda soluble in oil? *(no)* water? (yes)
- Is the road salt still visible in the oil? *(yes)* water? *(no)*
- Is road salt soluble in oil? *(no)* water? *(yes)*

When comparing the results of a solubility test, look to see whether the chunk of solid is still visible. The butter is no longer visible in oil, so butter is soluble in oil. The chunk of butter is still visible in water, so butter is not soluble in water. The baking soda and road salt are no longer visible in water, so they both are soluble in water. The baking soda and road salt are still visible in oil, so they are not soluble in oil.

Activity 2.2 – Investigating Solubility of Soap and Fat

Refer to Activity Sheet 2.1. Emphasize the Safety Guidelines, and show students the materials they will use to conduct their own experiments. Ask them how they might use these materials to investigate solubility.

Groups write their own procedures, using the procedures from the demonstration as a guide. Scientists write clear procedures before conducting an investigation, so they do not get confused while conducting it, and so that they can later reproduce their investigation to see if they get the same results. It is also important to keep a clear and precise record of the results in order to compare results with other groups.

Have groups carry out the investigation and share results with the class. Create a class data table to display groups' results. Discuss, and attempt to account for, or resolve, differences in results. Anticipate disagreement about the solubility of soap in water, as it is likely to be only "partially soluble."

Help students understand that because they observe the chunk of fat in water, fat is not soluble in water. However, the chunks of soap in water are smaller pieces and have made the water cloudy. Students can compare the water in the test tube containing soap to plain tap water. When a solid is not soluble in a liquid, the result looks like fat in water—a chunk is visible in the liquid, and the liquid looks like a plain sample of the liquid. The soap in water does not fit that description. The chunks of soap are smaller, and the water is cloudy because some of the soap dissolved in it. Soap is soluble in water. Often when this condition exists, scientists will say that the substance is *slightly soluble* in the liquid. This is why soap works for washing. When you wash with soap and water, soap traps the dirt, dissolves in water, and washes away from your body, taking the dirt along with it.

Wrapping Up the Lesson

Although students already know that these two substances are not the same, they are testing the properties of substances to learn why properties are important in science. Refer to the subquestion on the DQB. Ask: "What have we learned that helps us answer this question so far?" (*To find out if substances are the same or different, we can examine properties because different substances have different properties. We can observe some properties, like color and solubility, which help us tell substances apart.)*

Students should understand the following:

- Properties are unique characteristics that help identify a substance and distinguish one substance from another.
- Some properties, like solubility, can be measured with tools or quantitative techniques.
- Properties provide evidence to help determine *how* substances are the same or *how* they are different.

- As a learning tool, refer to the Driving Questions and subquestions in midactivity, in mid-discussion, at the end of activities for review, or at the beginning of a class period to frame a new lesson. The DQB should evolve as students' learning does. Add artifacts such as the following:
  - A completed activity sheet containing an argument, explanation, or model relevant to a particular subquestion or concept.
  - A copy of a reading or material that helped students make sense of a particular subquestion or concept.
  - Visual representations of any kind. Perhaps a student who likes to draw would enjoy drawing a setup from one of the investigations that could serve as a reminder of the activity in which a concept was learned. A student whose lettering skills are particularly good could add words, one by one, like the names of various properties as they are learned.
  - A sandwich bag of trail mix to represent a mixture, and a piece of chalk to represent a substance.

Introducing Reading 2.1 – Why Can I Easily Wash Soap off My Hands with Water?

Solubility is important in real life. Ask students if they can think of anything they would not want to dissolve in water? If students need a hint ask them about when it rains, or when people swim, or when you use water (dishes, laundry). It is important that fabrics, dishes, beach toys, and skin do not dissolve in water. The point is to see that solubility matters in their everyday lives in ways that they probably never think about. Let them know that they are going to read more about solubility as another property of substances. A review of student responses to the questions in the reading will be used to begin the following lesson.

Lesson 3

Do Fat and Soap Melt at Different Temperatures?

PREPARATION

Teacher Background Knowledge

Melting Point

Melting point is the point at which a solid starts to become a liquid. Expect students to experience difficulty measuring melting point consistently because the precise point of "starting to melt" with classroom equipment is not easy to obtain. Expect a range of measurements and the opportunity to talk about experimental error and the difficulties inherent in the design of this experiment. However, the results from the melting point lab provide students with further evidence that the amount of a substance does not affect the properties of that substance, as groups should be consistent as to their measurement of when 1-inch or 2-inch amounts begin to melt; they should begin to melt at the same temperature.

If you use probe software, students may have some experience reading *y* by *x* graphs (IQWST ES1). A critical aspect of science, but a struggle for many middle school students, is reading temperature graphs. You may wish to take class time to help students understand how to read a temperature by time graph, pointing out that the *y*-axis is the temperature portion and that it is the variable you are interested in. The *x*-axis is time and it goes on independently. Using PI: Heating Curve of a Substance, point out the three different regions of the graph.

Students may have studied that energy can enable things to happen (IQWST PS1). Explain that each of the regions on a temperature by time graph represents what is happening while energy is added to a substance. The first region is the substance when it is solid. By heating the substance over time (it gains energy), the temperature increases. Then the temperature seems to stay about the same for a period. Circle the point at which the temperature starts to stay the same; this is the melting point. The temperature stays the same because all the energy is being used to make the whole substance go from a solid to a liquid. It is not getting hotter; it is staying at the same temperature until the entire substance is melted. Then, the third region represents the substance, now in its liquid state, getting more energy. More energy means more molecular movement, which is measured as an increase in temperature.

Melting point also depends on pressure; however, this understanding of pressure is not a learning goal for this unit.

Explanation and Argumentation

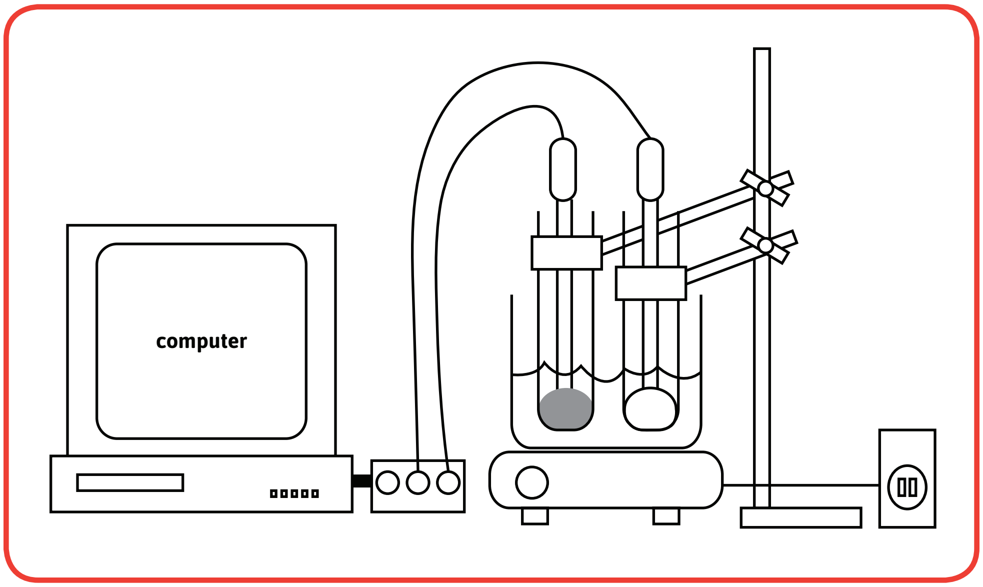
Students who have had previous IQWST units will be familiar with the claim, evidence, reasoning model of constructing explanations and engaging in argumentation. Activity Sheet 3.1 ends with conclusion questions that are easily written using this structure. (See IQWST Overview for details about the C,E,R format.) If your students have not yet encountered this model and the language of "explanation" and "argumentation," it will be addressed more fully in Lesson 5 of this unit. You may choose to address this more fully now, or you may choose to support students in answering in a less structured manner until Lesson 5. In any case, support students in learning what it means to "use data as evidence" to support their ideas.

Common Student Ideas

- Students might think that melting a substance changes the composition of a substance.
- Students might think that the characteristic properties of a substance that they can observe and measure are also true of the atoms or molecules that make up the substance. This is not the case. Although the atoms and molecules and the way they are structured give the substance the properties we can observe, the atoms and molecules do not have these properties. For instance, although a sample of copper might have a melting point of 1,083.0°C (1,981.4°F), the atoms that make up this sample do not melt.
- Students have everyday experiences with melting and may know that it takes longer to melt a larger quantity of something. A snowball takes longer to melt than a few snowflakes. However, items made of the same substance start to melt (melting point) at the same temperature regardless of amount. Emphasize that the time it takes a substance to melt is not a property. Melting point is the property. This is also discussed in the reading.

Setup

Set up one apparatus for the demonstration. See the following diagram.



Use these instructions for setting up the apparatus for the demonstration.

1. Use a small spatula (or craft stick) to place the butter inside one test tube so that there is approximately 1in. of butter in the tube.
2. Repeat Step 1 for margarine, using the second test tube.
3. Place a hotplate next to a ring stand.
4. Place a 500mL beaker filled with approximately 150mL of water onto the hotplate.
5. Fasten the two test tubes to the two test tube clamps. Fasten the clamps to the ring stand.
6. Adjust the test tubes in the water so that the water level outside the test tubes is just above the butter and margarine levels in the test tubes.
7. Place one temperature probe into the butter and one temperature probe into the margarine, making sure the probes are not touching the bottom of the test tube. Make sure that the butter and margarine completely surrounds the tips of the temperature probes. This is to ensure that the probes record the temperature of the substances rather than the temperature of the air surrounding the probes.
8. Set up the computer interface for the temperature probes to generate a temperature by time graph for the demonstration. Refer to the instructions that are included with the probes.

Temperature probes allow for more accurate readings and produce a temperature by time graph, and they make the data visible to the entire class. However, alcohol thermometers may be substituted. Thermometers should be held in place by clamping them to the ring stand.

If you are teaching this lesson to multiple classes, be sure to replace the water in the 500mL beakers at the end of each class. This will ensure that students in the next class will begin their investigations with water that is close to room temperature.

Safety Guidelines

- Water has a boiling point of 100°C (212°F), and the hot water and steam can cause serious burns. Beakers filled with too much water may boil over. Warn students never to touch hot beakers.
- The surface of a hot plate can cause serious burns. All plugs and cords should be kept away from the top of the hot plates, and arranged so that students will not trip over them.
- Temperature probes are highly recommended for this lesson. If thermometers are used, use alcohol thermometers. Mercury-based thermometers, if broken, can have detrimental health effects. (Most schools no longer have mercury thermometers in use, but you will want to be sure that is true.)
- Do not taste any of the materials.
- Teachers and students need to wear safety goggles during all activities.
- Lab aprons are useful for protecting student clothing.

Differentiation Opportunities

The last section of the reading addresses the nanoscale. It is a particularly challenging concept. You may wish to have most students skip this section of the reading in favor of an in-class description that you provide instead. Or, it may be that you wish to assign the last page only to some students that you feel are more able to go beyond the concepts and read well enough to begin to grasp this idea. Nanoscale-related images and applications abound on the Internet, and some students might be interested in, or assigned to do, Internet research in that area.

Lesson 3

Do Fat and Soap Melt at Different Temperatures?

TEACHING THE LESSON

Performance Expectations

Students will

- collect melting point and hardness data, and use data as evidence to argue that the two substances are not the same.
- carry out an investigation to determine whether the size of sample affects its properties. Use data to construct an explanation of the relationship between amount and properties.

Building Coherence

This lesson builds broader understanding of properties as students use melting point and hardness to compare and describe substances. The lesson also builds on prior experiences with states of matter and phase changes (IQWST IC1).

Timeframe

2–3 Class Periods

Overview

Activity 3.1

Observe as teacher demonstrates procedure for determining melting points.

Activity 3.2

- Determine melting points of fat and soap.
- Measure hardness on strips of zinc of different lengths.

Safety

- Hot water and steam can cause serious burns. Beakers filled with too much water may boil over. Warn students never to touch hot beakers, and to be careful of all hot substances.
- The surface of a hot plate can cause serious burns. Plugs and cords should be kept away from the top of the hot plates and arranged so that students will not trip over them.
- Do not taste any of the materials.
- Wear safety goggles.

Reading Follow Up

Students should understand (a) that they actually use what they know about solubility in their everyday lives, and (b) that solubility is a property of substances. A possible assessment question for Reading 3.1 might be the following: Based on your understanding, is it correct to say that sugar is soluble? Why? (A substance students have not read about could be used.) The point is that solubility must be expressed as whether Substance A is soluble in Substance B. Substances are not simply soluble. For example, sugar is very soluble in water, but it is not soluble in gasoline.

Introducing the Lesson

Discussion – Brainstorming

Purpose

Consider whether or not the amount of a substance affects its properties.

Suggested Prompts

- Does the amount of a substance affect the properties of the substance? Explain your ideas.
- Do two pieces of fat have the same properties? Explain your ideas.

"How do you know?" is another good follow-up question that requires students to consider prior knowledge and experiences and how they affect people's understanding of the world. Articulating their thinking helps students to be aware of how they make sense and what factors influence their thinking, and it helps a teacher assess what students do or do not understand at various points in the lesson or in the unit. Students will often provide examples from their everyday lives that the teacher or peers can then reference to build a sense of each classroom as a learning community with shared experiences and knowledge.

Students may know something about melting point already (IQWST IC1) (*Melting point is the temperature at which a solid turns into a liquid. If a solid is heated to a certain temperature, its melting point, it will turn into a liquid. The temperature will stay constant until all of the material becomes a liquid. When a solid melts, the molecules move faster.*)

Support students' understanding that melting point is measurable. Ask how they could measure melting point. If they struggle, you might suggest the following set of questions.

- Can you observe melting point? *(yes)*
- What do you think it means to say that something is a melting point?
- Can you measure melting point with your senses? *(no)*
- How is melting point measured? *(with a thermometer/probe, or it has to do with temperature)*

Students now revisit another property—melting point. Melting point provides another piece of evidence to compare substances. Students also test whether the amount of a substance affects its properties.

Materials – Activity 3.1

For the Teacher

- 30g butter* (about 1/4 stick)
- 25g margarine* (about 1/4 stick)
- demonstration apparatus (see Preparation Section; probes not included in your kit)
- PI: Heating Curve of a Substance

For Each Group

- vegetable shortening (about the size of an egg)
- (1) broken-off piece of soap
- (2) temperature probes or thermometers*
- (1) hotplate
- (2) test tubes
- (2) test tube clamps
- (1) ring stand
- (1) 500mL beaker
- water*
- (1) small metal spatula or pop craft stick
- (1) ruler*
- (1) plastic knife*

For Each Student

- Activity Sheet 3.1
- Reading 3.1

*This item is not included in the kit.

Activity 3.1 – Teacher Demonstration of Melting Points

Ask students to create a list of solids they know that change phase to become liquids. Demonstrate how to find the melting points of butter and margarine. Refer to the apparatus you set up prior to class. Explain the details of how you set up the apparatus. Review Safety Guidelines with students.

To facilitate students' attention to the demonstration and their own procedures in the investigation, have students turn to the diagram of the apparatus in their activity sheet for this investigation (Activity Sheet 3.1). They can label the materials in the diagram as you explain what they are and how to set them up.

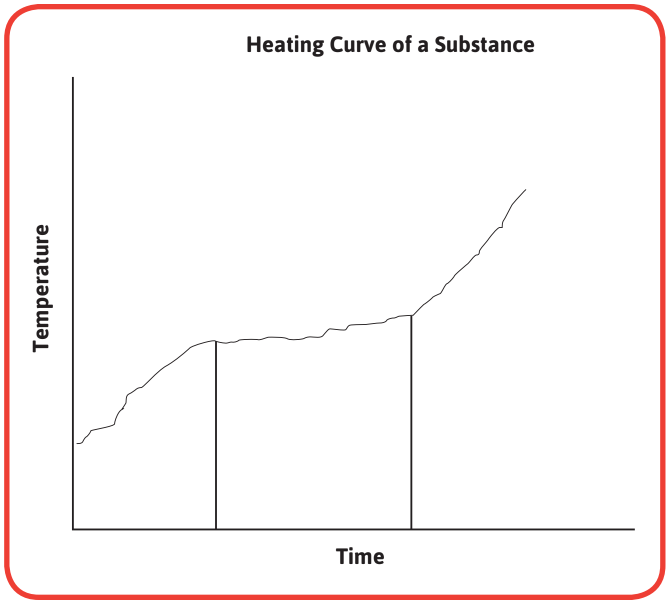
Turn the hot plate to high. Be aware that margarine and butter melt fairly quickly. Record the melting points for margarine and butter. Remind students that you are looking for the temperature at which the margarine and butter *start to melt*. Those temperatures are the melting points for margarine and butter.

If you use temperature probes, help students learn to read a temperature by time graph, so they understand what the different regions of the graph indicate (see Lesson 3 Preparation Section).

If you use a thermometer, explain that what happens is a substance is solid, it starts to melt, and it stays at the same temperature until the entire amount is melted. It does not continue to get hotter until after the substance is completely melted. Ask: "Then what would happen if we continued to heat the liquid?" *(It would boil and change to the gaseous phase.)*

Does the Amount of Something Affect its Properties?

Students will investigate whether the amount of a substance affects its melting point. To do that, they will measure the melting points of different amounts of fat and soap, just as you did for butter and margarine.



Assign half of the groups in the class a 1-inch amount of soap and fat to test and the other half of the groups in the class 2-inch amounts of soap and fat to test. Have each group record its assigned value on the activity sheet. Students will be doing this in order to determine whether the amount of a substance changes its melting point. This will provide evidence of whether melting point is a property of substances.

Student Investigation of Melting Point

Refer to Activity Sheet 3.1 for further notes regarding the procedure for this investigation. Students should not adjust the temperature probes or use them to stir the substances after the computer program has started. If the probes are disturbed, they may record the air temperature instead of the temperatures of the soap or fat, causing the temperature to suddenly go up or down.

Note on Student Investigation – Data Collection

- The fat should have a melting point around 65°C.
- The soap will not get hot enough to melt in this investigation because its melting point is greater than 100°C, the boiling point of water. However, students should be able to use this evidence to write an explanation that the melting point of soap is above 100°C and that its melting point is different from that of fat. The specific melting point of soap depends on the type of soap used.

Note on Student Investigation – Conclusions

Make sure students do not complete the conclusion questions until you have discussed the results of the investigation as an entire class.

Discussion – Pressing for Understanding

Purpose

Share results to conclude that (a) both 1-inch and 2-inch amounts of the same substance melt at the same temperature, and (b) fat and soap have different melting points.

Create a class table to summarize students' results. Expected responses should include the following:

	Material	Properties
	Melting point of 1-inch amount	Melting point of 2-inch amount
Fat	63–68°C	63–68°C
Soap	Higher than 100°C	Higher than 100°C

Students will likely observe a range for melting instead of a melting point. Ask: "What might be some of the reasons for our different results?" *(Groups judged the start of melting differently. Some groups may have judged the melting point to be the first indication of melting, while other groups may have judged that melting had not occurred until some of the substance had melted. Some groups moved the probes or thermometers during melting, and recorded the temperature of the air instead of the substance.)*

Building on students' responses, discuss the concept of experimental error in science. When two experiments that are supposed to be the same give results that are close but not exactly the same, sometimes the different results are due to experimental error. Techniques used in the two experiments could have been slightly different; stirring might account for a range of temperatures. In fact, when chemists determine melting point, it is typically with very small quantities to avoid the need for stirring. Experimental error happens all the time in science. Scientists have to judge whether different results for two experiments are really different or due to experimental error. Experiments are often repeated several times to average data and improve techniques. One of the challenges for engineers who develop this type of equipment, and for scientists who conduct experiments, is to minimize experimental errors.

This is a good point at which to address replication (by others) and repetition (multiple trials) if that language seems useful for your students.

Given the differences in measurement, help students see that the range of melting points for the groups is the same for the one- and two-inch amounts. Have students complete the conclusion questions on Activity Sheet 3.1 and then discuss.

- Melting point is a property of a solid substance—a substance always has the same melting point. Fat, for instance, always melts at the same temperature.
- Melting point, as a property, is the same regardless of the amount of the substance. Students can measure and test in the classroom. For example, fat has a melting point of 65°C regardless of how much fat you measure. A small piece of fat and a large piece of fat will have the same melting point.
- When two samples of substances have different melting points, this is evidence that they are not the same substance. Different substances have properties that are different. For this reason, scientists use many properties to identify substances and distinguish one substance from another. Two substances might share some of the same properties, but they will not share all of the same properties.

Students will next explore another property (hardness) to determine whether that property changes when the amount of the substance changes.

Introducing Reading 3.1 – Melting Points

You might ask students to draw what molecules are doing as a substance turns from a solid to a liquid (melts); but do not have them look at Reading 3.1, as it opens with a diagram that illustrates this. Another prereading activity might be to ask students whether they think that all substances have a melting point. This is likely to generate debate around whether oxygen (which they think of primarily in the gaseous state) has a melting point, or water (which they think of typically as a liquid) has a melting point. Let students know that this will be the topic of discussion after they have read.

Add to the DQB representations that students draw, or a photocopy of the one in their reading, or a drawn and colored replication of the one in the reading, so that it serves as a visual aid for students from this point forward.

Materials – Activity 3.2

For Each Group

- (1) long strip of zinc
- (1) short strip of zinc
- (1) strip of iron
- (1) strip of copper
- (1) strip of aluminum

For Each Student

- Activity Sheet 3.2
- Reading 3.2

Activity 3.2 – Does the Size of Something Affect Its Properties?

Reading Follow Up

Review responses to the question "Do all substances have a melting point?" This could also be used as an assessment. Be sure students understand what it means to make this theoretical argument—that oxygen, for example, could become a solid if the temperature were cold enough to freeze it (or any other gas), and then it could melt. To have a melting point, a substance must be able to be in the solid state and to undergo a phase change from solid to liquid.

Look at Activity Sheet 3.2. Students may have conducted hardness tests on strips of metal (IQWST IC1). If so, review how they tested hardness. *(They tried to scratch one strip with the edge of another strip to tell which was harder.)*

Demonstrate this procedure. Ask students if they think the results would be different if the metal strips were larger or thicker? They will investigate this question by comparing different amounts of zinc.

Students follow the procedure and answer the questions on Activity Sheet 3.2. Instruct them to create a relatively small scratch and leave some unscratched surface for other groups.

Use different lengths of zinc to test the strips of copper, iron, and magnesium. Neither length of zinc will scratch the iron nor copper strips. Both the 10cm and 25cm lengths of zinc have the same relative hardness. Discuss responses to the conclusion questions on Activity Sheet 3.2.

Wrapping Up the Lesson

- Melting point and hardness are properties of substances. A substance always has the same melting point and relative hardness. For example, fat always melts at the same temperature.
- Properties of a substance are the same regardless of the amount of the substance. For example, fat has a melting point of 65°C regardless whether you measure a small piece or a large piece. A 10cm strip of zinc has the same relative hardness as a 25cm strip of zinc.
- When two substances have different melting points, this is evidence that they are not the same substance.
- Because substances might have some properties that are the same, scientists test many properties to identify substances and distinguish one substance from another.

Ask: "How do properties help us think about the Driving Question?" (Scientists are specifically interested in substances and mixtures. In order to figure out if you have made new substances from old substances, you need to be able to tell substances apart. Melting point is a property that provides evidence to figure out if two samples of substances are the same substance or different substances).

Add the following ideas to the Scientific Principles list by the end of this lesson:

- Hardness and melting point are properties of substances. Melting point is the temperature at which a solid substance starts to become a liquid.
- Properties of a given substance are the same regardless of the amount of the substance.

Introducing Reading 3.2 – Which Properties Can I Use When?

Revisit the example of a ring that might have a diamond, a cubic zirconium, or a piece of glass in it, and use the Getting Reading section in class. Have students think about whether melting point would be a good test, whether solubility would be a good test, and whether hardness would be a good test to determine whether or not the stone is a real diamond. If you have time, have groups of students discuss, and then report their ideas on a particular property's usefulness for this particular example. The reading focuses on learning more about hardness, in particular.

The nanoscale aspects of this reading are difficult. What students need to understand is that, most of the time, they are referring to bulk amounts of substances—amounts they can see with their eyes and that they can measure in the classroom. They learn, for example, that properties of a substance stay the same, no matter how much or little they have, unless considering properties of substances in amounts at the nanoscale. It is difficult to say, in science, that something is always true, when there can be exceptions. It is important that students not learn a rule that does not always apply. However, students should not think that no rules govern the universe. This is a difficult concept, and it may be that review of the second half of the reading is necessary as a follow-up so that students come away with an appropriate and accurate understanding. Choose to discuss the concept of scale without using the reading, if you think the last section of the reading would be more confusing than helpful.

Lesson 4

What Other Properties Can Distinguish Soap from Fat?

PREPARATION

Teacher Background Knowledge

Density

Density is typically the most difficult property for students to understand. Mass is not a property because it changes as the amount of a substance changes. However, we can compare the mass of two substances if the two substances have the same volume (the same amount) and are in the same phase. By using this technique, we measure the mass of a substance in relation to its volume (the substance's mass per unit volume), a measurement called *density*.

If the mass of two substances is different at a constant volume, the substances have different density, and they are different substances. If the mass of two substances is equal at a constant volume, then their density is the same, suggesting that they are the same substance. However, many substances have similar densities; in order to determine whether the two substances are the same, you have to compare other properties.

Volume

In everyday experience, people equate size with volume—the amount of space that an object takes up. The volume of an irregularly shaped object can be obtained using the displacement method. First you put a large amount of water into a graduated cylinder and record the volume of the water. Then place the solid into the graduated cylinder. The difference that the water level rises is the volume of the solid. This is due to the fact that the solid pushes away (or displaces) the water as it takes up space in the cylinder, so the volume of the solid is related to the amount of water that is displaced. Obtaining the volume of an item using a liquid displacement technique involves less error than the technique of measuring the dimensions of the item ($l \times h \times w$) and multiplying.

In this lesson, differences in density between groups are likely due to experimental error as students use displacement. It is important to have students share data as a class. You will likely observe that the density of fat and soap cluster around a number. These clusters allow students to see that the density for soap and fat are different. Emphasize that each group found fat has a greater density than soap. You also can use qualitative observations (fat sank, soap floated) as evidence that soap is less dense than fat.

Discussion about fat sinking and soap floating in the rubbing alcohol assumes that you used a soap that is less dense than the alcohol. Several brands of soap float in rubbing alcohol, but not all possible brands have been tested in this activity. Therefore, in the event that you use soap that does not float, have students answer the question knowing that some soaps float in rubbing alcohol, but fat always sinks.

Common Student Ideas

- Students have a difficult time understanding the concept of density. They may think that the density of a substance should change if its volume or mass changes. They have a difficult time with the ratio (as volume changes, mass changes as well, but density remains the same).
- For this unit, it is sufficient if students understand that density means the amount of mass in a set volume of a substance. If the mass and a sample of substance are known, they can determine the density by dividing the mass by volume. If you think that introducing density as a ratio will help students understand the concept, then augment instruction accordingly.
- The pieces of fat and soap that students measured likely have different mass, volume, and density, so students may think that all of the data provide evidence that fat and soap are different substances. If students have trouble understanding that only density helps, ask them if they could find a piece of fat and a piece of soap that had the same mass? the same volume? the same density? Students should conclude that pieces of fat and soap could have the same mass or the same volume, but they could never have the same density, so density is the only evidence that fat and soap are different substances.

Setup

Activity 4.1

Iron and aluminum blocks work especially well for the teacher demonstration because, although they are similar in color, iron is significantly more dense than aluminum. Label the blocks *iron*, *aluminum*, and *unknown* before distributing them.

Activity 4.2

The pieces of fat and soap need to fit into the mouth of a 100mL graduated cylinder. Cut appropriate-sized pieces of fat and soap before class. An easy way to do this is to melt the fat, pour it into a pan, and freeze it. Once frozen, rectangular-shaped pieces are easy to cut. Cut the soap pieces in similar sizes. Dipping a knife in hot water helps. Because the fat tends to become liquid near room temperature, keep both the soap and fat in a cold environment until just prior to the lab. In order to compare density, the substances must be at the same temperature. Electronic balances are easy to use and reduce the chances of error; however, triple-beam balances may be used.

Your demonstration and the students' investigation involve determining volume through liquid displacement (obtaining the volume of a solid by obtaining the volume of a liquid, the volume of the solid submerged in the liquid, and determining the difference). This technique only works when the solid is not soluble in the liquid.

For the teacher demonstration, use water as the liquid. For their investigation, students use rubbing alcohol (70% isopropyl alcohol, 30% water). Fat sinks in the rubbing alcohol but soap floats in it, presenting a qualitative illustration of density. Do not use pure isopropyl alcohol or pure water—neither of these liquids will produce the desired effect. Ivory soap is recommended. Other brands of soap will likely float in rubbing alcohol, but because they are mixtures of various substances, there is no certainty that all brands will float.

Safety Guidelines

- Wear safety goggles.
- Rubbing alcohol is volatile and somewhat flammable. Keep it away from heat.
- Do not inhale vapor.

Differentiation Opportunities

Reading 4.1 suggests an at-home activity—creating a density column. Perhaps assign it as a weekend homework activity so that more students have an opportunity to do it. You may choose to provide materials and invite some students to do this as an after-school or lunch-period activity, especially for those less likely to have materials readily available at home. This visual model of density will further support students who struggle with the concept, but for all students, this activity is engaging.

Choose to have students illustrate rather than (or in addition to) having them write or tell about their results. A drawing could go on the DQB after the activity has been described so that everyone understands what happens in a density column.

Lesson 4

What Other Properties Can Distinguish Soap from Fat?

TEACHING THE LESSON

Performance Expectation

Students will collect, analyze, and interpret data, then use data as evidence to distinguish properties from nonproperties of substances.

Overview

Activity 4.1
Observe teacher demonstration of measuring density.

Activity 4.2
Investigate the density of fat and soap.

Safety

- Wear safety goggles.
- Rubbing alcohol is volatile and somewhat flammable. Keep it away from heat.
- Do not inhale vapor.

Building Coherence

Students wrap up the first learning set by exploring the final property they will study: density. In Learning Set 2, students use the properties they have learned to determine whether chemical reactions occur in various investigations.

Timeframe

2 Class Periods

Reading Follow Up

A possible follow-up question to the first half of Reading 3.2 might be, "Would odor be a good property to help you determine whether the stone in a ring is a diamond, cubic zirconia, or glass? Why?" Be sure that students answer this at the molecular level by asking them, "What do you know about properties and about odor that is important here?" *(Odor is not helpful because the stone is a solid and humans can only smell odors when they are in the air, in the gaseous state. We would need the substance to become a gas before we would know the difference in the odors of diamond, cubic zirconia, and glass. Students might also indicate that an odor test would destroy the ring.)*

Materials

For the Teacher

- (2) identical large boxes* (one filled with books, one with packing peanuts or other light-weight material)

*This item is not included in the kit.

Introducing the Lesson

Show students two large boxes that look identical and have the same dimensions, and emphasize their similarities. Although you have prepared the boxes differently, do not indicate this to students. Ask for two volunteers, stressing that they need to be especially strong to help with this demonstration. To have fun with the activity, choose a smaller student to lift the lighter box and a stronger student to lift the heavier box. (Make sure the student you assign to the heavy box has a good sense of self and sense of humor.) Have the smaller student stand by the lighter box and the other student stand by the heavier box. (Alternately, one student could lift both boxes.) Remind the class to make good observations during this demonstration.

Ask the smaller student to pick up the box in front of him or her. Then, ask if the student can lift the box overhead. Ask the stronger-looking student to lift the heavier box. The student will likely struggle and may or may not be able to lift the box. (So that the student does not get hurt, do not ask the student to lift the box overhead.)

Suggested Prompts

- What did you observe?
- What do you think is happening? *(One box is heavier; one has more stuff in it; one is empty.)*

Students may or may not bring up the concepts of mass and volume. At this point, the groundwork is being laid for these concepts. Students do not need to have the language of mass and volume applied to the activity.

Ask: "How do the two boxes compare?" *(They are the same size, but one is heavier/lighter, or they do not weigh the same.)*

Today students will examine another property of substances that these boxes helped to illustrate.

Materials – Activity 4.1

For the Class
- (2) metal blocks of the same size but different substances (e.g., aluminum, iron)
- (1) larger metal block of either substance.

For Each Group
- (1) balance
- (2) large pieces of white chalk
- (1) 100mL graduated cylinder
- 200mL water*
- (1) calculator*

For Each Student
- Activity Sheet 4.1
- Reading 4.1

*This item is not included in the kit.

Activity 4.1 – Exploring the Relationship between Mass and Volume

Show students two metal blocks that are the same size, and explain that both are solid metal. Do not tell them that the blocks are different substances.

- Do you think these two metal blocks are the same substance?
- How can you test whether the blocks are the same substance? *(Hold them and see which one is heavier; examine or test properties such as color, hardness, solubility, and melting point.)*

Talk with students about the properties they know.

- How does the color of the blocks compare? *(color is similar)*
- How does their solubility compare? *(If they tested them, they would find that neither block is soluble in water or oil, so their solubility would be the same.)*
- How do their melting points compare? *(No equipment in class [hot plate] gets hot enough to test the melting points.)*
- How does the hardness of the two blocks compare? *(Hit the two blocks together, and indicate that they both appear to be very hard, but that additional tools would be needed to test hardness.)*

Students might mention a scratch test. That test might provide useful information; however, the equipment to conduct a scratch test for these metals is not available in the class.

Explain that none of these properties help determine whether these blocks are made of the same or different substances. Give the two blocks to one student and ask whether the student thinks the blocks are the same or different substances and why. If the student does not bring up the mass of the blocks (or weight or heaviness), hand them to another student. Once students have mentioned mass, weight, or heaviness, ask whether other students agree. If they agree, then move on. If they do not agree, continue to pass the blocks around and ask students what they think is going on.

Hold up the two blocks and identify them as iron and aluminum. Have students hold and compare them *(same size/volume but different weight/mass).* Do not introduce density yet.

This discussion helps students construct a conceptual understanding of density before labeling it with the appropriate scientific language. (If anyone uses the term *density*, let it go, later reinforcing that the student mentioned it earlier.)

Based on the language students are using, conduct a review of measurements, so they move from size, weight, mass, to the appropriate science language needed for density:

- What scientific or mathematical terms do you know for talking about how these substances are different? *(mass–the amount of matter in a substance; volume–the amount of space something takes up)*
- How do scientists measure mass/volume? What are the units for mass/volume? *(To measure mass, you use a balance or scale. The major unit is grams [g]. To measure volume, you use a ruler to measure length × width × height [l × w × h], or put the object in water and measure how much water it displaced. This technique is especially useful if the object has an irregular shape. The major unit is liter. You can also use milliliters [mL] or cubic centimeters [cm^3].)*

Refer to the opening activity with the boxes.

- If we have two boxes that are the same size, what can we say about their volume? *(They have the same volume.)*
- If we only know their volume does that mean that they will have the same mass? *(Being the same size does not matter. They may or may not have the same mass.)*

Explain that by picking the boxes up, it is obvious that they have different stuff in them or are made up of different matter. It would not make a difference if one were filled with bricks and the other with feathers. If we were going to load 20 boxes into a van, whether they had bricks or feathers, they would still take up the same amount of space.

- If you only know the volume of a substance, how useful is that in helping determine what the substance is? *(Not useful, because if the size changes, you can still have the same substance.)*
- Do you think that volume is a property? *(Properties stay the same and we know that volume will change based on how much you have; so, volume is not a property.)*

Return to discussion of the two blocks. Ask: "What can you say about the mass and volume of the two blocks?" *(They are the same volume, but one has much more mass.)* Explain that these two blocks are similar to the two boxes. They are the same size, meaning they have the same volume, but one has much more mass than the other. It has more stuff or matter. Ask: "Are the two blocks the same substance?" Determine the measurements of each block using a balance. Draw a table on the board and record the mass.

	ALUMINUM	IRON	UNKNOWN BLOCK
Mass	26.3g	59.1g	

Tell students, but do not show them, about a third unknown block. Let them know that their task is to figure out whether the unknown block is made of aluminum or iron. Ask students how they could figure this out. *(We could measure the mass of the unknown. If the unknown block is iron, its mass should be 59.1g. If the unknown block is aluminum, its mass should be 26.3g.)* Measure the mass of the unknown block. Add another column to the table and record the number. *(48.6g)*

	ALUMINUM	IRON	UNKNOWN BLOCK
Mass	26.3g	59.1g	48.6g

Students can see that the mass of the unknown block does not match either the mass of the aluminum or the iron block. They may say that the third block is another substance, or they may say that the size of the block is different. Assure students that the block is either aluminum or iron. Show them the block. It is not the same size as either of the other two known blocks.

Suggested Prompts

- If you only know the mass of a substance, is that useful in helping us determine what that substance is? *(No, because two different objects that are the same substance could have different masses. The unknown block is a different size than the two known blocks, but it is either aluminum or iron.)*
- What would cause two substances that we know are the same to have two different masses? *(It depends how much you have.)*
- Do you think that mass is a property? *(Properties stay the same and we know that mass will change based on how much you have; so, mass is not a property.)*

It is likely that students will say that you need to know how big something is so that you can compare its mass with its volume. This will lead nicely into an introduction to Activity 4.1.

- Properties provide scientists with evidence to help distinguish how substances are the same and different because properties do not change based on the amount of the substance.
- Mass and volume are not properties because they change, even with the same substance, based on the amount. By themselves, mass and volume are not useful for distinguishing one substance from another.

What Other Properties Can Distinguish Soap from Fat?

Show students a piece of white chalk. Break it into one large and one small piece, and hold it up for students.

- What do we know about chalk—is it a substance or a mixture? Why? *(Chalk is a substance because it is made of only one material all the way through.)*
- What data could we collect to gather evidence? *(Solubility and melting points should be the same because the two pieces are made of the same substance.)*
- Are there some ways to describe the chalk that are different for the two pieces and are not properties? *(different volumes and masses)*

Pull out another whole piece of chalk so that you now have three pieces of chalk (small, medium, large). Direct students to work in groups (briefly) to come up with a summary statement about the mass and volumes of the three chalk pieces.

- Is there a pattern that will emerge based on mass?
- Is there a pattern that will emerge based on volume? *(The larger the chalk, the more mass it will have. The larger the chalk, the more volume it has.)*

Students should make predictions on Activity Sheet 4.1.

This activity is written as a teacher demonstration. Alternatively, have students conduct the activity, which will require additional time. It is very important to measure accurately, as human error will result in differences in density. The procedure is similar to the procedure for the following student lab.

Students measure the mass of each piece of chalk and then the volume of each piece. They then determine whether there is a consistent relationship between mass and volume that may help scientists identify and describe substances.

Direct students to look at Procedure Step 1. Create a table on the board to record results. At this point, fill in only the Mass column. Have students fill in the Data Table on their activity sheets. Hold up the pieces of chalk and ask students whether the two pieces have the same volume or different volumes. *(different; the larger piece takes up more space)* Students may recall two ways to measure volume (IQWST IC1)—displacement and measuring $l \times w \times h$. They may also know the $l \times w \times h$ formula from mathematics. Have students determine the volume of each piece of chalk using liquid displacement.

Data Table 2

Have students record the volume of the chalk. Remind them that when an object is put in water, it will push the water away or displace the water because it takes up space. The amount that the water is displaced is equal to the volume of the object. Have students get a reading of the water level before they put the chalk in, and then again after they put the chalk in. Once they have the two readings, have students subtract the number without the chalk from the number with the chalk. This will be the volume of the chalk alone. The answer will be in mL. Tell students that 1mL is equal to $1cm^3$. These two units—1mL and 1 cm^3—are interchangeable. The reading assignment will address this in more detail.

Ask: "Do you see any patterns in the data you have collected?" *(The smaller pieces of chalk have less mass and volume than the bigger pieces of chalk. As the mass increases, the volume increases. As the mass decreases, the volume decreases.)*

- Does everyone agree that the pieces of chalk are the same substance? *(yes)*
- Look just at the column for mass. Even though they are the same substance, what do you notice about their masses? *(They are different.)*
- Why are they different? *(Mass is not a property and changes based on how much you have.)*
- Is the same true for the volume column? *(Yes, volume changes based on the size; but, it is still chalk.)*
- Take two pieces of the chalk where one looks to be twice as big as the other. Compare them visually. This may have to be changed to 1/3 the size, depending on the sizes of your chalk.
- What do you notice about the two of these? *(One looks twice as big.)*
- If one is twice as big as the other, what would you predict about their masses and volumes? *(The larger one's mass will be twice as much as the smaller and have twice the volume.)*
- Direct students to the Data Table. Ask them what they see. *(The piece of*

chalk that is twice as big also has about twice the mass. Its volume is twice as much as well.)

- Is there a relationship between mass and volume?

Direct students to perform the following calculation: Mass of Chalk / Volume of Chalk (mass of the chalk divided by the volume of the chalk). Before continuing, add a fourth column to Data Table 1 labeled Mass/ Volume ratio (g/mL). Add this number to the last column in Data Table 1. Ask students for their observations of this calculation. All pieces of chalk should have the same ratio: 2.4 g/cm^3. Tell students that, in fact, there is a relationship between mass and volume and that this is called density.

Data Table – Density

Explain that density is the amount of mass in a set volume of a substance. If the mass and volume of a sample of a substance are known, then the mass can be divided by the volume (mass ÷ volume) to obtain the density of a substance. By dividing the mass of the chalk by the volume of the chalk, students are calculating the amount of mass in one cubic centimeter.

Suggested Prompts

- What do you notice about mass and volume of each piece of chalk? *(They are not the same.)*
- What is the same for all of them? *(density)*
- What can you say about density? *(Density must be a property. The ratio is a characteristic of chalk and will not change.)*

Scientists often want to compare the density of two objects that are not the same size. In order to do this, scientists figured that the ratio of the mass to volume is always the same for a substance and that this ratio allows them to compare the density of two substances. If the ratio is different between two different samples, then there is evidence that they are not the same. The ratio of mass to volume allows them to determine the mass in a set volume of a substance. The set volume that they chose was one cubic centimeter ($1cm^3$).

Consequently, a really large piece of chalk that is 2,000g and a really small piece of chalk that is 10g will have the same density. The amount of mass compared to the volume will be the same. Every $1cm^3$ of chalk (its volume) always has the same mass. In other words, no matter where $1cm^3$ is taken from the chalk, the mass compared with this volume (or the mass per volume ratio), will be the same. Ask: "Is the ratio of mass to volume for any one substance a constant number, or do you think this is only true of chalk?" Direct students to the boxes and the blocks from the beginning of the lesson.

Suggested Prompts

- These boxes are the same size. What does that mean? *(They have the same volume.)*
- What is different about them? *(They have different masses.)*
- We had three blocks with three different masses, but we know that two of them are the same substance. What should we do to find out which two are the same? *(Determine the ratio of their mass and volume to determine the density to see which two have the same density.)*

Students are going to apply what they just discussed about mass, volume, and density to an investigation of fat and soap. They will calculate the density of soap and fat to collect more evidence about how fat and soap are different substances.

Introducing Reading 4.1 – How Can Two Objects that Are the Same Size Have Different Masses?

Have students do the Getting Ready activity in Reading 4.1 in class without looking at their books. Compare any other two items that you could bring in and set out as props to help students get a clear visual representation. Let them know that density is a challenging concept as they try to understand it and how it is determined mathematically. Call students' attention to the fact that they know the answer to the bread/cement block question, and that fact indicates that they already know something about density.

The reading is lengthy because density is such a difficult concept. Divide the reading as makes sense for the students, assigning some sections now and the remaining sections after the next class. Read sections aloud and review together those that you feel are especially challenging or those that you feel would be especially helpful if read aloud by you, a good reader.

Materials – Activity 4.2

For Each Group

- fat (cut to fit into a graduated cylinder without rubbing along its sides)
- soap (cut similarly as the fat pieces)
- (1) balance (electronic recommended)
- (1) 100mL graduated cylinder
- 50mL rubbing alcohol (70% isopropyl alcohol, 30% water)
- (1) calculator*

For Each Student

- Activity Sheet 4.2

*This item is not included in the kit.

Activity 4.2 – Do Fat and Soap Have the Same Density?

Reading Follow Up

Follow up on the density column activity, having students report what happened and what the activity illustrated about the concept of density.

In this investigation, students calculate the density of soap and fat to collect more evidence on how fat and soap are different substances. Ask: "What is density? How is it calculated?" *(Density is the amount of mass in a set amount of volume of a substance. We divide mass by volume to obtain density.)*

Students read What Will We Do? and then write a prediction on Activity Sheet 4.2. Emphasize Safety Guidelines and accurate measurements. Students will use rubbing alcohol as the liquid. Have students complete the investigation. After they finish, have each group report density data to the class. Have students discuss any differences between their density data, but point out that each group found that fat has a greater density than soap.

Review the conclusion questions on the activity sheet. Point out to students that fat and soap are substances, so they have now collected additional evidence about the consistent mass to volume ratio (density) of substances.

Wrapping Up the Lesson

Discussion – Making Sense

Purpose

Realize that density is a property because it does not change for a particular substance.

Suggested Prompts

- How is density determined? *(mass ÷ volume)*
- Why is density a property of substances? *(It does not change based on the amount or size of a substance.)*
- Why are mass and volume not properties? (*They change based on the amount or size of a substance, so they are not helpful for telling what is alike or different about substances.)*
- How is density useful for determining whether two samples are the same or different substances? *(Density provides evidence because if the densities are different, the substances are different. If the densities are the same, the substances might be the same; more tests of more properties are needed to know for certain.)*

By the end of this lesson, add to the Scientific Principles list: Density is the mass in a set volume of a substance. It is calculated mathematically by determining the ratio of the mass of a sample to the volume it occupies.

Lesson 5

How Are Fat and Soap Different?

PREPARATION

Teacher Background Knowledge

Developing Scientific Explanations

When you explain something, you provide important details about the thing you are trying to explain. In and outside of science class, people get asked to explain their ideas. Sometimes explaining means telling how something happens or why it happens. Explaining is never just a simple answer.

You may have learned an important way that scientists explain things; they develop scientific explanations. When you need to explain like a scientist, you need to give a scientific explanation instead of just explaining like you usually do. A scientific explanation includes three important parts. In previous IQWST units, you may have practiced providing claims, evidence, and reasoning. The following sections will remind you of what you did last year. If you did not do these things because you used different science materials in your class, these sections will help you understand scientific explanations.

A claim is a statement that tells what happened or that answers a question. Sometimes when you finish an investigation, you might be asked, "What can you conclude?" The answer to that question can be a claim. If you are asked whether two substances are the same or different, your claim could be the following: Substance X and Substance Y are two different substances. Your claim could be that X and Y are the same substance. A claim is often the first sentence in a scientific explanation.

Evidence is what you use to support your claim. In an investigation, you might collect data from observations or from tests you did in class. Your data become evidence when you use them to support a claim. Using evidence makes a scientific explanation different from everyday explanations. In everyday explanations, you might give more details, but you do not necessarily need to use data. In science, however, you must use data as evidence to support every claim you make. Data can come from an activity you did or from tests scientists have done. Data can be qualitative, like describing what you observe, or quantitative, like measurements you made.

In a scientific explanation, reasoning is a way of connecting the evidence to the claim. Reasoning shows why the claim makes sense, given what scientists know about the world. Reasoning often includes important scientific principles. If students studied the IQWST IC1 unit, they made a list of scientific principles as you studied different topics. Each time you learned something new, you added it to the scientific principles list. This list contained many ideas that you had learned in science. When you used these ideas in your explanation, you were using reasoning.

You might ask yourself a question like "What do I know in science that can help me explain what happened in my investigation?" Anyone can make a claim, but a good scientific explanation includes the evidence and reasoning that supports the claim.

Developing good scientific explanations is a skill. You learn it by talking about explanations, reading explanations, writing explanations, and critiquing explanations. In this unit, you will have several opportunities to develop scientific explanations.

This lesson focuses on helping students construct an argument that includes a claim, evidence, and reasoning collected from several prior lessons. Students who have had other IQWST units (LS1, ES1) will have engaged in this important scientific practice previously, and this activity will serve as a review of using data as evidence to construct an argument that properties can be used to determine, scientifically, that substances are the same or different.

Setup

Specific instructions for activity setup are embedded within the lesson.

Safety Guidelines

Refer to IQWST Overview.

Differentiation Opportunities

1. Students might write an initial explanation individually, in pairs, or in groups.
2. The Wrapping Up the Lesson section of this lesson includes a Checkpoint with a list of terms and concepts encountered thus far in the unit. You may choose to develop them with students (or assign to individuals) a concept map or other graphic representation to support them in visualizing the relationships among these key ideas. Alternatively, students could arrange words written on index cards to show relationships. They could also draw/color representations of the terms and concepts so that rather than only words, they have other visual cues to support them in making sense of new language and new concepts.

Lesson 5

How Are Fat and Soap Different?

TEACHING THE LESSON

Performance Expectation

Students will use data as evidence to construct an argument that it is *properties* of matter that must be used to distinguish substances from one another scientifically.

Overview

Introducing the Lesson
The lesson begins with a discussion about all of the properties students have explored over the last four lessons.

Activity 5.1
Review previous four lessons before constructing an evidence-based explanation that describes how soap and fat are different.

Introducing the Lesson

Reading Follow Up

Follow up students' responses to the questions about the data table.

Building Coherence

This lesson concludes the first learning set. Students synthesize all they have learned about properties generally, and about soap and fat in particular, to construct an explanation of how they know that fat and soap are different substances.

Timeframe

1 Class Period

Materials – Activity 5.1

For the Teacher
- PI: Scientific Explanations (Optional)

For Each Student
- Activity Sheet 5.1
- Reading 5.1

Activity 5.1 – Are Fat and Soap the Same or Different Substances?

Refer to Activity Sheet 5.1 and have students fill in the data from the previous four lessons.

The color-coded version of this PI is accessible on the IQWST Portal.

PI: Scientific Explanations

CLAIM = RED **EVIDENCE = BLUE** **REASONING = PURPLE**

EXPLANATION #1
Fat and soap are both stuff, but they are different substances (correct claim). Fat is used for cooking and soap is used for washing. They are both things we use every day. The data table is my evidence that they are different substances (incorrect evidence). Stuff can be different substances if you have the right data to show it (incomplete or vague reasoning).

EXPLANATION #2
Fat and soap are different substances **(correct claim). Fat is off white and soap is milky white. Fat is soft and squishy and soap is hard. Fat is soluble in oil, but soap is not soluble in oil. Soap is soluble in water, but fat is not. Fat has a melting point of 47°C and soap has a melting point above 100°C. Fat has a density of 0.92 g/cm^3 and soap has a density of 0.84 g/cm^3 (correct evidence).** These are all properties. Because fat and soap have different properties, I know they are different substances. Different substances always have different properties **(correct reasoning).**

EXPLANATION #3
Fat and soap are different substances **(correct claim).** Fat is off white and soap is milky white. Fat is soft and squishy and soap is hard. Fat and soap have different solubility. Fat is soluble in oil, but soap is not soluble in oil. Soap is soluble in water, but fat is not. Fat has a melting point of **47°C and soap has a melting point above 100°C. Fat has a density of 0.92 g/cm^3 and soap has a density of 0.84 g/cm^3 (correct evidence).** Because the color, hardness, solubility, melting point, and density are different, I know they are different substances **(correct, but incomplete reasoning).**

Discussion – Connecting
Purpose

Analyze and interpret data, preparing students to construct an argument of whether fat and soap are the same or different substances.

Review the following claim/evidence/reasoning approach with writing a scientific explanation/argument to students.

- Claim—answers the original question

In this case, the original question is whether fat and soap are the same substance or different substances. Suggest to students that when they are writing their claim, they ask themselves, "What is my answer to the question?" *(Are fat and soap the same or different substances?)*

This is the simplest part of a scientific explanation. One of the purposes in focusing on scientific explanations is to help students include more than a claim in their writing.

Example claim—Fat and soap are different substances.

- Evidence—scientific data used to support the claim

Discuss with students the importance of whether their data support their claim and whether they have enough data. For this question, discussing that soap is used to wash clothes while fat is not, does not support their claim because it is not appropriate for their claim. It is also not appropriate to include volume or mass as evidence, even though these seem like more scientific data. This is because volume and mass are not properties, so they cannot be used to compare substances.

Students need to use properties like melting point or solubility to support their claim. Students should also consider whether or not they have cited enough data. It is not enough evidence to include only one property. Instead, students need to include a number of properties to support their claim.

When students are selecting their data to use as evidence, they should consider both whether it is appropriate to support their claim and whether they have enough data to support their claim. Suggest to students that when they are writing their evidence that they ask themselves what specific data they should use to support their claim.

Evidence can be provided at different levels of detail. Students can make a general statement about the densities being different *(fat and soap have different densities)*, or they can provide the data *(fat has a density of 0.92g/cm^3 and soap has a density of 0.84g/cm^3).* Encourage students to include more detail in their evidence. *(Example of evidence: Fat and soap have different colors, solubility, hardness, melting point, and density. For example, fat has a melting point of 47°C and soap has a melting point above 100°C.)*

- Reasoning—justifying how or why the data count as evidence to support the claim, usually by describing appropriate scientific principles

The reasoning ties in the scientific background knowledge or scientific principles that justify making the claim and choosing the appropriate evidence.

When writing the reasoning, students should ask why they selected the data to support the claim. What science concepts support the claim and evidence? *(Example of reasoning—color, hardness, density, solubility, and melting point are all properties. Different substances have different properties. Since fat and soap have different properties, I know they are different substances.)*

Use PI: Scientific Explanations. Critique each explanation, asking students what is good and not so good about each one. This activity enables students to practice articulating their understanding, and practice giving the kind of feedback they could give to a peer.

Model language such as, "This explanation has a good claim because . . ." and "This evidence is not as good as it could be because . . ." so that students learn to (a) articulate specific details, (b) use the claim/evidence/reasoning language of explanations in IQWST, and (c) focus on the explanation, not on the person who wrote it. Rather than, "You did not put the right evidence in," model language like, "This explanation does not have all the evidence from the table."

- Do these explanations include claim, evidence, and reasoning? Tell what each explanation includes and where in the explanation that part is.

- Explanation 1 includes a claim, inaccurate evidence, and vague or incomplete reasoning. The explanation begins with the claim that they are different. Then the explanation uses everyday knowledge as evidence instead of using the data from class. The evidence should always be in the form of scientific data. The reasoning is incomplete or vague. It just states that if you have the right data you can tell substances apart, but it does not elaborate on what the right data means.
- Explanation 2 is the best explanation because it includes accurate and complete claim, evidence, and reasoning. The explanation starts with the claim that the two substances are different. Then it includes evidence in the form of data from the experiments. Finally, it includes reasoning. The reasoning is the scientific background knowledge that different substances have different properties. It is important to include this scientific background knowledge because it justifies why you can use that evidence to support your claim.
- Explanation 3 includes a claim and evidence but incomplete reasoning. It starts with the claim that the two substances are different. Then, like Explanation 2, it provides evidence in the form of data from the experiments. The last piece is the reasoning, but it is incomplete. This reasoning links the claim to evidence, but it does not include the scientific background knowledge that tells you why the evidence supports the claim. It is missing the justification component of reasoning.

As you discuss the parts of the scientific explanations (claim, evidence, and reasoning) on PI: Scientific Explanations, underline the parts in different colors. This may help the students see what is missing or incomplete.

Have students complete their explanations on the activity sheet. After students complete their explanations and use the checklist at the bottom of the page, have them exchange with a peer. Partners could identify and label the three components in their peer's work (in colors, if that is helpful). Students could use the checklist for peer critique sessions. Have students provide feedback in the manner practiced as a class. Allow for revision, perhaps encouraging partners to help one another. Invite students to share some of their explanations.

Introducing Reading 5.1 – What Evidence Would I Use to Tell if the Stones in a Ring Are the Same or Different?

You might do the Getting Ready activity for Reading 5.1 as a whole class. You could list students' ideas on the board and lead a discussion about claims that are devoid of evidence, and how their everyday need for evidence is much like scientists' need for evidence. Sometimes what counts as evidence is different, but claims without evidence raise questions for students. Examine an article (or just a sentence) from a newspaper or magazine, or make one up to help students see that inappropriate use of evidence is a problem in and out of science class. Let students know that you will review their arguments from the reading in the next class period. They need to make sure that they use the data from the table carefully as evidence for their claim.

Reading Follow Up

Reviewing these arguments can take as much or as little time as you wish to spend with the activity. Options for this activity include the following options:

- Collect responses and provide written feedback.
- Have peers read and respond to one another's arguments.
- Read all responses, post two or three for anonymous critique, and then have students revise what they wrote.
- Do some combination of the above, and ask students to turn in their best argument for a grade.

Wrapping Up the Lesson

Review the following concepts and principles:

- Stuff (matter) is anything that takes up space and has mass. Examples of stuff include pizza, soil, water, fat, and aluminum.
- A substance is made of only one type of atom/molecule throughout. Examples of substances include water, aluminum, salt, and plastic.
- A mixture is made of more than one substance. This means that a mixture is made of two or more types of molecules/atoms throughout. Examples of mixtures include soil, pencils, pizza, and air.
- Properties are characteristics of substances that scientists use to describe substances, to help identify substances, and to distinguish substances from each other. Properties are independent of the sample. Examples of properties include color, hardness, solubility, melting point, and density.
- Mass and volume are not properties of a substance. They change based on the amount or size of a substance. Density is calculated as mass divided by volume (mass ÷ volume).

Students should be familiar with the concepts learned in the first learning set: stuff, substance, mixture, property, color, hardness, solubility, melting point, solid, liquid, density, mass, volume, length, width, height, atoms, and molecules.

Discussion – Connecting

Purpose

Relate the content of the first learning set to the Driving Question.

Suggested Prompts

- How do you think determining if two substances are the same or different relates to the overall Driving Question: How can I make new stuff from old stuff?
- How can you tell if new stuff is made?

- How can you tell if substances are the same or different? *(In order to be able to tell if you have new stuff, you need to be able to tell the difference between new stuff and old stuff. Instead of talking about stuff, scientists talk about substances. To know if you have new substances, you need to be able to distinguish new substances from old substances. You can do this by examining whether or not the properties of the old substances differ from those of the new substances. During the last couple of activities, we have been learning about properties in order to be able to distinguish substances.)*

Now that students can tell substances apart, they will be moving on to the next subquestion for the Driving Question: How can I make new substances? Students will explore different processes involving substances and try to determine if they have new substances, or the same old substances, after each of the processes.

Before Reading

The student version of Reading 6.1 contains only a short version of the fairy tale Rumpelstiltskin. Depending on the make up of your class, explain fairy tales, their nature, purpose, and language. If you prefer to read students the full-length version, it is provided. Even if you read the full-length version, the shortened version and the questions on the second page could still be assigned as homework. The questions set up Learning Set 2. Students know that straw cannot be turned into gold. The question is, how do they know that? They have a sense already that some things can only be turned into certain other things, which is the essence of chemical reactions. Many students will not know what straw is, so be sure they do not read (or listen to you read) thinking that the tale is about drinking straws.

Lesson 6

What Happens to Properties When I Combine Substances?

PREPARATION

Teacher Background Knowledge

Fairy Tales: Rumplestiltskin

Some students may not be familiar with fairy tales. Provide some background information that indicates they are imaginary stories for children and are not based on events that could really happen.

Sandwich Bag Experiment

- In this experiment, a chemical reaction occurs between sodium bicarbonate (baking soda) and calcium chloride (road salt).
    - o Sodium bicarbonate + calcium chloride → sodium chloride + calcium carbonate + carbon dioxide + water
    - o The gas produced in the reaction is carbon dioxide, which is responsible for the bubbles that expand the bag.
    - o The water that is added to the sodium chloride and sodium bicarbonate is not involved in the chemical reaction, but is necessary to dissolve the sodium chloride and sodium bicarbonate so that they can react.
    - o The bag gets hot because the reaction is exothermic, meaning it releases heat.
- After the chemical reaction, sodium chloride is dissolved in solution. Calcium carbonate is not soluble. Any solid in the bag is calcium carbonate and some solid reactants or products that exceed the amount that will dissolve.
- You could have students filter off the solid and show that it will not dissolve when they add water. Once you filter the solid from the solution, you could have students evaporate the water to let them see that there was a solid (sodium chloride) dissolved in the solution.
- After the chemical reaction, sodium chloride and H+ are soluble in the liquid. Calcium carbonate is not soluble. Any solid in the bag is probably calcium carbonate and some solid reactants or products that exceed the amount that will dissolve in the liquid.
- It is not important that students know the equation for this reaction. The focus is only on changes in properties.
- Students may not yet understand that the bubbles and the expanding bag are evidence that a gas formed. This notion is addressed during the subsequent class discussion of the investigation—described in Lesson 7.

Chemical Reactions

- In many chemical reactions, two or more substances interact to form something new. The new can be either one substance or more than one substance. Students observe a chemical reaction—two substances interacting to form new substances. In Lesson 9, they will observe electrolysis of water, a chemical reaction in which only one substance (water) is broken down into new substances (hydrogen and oxygen) by an electrical current. Most important for students to understand is that in a chemical reaction, what they end up with is always different from what they started with. They can begin with one or more substances; they can end with one or more substances. The before/after substances will always be different from one another. The evidence for this is that the materials have different properties. In a chemical reaction, the before/after differences are the result of atoms rearranging so that the before/after substances have different properties. In the next lesson, students will learn the language of reactants and products.

- In a chemical reaction, the atoms rearrange to form new substances. The third learning set focuses on conservation of mass: Atoms are neither created nor destroyed.

Signs of Chemical Reactions

The idea of signs/indicators is introduced in this lesson and built upon in later lessons. Emphasize that if students see signs of a chemical reaction, their observations are not conclusive, but they do suggest that a chemical reaction might have occurred when two or more substances are mixed together.

Scientists observe four common signs of chemical reaction: temperature change, light or heat, bubbles, and a precipitate. A precipitate is comprised of small grains of a solid that fall out of a solution. The formation of a precipitate indicates that a new substance is formed.

However, signs can be confusing (e.g., when a substance such as water boils, it produces bubbles, but those bubbles are not a sign of a chemical reaction). Testing properties is, therefore, the best way to know whether a chemical reaction occurred.

Chemists and other scientists typically compare properties of substances at standard temperature and pressure (0°C and 1 atmosphere of pressure) as properties such a density and boiling point change with temperature and pressure. However, at this point, students do not need to know these nuances.

Particle Nature of Matter

An understanding that all matter is made of particles in constant motion and with empty space between them is prerequisite knowledge for understanding chemical reactions (IQWST IC1). Review that all matter is made of particles called atoms and molecules.

Atoms and molecules are always in motion. In solids, the atoms are closely locked in position and can only vibrate. In liquids, the atoms or molecules have higher energy, are more loosely connected, and can slide past one another; some molecules may get enough energy to escape into a gas. In gases, the atoms or molecules have still more energy and are free of one another except during occasional collisions.

Common Student Ideas

Students may have difficulty recognizing that chemical reactions are the result of mutual interactions. Students might identify only one substance that causes the change and not take into account all reactants. They might think that a chemical reaction occurs because the product was inside the materials (for example, the smoke from burning wood comes from inside the wood, or rust comes out of the metal). Students might think the old substances go away or disappear. They might think the reactants mutate into the products. These ideas will be addressed over time.

Setup

1. Students need to have read *Rumpelstiltskin* before engaging in Lesson 6 activities. Questions following Reading 6.1 encourage students to think about the possibility of making gold from straw before they learn about chemical reactions from a scientific perspective. Students should be prepared to discuss their responses in class.
2. For ease of distribution, prepare three cups for each group, each one containing enough baking soda, calcium chloride, and water for the activity.

Safety Guidelines

Refer to IQWST Overview.

Differentiation Opportunities

Refer to IQWST Overview.

Lesson 6

What Happens to Properties When I Combine Substances?

TEACHING THE LESSON

Performance Expectations

Students will

- carry out an investigation and analyze data to determine whether what happened meets the criteria for a chemical reaction.
- use data as evidence to construct an argument that what happened in their investigation was, indeed, a chemical reaction.

Overview

Activity 6.1

Combine substances and observe results as an introduction to chemical reactions.

Building Coherence

In Learning Set 1, students learned that properties distinguish substances from one another. In Learning Set 2, they observe properties before and after a process to determine whether properties change as evidence that new substances have formed—key to defining a chemical reaction. In forthcoming lessons, students examine chemical reactions on a molecular level.

Timeframe

2 Class Periods

Safety

- Wear safety goggles and aprons.
- Wash hands after completing the investigation.
- Do not ingest any of the chemicals.
- If students mix together too large a quantity of the reactants during the activity, enough gas may form to cause the bag to pop and release the products. If a bag becomes too full, open it to release some of the gas.

Introducing the Lesson

Ask: "Now that we have learned some more science language to replace *stuff*, how might we revise the Driving Question: How can I make new substances from old substances?"

Reading Follow Up

Follow up responses to the questions in the reading. Students are likely to know that given materials can only be turned into certain other materials—the possibilities are not endless. This knowledge will help them make sense of chemical reactions in light of what they already know to be true. One reaction to *Rumpelstiltskin* may simply be that you cannot start with straw and end up with gold except in fairy tales.

Materials – Activity 6.1

For the Class

- (1) container or large plastic trash bag for disposal of materials*

For Each Group

- (1) plastic bag with zip seal
- (1) plastic spoon
- (1) 100mL graduated cylinder
- (1) film canister or small container
- (1) plastic spoon full of sodium bicarbonate (baking soda)
- (1) plastic spoon full of calcium chloride (road salt)
- 10mL water*

For Each Student

- Activity Sheet 6.1
- Reading 6.1
- Reading 6.2

*This item is not included in the kit.

Elicit background knowledge and encourage students to think about possible outcomes of combining substances. Correct answers are not important; the activity itself will address many of the ideas that students raise here. Begin by asking what students think might happen when they mix substances together with other substances. *(Nothing; they mix together; something happens such as light, fire, explosion, loud noise, gas, bubbles, dissolving; a chemical reaction occurs.)* Then ask: "How would you know whether new substances formed?" *(The properties will change; there will be a higher/lower density or melting point; the properties might blend together into something new, such as combining a white with a red substance might result in a pink substance.)*

Have students indicate why they might expect particular outcomes. Show students the calcium chloride (road salt), sodium bicarbonate (baking soda), and water. Explain that they will conduct an investigation to find out what happens when they mix these substances.

Activity 6.1 – Teacher Demonstration of Investigation Procedure

Distribute Activity Sheet 6.1. Demonstrate the procedure outlined on the activity sheet—but do not actually tip the container of water into the other substances.

As you demonstrate the procedure, perform the following tasks.

- Make and record careful, thorough observations of each substance.
- Retrieve solubility-in-water data from Lesson 2 (when you demonstrated the procedure for measuring solubility using baking soda and road salt in water). It is important that students know that the initial products are soluble in water.
- Demonstrate taking care to place container of water in the bag without spilling, then carefully seal the bag. (It is easiest to have one person hold the bag and the container while another person closes the bag.)
- Remind students to be thorough and complete as they record their observations.
- Save the sealed bags for discussion following the investigation.

What Happens When I Combine Substances?

In groups, have students complete the investigation, record observations, and answer the conclusion question on Activity Sheet 6.1. The focus is on whether they think new substances formed when they mixed together the old substances.

Discuss students' responses to the conclusion question. They should use their data table as evidence as they talk about why they would claim that new substances formed (or not).

Discussion – Pressing for Understanding

Purpose

Develop an initial understanding of chemical reactions.

The process they observed and described on their activity sheets is what scientists call a chemical reaction. What do they think a chemical reaction is?

Suggested Prompts

- How do the substances that you ended up with compare to what you started with?
- What do you notice about properties that might help you define a chemical reaction?
- What evidence do you have that new substances were made from the old substances?

Knowing how to tell when a chemical reaction has occurred involves looking for changes —comparing substances before and after a process. A change in properties is one way to tell that a new substance was formed and that a chemical reaction occurred. Ask students to recall the meaning of property. *(A property is a characteristic that helps identify a substance and distinguish one substance from another. All substances have properties that are the same for that substance whether you test a little or a lot of it.)*

When substances are mixed together and a chemical reaction occurs, new substances form. The resulting new substances have properties different from the properties of the old substances, thus a change in properties is key to recognizing a chemical reaction.

Ask students to describe the changes that occurred when they mixed the substances. List the changes on the board.

- Temperature change: room temperature → hot
- Formation of a precipitant: substances in a solution (dissolved) → a solid formed
- Other changes: no bubbles → bubbles; an expanded bag

At this point, students should construct a meaning for chemical reaction that involves substances combining to form new substances with new properties. (They have learned that substances have characteristic properties, so new properties are evidence of new substances.)

Have students carefully examine the substances in their bags. Help them to see that several of their observations provide evidence that a change in properties occurred. They know from a previous investigation, as recorded in their data table, that the original substances were both soluble in water. However, after mixing, a substance formed that is not soluble in water. The white substance—with a new property—is evidence of a new substance. Introduce the word *precipitate* in this discussion.

As an optional activity, and to provide additional evidence, have students filter the substance and then try to dissolve it in water.

Ask students what new substance could have formed—as indicated by the bubbles. They may be familiar with the characteristics of gases, such as taking up the space of the container (IQWST IC1). *(The bubbles indicate that a gas formed. Other evidence that a gas formed is my observation that the bag expanded. The bag probably expanded as the gas filled it up because gases take the shape of the container.)*

The bubbles were also a sign that might indicate a new substance was formed. If what happened was a phase change, then the gas that formed would return to a liquid upon cooling. (Students may need support to recall what they have previously learned about the phase change from gas to liquid.) If what happened were a chemical reaction, then the gas would remain even as the substances cooled to room temperature. In this investigation, the gas remains.

The gas produced in this reaction is carbon dioxide. You could demonstrate or have students use a burning splint (or match) to test for carbon dioxide. The bag used for teacher demonstration of the procedure (in which substances were not combined) can be used as the before-mixing example. If a burning splint is inserted in the bag before the reaction, the splint will burn until all the oxygen is used up. If you insert a burning splint into a bag after the reaction, the flame will go out immediately, as the new gas is carbon dioxide. Emphasize that the effect on a glowing/burning splint is also a property unique to specific gases.

Both changes in properties of substances and signs of chemical reactions can provide evidence that a chemical reaction has occurred. Emphasize that although they examined only observable properties, they could also measure the solubility, melting point, and density of all the substances before and after mixing them. These measurements would provide even more evidence that a chemical reaction occurred. While students did not measure these properties in the experiment, they will read about those properties in the reading. They will also use solubility, melting point, and density in future experiments to determine whether a chemical reaction occurred.

✓ Students should have a basic understanding of chemical reaction that will be developed in more depth over the course of the second learning set.

Update the DQB with the shared definition of a chemical reaction. A sandwich bag from the investigation could be tacked onto the DQB as a reminder of the data collected in Lesson 6. Ask students how they would answer the Driving Question, "How can I make new substances from old substances?" based on what they have learned thus far during the unit.

- New substances can be made from old substances through a chemical reaction.
- Sometimes when you mix substances together, they interact to form new substances (chemical reaction).
- You can measure the properties of all the substances before and after you do something to them. If the substances have different properties before and after, you know that a new substance was made and a chemical reaction took place.
- Signs of a chemical reaction (bubbles, color change, heat, and formation of a precipitate) indicate that a new substance has been made from old substances through a chemical reaction.

By the end of this lesson, add to the Scientific Principles list: A chemical reaction happens when two or more substances combine in ways that make new substances form that have different properties from the beginning materials.

Challenge students to use the particle model of matter to explain how they can make new substances from old substances and to explain why some substances can only be turned into certain other substances. The point is not that students arrive at the correct answer, but that they think about the molecular aspect of chemical reactions, which will be covered in the following lessons. *(Students might say, for example, that the molecules could be coming apart or that the atoms are moving around because of a phase change. They might say that atoms could be connecting to make molecules.).*

Continuing to Make Sense of Chemical Reactions

Introducing Reading 6.2 – What Is a Chemical Reaction?

Review the Getting Ready section of Reading 6.2 in class or discuss a specific characteristic such as bubbles and whether bubbles always indicate a chemical reaction. Students saw bubbles in the sandwich bag experiment. Do they think bubbles always occur when there is a chemical reaction? Do they think that if they see bubbles they know for sure that a chemical reaction has taken place? You might list on the board examples of other times students can think of that they see bubbles, and you could analyze them as chemical reactions or not chemical reactions. *(boiling water, opening a can of soda, pouring dish soap or laundry detergent in water, pouring bubble bath in water)*

Students use class observations and the information in their reading to construct an argument about what happened in the sandwich bag experiment, making a claim as to whether it was or was not a chemical reaction.

Support students, as needed, in recalling the purpose and the parts of a scientific explanation or argument before they write, and in checking for all three components (claim, evidence, and reasoning) after writing.

Reading Follow Up

Reviewing students' arguments can take as little or as much time as you wish to spend with the activity. This is a review, but it now has students applying their understanding to data you have not interpreted as a whole class. Thus, it may be worthwhile to spend a fair amount of time reviewing their work. Some options for reviewing students' work include the following:

- Have peers read and respond to one another's work and then provide time for revision.
- Read all responses, post two or three for anonymous critique, and then have students revise their own.
- Do some combination of the above, and have students turn in their best argument as an assessment.

In addition, be sure to follow up students' responses to the final question in the reading about the scientific reason that straw cannot be turned into gold. In essence, students should recognize that what you end up with (also true in the cake baking example) depends on what you start with. More specifically, they know that gold is a substance made of only gold atoms. Straw is not made of gold atoms; it is a different material. Without gold in the straw, it does not make sense that they end up with gold at the end of a process of weaving straw. Right answers are not as important here as deep thinking about what makes sense given students' prior knowledge, the reading, and the class activities. Students will continue to pursue macroscopic and microscopic considerations of chemical reactions for the remainder of the unit.

Rumpelstiltskin

(Longer Version) by the Brothers Grimm

Once there was a miller who was poor, but who had a beautiful daughter. Now it happened that he had to go and speak to the king, and in order to make himself appear important, he told the king that he had a daughter who can spin straw into gold. The king said to the miller, "That is an art which pleases me well. If your daughter is as clever as you say, bring her tomorrow to my palace, and I will put her to the test."

And when the girl was brought to him, he took her into a room which was quite full of straw, gave her a spinning-wheel and a reel and said, "Now set to work, and if by tomorrow morning early you have not spun this straw into gold during the night, you must die."

Thereupon he himself locked up the room, and left her in it alone. There sat the poor miller's daughter, and for the life of her could not tell what to do. She had no idea how straw could be spun into gold, and she grew more and more frightened, until at last she began to weep.

Suddenly the door opened, and in came a little man. "Good evening, mistress miller. Why are you crying so?"

"Alas," answered the girl, "I have to spin straw into gold, and I do not know how to do it."

"What will you give me," said the little man, "if I do it for you."

"My necklace," said the girl.

The little man took the necklace, seated himself in front of the wheel, and whirr, whirr, whirr, three turns, and the reel was full. Then he put another on, and whirr, whirr, whirr, three times round, and the second was full too. So it went on until the morning, when all the straw was spun, and all the reels were full of gold.

By daybreak the king was already there, and when he saw the gold he was astonished and delighted, but his heart became only greedier. He had the miller's daughter taken into another room full of straw, which was much larger, and commanded her to spin that also in one night if she valued her life. The girl knew not how to help herself and was crying when the door opened again, and the little man appeared and said "What will you give me if I spin that straw into gold for you?"

"The ring on my finger," answered the girl. The little man took the ring, and again began to turn the wheel. By morning the little man had spun all the straw into glittering gold.

The king rejoiced beyond measure at the sight, but still he had not gold enough, and he had the miller's daughter taken into a still larger room full of straw, and said, "You must spin this, too, in the course of this night, but if you succeed, you shall be my wife."

Even if she be a miller's daughter, thought he, "I could not find a richer wife in the whole world."

When the girl was alone the little man came again for the third time, and said, "What will you give me if I spin the straw for you this time?"

"I have nothing left that I could give," answered the girl.

"Then promise me, if you should become queen, to give me your first child."

"Who knows whether that will ever happen," thought the miller's daughter, and, not knowing how else to help herself in this strait, she promised the little man what he wanted, and for that he once more spun the straw into gold.

When the king came in the morning, and found all as he had wished, he took her in marriage, and the pretty miller's daughter became a queen.

A year later, the new queen brought a beautiful child into the world. She never gave a thought to the little man. Suddenly he came into her room, and said, "Now give me what you promised."

The queen was horror struck, and offered the little man all the riches of the kingdom if he would leave her the child. The little man said, "No, something alive is dearer to me than all the treasures in the world."

Then the queen began to lament and cry, so that the little man pitied her. "I will give you three days time," said he, "if by that time you find out my name, then shall you keep your child."

So the queen thought the whole night of all the names that she had ever heard, and she sent a messenger over the country to inquire, far and wide, for any other names that there might be. When the little man came the next day, she began with Caspar, Melchior, Balthazar, and said all the names she knew, one after another, but to everyone the little man said, "That is not my name."

On the second day she had inquiries made in the neighborhood as to the names of the people there, and she repeated to the little man the most uncommon and curious. "Perhaps your name is Shortribs, or Sheepshanks, or Laceleg."

The little man always answered, "That is not my name."

On the third day the messenger came back again, and said, "I have not been able to find a single new name, but as I came to a high mountain at the end of the forest, where the fox and the hare bid each other good night, there I saw a little house, and before the house a fire was burning, and round about the fire quite a ridiculous little man was jumping, he hopped upon one leg, and shouted, 'Today I bake; tomorrow brew; the next I will have the young queen's child. Glad am I that no one knew that Rumpelstiltskin I am styled.'"

You may imagine how glad the queen was when she heard the name. Soon afterwards the little man came in, and asked, "Now, mistress queen, what is my name?"

At first she said, "Is your name Conrad?"

"No."

"Is your name Harry?"

"No."

"Perhaps your name is Rumpelstiltskin?"

"The devil has told you that. The devil has told you that," cried the little man, and in his anger he plunged his right foot so deep into the earth that his whole leg went in, and then in rage he pulled at his left leg so hard with both hands that he tore himself in two.

Lesson 7

Is Burning a Chemical Reaction?

PREPARATION

Teacher Background Knowledge

Burning as a Chemical Reaction

Students collect data to show that burning is a chemical reaction. The substances before and after burning are different because their properties are different. Students examine molecular models of the substances before and after burning magnesium. The molecular models demonstrate why none of the substances burn away or disappear. However, students do not determine the mass of the substances before and after burning to explore conservation of matter, nor is it necessary for them to connect the molecular models to the concept of conservation of matter at this point. The third learning set addresses these ideas.

When magnesium burns, it reacts with oxygen gas to form magnesium oxide. The equation for the chemical reaction is as follows:

magnesium	+	oxygen	→	magnesium oxide,
(solid, hard metal, silver color)		(gas)		(solid, soft powder, white color).

In symbolic form it appears as follows:

$$2Mg + O_2 \rightarrow 2MgO$$

You will discuss the word equation for the reaction with students after testing the properties of magnesium and magnesium oxide.

Common Student Ideas

Beyond the observable effects of burning a material (many materials turn black and/or appear as ash when they burn), many students think a material burns away—some of the material disappears—and/or the material weighs less. Middle school students often do not know that burning is a chemical reaction in which a material reacts with oxygen gas to become a different substance (an oxide). When wood burns, carbon dioxide forms, which is a gas, and gives the impression that the material after burning has less mass.

Setup

Activity 7.1

Set up the experimental apparatus for the burning magnesium demonstration as follows:

1. Attach a metal clamp to a ring stand.
2. Cut a strip of magnesium approximately 8cm long.

3. Attach the magnesium strip to the metal clamp, so the strip points horizontally outward.
4. Be sure that you have a flame-retardant tabletop, or obtain a flame-retardant plate (ceramic, stoneware, or metal), over which to burn the magnesium.
5. Do not look directly at the flame.
6. Using toothpicks and marshmallows, construct a molecular representation of an oxygen molecule to use in the demonstration. Connect two marshmallows of the same color using a toothpick to represent an oxygen molecule. Select two or more marshmallows of another color to represent magnesium atoms, like the graphic shown.

Safety Guidelines

Magnesium strips burn rapidly and completely. Do not hold the magnesium strip in your hand when you burn it. Follow the procedures (see Setup) for securing the magnesium strip to a clamp and ring stand before burning it. Burn the magnesium over a flame-retardant tabletop or plate. Instruct students not to look at the magnesium as it burns. Wear goggles.

Differentiation Opportunities

Students might investigate other types of burning (e.g., fuels) on the Internet to support the understanding that all burning involves a chemical reaction. Students could report about their findings formally or informally, or they could write, draw, or make a chart to represent what they learned.

LESSON 7

Is Burning a Chemical Reaction?

TEACHING THE LESSON

Performance Expectations

Students will

- collect and analyze data about the properties of magnesium before and after burning it, and use the data as evidence to argue whether burning is a chemical reaction.
- develop and use models to represent chemical reactions—word equations, chemical formulas, and molecular models.

Building Coherence

In order to deepen students' understanding of chemical reactions, this lesson investigates the everyday reaction of burning. It also introduces various representations of chemical reactions—word equations, chemical formulas, and molecular models.

Timeframe

1 Class Period

Overview

Activity 7.1

- Make observations as teacher burns magnesium.
- Use observations to make connections among different representations of chemical reactions.

Safety

- Wear safety goggles.
- Use prepared apparatus; do not hold magnesium to light it.
- Burning magnesium produces a bright flame. Before lighting, tell students not to look directly at it.

Introducing the Lesson

Ask students to think of a change they have observed at home or outside of science class that they think might be a chemical reaction. The class (or groups) should discuss whether the examples are or are not chemical reactions. Provide specific examples to stimulate thinking (*rusting? an apple turning brown after you cut it?*) Refer to the DQB to review what makes something a chemical reaction. *(A chemical reaction is a process in which substances interact to form new substances with properties different from the old substances. Substances before and after a chemical reaction are different.)*

Materials – Activity 7.1

For the Teacher
- 30mL warm tap water*
- (2) large test tubes
- (2) stoppers
- (1) small spoon or scoop
- (1) test tube rack
- marshmallow molecules* (Refer to Lesson 7 Preparation section.)

For Each Student
- Activity Sheet 7.1
- Reading 7.1

*This item is not included in the kit.

Activity 7.1 – Is Burning a Chemical Reaction?

Discussion – Brainstorming

Purpose

Elicit prior knowledge and experience with burning.

Suggested Prompts
- Do you think burning is a chemical reaction? Explain your ideas.
- If you light a substance and it burns, do you think the properties of the substance are the same or different before and after you burned it? Explain your ideas.

Demonstration and Discussion about Burning Magnesium

Refer to the experimental apparatus for your demonstration that you prepared prior to class. (See Setup.) Place the apparatus on a flame-retardant tabletop, or place a flame-retardant plate under the magnesium strip. Be sure to wear safety goggles.

Caution students that when you burn the magnesium, the flame will be very bright. Emphasize that they not look directly at the flame. Light the magnesium strip, and back away from the apparatus when the magnesium starts to burn. The magnesium should burn rapidly and completely.

After the magnesium has finished burning, ask students if they can think of any everyday phenomena that involve burning magnesium. Sparklers often have magnesium in them. Fireworks also can contain magnesium, but fireworks tend to include other substances as well, which is why they create different colors, such as red and green.

Cut another strip of magnesium so that students can compare the solid magnesium before burning to the solid after burning. Have groups observe both solids. Ask students to describe properties of the solids before and after burning. Create a table to record their descriptions as students record them on Activity Sheet 7.1.

PROPERTIES			
Solid	Color	Hardness	
Before Burning	Silver or gray	Hard	
After Burning	White	Soft Powder	

Ask students what other properties they could test to compare the solids before and after burning. *(We could test their density, solubility, and melting point.)*

Testing for Changes in Properties

Because there is only a little sample of the solid after burning, it is difficult for us to test its density and melting point using the techniques learned in class. However, a test of the solubility of the solids in water can be done.

Demonstrate a solubility test on the solids before and after burning:

1. Place the strip of magnesium into a large test tube.
2. Use a spoon or scoop to collect some of the solid after burning; put the sample into a different test tube.
3. Pour warm tap water into the test tubes. Each test tube should be approximately 2/3 full.
4. Place stoppers on the test tubes.
5. Shake the test tubes vigorously. (To hold a test tube for shaking, lightly squeeze the test tube in the palm of your hand by wrapping your fingers around the test tube, as if giving a "thumbs up." Place your thumb on top of the stopper to hold it in place. Then shake the test tube in a fast up-and-down motion.)
6. Place the two test tubes in a rack. Have students observe the results and record their observations in the table.

PROPERTIES			
Solid	Color	Hardness	Solubility in Water
Before Burning	Silver or gray	Hard	Not Soluble
After Burning	White	Soft Powder	Not Soluble

The solubility is the same, so what does that tell us about whether a chemical reaction occurred? This information only tells that the substances share this property. However, it might be necessary to test other properties and learn that the substances are not the same. This is important: If you learn that two properties are different, you know that the substances have to be different because substances have characteristic properties that are always the same for a given substance. However, if you find that two properties are the same, you do not know for certain that the substances are the same. Testing additional properties is essential before you can make a claim.

Testing the Reactivity of Magnesium (Optional)

An additional property of metals is reactivity. Reactivity is the ability of a substance to undergo a chemical reaction: $Mg (s) + 2HCl (l) \rightarrow MgCl_2 + H_2 (g)$.

Teacher Demonstration

Test to see if magnesium reacts or does not react with HCl.

1. Add 5mL aqueous HCl (hydrochloric acid) in a test tube.
2. Add a small piece of magnesium ribbon to acid.
3. Hold a second test tube over the one containing magnesium and the acid.
4. Once the reaction finishes, light a match, quickly turn over the test tube, and place a match near the mouth of the test tube. (There should be a loud pop.)

In this case, you cannot determine the density and melting point of magnesium and the solid after burning in class, so you must look up these properties in tables. Scientists have already determined the properties of these substances using tools and techniques that would not be appropriate for a middle school science class. Add their findings about additional properties to the table on the board.

PROPERTIES					
Solid	Color	Hardness	Solubility in Water	Density	Melting Point
Before Burning	Silver or gray	Hard	Not soluble	1.74 g/cm^3	650°C
After Burning	White	Soft Powder	Not soluble	3.58 g/cm^3	2800°C

Ask: "Is burning a chemical reaction?" Have students use their data as evidence to construct an argument as to whether a chemical reaction occurred when magnesium was burned. *(A chemical reaction occurred when the teacher burned magnesium. [Claim] While the two solids have the same solubility, the magnesium (the solid before burning) has a different color, hardness, density, and melting point, than the solid after burning. [Evidence] The products of a chemical reaction are different substances from the reactants. The properties of the solids are different, so a chemical reaction occurred. [Reasoning]*

Ask students to identify the claims, evidence, and reasoning in their classmates' explanations or arguments throughout the unit.

Representing Chemical Reactions

Review

- What was the old substance? *(magnesium)*
- What is the new substance? Even if you do not know what the substance is, what do you know about it? *(A new substance is something other than magnesium; it is not magnesium because the properties are different; it is magnesium oxide.)*

Scientists sometimes write word equations to represent what happens in a chemical reaction. Write on the board the word equation for this reaction: magnesium + oxygen → magnesium oxide.

Have students record the equation on Activity Sheet 7.1. Scientists call the substances that react with each other the *reactants*. The reactants are written before the arrow; they are the old substances, before the chemical reaction happened.

Scientists call the substances that are formed *products*. Products are written after the arrow; they are the new substances produced after the chemical reaction happened. Write on the board:

magnesium + oxygen	→	magnesium oxide
reactants	go to form	products
old substances		new substances

- This is a good place for word study. In the case of reactants and products, students' everyday use of these words will be helpful in their understanding. They do not need to think of these as two more words to be memorized, but as names that make sense given what they already know from experience.
- Indicate the common root word *act* in react, interact, interaction, and reactant. The substances react or interact—they do something.
- Products are what are produced—not unlike the way students can think about products they purchase in a store or the product that is the result of a mathematical operation (multiplication). They are the end thing, just as they are in a chemical reaction.

Ask: "What does it mean for substances to interact and change during a chemical reaction?" *(Students may talk about atoms and molecules, or pieces of combining, or pieces breaking apart.)* Pay attention to what scale students are imagining, whether it is particulate (atoms, molecules) or larger (tiny pieces like grains).

Review what matter is made of (atoms and molecules in solid, liquid, and gaseous states). Explain that even though they can easily observe signs of a chemical reaction *(a gas was formed)* while it is happening, interactions happen at the molecular level that cannot be observed directly. Ask: What do you think might have happened to the atoms and molecules in this chemical reaction?

Students may have used models in previous IQWST units to show what a substance might look like if they were able to look at it through a special instrument that would enable them to see the millions and millions of atoms and molecules in a tiny piece of any substance (IQWST IC1).

Ask: "Why is a model useful for learning about atoms and molecules?" *(Models can represent things too small to see with the naked eye. Models help explain and predict phenomena.)* The particle model can be used to help explain how substances interact during a chemical reaction.

Discussion – Pressing for Understanding

Purpose

Recognize that when students *observe* a change, change is also happening at the molecular level.

Suggested Prompts

- What are the particles that make up all substances? *(atoms)*
- How are atoms and molecules related? *(Molecules are arrangements of atoms.)*
- What is the difference between two different substances at the molecular level? *(different atoms, different molecules, different number of atoms, different arrangements of atoms)*
- If we say that new substances are made by a chemical reaction, what needs to happen to make a new substance? *(There have to be new atoms, or new molecules, or a new arrangement of atoms, or a different number of atoms.)*

Use ball-and-stick models (molecular representations) to help make sense of what happens in a chemical reaction. Show students your pre-prepared model of an oxygen molecule. Ask: "What is an oxygen molecule made up of?" *(two oxygen atoms)*

Show your model of magnesium and ask what it is made up of. *(two atoms of magnesium)*

Students should realize that each ball = 1 magnesium atom and in this model, there are two magnesium atoms. *(They are not connected.)*

Remind students of the gases in air, such as nitrogen and oxygen. Explain that the magnesium atoms represent the magnesium element (and could be represented as billions of magnesium atoms), and one molecule of oxygen has two oxygen atoms. Write the molecular formula of magnesium (2Mg) and oxygen (O_2) on the board under the word *equation*.

Ask students how the two substances change. Remind them that if substances are different, the number and/or arrangement of the atoms that make up each substance are different. Use the Mg and O_2 to show they are made of different atoms, so they are different. Ask: "How can those two molecular representations change so that there is a new different representation (and therefore different substance)?" *(Students may say Mg_2O_2, MgO_2, or MgO.)* Record students' responses on the board. Explain that scientists have studied this reaction and the product and found that the new substance is MgO, which is called magnesium oxide.

Write the molecular formula of magnesium oxide in the equation on the board (MgO). For example,

magnesium + oxygen → magnesium oxide,

reactants go to form products,

$2Mg + O_2 \rightarrow 2MgO$.

Show students that they have just written a chemical equation that represents a chemical reaction. Ask students what the plus signs and the arrows might represent. The plus sign is a little different from mathematics. In a chemical equation, the + means coming together or interacting. The arrow represents a change that occurred from the beginning to the end of the reaction.

The arrow can represent the phrase "interact, which produces" or "forms," or "goes to form," so if we look at the equation we can say: "Two substances—magnesium and oxygen—interact, which produces magnesium oxide, which is a new substance."

A chemical equation describes what is happening and how substances interact with each other in the form of symbols instead of words in sentences.

Scientists use symbols and equations to represent elements, number of atoms, and number of molecules. Ask: "What does each symbol represent in the molecular formula?" *(Each chemical formula shows the number and types of atoms that are in that substance. The numbers before each molecular formula, the coefficients, show how many of the models would need to be used to make the chemical reaction work. The symbols tell what types of atoms, what elements, are in the substance, and the subscript numbers tell how many atoms of that specific element are in the substance.)*

Return to the molecular ball-and-stick representations. Use these representations to demonstrate what is happening during the chemical reaction of magnesium burning at the molecular level. Ask students what you should do (what needs to happen) for the product magnesium oxide (MgO) to form.

Have students use the ball-and-stick models to determine the steps needed for the reaction to occur. As a class, students can discuss how the reaction occurs on the molecular level.

Ask students to give you directions, step by step, for what you should do.

1. Take apart the oxygen atoms of the oxygen molecule.
2. Take one of the magnesium atoms.
3. Use a toothpick to combine one magnesium atom with one oxygen atom.
4. Do the same with the other oxygen and magnesium atoms.

This is a model of what happens on the molecular level during the chemical reaction of magnesium burning. The magnesium interacts and reacts with the oxygen to produce magnesium oxide. The atoms are rearranged to create something new, in this example magnesium oxide.

Suggested Prompts

- What atoms did we start with? *(oxygen and magnesium)*
- What atoms were present in the product? *(oxygen and magnesium)*

Explain that the atoms present in the reactants are present in the products. In a chemical reaction atoms are neither created nor destroyed. The atoms are rearranged into something new. The purpose for asking these questions is to introduce the conservation of matter. This topic will be further addressed in the third learning set.

Wrapping Up the Lesson

In this activity, students observed a demonstration of magnesium burning and, through a discussion, have determined that burning is a chemical reaction. Using the magnesium reaction, different ways to represent chemical reactions were introduced—word equations, chemical formulas, and molecular representations. A model was used to show the chemical reaction of burning of magnesium on a molecular level, to represent the interaction of the substances involved in the reaction, and to point out that in a chemical reaction the atoms rearrange. Atoms are neither created nor destroyed, but rather rearranged into something new.

- Students should identify burning magnesium as a chemical reaction because the properties before reacting are different from the properties after reacting.
- Students can represent chemical reactions using words, formulas, and molecular models.

Discussion – Summarizing

Purpose

Connect the new material presented in this lesson to the Driving Question.

Remind students of the subquestion for this section of the unit: How can I make new substances? Ask them how they would answer the question at this point. *(We can make new substances through a chemical reaction. When we combine different substances and a chemical reaction occurs, the substances interact. The atoms rearrange to form new substances.)*

Suggested Prompts

- How do you determine whether there are new substances after a chemical reaction? *(You can compare the properties of substances before and after the reaction. If their properties are different, the substances before and after the reaction are different. We also can suggest that a chemical reaction occurred if we observe signs of a chemical reaction like bubbles or heat.)*
- If students only mention that you can determine whether there are new substances by comparing properties of substances before and after the reaction, remind them that you can also determine whether there are new substances by looking for signs of a chemical reaction.
- How can we represent chemical reactions? *(words, chemical formulas, molecular models)*

Tell students that in this lesson they further explored chemical reactions. They created different representations of the chemical reaction and explored the reaction on the molecular level.

Add to the Scientific Principles list:

- Burning is a chemical reaction in which a substance reacts with oxygen to form water and carbon dioxide.
- A reactant is a starting substance in a chemical reaction. A product is the substance made by a chemical reaction.
- A chemical reaction occurs when substances interact and their atoms combine in new ways to form new substances. The new substances and the old substances are made of the same atoms, but those atoms are arranged in new ways. As a result, the new substances have different properties from the original materials.

Introducing Reading 7.1 – Is Burning a Chemical Reaction?

Students could brainstorm in small groups about the Getting Ready section of Reading 7.1. The magnesium reaction you demonstrated is like the reaction that makes sparklers, and that reaction is similar to the one in fireworks. They are going to read more about fireworks. Let students know that tomorrow you will ask them some questions about fireworks, so they need to be ready!

Lesson 8

Does Acid Rain Make New Substances?

PREPARATION

Teacher Background Knowledge

The Copper Experiment

Vinegar (acetic acid) and a copper square react chemically to produce a green substance on the surface of the copper (copper acetate) and hydrogen gas.

$$2CH_3COOH\ (aq) + Cu\ (s) \rightarrow$$
$$Cu(CH_3COO)_2\ (aq) + H_2\ (g)$$

The effect of the chemical reaction (a visible green substance on the copper square) will be visible the next day. Students investigate the effect in Activity 8.2, which can be completed the following day or at a later point (after a weekend).

The following information is for teachers only, and not for middle school students. Carbon atoms are typically involved in four bonds. These bonds can be to four different atoms, such as CH_4, but also can be double bonds to the same atom, such as in O=C=O, or various combinations of single, double, and triple bonds of carbons atoms.

Acetic acid (vinegar) can also be written as $C_2H_4O_2$, but other molecules also have two carbon atoms, two oxygen atoms, and four hydrogen atoms. The formula written as CH_3COOH instead tells scientists how the atoms are arranged—what atoms are connected to each other and what typical functional groups are a part of the molecule. For instance, an organic acid (an acid in a carbon-based compound) is almost always represented as COOH, which means that both oxygen atoms are connected to the same carbon atom, one oxygen is a double bond with the carbon and the other oxygen is also bonded to a hydrogen atom.

The chemical formula for copper acetate can also be written in multiple ways. The most common chemical formula for copper acetate is $Cu(CH_3COO)_2$. However, the subscript 2 does not refer to a specific atom. Instead, the 2 tells that in this compound there are two sets of whatever is in the parenthesis (the CH_3COO). To make this less complicated for the students, copper acetate can be written as $CH_3COO\text{-}Cu\text{-}OOCCH_3$.

A molecule of acetic acid has a specific shape due to the angles of the bonds within the molecule (for example, the connection C-O-H bonds are not linear but bent due to the unshared electrons of oxygen). Because students do not have conceptual understandings about bonding yet, it is okay that students' models have linear shapes.

This activity also does not focus on the double bonds associated with the carbon and oxygen atoms in a molecule of acetic acid. The activity only focuses on chemical connections, or chemical attractions, which are represented by a connection with a stick. Discussion of bonds and why bonds form is a high school standard.

Although copper acetate contains an ionic bond with the copper and acetate molecules, the bond is represented as a chemical connection with a stick.

Students may have learned (IQWST IC1) that different arrangements of carbon, hydrogen, and oxygen atoms make up different molecules with different odors. Many of the different compounds in the world are made of common elements such as carbon, hydrogen, oxygen, and nitrogen. In fact, many compounds differ only by the number of atoms of these common elements and how the atoms of these elements are arranged.

Reading the Chemical Formulas

- Students may say "one atom of copper reacts with two molecules of acetic acid and one molecule of copper acetate." However, the coefficients actually represent a mole of the substance, which is a huge number of molecules (1 mole of any substance contains 6.02 × 1,023 molecules). The coefficients represent a ratio of how much of each substance is needed for the reaction to be complete. The molecular ratio the students describe is correct (the number of moles is proportional to the number of molecules). In any chemical reaction, millions and millions of molecules and atoms react.
- The modeling activity will help students to elaborate what it means to interact or react. Later, students will change their definition of chemical reaction to include that the atoms rearrange to form new substances.

On Activity Sheet 8.3, in Question 8, students recognize that sometimes substances can be produced even though they do not see the substance. Hydrogen gas does form from this reaction. However, students would not notice this because the reaction occurs in an open system and the gas is allowed to escape and it also cannot be seen.

- This question can lead to a discussion that relates to the conservation of mass—that atoms cannot be created nor destroyed, and therefore mass is conserved. If the hydrogen atoms were there before (they did not just appear), and the atoms will be there after the reaction (they do not go away, but combine to form another substance). Students will learn about conservation of mass in the next learning set.
- The correct and balanced chemical equation for the reaction is

  copper + acetic acid (or vinegar) →
  copper acetate + hydrogen gas.

The next lesson presents the balanced equation for students.

- Question 8 is another opportunity to talk about the number of each type of atom in the reactants and that it will equal the number of each type of atom in the reactants.

Common Student Ideas

- Students may have difficulty recognizing that the chemical equations are closely linked to the chemical reactions they observed during the investigation. Focusing on students' observations as you introduce the chemical equation may help students connect the representation of a chemical reaction (the chemical equation and the molecular models in the equation) to what they actually experienced.
- Students also have difficulty linking what they observe (the macroscopic phenomena) to what occurs at the microscopic level.

- Students may know that copper metal is made of copper atoms. They may believe, however, that a copper atom is a copper color, when in fact copper atoms are not copper color.
- Creating the copper acetate model may depend on how well the students understand what the molecular formula means. For example, students may have difficulty understanding the subscript 2. It might be helpful to mention that during a chemical reaction, not all of the atoms of the model disassociate and rearrange—that some of the atoms can stay connected while other atoms in the model rearrange. It is also not important if the students incorrectly arrange the atoms, as long as the models have the correct number and type of atoms in their model.

Setup

Specific instructions for activity setup are embedded within the lesson.

Safety Guidelines

This lesson uses modeling clay, to which some students may be allergic. Students can avoid doing the investigation set up thus avoid handling the material.

Differentiation Opportunities

1. To have students apply the lessons learned in this activity to another everyday context, obtain pennies dated before 1982. They contain enough copper for the same reaction to take place as takes place with the copper square. Before 1982, pennies were 95.0% copper and 5.0% zinc, whereas after 1982 pennies became 97.6% zinc and 2.4% copper. Students could be given two pennies and set up an experiment to compare the two. They will conclude that something must be different about the two pennies, and they could engage in argument about what the difference could be due to. This might provide an interesting extension activity for some students.

2. Instead of setting up the control experiment for Activity 8.1 yourself, one of the groups or each group can set up a control experiment. To do this, you will need additional materials. You could also have students discuss how they might set up a control and then use their ideas to develop a class procedure.

3. Have a student (or one student in each class) be responsible for taking a photo of one of the copper squares when they first set up the investigation, again at the end of the school day, then first thing the following morning. The photos will provide students with a sense of how the copper square changed over time.

Lesson 8

Does Acid Rain Make New Substances?

TEACHING THE LESSON

Performance Expectations

Students will

- conduct an investigation using data as evidence to explain why the Statue of Liberty and a piece of copper "turn green" in the rain.
- construct and use models (word equations, chemical formulas, molecular representations) to explain what happens at the molecular level in a chemical reaction.

Building Coherence

In this lesson, students investigate everyday chemical reactions to connect the science to their daily lives. Lesson 7 introduced various representations of chemical reactions; students use these representations to explore a new chemical reaction at the molecular level.

Timeframe

2–3 Class Periods

Overview

Activity 8.1
Investigate the effect of vinegar (acetic acid) on copper to simulate acid rain.

Activity 8.2
Examine properties of the substances to determine whether a chemical reaction occurred.

Activity 8.3
Discuss different representations of chemical reactions.

Safety

- Wear safety goggles during investigations.
- Wash hands after handling copper acetate in Activity 8.2. Although copper acetate is not harmful to touch, washing residue from hands will prevent accidental ingestion.
- To avoid spills and broken test tubes in Activity 8.2, you may wish to again demonstrate the procedure that you used in a previous solubility lesson. Do not allow students to shake test tubes with copper in them, as the test tubes may break.

Reading Follow Up

Review students' representations on the last page of Reading 7.1. One option is to provide a chemical equation with which students are likely familiar, and have them label the reactants and products and explain each. One student could identify and explain to a peer what the reactants are, and the peer could then identify and explain the products. Each could check and score the others' understanding. If they find themselves uncertain, they could refer to the reading to clarify. The goal is to give students an opportunity to articulate their understanding in the context of a familiar chemical reaction.

Introducing the Lesson

Direct the discussion to the molecular aspect of chemical reactions:

- What does it mean for substances to interact during a chemical reaction? What is going on at the molecular level? *(The atoms/molecules are rearranging.)*
- What is the difference between the reactants and products (different substances) at the molecular level? *(different arrangements of atoms)*

Read and discuss Reading 8.1, "Why Is the Statue of Liberty Green?" This sets the context for the lesson. The effect of acid rain on buildings, like the Statue of Liberty, happens over a long period of time, so investigating the effect takes time. Students may have studied the rock cycle and water cycle (IQWST ES1), for example, which are detailed processes; point out that it would take more time than it is possible for students to study in depth. To understand large-scale problems, scientists often investigate similar problems on a smaller scale in their labs by setting up a model of what is happening (stream table, IQWST ES1). You may have students recall and talk briefly about other IQWST models and how they were used. Review how a stream table works (IQWST ES1) to model how water shapes the earth. The stream table allowed students to model what happens over long periods of time in a way they could study in class.

Suggested Prompts

- When do scientists use models?
- Why do scientists use models? *(They use them to help describe, explain, and predict phenomena. Models are used to represent phenomena too large or too small to see unaided.)*
- How could we study the effect of something like acid rain?
- What components of the real world should be represented in the model? *(the substance that makes up the Statue of Liberty, the substance that makes rain acid)*
- How can we get something copper without trying to fit the Statue of Liberty in the classroom?
- How can we use acid water without collecting acid rain? *(Investigate the effect of the same type of acid on a copper substance or a different type of acid on a copper substance.)*

Students will investigate how one type of acid—vinegar—affects copper, similar to the effect of acid rain on the Statue of Liberty. The investigation involves a different type of acid, but the same copper substance. However, the effect happens more quickly, so students can examine the problem in the classroom. The effect takes one day, so set up the experiment today and observe the effects in the next class period.

Materials – Activity 8.1

For the Teacher
- materials for groups, except the distilled vinegar
- 10mL tap water*

For Each Group
- (2) copper squares
- 10mL distilled vinegar* (store-bought; acetic acid diluted with water)
- (1) Petri dish (preferably plastic)
- (1) clear plastic cup (circumference of its rim needs to fit inside the Petri dish)
- clay, putty, or similar material (about the size of a large grape)
- label or tape*

For Each Student
- Activity Sheet 8.1
- Reading 8.1

*This item is not included in the kit.

Activity 8.1 – How Can I Investigate Acid Rain in My Classroom?

Use Activity Sheet 8.1 to set up the investigation. Discuss the importance of a control in this experiment. As groups set up, you should follow the same procedure except with tap water instead of vinegar, to demonstrate that the reaction is due to acid and not water.

Suggested Prompts
- How can we tell that the acid is responsible for the reaction and not just water?
- What kind of control do we need? *(a control with water instead of vinegar)*

Encourage students to use information from the reading in making their predictions on the activity sheet.

Discussion of Prediction Question on the Activity Sheet

Prompt students to think about what the vinegar (acid) will do to the copper. Have students observe the liquid by wafting the air near the liquid in order to smell the vinegar. Relate their ability to smell the liquid to their previous experiences with the IQWST IC1 unit. Being able to smell the vinegar is a sign of the vinegar evaporating quickly. Let them know that because vinegar evaporates so quickly, they will use the upside-down cup to trap the vinegar vapor inside. The vinegar vapor inside the cup is similar to acid rain in the air.

It is not necessary that students recognize that the interaction of copper and acid is a chemical reaction. Students will gather evidence to determine whether or not the interaction is a chemical reaction in Activity 8.2. Students will evaluate their predictions when they examine the results of their experiment in the following class period.

Introducing Reading 8.1 – Why Is the Statue of Liberty Green?

Let students know what you would like them to be able to talk about in the next class period, so they have a purpose and focus for their reading.

Materials – Activity 8.2

For Each Group
- experimental setup from Activity 8.1
- (1) copper square (in addition to copper squares from Activity 8.1)
- 30mL warm tap water*
- (2) large test tubes
- (2) stoppers
- (1) test tube rack
- label or tape*

For Each Student
- Activity Sheet 8.2
- Reading 8.2

*This item is not included in the kit.

Activity 8.2 – Does Acid Rain Make New Substances?

Reading Follow Up

Follow up with ideas you determined before assigning the reading.

Students will now determine whether a chemical reaction occurred in the experiment. Review Safety Guidelines for Activity 8.2. Students perform a solubility test in their investigation and review the appropriate method for doing so, as you demonstrated in previous lessons.

Students determine the color, hardness, and solubility in water of both a copper square before the experiment and the solid on the copper square after the experiment. However, data about the density and melting point of the two solids are given to them, as are the properties of vinegar.

Have groups observe the control experiment, if only one was set up during Activity 8.1.

Suggested Prompts
- What do you observe about the combination of a copper square and water?
- Is the effect in the experiment due to water? How do you know? *(The copper square looks the same as it did before you combined it with water. The effect in the experiment is not due to water.)*

Discussion of Investigation

Create a table similar to the following one to review students' results.

		PROPERTIES				
		Color	Hardness	Solubility in Water	Density	Melting Point
Before Experiment "Old Substances"	Copper Square	Bronze	Very hard	Not soluble	8.96 g/cm^3	1084°C
	Vinegar	No color	Liquid	Soluble	1.04 g/cm^3	17°C
After Experiment "New Substances"	Solid on copper square after experiment	Green	Soft solid	Soluble	1.88 g/cm^3	115°C

Discuss the conclusion questions, and review students' scientific arguments. Arguments should indicate that a reaction did occur because the properties of the substances before the reaction are different from the properties of the substances after the reaction.

Write the following equation on the board

old substances	interact/react to form	new substances,
copper + vinegar	→	copper acetate + hydrogen gas
reactants	→	products

Students should keep their experiment setup for the next activity, in which they create molecular representations of the reaction.

By the end of the activity, students should recognize that combining copper with vinegar is a chemical reaction because the substances they started with (copper and vinegar) are different from the substances observed after 24 hours (copper acetate). Students can tell the substances are different because the properties are different.

Introducing Reading 8.2 – Does Acid Rain Make New Substances?

Ask: "Has anyone ever heard of getting green hair from swimming?" Students are going to read about that—and about how it relates to what they are doing in class. The reading also contains explanations for students to critique. These will be the focus of discussion in the next part of the lesson.

Materials – Activity 8.3

For Each Group

- illustrations of marshmallow models: copper (Cu), vinegar (CH_3COOH), copper acetate, $Cu(CH_3COO)_2$

For Each Student

- Activity Sheet 8.3
- Reading 8.3
- marshmallows or Styrofoam balls to represent atoms* [4 different-colored marshmallows are needed to represent each element for a total of 17 marshmallows: 1 copper atom (Cu), 4 carbon atoms (C), 8 hydrogen atoms (H), and 4 oxygen atoms (O)]
- toothpicks to serve as chemical connections for joining the atoms

Activity 8.3 – Representing Chemical Reactions in Words and Symbols

Reading Follow Up

Review students' ideas for improving their arguments. This activity could take as much or as little time as you deem necessary for your students' understanding of writing good scientific explanations and arguments. Be sure suggestions for improvement are detailed and supported. *(Not, "this one should have more evidence," but "this one should tell which properties are different, like solubility in alcohol, melting point, and density because if the properties are different, the substances have to be different; you cannot just say the properties are different without using data that show that they are different.")*

Description of Substances:	Metallic Orange Solid/ Copper Square	and	Clear Liquid/ Vinegar	Interact to Produce or Go to Form	Green Solid	and	Clear, Colorless Gas
Names of Substances:	Copper (solid)	+	Acetic Acid (liquid)		Copper Acetate (solid)	+	Hydrogen (gas)
Chemical Formula of Substances:	Cu (s)	+	$2CH_3COOH$ (l)		$Cu(CH_3COO)_2$ (s)	+	H_2 (g)

Discussion – Connecting
Purpose

Explore different models (word equations, formulas, and molecular representations) that can be used to explain what occurred in the chemical reaction in this investigation.

Suggested Prompts

- What did we have before the change occurred?
- What did you observe about the copper and the vinegar?

Record students' descriptions on the board in a format similar to the table. Be sure to write the word *equation* of the reaction below the descriptions. While discussing the chemical formula of the substances, first focus on the beginning equation of the chemical reaction (the reactants and the arrow). Ask students questions about what they observed, similar to the questions asked about the burning magnesium reaction.

Suggested Prompts

- How might we represent copper?
- What is in copper, what is it made of?
- What types of atoms make up a sample of copper?

Ask similar questions for vinegar (acetic acid) and write the chemical formula of the reactants in a format similar to in the table. Explain that the formula CH_3COOH represents not only the type of atoms that make up the molecules, but also the specific arrangement, which is typical to vinegar. Direct students to the right side of the arrow, and continue the discussion.

Suggested Prompts

- What is new?
- Notice that the green stuff is covering the copper square, but it is not in the air. Where did that green substance come from? It is not on the cup; it is not in the vinegar. What might this tell you?
- What might be a component of the new green stuff and how can it be represented?

Write the molecular formula of copper acetate $CH_3COO\text{-}Cu\text{-}OOCCH_3$ or $Cu(CH_3COO)_2$. Show students that they have just made a chemical equation that represents a chemical reaction. The chemical formula shows the number and types of atoms in each substance. The numbers before each molecular formula (coefficients) show how many of the models would need to be used to make the chemical reaction work. The symbols tell what types of atoms (elements) are in the substance, and the subscript numbers tell how many atoms of that specific element are in the substance.

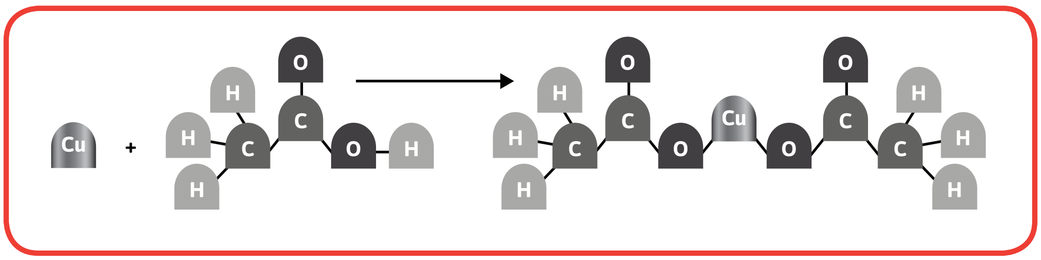
As with the burning magnesium reaction, students can use the symbols to describe the chemical reaction.

- What do the plus signs and the arrows represent? *(The plus sign means an interaction. The arrow represents a change that occurred from the beginning to the end of the reaction. The arrow can represent the phrase* interact, *which produces or forms. So if we look at the equation we can say, "Two substances, copper and acetic acid, come together or interact/react to form copper acetate, which is a new substance.")*
- What are the reactants and products in this reaction?
- What makes something a reactant and what makes something a product? *(Copper and vinegar are the reactants. A reactant is a substance that you start with before the change occurred, and they are the materials that react with each other. The copper acetate is the product. A product is the new substance that is produced from the interaction of the old substances.)*

Using their knowledge of the particle nature of matter and working with molecular models (ball-and-stick models) of the substances will help students understand what happens when the substances interact.

Draw molecular representations (ball-and-stick model) of copper (Cu) and acetic acid (CH_3COOH) under the chemical formulas. Show students that the copper metal is only made up of copper atoms, and show how the atoms of the acetic acid model match up with its molecular formula. (The H_3 tells us that the three hydrogen atoms are connected to the carbon, and that there are two carbon atoms, two oxygen atoms, and another hydrogen atom connected to one of the oxygen atoms.)

Remind students that although one atom of copper and two molecules of vinegar are represented, the number of actual particles taking part in the chemical reaction is huge—millions and millions.



Representing Chemical Reactions: Ball-and-Stick Models

Students construct marshmallow models and use them to explain what happens to copper atoms and vinegar molecules as the substances interact, and why and how copper acetate is made during the reaction.

To get a better idea of the atoms and molecules from substances reacting with each other, have students imagine two or three people walking up to each other, shaking hands, and then walking away. Then imagine if everyone in the world was in one small space, and they would be walking up to each other shaking hands and walking away toward other people to shake hands. Although we can focus on only two or three models, we are actually talking about this interaction occurring with trillions of atoms and molecules.

Remind students of the demonstration performed with the magnesium and oxygen reaction to produce magnesium oxide. Students will use a similar process to make their product from the copper and vinegar reaction.

Provide each group with Activity Sheet 8.3 and 17 marshmallows of four different colors. Have students choose a color to represent each of the elements.

Discussion – Pressing for Understanding

Purpose

Help students understand the meaning of the two remaining hydrogen atoms.

Suggested Prompts

- What is the difference between your model of copper and your model of acetic acid?
- What does each marshmallow represent?
- How many types of atoms are in one acetic acid molecule?

Conclude this discussion by reviewing the results of the investigation. Question 8 asks students about the two atoms of hydrogen. Discuss not only that hydrogen gas was formed, but also what might be some ways to test whether hydrogen gas was made. If students think that H_2 is formed from the chemical reaction, and if they let this reaction go on and on, how could they tell if H_2 was made? *(Students might say they need to collect the gas and test its properties.)*

It is important to explain that the same type of atoms present in the reactants are present in the products. In a chemical reaction, atoms are neither created nor destroyed. The atoms are rearranged into something new.

Wrapping Up the Lesson

☑ Students should have a basic understanding of a chemical reaction both in terms of the macroscopic phenomena and in terms of the atoms combining in new ways. These ideas will be revisited and explored in more depth over the course of the second learning set.

Conclude by emphasizing what students learned thus far and updating the Driving Question Board:

- Add to Scientific Principles list: A chemical reaction is a process in which two or more substances interact and and their atoms combine in new ways to form new substances with properties different from those of the old substances.
- The new substances are made of the same atoms as the old substances, but the atoms are arranged in new ways.
- The old substances at the beginning of the reaction are called reactants and the new substances are called products.
- Although reactants and products are different molecules or groups of atoms, the types of atoms before and after a reaction stay the same.
- The atoms have just recombined or come together in new ways to make new molecules or new groups of atoms.
- Atoms are not destroyed; they are just rearranged.
- We can represent chemical reactions using molecular representations, word equations, and chemical formulas.

Suggested Prompts

- How do the copper square and vinegar reaction and this modeling activity relate to the Driving Question: How can I make new substances from old substances? *(New substances are made from old substances through chemical reactions. A chemical reaction is when one substance breaks down, or two or more substances interact and their atoms combine in new ways to form new substances with different properties from the old substances. This recombination of atoms is necessary to make new substances.)*
- How does this new definition of a chemical reaction relate back to the fairy tale about making straw from gold? *(Straw cannot be made into gold because straw is made of different atoms than gold. There are no gold atoms in straw. Atoms cannot be created or destroyed. Atoms can only be rearranged to make new combinations. Since there are no gold atoms in straw, it cannot be used to make gold.)*

Explain that students have defined a chemical reaction as a process in which two or more substances interact and their atoms combine in new ways to form new substances with different properties from the old substances. Try to get students to think about other possible reactions.

- Do you think a chemical reaction always needs two or more substances (or reactants)?
- Do you think one substance can break down into something new?
- Can one substance be rearranged into two different substances?
- Can the atoms of one substance break apart into something new?

Let students know that in the next lesson they will explore whether or not one substance can break down into something new and refine the definition of a chemical reaction.

Introducing Reading 8.3 – What Are the Many Ways of Representing Any Chemical Reaction?

The emphasis is on different ways of representing a chemical reaction. Students may be helped by reinforcing that these are, in fact, different ways of representing the same reaction. Suggest that as students read, they look back and forth between the section they read and the diagram below it. Movement between text and visual representation is often difficult for students. If time permits, spend more time on this reading skill that is very important in science by reading aloud and modeling for students your own process. Different representations might be helpful for different reasons. This reading also reinforces a common standardized test–related topic that burning is always a chemical reaction.

LESSON 9

Is This a New Substance?

PREPARATION

Teacher Background Knowledge

Flame Test

- Students might be familiar with flame tests (IQWST IC1) if they have observed different gases and identified gases based on their properties, one of which is how the gas reacts during a flame test.
- In oxygen, the match should burn brightly until the oxygen is depleted. In hydrogen, the students should hear a popping sound.
- Hydrogen gas has twice the amount of hydrogen as the oxygen gas since there are two hydrogen atoms for each oxygen atom for every molecule of water.

Note: The sulfuric acid is not a reactant in electrolysis but rather it is a catalyst. It allows the chemical reaction to go faster without being part of the reaction.

Setup

1. Build one marshmallow representation of a water molecule.
2. Cut paper into small squares, roughly 2-inches by 2-inches (2–4 per group).

Materials – Activity 9.1

For Each Group
- 300mL of water*
- 50mL of 1M sulfuric acid
- (1) 500mL beaker
- (1) stirring rod
- (2) test tubes
- (2) rubber stoppers
- (2) electrodes (each shaped into a hook at one end)
- (2) wires with alligator clamps
- (3) 9-volt batteries
- (2+) matches*
- (1) ring stand
- (2) test tube clamps
- tape*

For Each Student
- marshmallows* (4 of one color, 2 of a second color—to build 2 molecules of water)
- toothpicks
- Activity Sheet 9.1
- Reading 9.1

*This item is not included in the kit.

⚠ Safety Guidelines

Use wooden matches from a box because they are longer than matchbook matches and will enable students to keep their hands farther away from the test tubes.

Differentiation Opportunities

Refer to IQWST Overview.

Lesson 9

Is This a New Substance?

TEACHING THE LESSON

Performance Expectations

Students will

- carry out an investigation to determine whether a single substance can undergo a chemical reaction.
- analyze data and use it as evidence to support an argument that a chemical reaction can also occur when only one reactant's atoms rearrange into two products.

Building Coherence

The lesson builds on prior experiences of chemical reactions and phase changes, demonstrating that chemical reactions do not always have multiple reactants; one substance can break down into new substances through a chemical reaction, as well.

Timeframe

2 Class Periods

Overview

Activity 9.1

- Investigate electrolysis—one substance undergoing a chemical reaction to become two new substances.
- Build molecular representations of the chemical reaction.
- Compare boiling and electrolysis; describe how the same substance can behave differently under different conditions.

Safety

- Wear safety goggles.
- Wash hands following the lesson.
- Be careful with matches and be sure they are fully extinguished before throwing away.
- Students should sit down when conducting the flame test. They should keep the test tubes in a test tube rack. The results may surprise students, and they could drop the test tubes.
- Students should not touch the electrodes, alligator clamps, or batteries when setup is complete and running.
- Students should avoid touching batteries with their tongues. If using three 9V batteries for the experiment, 27V could provide students with a jolt.

Reading Follow Up

Ask students what they have learned about chemical reactions and what counts as evidence for a chemical reaction in the previous lesson. (*A chemical reaction is a process in which two or more substances interact and their atoms combine in new ways to form new substances. Evidence that a chemical reaction has occurred can include a change in properties of substances or an indicator, such as bubbles.)*

To reinforce that burning is always a chemical reaction, you might follow up by asking about burning in another context (burning wood in a campfire or in a fireplace, or holding a marshmallow over the fire so long that it burns).

Introducing the Lesson

At the end of the last lesson, students were asked to think about whether or not a chemical reaction needs two reactants. Can one substance be broken down into something new? Can one substance be rearranged into two or more different substances? Discuss students' ideas.

Materials – Activity 9.1

For the Teacher
- (1) splint for flame test

For Each Group
- 300mL of water*
- 50mL of 1M sulfuric acid
- (1) 500mL beaker
- (1) stirring rod
- (2) test tubes
- (2) rubber stoppers
- (2) electrodes (each shaped into a hook at one end)
- (2) wires with alligator clamps
- (3) 9-volt batteries
- (2+) matches*
- (1) ring stand
- (2) test tube clamps
- tape*

For Each Student
- marshmallows* (4 of one color, 2 of a second color—to build 2 molecules of water)
- toothpicks
- Activity Sheet 9.1
- Reading 9.1

*This item is not included in the kit.

Activity 9.1 – Does Electrolysis of Water Make New Substances?

Introducing Reading 9.1 – What Is the Same and Different about Boiling Water and Electrolysis?

Review what students learned about phase changes in the previous IQWST Introduction to Chemistry unit. Students learned that energy must be added to a substance so that it can undergo a phase change. For example, in order for liquid water to become gaseous water, energy from a hot plate was transferred to the water. Energy was first used to heat the water to 100°C; then energy caused the water in the liquid state to change phases to a gaseous state. Energy was needed to overcome the attractiveness of one water molecule to other water molecules. (There is no need to go into detail about the atoms or molecules. This will be done in the reading.)

Ask students what they think the word *electrolysis* means. Write the word on the board to separate it so that students can think about *electr-* as in electricity, and *-lysis* (which means to break apart). *(Electrolysis means to break apart by electricity.)*

Electrolysis involves sending electricity (an electrical current) through a substance to break it apart. Instead of using a hot plate to supply energy to water to cause it to boil, as students may have done in previous chemistry study, they are going to use batteries and send an electric current through water. The students will investigate the electrolysis of water by sending an electric current through water and observing what happens.

Direct students to Activity 9.1. Read the opening section with students and have students write their predictions. This experiment can be tricky. First demonstrate how to set up and conduct the experiment. Explain the steps in the procedure to students as you perform them. Refer to the activity sheet for a diagram of the apparatus. You will also need to demonstrate how to remove the test tubes from the water after the experiment. You may choose to do this as part of the following demonstration or you may do this after the completion of the experiment.

Teacher Demonstration of Electrolysis of Water: Procedure

1. Pour 300mL water into a 500mL beaker.
2. Completely fill a test tube with water. Place 2-inch by 2-inch paper over the mouth of the test tube and tap until secure. Invert the test tube. (It should stay full of water.) Submerge the test tube in the water in the 500 mL beaker. (The paper should fall off and can be removed.)
3. Slowly raise the test tube, keeping its open end underwater and making sure it remains completely filled with water. (There should be no air in the test tube.)
4. Attach a test tube clamp to the test tube. Hold the test tube in place by attaching the clamp to the ring stand. (Note: This step can be removed and the test tubes can rest against the sides of the beaker while sitting on the bottom. It means less equipment and takes less time.)
5. Repeat Steps 2–4 for the second test tube. Make sure that the two test tubes end up held in place at even heights and at least 2 inches apart in the beaker.
6. Lower an electrode into the water and hook it under one of the test tubes (use electrodes that are shaped into a hook at one end). You may need to hold the electrode in place by taping it to the exposed part of the test tube.
7. Repeat Step 6 for the other test tube and electrode.
8. Attach the exposed ends of the two electrodes to different alligator clamps. Note that the other ends of the alligator clamps should not yet be attached to the battery.
9. Add 50mL of 1M sulfuric acid. Stir the mixture with the stirring rod.

Tell students that they will set up the equipment the same way that you did.

- This activity could be performed only as a teacher demonstration. However, it would be advisable to set up two demonstrations. There is always the possibility, whether this be done as a demonstration or in student groups, due to experimental error, that the oxygen and hydrogen gases will escape during the procedure to remove the test tubes.
- A video of the electrolysis of water is available. The video could be watched instead of the demonstration or in addition, but it is recommended as a supplement rather than a replacement for the investigation in class.

Have students complete the observations in the *Before Electrolysis* column of the Data Table on Activity Sheet 9.1. Have students set up the experiment. Check groups' setup before they connect the batteries.

Have students start the electrolysis by connecting the alligator clamps to the batteries. By connecting three 9-volt batteries together, the experiment will go faster. Hydrogen and oxygen gas will collect in the test tubes. Allow the experiment to run for at least 10 minutes or until there are one to two inches of gas produced. The experiment can run longer. However, if multiple classes are using the batteries, you will want to ensure that the batteries are not dead for later classes.

Students should record observations in the *During Electrolysis* column of the Data Table.

Procedure to Remove Test Tubes from the Water

1. Drop the two rubber stoppers for test tubes into the beaker of water and let them fall to the bottom of the beaker.
2. Push one test tube on top of one rubber stopper. Make sure the stopper is secure so the test tube is pulled out and the gas does not escape. Repeat with the second test tube.
3. Turn the test tubes right side up. Put them into a test tube rack.

Students should record observations in the *After Electrolysis* column of the Data Table. Once all groups have the tubes in the test tube racks, they are ready for flame tests with matches.

Procedure for Flame Tests

Conduct the flame tests as an entire class. It is likely that some groups may not have oxygen or hydrogen left in their tubes; the gases may have escaped due to experimental error when students tried to cork and turn their test tubes right side up. All students will experience the results if the flame test is done as a demonstration. You may also want to light the match, and have a student pull out the cork at your direction. This will help the timing and the results.

Two tests will be used; one test will be a burning match, and another will be a glowing match or splint. (Note: Wood coffee stirrers make good splints.)

1. Light a match and put it near the test tube.
2. Ask a student to pull the stopper out of one of the test tubes and place the lit match above it.
3. Repeat with the second test tube.
4. For the next group, light a match, but blow it out. The tip of the match should still be glowing.
5. Ask a student to pull the stopper out of one of the test tubes and place the lit match above it.
6. Repeat with the second test tube.

Ask students if they see a pattern. The test tube with more gas pops and the test tube with less gas glows brighter. Once this pattern is established, you may want to simply put the lit match in the test tube with more gas and a glowing splint in the other test tube with less gas.

- You may want students to do the flame tests in groups.
- Split the class in half; half the groups will use a burning match and half will use a glowing match.
- Light a match. Tell the burning-match students they should then pull the stopper out of one of the test tubes and place the lit match above it. They will then repeat the same procedure with the second test tube.
- Blow out the match. The tip of the match should still be glowing. Tell the glowing-match students they should then pull the stopper out of one of the test tubes and place the glowing match above it. They will then repeat the same procedure with the second test tube.

Making Sense of Electrolysis

Have students share their observations before, during, and after electrolysis.

- Before electrolysis: There is a clear liquid in both test tubes (water).
- During electrolysis: Bubbles appear at the ends of each electrode and go to the top of the test tubes. There are more bubbles on one electrode than on the other.
- After electrolysis: Both test tubes contain clear gases. One test tube has twice as much gas as the other test tube.
- Flame tests; after electrolysis:

    - o Burning match – burns brighter in the test tube with less gas (oxygen) and should make a pop sound in the test tube with twice as much gas (hydrogen).
    - o Glowing match – should not do anything in the test tube with twice as much gas (hydrogen) and should glow brighter, and in some cases relight, in the test tube with the less gas (oxygen).
    - o At this time, do not identify the two gases as hydrogen and oxygen. Some students might say one is oxygen and one is hydrogen. If they do, ask what their evidence is and let them know that you will be exploring this. Remember to refer back to their ideas in subsequent discussion.

Suggested Prompts

- Do you think new substances were made? *(We started with a clear liquid. Now there are two new gases. The gases are different from each other because one is twice as much as the other and they had different results for the flame tests.)*
- Do these substances have different properties from the original substance? *(We know that gases are less dense than water. That is why they rise.)*

Some students may think that new substances were not made—that there was a phase change and the gas is water vapor.

- How do we know that the gases are not water vapor? Do we have evidence to suggest that what happened was not a phase change? *(When we did the flame test, one of the test tubes popped and the other glowed more brightly. If the gas were water vapor, nothing would have happened and perhaps the burning match would go out. Another piece of evidence is that there were two different amounts of gas in the test tubes.)*
- If new substances were made and they have different properties from the original substance—water—did a chemical reaction occur even though there was only one reactant? What does this mean? *(Yes, a chemical reaction did occur. It means that*

chemical reactions can occur with only one reactant.)

- If the gases are not water vapor, then what do you think the two new gases are and where do you think they came from?

In order to explore these questions, tell students that they are going to build molecular models of the electrolysis process using marshmallows and toothpicks. Show students a marshmallow model of water. Draw a model on the board. Ask students what atoms are in the water and how many of each atom make up one water molecule. . *(Hydrogen and oxygen atoms are in water; two hydrogen atoms and one oxygen atom are in every water molecule.)*

Direct students to draw a molecular representation of a water molecule in the space provided on the bottom of Activity 9.1 in Question 2. Have students follow the instructions to complete the marshmallow model activity. Ask students to determine what the gases are. Move from group to group and ask students to tell (1) what the gases are, and (2) why they think those are the gases.

Ask: "What gases do you think were produced during electrolysis and why do you think this?" *(Hydrogen and oxygen atoms are present in water molecules. Maybe the gases in the tubes are hydrogen and oxygen gases. Water is made of hydrogen and oxygen, so if it broke down only hydrogen and oxygen could be present.)*

Discussion – Pressing for Understanding

Purpose

Understand that the electrolysis of water is a chemical reaction because the atoms of water were rearranged into something new.

Suggested Prompts

- What did you start with before the electrolysis of water? *(water)*
- What did you end up with after the electrolysis of water? *(After electrolysis, we had hydrogen and oxygen gases.)*
- Was what you ended up with a new substance or substances? *(These two gases are new substances.)*
- Did a chemical reaction take place? How can you tell? *(A chemical reaction did take place because the atoms of water were rearranged into something new—hydrogen and oxygen gas.)*
- Did you observe any signs of a chemical reaction? *(The molecules of water were broken down during electrolysis, which is a chemical reaction.)*

The substances after electrolysis are different from the substance before electrolysis. Before electrolysis, we had a clear liquid—water. After electrolysis, we had a clear gas and a liquid in each of the test tubes. The two test tubes contained different gases because one had twice as much as the other and they had different results with the matches. A chemical reaction did occur because electrolysis resulted in new substances with new properties.

Water is made of hydrogen and oxygen—H_2O. The electricity causes the water to split into hydrogen and oxygen. Electrolysis is a chemical reaction because it created two gases from water.

Wrapping Up the Lesson

Have students complete Reading 9.1 before they write the explanation at the end of the activity sheet and before you wrap up this lesson. Discuss questions students have after reading. Include a comparison of boiling and electrolysis as beginning with the same substance—water—but with different results. One (boiling) results in the same substance and the other (electrolysis) results in different substances.

Revise the class definition of a chemical reaction:

- Add to the Scientific Principles list: A chemical reaction is the process of one substance breaking down, or two or more substances interacting, and their atoms combining in new ways to form new substances with different properties from the old substances.
- The new substances are made of the same atoms as the old substance, but the atoms are arranged in new ways.
- Although the reactants and products are different molecules, or groups of atoms, the types of atoms before and after a reaction stay the same.
- The atoms have broken down or rearranged in new ways to make new molecules or new groups of atoms.
- Atoms are not destroyed; they are just rearranged.

Have students complete the conclusion question in Activity 9.1 using ideas from the activity, the reading, and the class discussion.

☑

- Students should understand that electrolysis is a chemical reaction.
- Students should understand how boiling and electrolysis differ.

Lesson 10

How Is a Mixture Different from a Chemical Reaction?

PREPARATION

Teacher Background Knowledge

Substances and Mixtures

One way to decide whether substances interact to form new substances is to try to separate the substances you combined. If you cannot separate something into its original substances, then the substances interacted to form new substances through a chemical reaction. This is critical. Often, a mixture can have different properties from the substances. For instance, 14k gold is not as soft as 24k gold (which is pure gold). Recall that 14k gold is a mixture of silver, copper, and gold. What you do know is that 14k gold is not pure gold because it has different properties. However, different properties cannot necessarily tell you if a chemical reaction occurred. If you can separate the combination into the original substances using a process that is not a chemical reaction, then the combination was a mixture of substances and the molecules did not rearrange. For example, after combining the oil and vinegar, the original substances, oil and vinegar, could be separated by just letting the container sit.

Common Student Ideas

- Students have less difficulty recognizing heterogeneous mixtures (oil and vinegar salad dressing) than homogeneous mixtures (drink mixture). They may have a difficult time recognizing that the combination of powdered drink mix and water is a mixture of substances and not a single substance.
- Reviewing mixtures (IQWST IC1) may be helpful. A mixture contains more than one type of material or more than one type of molecule. Air is a mixture of O_2, CO_2, N_2, water vapor, and odors.

Setup

Combine oil and vinegar in a clear container with a cover. The materials need to be in two distinct layers to begin the demonstration.

Assemble the rubber stoppers with glass tubing for students. Cut the glass tubing (using a glass tube cutter, knife, razor blade, or file) and insert it into the stoppers. Using water or an oil rubbed on the tube as a lubricant will help it slide into the rubber stopper more easily. Be sure to use a cloth towel to insert the tube in case of breakage.

To use a file, scratch tubing where you want it to break. Wrap the tubing with a towel. Hold the wrapped tube in your hands with the scratch on the tubing facing outward. Apply gentle pressure with your thumbs at the back of the tube where you made the scratch. The tube should break easily.

Safety Guidelines

Refer to IQWST Overview.

Differentiation Opportunities

Refer to IQWST Overview.

Lesson 10

How Is a Mixture Different from a Chemical Reaction?

TEACHING THE LESSON

Performance Expectation

Students will carry out an investigation and use data as evidence to argue whether combining drink mix and water is a chemical reaction.

Overview

Activity 10.1

Investigate powdered drink mix by mixing, boiling, condensing, and separating it into water and powder again to compare processes on both the macro- and molecular levels.

Building Coherence

Students build on and extend their understanding of chemical reactions, phase changes, and mixtures by engaging in activities that support differentiating among them.

Timeframe

2–3 Class Periods

Safety

- Wear safety goggles.
- Remind students to treat hot plates like hot stoves.
- Keep cords and papers away from the hot plate.
- Do not taste anything in the lab, including the drink solution, due to possible contamination.

Introducing the Lesson

Students should understand that

- boiling is a phase change (liquid to gas) and not a chemical reaction, and
- a chemical reaction can occur with one, two, or more reactants.

Sometimes, substances are put together that do not interact to form new substances (chemical reaction) but instead create a mixture (always more than one type of substance). Show a bottle of oil-and-vinegar salad dressing, or pour oil and vinegar into a covered glass container. Ask: "What do you notice? What do you expect to happen when I shake the container?

Explain your ideas." Shake. Then ask: "Do you think what we see here is a new substance? What data could we collect to determine whether this was a chemical reaction?" *(Test properties of the substances before and after shaking the bottle.)*

Oil and vinegar is a mixture. In a mixture, the substances do not interact to form new substances. The same substances are still there. The atoms and molecules have not changed.

Materials – Activity 10.1

For the Teacher

- oil*
- vinegar*
- (1) clear container with lid

For Each Group

- 1tsp powdered drink mix (red or purple)
- 100mL water*
- (1) 100mL graduated cylinder
- (1) balance (electronic recommended)
- (1) calculator*
- (2) 250mL Erlenmeyer flasks
- (1) rubber stopper with hole (#7 for 250mL Erlenmeyer flask)
- (1) 5mm glass tubing for rubber stopper
- (1) rubber hose (must fit securely on glass tubing)
- (1) hot plate
- (1) ring stand
- (1) ring clamp
- (1) ice bath* (container of ice water, large enough to hold 250mL Erlenmeyer flask)
- tape*
- (1) coffee filter

For Each Student

- Activity Sheet 10.1
- Reading 10.1

*This item is not included in the kit.

Activity 10.1 – Do I Always Make New Substances When I Put Substances Together?

Students investigate whether combining powdered drink mix and water is a chemical reaction. Students should read the procedure on Activity Sheet 10.1 and then record their predictions.

Emphasize use of only 50mL of drink solution in Flask 1 because students need to boil off all the liquid in one class period. Remind them not to put a stopper into Flask 2; this can cause pressure to build up in the flask. Pay careful attention to Flask 1, so the contents do not burn. After boiling the drink solution, wait until Flask 1 is cool enough to touch before pouring its contents onto filter paper.

Have students write predictions for the investigation by answering the two questions on the activity sheet. If students have difficulty with the predictions, review what they learned in Activity 9.1. Ask: "When you boil a liquid, how many substances are involved in the phase change? What do you think happens when you boil a mixture? Discuss predictions before completing the investigation."

Students should record data about substances before and after putting them together. Remind students to measure densities at the same temperature.

Discussion – Summarizing

Purpose

Share and compare results.

Ask students for the results of their investigation. Students may have some difficulty calculating accurate density data. On the board, record each group's density data before boiling and after the experiment. Then use the classes' data to point out that the density range is the same before and after the experiment. Discuss experimental error as well. Because temperature affects density, the densities need to be measured at the same temperature; the density of a substance changes with temperature. Help students recall that as temperature increases, molecules move faster and increase the distance between adjoining molecules.

Discuss the data interpretation for the investigation. If students have difficulty answering the question, remind them to evaluate the predictions they wrote. Ask them to think about the following questions.

- What were your observations of the drink solution in Flask 1?
- When you boiled and condensed the liquid, what did you collect in Flask 2?
- What did you predict that you would collect in Flask 2?

Discuss the conclusion questions for the investigation. If students have difficulty answering the question, ask them to think about the following questions.

- What does powdered drink mix contain?
- Does it contain more than one substance?
- What did you learn in previous lessons about the properties of a mixture of substances?

One way to decide whether substances interact to form new substances or make a mixture is to attempt to separate the substances. In this investigation, students boiled and condensed a combination of powdered drink mix and water. They determined that the liquid substances before and after combining and separating were the same because they had the same properties. Since the substances before and after combining and separating were the same, a chemical reaction did not occur. The combination of powdered drink mix and water was a mixture of substances that you were able to separate back into the original substances.

As part of their homework, students will do a similar experiment at home.

Students might remember the difference between chemical reactions, mixing, and phase changes by, "In a chemical change, the atoms rearrange."

Wrapping Up the Lesson

Discussion – Pressing for Understanding

Purpose

Understand the differences among phase change, mixture, and chemical reaction.

Suggested Prompts

- What processes can you use to make new substances? *(Chemical reactions make one or more new substances.)*
- What processes do not make new substances? *(Phase changes and mixing do not make new substances. A phase change involves one substance only. A mixture is a combination of two or more substances that do not interact.)*
- What data help you decide whether a process is a chemical reaction or not? *(properties of the substances before and after the process; determining whether we can separate new substances back into the old substances)*
- How do you know when you have made new substances from old substances? *(New stuff is new substances with new properties. Those new substances are made of new molecules.)*
- Why are phase changes not chemical reactions? *(It is the same substance before and after, just in different states—gas, liquid, or solid; molecular models show that the atoms do not combine in new ways; it is the same type of molecules before compared to after the change.)*
- Why are mixtures not chemical reactions? (*You do not have a new substance after mixing two substances together; it is the same molecules; you can separate the substances in a mixture and turn them back again.)*

Use the Internet to support students' understanding of phase change, and of mixing, by searching for related simulations and models.

Students should understand why phase changes and mixing are not chemical reactions. By the end of this lesson, add to the Scientific Principles list: "Phase changes and mixing do not make new substances" and "Atoms do not combine in new ways during a phase change or mixing."

To review, construct a table on the board similar to this, and complete as part of a class discussion.

Suggested Prompts

- What are examples of each of the processes? What observations did you make?
- What happens to the atoms/molecules during the processes?

PROCESS	PHASE CHANGE	MIXTURES	CHEMICAL REACTIONS
Example	water boiling	salad dressing, air	Mg burning, baggie reaction, copper square and vinegar, Statue of Liberty, electrolysis of water
What process did you explore today? Observations	bubbles, vapor, less liquid in the beaker	Two layers before shaking the bottle. The two layers separate out after leaving the bottle undisturbed.	light, color change, property changes, bubbles, temperature change
What happens to the atoms/molecules?	spread apart	mix together	rearrange
Did the atoms rearrange?	No	No	Yes

Explain to students that in the next lesson they will return to the original focus on two substances—soap and fat—and investigate whether they can make soap from fat through a chemical reaction.

Introducing Reading 10.1 – What Happens to Atoms and Molecules When I See Different Processes?

Reading 10.1 focuses on the difference between substances and mixtures, but at the molecular level. The Getting Ready section is a good way to have students begin thinking about what happens to atoms and molecules in a chemical reaction versus what happens to them in a mixture. The reading will help clarify their understanding. You might focus students' attention on the diagram on the second page, reading with them the section on salt water, but focusing your support on helping them to see how the text and the diagram work together. The multiple-choice question at the end of the reading asks them to make a choice and explain it, but also to choose one of the other answers and talk about it. Students may need guidance as to what the second question is asking them to do. This question provides an assessment opportunity.

Lesson 11

How Can I Make Soap from Fat?

PREPARATION

Teacher Background Knowledge

Making Soap

For each group, you will need to pour 20mL of sodium hydroxide solution into the small beaker already containing fat and rubbing alcohol. Remind students that sodium hydroxide is potentially harmful. If they splash it on themselves, they need to tell you right away.

For each group, you will need to pour their mixture (small beaker) into the salt solution (large container) because the small beaker is warm from the hot plate. Remind students not to stir the mixture.

Several minutes into the investigation, some students may observe that soap is starting to form in their beakers. Others may not see soap forming. These students may be concerned that their experiment was not successful. Remind students that they should not stir the mixture, regardless of what it may look like. Tell them that this is not unusual and that it takes about 24 hours for the soap to begin to form and harden.

Talk with students about safety while handling sodium hydroxide. It is the main ingredient in drain cleaners. You may wish to mention specific brands or bring in a bottle or advertisement to show students. If you bring in a bottle, you could have a student read the ingredients from the bottle.

Although the chemical reaction occurs between the fat and sodium hydroxide, students will be using other ingredients (salt, water, and rubbing alcohol) to help speed up the soap-making process. For example, rubbing alcohol is used to dissolve the fat.

Some students' chemical reaction may not work for a variety of reasons. Possible sources of error include the following: they may have measured one of the ingredients incorrectly, turned the hot plate too high, not stirred constantly when the beaker was on the hot plate, or stirred after they poured the product into the salt water. These students may respond, in Conclusion Question 1, that a chemical reaction did not occur.

Common Student Ideas

Some students may bring up different signs as evidence of a chemical reaction. While looking for a precipitate is valid evidence in this experiment, temperature change and bubbles cannot be used as evidence of a chemical reaction. Temperature change and bubbles cannot be used because they used an external heat source (the hot plate), similar to Lesson 10 where they investigated whether boiling is a chemical reaction. Since there is an external heat source, they cannot tell if the temperature increase and bubbles are caused by the heat source (phase change) or if they are caused by a chemical reaction. If they are just mixing substances without using a heat source, bubbles and temperature change can be used as evidence for a chemical reaction, but in this experiment they need to examine the properties.

Setup

Prepare cups containing table salt, water, fat, and rubbing alcohol for each group. Either prepare precise quantities, or provide materials and have students measure according to Activity Sheet 11.1 instructions. Alternatively, set up a table with all supplies and empty cups so that students can get their own materials.

The exception is sodium hydroxide. Do not provide students with sodium hydroxide in cups or leave sodium hydroxide on the table. Keep the substance and the solution away from students until it is needed. Students should not pour the sodium hydroxide.

Whole-Class Soap-Making Procedure

An alternative to having groups make soap is to have some components of this experiment done as a whole class. This could be done for reasons such as equipment shortage (e.g., not enough hot plates for each group to have one), or for time or safety concerns, at the teacher's discretion. One drawback to this method is that if one group measures ingredients incorrectly, the entire batch may be ruined. This could result in no soap forming, or in the reaction not going to completion.

The ability to make their own soap and compare results with peers' results is highly engaging for all students, and students feel ownership for their own experiment and its product.

- Each can make their own salt solution, and measure the fat and alcohol. Instead of groups heating the soap themselves, they can pour their measured fat and alcohol into one large beaker. Then you can add the appropriate amount of sodium hydroxide. (For example: five groups × 20mL = 100mL.) This large beaker will have to hold approximately 50mL for each group (20mL rubbing alcohol + 11g fat + 20mL sodium hydroxide). If you have six groups, you may want to use a 500mL beaker.
- After adding the sodium hydroxide, heat it as a demonstration, and have individuals stir. During this time, discuss what students have done so far. Suggested prompts:
    - When the salt and water were mixed, do you think a chemical reaction occurred? How do you know? Explain your ideas.
    - What about when the alcohol and fat were mixed, do you think a chemical reaction occurred? How do you know? Explain your ideas.
    - Is there a chemical reaction occurring as the fat, alcohol, and sodium hydroxide are heated?
    - How could we test whether a chemical reaction has occurred? Explain your ideas.
    - Explain that some reactions happen faster (like burning) while other reactions happen slower (like making soap).
- When the liquid turns slightly yellow, remove it from the heat. Then pour some of the liquid into each group's beaker with salt water.

Safety Guidelines

As Noted in Previous Section

Using Sodium Hydroxide (NaOH)

- Concentrated or solid sodium hydroxide can cause severe burns; therefore, the sodium hydroxide solution should not contact the skin or eyes. If the solution touches the skin or eyes, the area should be rinsed with water and a school nurse or medical personnel notified.
- Rubbing alcohol is a volatile and somewhat flammable liquid. Keep the rubbing alcohol away from heat, and do not inhale its fumes.
- Wear safety goggles and gloves at all times.
- Students should be reminded of safety precautions when using hot plates.

To dispose of sodium hydroxide solution, dilute it by pouring the solution into a beaker of ice water. After the sodium hydroxide is diluted, it can be poured and flushed down the drain.

Differentiation Opportunities

Options for Experiment

1. Prepare cups containing precise amounts of table salt, water, fat, and rubbing alcohol for each group.
2. Prepare cups containing materials, but have students measure according to Activity Sheet 11.1 instructions.
3. Set up a table with all supplies and empty cups so that students can get their own materials.
4. Set up stations with supplies and empty cups. Pre-prepare slips of paper with items to be measured and the quantity (or simply with item—"salt"—and have students use Activity Sheet 11.1 for the amount). Distribute slips as a way to assign students to materials collection using your discretion about ability to follow instructions, measure accurately, handle materials safely, etc.

As in any investigation, roles of measurer, mixer, stirrer, observations recorder, etc. may be assigned as appropriate for students' abilities, interests, and safety.

Additional Experiment: A Banana

To illustrate a simple chemical reaction, either in class or at home, have students observe an unripe banana every day for several days. As it ripens, the starch in a banana oxidizes and creates sugar (64% sucrose, 14% fructose, and 22% glucose) as a result of a chemical reaction. Students can explore the following properties to determine whether or not ripening of the banana is a chemical reaction:

Color: The inside of a ripe banana is pale yellow; the inside of an overripe banana is dark yellow.

Glucose content: Obtain test strips from a science supply company. Mix a small amount of unripe banana and the same amount of ripened banana each with a small amount of water. Test each using glucose test strips. As a banana ripens, the amount of glucose increases.

Taste test: An unripe banana tastes bitter; a ripened banana tastes sweet.

Lesson 11

How Can I Make Soap from Fat?

TEACHING THE LESSON

Performance Expectation

Students will carry out an investigation in which they collect data as evidence that a chemical reaction can turn surprising "old stuff" into "new stuff".

Overview

Activity 11.1
Combine old stuff (fat, sodium hydroxide) to make new stuff (soap).

Activity 11.2
Analyze data (properties) as evidence that a chemical reaction can turn fat used for cooking, and a material used for cleaning drains, into something people use to wash with.

Building Coherence

Students have learned about substances and their properties by investigating soap and fat. They will now combine fat and another substance to make their own soap, and will build on their knowledge of properties and the particle nature of matter as they examine the chemical reaction at the particle level.

Timeframe

2 Class Periods

Safety

- Sodium hydroxide solution (NaOH) is caustic. It can cause severe burns; therefore, the solution should not contact the skin or eyes. If contact occurs, the area should be rinsed with water and a school nurse or medical personnel notified.
- Rubbing alcohol is a volatile and somewhat flammable liquid. Keep the rubbing alcohol away from heat, and do not inhale its fumes.
- Wear safety goggles and gloves at all times.
- Remind students of safety precautions for using hot plates.
- To dispose of sodium hydroxide solution, dilute it by pouring the solution into a beaker of ice water. The solution can then be flushed down a drain.

Reading Follow Up

The multiple-choice question may be used to assess students' understanding of chemical reactions, phase changes, substances, and mixtures. If you did not do it in class, ask whether anyone did the at-home activity, and have students share what they found.

Introducing the Lesson

Students need to work quickly and efficiently to make soap in one class period. Alternatively, divide the investigation over 2 days. Day 1: measure the water, rubbing alcohol, salt, and fat, and review the procedure. Day 2: mix the materials and review the reading.

Materials – Activity 11.1

For Each Group

- (1) large plastic cup**
- 1) 150 mL beaker***
- (2) stirring rods or plastic spoons
- (1) hot plate
- (1) balance
- (1) graduated cylinder
- masking tape or markers* (so students can label their large container with their names)
- (4) paper cups or other containers for the salt, water, fat, and rubbing alcohol
- (2) coffee filters or paper cups to mass the salt and fat
- 50g table salt* (sodium chloride)
- 175mL water*
- 11g fat
- 20mL rubbing alcohol
- 20mL 6M sodium hydroxide solution
- (1) paper towel or paper plate*

For Each Student

- Activity Sheet 11.1
- Reading 11.1

*This item is not included in the kit.

**Note: Groups will leave their soap in this container until the next day. Consequently, if you have five class periods with six groups in each period, you will need 30 containers. A large, plastic disposable cup can be used instead of the beaker. The cup needs to be a relatively thick, high-quality plastic cup because the soap is basic when it is poured into the cup, and the solution can cause a thin cup to deteriorate. Do not use paper or Styrofoam. Also, it is preferable for the cup to be clear in order for students to see the soap form at the top of the salt solution.

***Note: This beaker does not have to be exactly 150mL. You need to have one small container and one large container.

Activity 11.1 – How Can I Make Soap from Fat?

Hold up some fat and soap. Remind students that you discussed on the first day of class: Do you think soap can be made from fat? Why? *(A chemical reaction would probably need to happen; fat would probably have to be mixed with something else to make it soapy; you would have to do something to it first, like mix in other things or cook it; some kind of fat can be used to make soap, but probably not cooking fat.)*

Students will begin the activity today, but will not be able to see the results until the next class period.

Suggested Prompts

- What do drain cleaners do? *(Drain cleaners break down anything that is stuck in a drain, like hair, dirt, and soap scum.)* What do you think drain cleaners might do to your skin or your clothes? *(Drain cleaners can burn skin or clothes. Gloves and goggles are important. If the sodium hydroxide solution splashes, students need to tell you immediately and rinse it off immediately.)*
- What do you think about mixing a liquid that cleans drains (sodium hydroxide) with something you use in cooking (fat), to make something you use to clean your body (soap)?
- Do you think this is surprising? Explain your ideas.
- What do you think would have to happen before mixing these things could result in making soap?

Use Activity Sheet 11.1 to review equipment students will need to conduct their experiments. Review Safety Guidelines and Procedure. The chemical reaction will only occur if measurements are precise. The reactants need to continue reacting overnight and will not be ready for observations until the following class period.

Introducing Reading 11.1 – Do People Really Make Soap from Fat?

Reading 11.1 tells a little about the way soap used to be made before factories started to make it. Some students may have a friend or family member who makes soap (often sold at craft shows). Students may want to learn how that process compares with what they did in your class or what colonists did long ago.

Activity 11.2 – Testing the Properties of Soap

Reading Follow Up

Discuss responses to the questions in the reading. Discuss similarities and differences between the way soap was historically made and how students made soap in class.

Although soap formed overnight, the chemical reaction is still occurring. Some reactions occur quickly, like the sandwich bag experiment (Lesson 6) or burning magnesium (Lesson 7), which took place in minutes. Other reactions take longer, like the copper square (Lesson 8). Others, like when a banana ripens, occur over several days. Others take years, like the Statue of Liberty took 20 years for the copper to react with acid rain to produce copper sulfate. Students' soap will take about a week to reach completion.

Students complete Activity Sheet 11.1 where they remove the soap from the salt water (Step 8) and complete the conclusion questions. Continue to wear gloves and goggles, as soap will have trace amounts of unreacted sodium hydroxide and fat for several days and should not get on hands.

During discussion, students may suggest that they need to test the properties of the soap to determine whether a new substance was made. This would be an ideal next step; however, the soap that they have just made has not completely formed. They probably noticed that when they rinsed their soap, it was very soft. Their soap is still in the process of forming because the chemical reaction is still occurring. Once the soap has completely formed, they will be able to measure its properties and even compare the properties of their homemade soap to those of commercially made soap. In about one week, they will return to their soap and test the properties.

Wrapping Up the Lesson

Students should understand the concept of chemical reactions both in terms of what is occurring at the macroscopic level and at the particulate level. Students should also understand that phase changes and mixtures are not chemical reactions and why.

Discussion – Pressing for Understanding

Purpose

Review core ideas in this learning set and update the Driving Question Board.

Suggested Prompts

- How can we now answer the subquestion: "How can I make new substances?"
- What are some examples of when new substances are made? *(rusting, burning, baking a cake, fireworks, ripening banana, cutting onions)*
- How can you tell when a chemical reaction has occurred? (*New substances are made*; *there are signs like a temperature change, gas/bubbles, and the formation of a precipitate*; *the properties of the substances change like color, hardness, solubility, density, or melting point.*)
- Why do you end up with a new substance? (*The same atoms are in the old and new substances, but they rearrange in a chemical reaction.)*
- How do you know that a new substance was not made? *(In phase changes, the molecules move faster or slower and are more or less tightly packed, but they are all the same atoms/molecules. In a mixture, the same molecules are there, too; the atoms do not rearrange into new substances.)*

Students have one more question to answer in order to completely understand the Driving Question: Do new substances always come from old substances?

LESSON 12

Does Mass Change in a Chemical Reaction?

PREPARATION

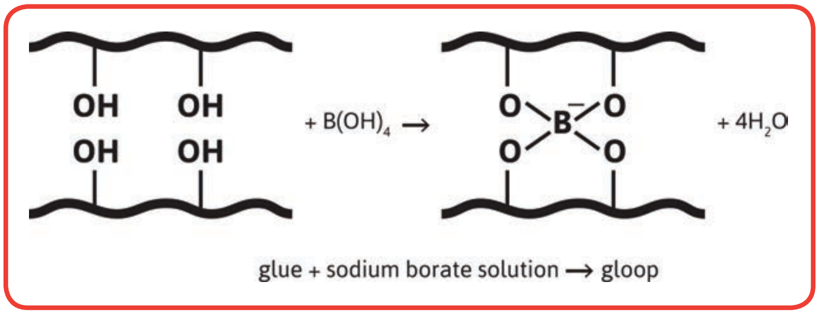
Teacher Background Knowledge

Open and Closed Systems

- Mass is conserved for all chemical reactions. On an atomic level, the numbers of each type of atom are conserved for all chemical reactions. In a closed system, conservation of mass can be measured.
- A chemical reaction in a closed system means that nothing enters or leaves the system. A chemical reaction in an open system means that something can enter or leave the system (such as gases), but atoms are still neither created nor destroyed.
- On the atomic level, a chemical reaction in a closed system means that atoms do not enter or leave the system. A chemical reaction in an open system means that atoms can enter or leave a system.
- Students are introduced to these ideas during this lesson.

Making Gloop

The reaction for making gloop can be explained by the following model. In this example, a boron atom connects to four oxygen atoms in glue molecules. This connection happens with all of the oxygen atoms in the glue molecules, to make long chains. These long chains are called polymers. The hydrogen atoms that are no longer connected to the glue molecules combine with OH-groups that were previously connected to the boron atom to form water. The molecules and the atoms that make up the molecules all have mass. From the reaction, you can see that there is the same number of atoms before the reaction as after the reaction. You can do this by counting the number of atoms to the left of the arrow and the number to the right of the arrow.



- The bubbles indicate that a gas was produced due to a chemical reaction. The mass seemed to change in the reaction because students did not measure the mass of the gas that was produced. The procedure allowed the gas to escape from the bottle without a cap, so the mass of the gas was not included in the total mass after the

reaction. Many students may think that a gas does not have mass, so this could cause confusion.
- This is a chemical reaction in an open system, so the gas product leaves the system. Conservation of matter cannot be measured in an open system. However, atoms are not destroyed. In an open system, you do not mass all of the substances. Students need to use a closed system (a capped bottle) to test whether or not conservation of matter holds for this reaction, which is the focus of Lesson 13.2. In a closed system, none of the substances can escape, so the mass of all the atoms can be measured.
- Do not give students the caps for the soda pop bottles in Activity 13.1. Save the caps for Activity 13.2. Students should complete this investigation in an open system. In 13.2 they will repeat the same reaction in a closed system.

Writing about Conservation of Mass

In previous lessons, students have constructed arguments as to whether two things are the same substance or about whether a new substance was produced (chemical reactions). Since this is the first time students have written an explanation or argument for a question about whether mass changes, they may be confused by what counts as evidence and reasoning. You may wish to stress the importance of including the actual numbers for the mass in the evidence. You also might want to discuss that since students do not know as many science principles or theories about whether mass changes in a chemical reaction (since it is a new topic) that they will not have as many science principles to include in their reasoning. Students should still use their observations (about the bubbles) to include some reasoning. The bubbles indicate that a gas was produced due to a chemical reaction. The mass seemed to change in the reaction because students did not measure the mass of the gas that was produced. The procedure allowed the gas to escape the bottle without a cap, so the mass of the gas was not included in the students' total mass after the reaction.

Common Student Ideas

- Students may think that mass changes during a chemical reaction based on their everyday experiences. For example, they may think that mass changes when materials burn or rust because the reactants seem to get used up or the products are added. They may think that the materials disappear or appear.
- Student perception of mass (if they confuse the terms density, weight, and mass) may influence what they think happens to mass during a chemical reaction.
- Students may not understand that mass is conserved during a chemical reaction that involves gases as reactants or products if they do not believe that gases have mass (IQWST IC1).
- Students should be learning that language such as *appear* and *disappear* is inappropriate for describing matter in chemical reactions. Atoms (matter) cannot be created or destroyed. Likewise, in earlier lessons, students learned that dissolving is not a chemical reaction. One substance dissolved in another gives a mixture. However, students have been told that a seltzer tablet is a chemical reaction and not a mixture. If students suggest that the seltzer tablet dissolved in water, probe their thinking about dissolving.

Setup

Preparation

Optional Activity 12.A

- Prepare the sodium borate solution by mixing 20g (1/6 cup) of laundry borax (sodium tetraborate decahydrate, $Na_2B_4O_7 \bullet 10\,H_2O$) into 1L (about 1qt) of water while stirring. All of the borax may not dissolve.

Materials – Activity 12.A (Optional)

For Each Student
- Activity Sheet 12.A
- (1) 8oz plastic or paper cup
- 6 tsp (30mL) white glue
- 5mL water*
- 15mL sodium borate solution (liquid laundry starch)
- (1) craft stick
- (1) graduated cylinder
- (1) mass balance
- plastic bags

*This item is not included in the kit.

Materials – Activity 12.1

- For the beginning of Activity 12.1, gather all of the equipment students can use for their experiment at the front of the room. Show them the materials they can use to design their procedure.

Safety Guidelines

Refer to IQWST Overview.

Differentiation Opportunities

Refer to IQWST Overview.

Lesson 12

Does Mass Change in a Chemical Reaction?

TEACHING THE LESSON

Performance Expectations

Students will

- design and carry out an investigation to investigate what happens at the macro- and microlevels in a chemical reaction in an open and a closed system, thus experiencing conservation of matter.
- use data as evidence to construct an explanation of the principle of conservation of mass.

Building Coherence

Begin Learning Set 3 by building on understanding of chemical reactions (atoms rearranging) to address conservation of matter in open and closed systems, and the final subquestion: Do new substances always come from old substances?

Timeframe

2 Class Periods (optional activity 12.A adds an additional class period)

Overview

Activity 12.A (Optional)
Make gloop as a way to investigate whether mass stays the same or changes during a reaction that does not involve a gas.

Activity 12.1
Investigate whether measuring the mass of reactants and products when a seltzer tablet reacts with water could provide evidence of whether new substances always come from old substances.

Activity 12.2
Design and carry out an investigation to account for the mass of the gas produced in the seltzer tablet reaction in a closed system to learn about conservation of matter.

Safety

- For the optional Activity 12.A, gloop is not toxic. Students can touch gloop with bare hands. However, you may wish to have students wear safety goggles as a general lab rule.
- For Activities 12.1 and 12.2
  - o Wear safety goggles.
  - o Do not taste any object in the science lab, even if a substance is familiar and edible.

Introducing the Lesson

Activities address the last section of the unit: Do new substances always come from old substances?

- What happens to the atoms in a chemical reaction? (*Atoms we start with—in reactants—combine in new ways so the substances we end up with—products—have different properties.)*
- Where do the new substances come from? (*the atoms of the old substances; reactants*)
- Could the new atoms come from somewhere else? *(Atoms need to come from somewhere; they cannot just appear.)*
- Would you expect the mass of the reactants to be the same or different from the mass of the products after a chemical reaction?
- Provide an example or two from class: Do you think the mass of the copper and acetic acid had the same mass as the copper acetate and hydrogen gas produced during the reaction? *(Mass stayed the same because there were the same number and type of atoms before and after the reaction; mass decreased because there was air that escaped or because gases have less mass; mass increased because there was another substance on the copper square so the copper square had greater mass.)*

Describe: If the mass of the new substances and the old substances were the same, this would be evidence that new substances always come from old substances. If the mass of the new substances is greater, this suggests that the new substances are coming from somewhere else and new matter is being created. If the mass of the new substances is less, it suggests that some of the new substances are escaping or that matter is destroyed. Therefore, mass is important data as to whether mass can be created or destroyed in a chemical reaction.

Activity 12.A – Making Gloop (Optional)

Students conduct an experiment to test whether mass stays the same or changes in a chemical reaction. Review the procedure on Activity Sheet 12.A. Write the following reaction on the board:

Reactants	Products
glue + water (H_2O) + sodium borate in water →	gloop

Groups carry out the activity, then share observations and discuss responses to the following conclusion questions:

- What happened to the mass in this reaction? (*It did not change.*)
- Do you think mass stays the same in all chemical reactions?
- Can you think of any reactions where it would not stay the same? Explain your ideas.

In the next activity, students will explore a different chemical reaction to determine what happens to mass.

Materials – Activity 12.1

For Each Group
- (3) seltzer tablets
- 50mL water*
- (1) small cup
- (1) 20oz empty, clear soda pop bottle without the cap*
- (1) balance or electronic scale

*This item is not included in the kit.

For Each Student
- Activity Sheet 12.1
- Reading 12.1

Activity 12.1 – Does Mass Change When Seltzer Tablets React?

Show students what happens when seltzer tablets are placed in water.

Suggested Prompts
- Is this a chemical reaction? Explain your ideas.
- Would you expect the total mass before to be the same or different from the mass after we combined seltzer tablets and water?

Review the procedure on Activity Sheet 12.1. Ask: "Why is it acceptable to include the mass of the cup and the bottle?" *(They will compare masses before and after the chemical reaction, so the constant mass of the containers does not matter.)* "Why do you know why you need to include the mass of the empty cup?" *(Since they included the mass of the cup with the reactants, they have to include the mass of the cup with the products.)*

Carry out Activity 12.1 in groups.

Discussion – Making Sense

Purpose

Establish that gas escaped; therefore, capping the bottle is necessary before comparing mass.

Suggested Prompts
- Why do you think the mass changed during the seltzer tablet reaction?
- What do the bubbles indicate?
- Does gas have mass?
- Is there anything that you could do differently and the mass would stay the same?
- Why is it important to include the masses of all products (including the gas)? *(The seltzer tablets made bubbles or a gas. The bubbles escaped; so, the mass of the gas was not included in the total mass after the reaction. We need to include the masses of all products in the measurement of the total mass after the reaction.)*

Explain that a system is a group of interacting elements, and that the system in this investigation is everything involved in the chemical reaction.

Suggested Prompts

- What was (and was not) included in the system of the chemical reaction for your investigation? *(The system of the chemical reaction included seltzer tablets and water in the bottle. The system did not include the gas that was produced. The system also did not include everything else outside of the seltzer tablets and water in the bottle.)*
- In chemistry, there are both open and closed systems. What do you think an open system is? *(Something can enter or leave the system.)* a closed system? *(Nothing can enter or leave the system.)*
- Was this investigation done in an open or closed system? *(open; the gas escaped)*
- How could you investigate this chemical reaction in a closed system?

Students now redesign the procedure to create a closed system, so they can include the mass of the gas in the total mass of the products after the reaction.

Introducing Reading 12.1 – What Happens to Mass During a Chemical Reaction in an Open System?

Have students do the Getting Ready activity in Reading 12.1 as individuals, pairs, small groups, or a whole class. One goal of this reading is for students to understand what it means for a system to be open or closed, so let them know that that will be part of your discussion in the next class period. Ask students whether they think the sandwich bag experiment they did was an open or a closed system and why. Ask what they think might have been different if they had not sealed the bag. These questions will help students think about open and closed systems and what might be important about those before they read and learn more about both.

Materials – Activity 12.2

For Each Group

- (3) seltzer tablets
- 50mL water*
- (1) small test tube
- (1) empty, clear soda pop bottle (20oz) with the cap*
- (1) small cup
- (1) balance or electronic scale
- match**

For Each Student

- Activity Sheet 12.2
- Reading 12.2

*This item is not included in the kit.

**Note: This is not for students to use in Activity 12.2. You will instruct students to use the match to test the gas produced in the reaction after they have finished their experiments.

Activity 12.2 – Does Mass Really Change When Seltzer Tablets React?

Reading Follow Up

Discuss responses to the questions in the reading and the ideas used to introduce the reading.

Redesigning the Investigation

- How could you redesign the experiment to test whether mass really stays the same or changes when seltzer tablet reacts in water?
- How could you redesign the experiment to investigate this chemical reaction in a closed system?
- How can you include the mass of all products of the reaction, including the gas?

Students write a purpose for the investigation as described on Activity Sheet 12.2. Show students the equipment they have to redesign the experiment: an empty soda pop bottle, the cap for the bottle, cup, and a small test tube. They must use the same quantities: 50mL of water and three seltzer tablets. You may wish to ask a question about quantities to get at the idea of controlling these variables, so students can compare their results from this experiment to the last experiment.

Have each group plan an investigation for a closed system that accounts for the mass of all products of the reaction. Students should draw and/or write their procedure on their activity sheet. Groups might share and compare procedures. Emphasize important steps in their designs that differ from the original procedure (e.g., the bottle cap is now part of the system). Record steps on the board.

- Which procedures allow them to include the mass of the gas produced in the reaction in their total mass after the reaction?
- How will they find the total mass after the reaction?

Have students record the same pieces of evidence as in their first investigation: total mass before the reaction, total mass after the reaction, and observations of the chemical reaction. Students should include the masses of the bottle, the cap, and the test tube in their totals, without subtracting. The containers are not involved in the reaction. They will compare masses before and after the chemical reaction, so the constant mass of the containers does not matter.

Students must create a data table or other means of recording data. You may want to require that each group check its procedure and data table with you before starting the investigation.

Students carry out investigation 12.2 in groups.

Discussion – Making Sense

Purpose

Explain why the mass changed in an open system, but did not change in a closed system. *(The mass does not change, but our ability to measure the mass is affected by an open or closed system. Generalize the conservation of matter to all chemical reactions.)*

Suggested Prompts

- What do you think would happen to the mass if the cap were taken off the soda bottle?
- Why do you think that would happen? *(The mass w ould decrease by 1.5g. This happens because it would then be an open system and the gas atoms can escape the bottle.)*

Have students take the cap off their bottles, set the cap on the balance (next to the bottle), and then observe what happens to the mass. If they no longer have sealed soda bottles, you may want to do this as a demonstration.

Reviewing all Chemical Reactions from the Unit

- Was the sandwich bag experiment in an open or closed system? *(The sandwich bag experiment was a closed system because we did it in a sealed plastic bag. No atoms could enter or leave the system. The measured mass would have stayed the same.)*
- Was the copper square experiment in an open or closed system? *(The copper square experiment was in an open system because the cup did not completely cover the Petri dish. The vinegar could still evaporate out of the Petri dish and the gas atoms could escape because the seal was not airtight. The measured mass would have changed because the gas atoms could leave the system and not be included in the final mass measurement.)*
- Was the soap-making experiment in an open or closed system? *(Making soap was in an open system. The measured mass would have changed. Everything was combined in an open beaker so atoms could enter or leave the system.)*
- If you had determined the mass before and after the reactions, what do you think you would have found?
- When you built the models of these reactions, were any atoms created? Were any atoms destroyed?
- What happened to the atoms you started with? How can you account for the atoms in the products? Where did they come from? *(In the models, all the atoms present in the reactants were present in the products.)*
- Do you think the burned magnesium reaction was in an open or closed system? *(Burning magnesium was in an open system because materials could enter or leave the system. The magnesium reacted with the oxygen in the air to form the new substance, magnesium oxide. The magnesium oxide had a greater mass than magnesium because it was made of both magnesium and oxygen.)*
- If you had determined the mass before and after the reactions, what do you think you would have found? Would the mass have changed? *(Students may not think that the magnesium oxide has a greater mass because it was a powder and the magnesium ribbon was a solid metal. Demonstrate this to students by repeating the experiment and massing the magnesium ribbon before burning and then the magnesium oxide after burning.)*

Have students compare the two seltzer tablet reactions. The chemical reaction is the same whether it takes place in a closed or open system. Our ability to collect and mass the reactants and products is what changes.

- Why does the ability to mass the reactants and products change? *(In the first seltzer tablet experiment, the gas could escape. We could not collect and measure the mass of the gas. In the second experiment, we designed a method to collect the gas to include the mass of the gas in our mass measurements.)*

For a chemical reaction that takes place in an open system you cannot measure the mass of a gaseous reactant (such as the oxygen in magnesium burning) or products (seltzer tablet, copper square). The reaction is the same in open and closed systems. The ability to gather complete data is different.

In a closed system the measured mass always stays the same and scientists call this concept the conservation of matter. The conservation of matter states that the total mass before the reaction is equal to the total mass after the reaction in a closed system (or the total mass of reactants was equal to the total mass of products). Emphasize that conservation of matter is always true.

Suggested Prompts

- Are atoms created in a chemical reaction? *(no)*
- Are atoms destroyed in a chemical reaction? *(no)*
- Why is mass conserved in a chemical reactions? *(Mass is conserved because the number and type of atoms always stays the same during a chemical reaction. There are the same number and type of atoms before the reaction as after the reaction. The atoms are just combined in new ways to form new substances.)*

Atoms can never be created nor destroyed, which is why mass is always the same before and after a chemical reaction in a closed system (conserved). Scientists call this *conservation of matter*. Conservation of matter implies that no matter how substances interact with each other, the numbers of each type of atom in a chemical reaction stay the same. If the number of atoms stays the same no matter how they are rearranged, then their total mass stays the same.

Repeat either the sandwich bag experiment from Lesson 6 or the copper square experiment in Lesson 8 and this time measure the mass before and after the reaction. Set up two versions of each experiment, one in an open system and the second in a closed system.

Explain that conservation of matter also applies to other processes besides chemical reactions. Conservation of matter occurs during phase changes (such as boiling or freezing), creating mixtures, and other processes as well. The conservation of matter can be measured by taking the mass of the substance before and after the process, just like students did in this lesson for chemical reactions.

Wrapping Up the Lesson

Ask: "Do new substances always come from old substances?" (*New substances always come from old substances. What you end up with depends on what you start with. Mass stays the same because you always have the same number and types of atoms; they are just arranged differently into new molecules. Matter cannot be created or destroyed, just changed.)* Add ideas about conservation of atoms, mass, and matter to the Scientific Principles list.

- Students should understand open systems, closed systems, and conservation of mass in terms of the number and type of atoms always staying the same in a closed system.
- In a closed system, mass can be measured before and after a chemical reaction as evidence that the atoms present in the reactants now make up the products.
- In an open system, some of the atoms may escape as a gas.
- If you feel that your students are confused by these ideas and you skipped activity 12.A, you may want to complete that activity before continuing to the next lesson.

Introducing Reading 12.2 – What Happens to Mass during a Chemical Reaction in a Closed System?

Review the Getting Ready section by asking students about their experience with glow sticks and what they think is happening to make a glow stick "work."

Lesson 13

Is My Soap a New Substance?

PREPARATION

Teacher Background Knowledge

The glycerol from the chemical reaction was part of the solution that students poured out the day after they made their soap. The glycerol is not part of their soap.

Setup

Set up the materials for testing the properties similar to Lessons 2, 3, and 4. Gather all of the materials in a central location for easy student access.

- Solubility: The homemade soap dissolves better in warm water and oil. Warm water from a faucet will work well. To warm the oil, place a beaker filled with enough oil for all of the groups on a hot plate set on low. Another method for warming the oil is to place it in a microwave. The oil should be warm to the touch, yet comfortable enough to leave your finger in.
- Melting point: Set up one apparatus as a model for students to use in setting up their experiment. Refer to Lesson 3 for a complete description and illustration.
- Density: The piece of soap will need to fit into the mouth of a 100mL graduated cylinder. Cut appropriate-sized pieces of the students' soap before class, and then dispense them. Electronic balances are recommended because they are easy to use, reducing chances of error. However, triple-beam balances are an option.

Safety Guidelines

The safety guidelines for each of these activities, when done initially, apply here.

Differentiation Opportunities

Options for Structuring the Activity

1. One way to structure this lesson is to allow student groups to proceed in their own order and at their own pace as they measure properties.
2. Another way to structure this lesson is to have all groups conduct the same measurements at the same time, one measurement of each property after another.
3. A third way to structure this lesson is to have testing stations. This would allow students to move from station to station to measure the properties of their soap.

4. A fourth way to structure this lesson is to have each group in charge of one property. For example, you could have one group determine the melting point of all the different soaps produced in the class. (They could place a number of test tubes in one beaker.)

Have students search the Internet for soap recipes and compare them to what they did in class.

LESSON 13

Is My Soap a New Substance?

TEACHING THE LESSON

Performance Expectation

Students will plan and carry out an investigation in which they gather data about the properties of their soap, and use those data as evidence to construct an explanation that a chemical reaction explains how fat and sodium hydroxide can interact to become soap.

Overview

Activity 13.1

Examine the properties (color, hardness, solubility, melting point, density) of their soap and compare with properties of original substances.

Building Coherence

Students use everything they have learned to investigate the soap they made, using properties to determine whether the new soap is the product of a chemical reaction. This lesson enables students to use their data as evidence to answer the Driving Question.

Timeframe

2 Class Periods

Safety

- Wear gloves throughout these activities.
- Refer to Lesson 2 Safety Guidelines for testing solubility.
- Refer to Lesson 3 Safety Guidelines for testing melting point.
- Students' soap should not be given to them to take home because there may be trace amounts of unreacted sodium hydroxide.

Reading Follow Up

Review students' explanations, or their responses to the final two questions, as opportunities for discussion and for assessment.

Introducing the Lesson

Review Lesson 11 on soap making. Ask: "Is the soap that formed a new substance? Explain your ideas." *(Typical responses include [1] the soap is a new substance because it was made from fat and sodium hydroxide, [2] the soap is a mixture and not a new substance, and [3] more information is needed.)*

Ask: "How might you determine which of those is true?" *(Compare properties of the soap to properties of the original substances; if our soap has different properties, then it is a new substance.)*

Students will now test and compare the properties of the soap with the properties of the original ingredients.

Materials – Activity 13.1

For the Teacher
- PI: Molecular Model of Fat and Soap
- PI: Comparing the Structures of Fat and Soap

For Each Group

Measuring Density
- (1) balance (electronic recommended)
- (1) 100mL graduated cylinder
- 50mL rubbing alcohol (store bought: 70% isopropyl alcohol, 30% water)
- (1) calculator*
- (1) broken-off piece of students' soap

Measuring Solubility
- 15mL warm tap water*
- 15mL warm cooking oil*
- (1) test tube
- (1) stopper
- (1) small broken-off piece of students' soap

Measuring Melting Point
- (1) broken-off piece of students' soap
- (1) temperature probe,* or thermometer 
- (1) hot plate
- (1) test tube
- (1) test tube clamp
- (1) ring stand
- (1) 500mL beaker
- tap water*
- (1) small metal spatula, or craft stick

For Each Student
- Activity Sheet 13.1
- Reading 13.1

*This item is not included in the kit.

Activity 13.1 – Is My Soap a New Substance?

Students measure the properties of their soap and compare them to the properties of one of the original substances (fat) to determine whether the soap is a new substance that is the product of a chemical reaction. Since they have investigated the properties of fat already, students will compare the properties of the soap to the properties of fat. They could compare the properties to those of NaOH too, but since it is a harmful substance, the investigation has been limited to comparing the properties of their soap to only the fat.

Show students the equipment they will need. Groups will measure only the properties of their newly made soap. They will refer to Activity Sheets 2.1, 3.1, and 4.1 for procedures for measuring solubility, melting point, and density, and to copy data about fat that they collected previously.

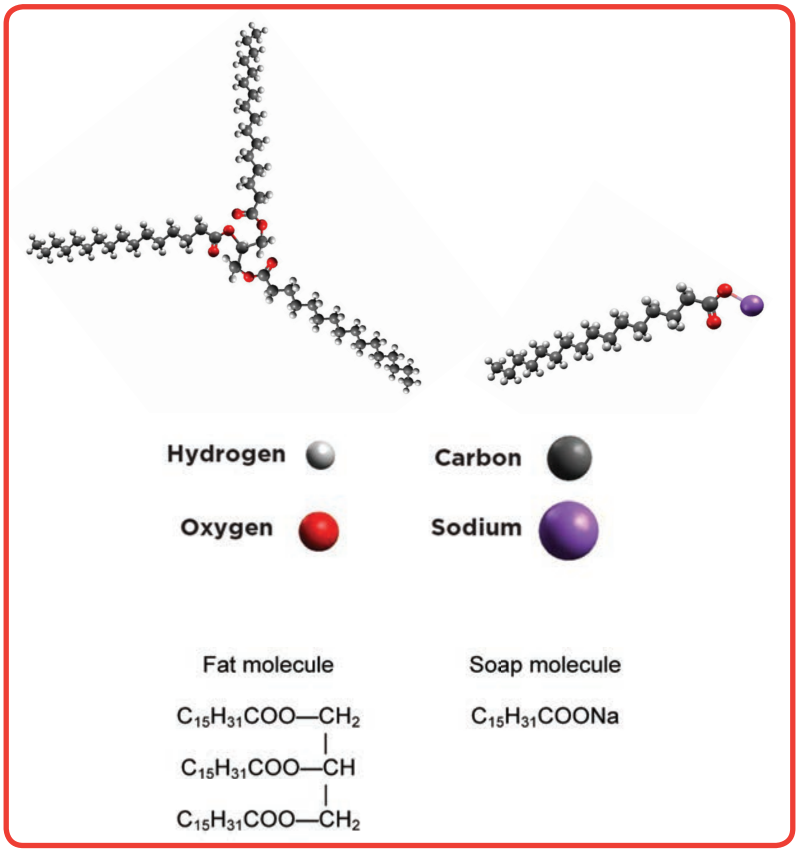
After the investigations have been completed, record each group's data on the board. Discuss differences and possible causes for these differences.

Discussion – Making Sense

Purpose

Support students in understanding this chemical reaction at the molecular level.

Show PI: Molecular Model of Fat and Soap.

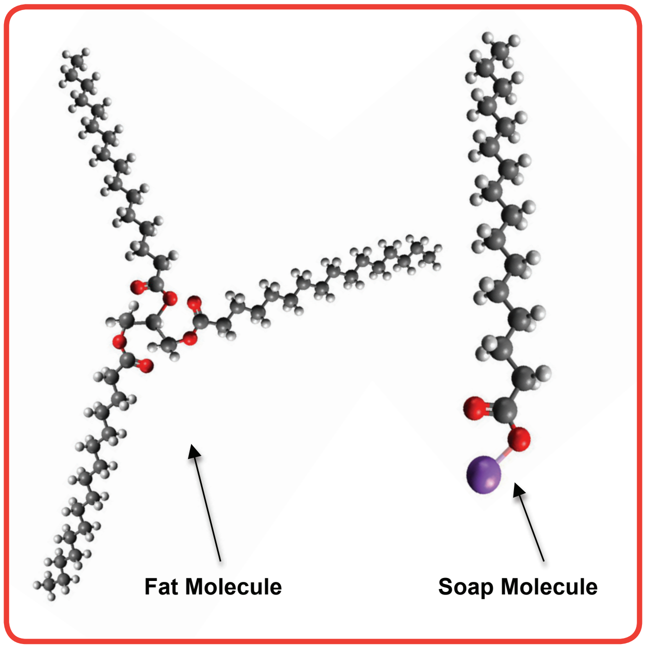


Suggested Prompts

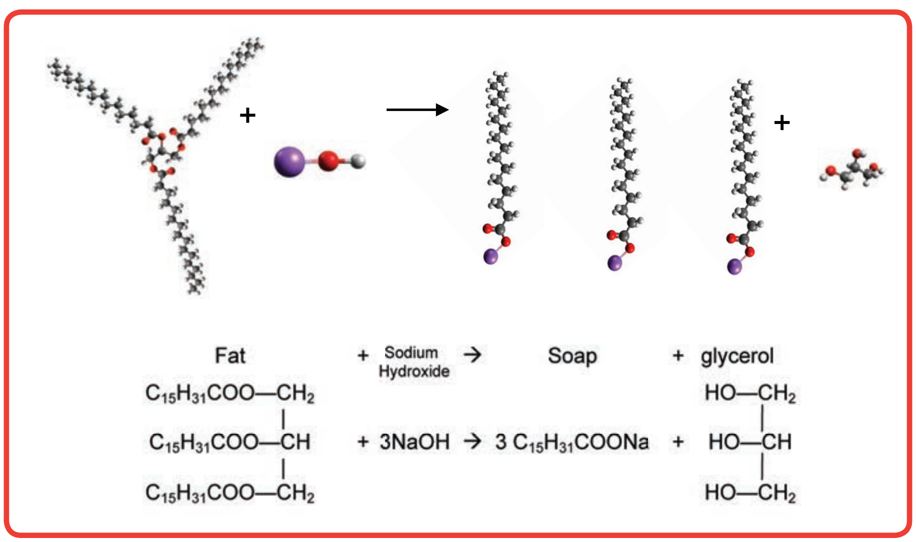
- What does each colored ball represent? *(gray = carbon, red = oxygen, silver = hydrogen, purple = sodium)*
- What do the lines connecting the atoms represent? *(They show that the atoms stick together.)*

These models are more complicated than other models used in this unit. They are one way scientists represent soap and fat. The molecular models also show the shape of the molecule or parts of it, such as a ring (sugars), a long chain (soap), or three long carbon chains (fat).

Show PI: Comparing the Structures of Fat and Soap. Compare molecular models of soap and fat.



Show PI: Making Soap from Fat.



- How does the chemical reaction occur? *(Sodium hydroxide and fat interact; each of the chains from the fat split off to become a soap molecule. The sodium from the sodium hydroxide sticks to one of the long chains. The other part of the sodium hydroxide becomes part of the glycerol molecule. You need three sodium hydroxides because fat contains three long chains. One sodium hydroxide is needed for each chain.)*

Suggested Prompts

- Does your description (of the reaction) explain how soap was made from fat and sodium hydroxide? *(Yes, because the fat and sodium hydroxide interact and their atoms recombine and stick together in new ways to form soap and glycerol.)*
- How can we see the idea of conservation of mass in this representation? *(When you count the number and types of atoms, they are the same before and after the chemical reaction, but they are in different arrangements.)*
- What do you think a molecular model of store-bought soap would look like? *(It might be a mixture of other molecules such as a scent, dye, and moisturizer.)*

Store-bought soap is usually a mixture because it has other substances added to it. The soap students made in class is a substance because it is only made of soap throughout.

Wrapping Up the Lesson

- Would you rather use the soap you made or soap from the store?
- Do you know anyone who makes his or her own soap today? Why would anyone make their own soap when they can purchase soap from stores?

Introducing Reading 13.1 – How Does My Soap Compare with Colonial Soap and Modern Soap?

The reading is about comparing the colonists' soap to the soap students made in class. You might ask: "Is some soap better than other soap?" "What makes it 'better'?" The reading addresses the need to test results. For example, because something looks like soap does not mean that it will be good soap.

These questions set the stage for the final lesson of the unit, in which students compare soaps.

LESSON 14

How Does My Soap Compare or How Can I Improve My Soap?

PREPARATION

Teacher Background Knowledge

Designing Investigations

Emphasize that students need to design a procedure that is replicable (repeatable).

Measuring Lather

1. Place a dime-size piece of the homemade soap in a 100mL graduated cylinder.
2. Add 30mL of water to the cylinder. Cover the top of the cylinder with plastic wrap or aluminum foil using a rubber band.
3. Carefully shake the cylinder 25 times, and then put it on the table.
4. Find the amount of lather by observing how high the lather rose in the cylinder. Record your observation in the table.
   - Repeat Steps 1–4 with the store soap.
   - (Variables to control for include the size of each piece of soap, the amount of water added to the graduated cylinder, and the number of times a cylinder is shaken.)

Measuring Cleaning Ability

1. Dip the homemade soap in water. Work up a lather with the homemade soap.
2. Rub the homemade soap over a cloth, stained with a spoonful of oil, for one minute and observe how well it removes the oil.
3. Repeat Steps 1–2 with the store soap.
4. Compare the two cloths with an unwashed cloth to determine which soap worked better.
   (Variables to control for include all three cloths are soiled with the same dirt, charcoal, oil, or marker, and the amount of time that the soap is rubbed or number of rubbing strokes.)

Making New Soap

The procedures for making soap are the same as in Activity 12.1, except for Step 3. Refer back to the teacher version of Activity Sheet 12.1 for notes on the soap-making procedure.

(Step 3 is the point in the procedure during which you may want to have students try different variations. For instance, the fat can be an oil, or a combination of fat and oil. Students could add 3–5 drops of an extract to the fat and rubbing alcohol mixture. Extracts should only be used in combination with fat and/or oil, not to replace it.)

Setup

Activity 14.1

Gather all of the materials needed for the lather and soap-cleaning investigations in a central location for easy student access. Show students these materials when they are designing their experiments.

Activity 14.2

- Have cups containing table salt, water, fat, and rubbing alcohol for each group. Be sure students are aware that you have not provided them with exact quantities.
- Another alternative is to set up a table with all of the substances and empty paper cups. Students can get their own materials from the table.
- Do not provide students with sodium hydroxide in cups or leave the sodium hydroxide sitting out on a table. The sodium hydroxide solution should be kept away from students and in your possession until needed. For Step 4 of the experiment, it is recommended that you pour the sodium hydroxide for students.
- Be sure to wear gloves and goggles when handling the sodium hydroxide solution.

*Note: Students leave their soap in this cup until the next day. Consequently, this container cannot be reused in subsequent classes. For example, if you have 5 periods of science and 6 groups in each period, 30 containers will be needed. A large plastic disposable cup can be used instead of a large beaker. The cup needs to be a relatively thick, high-quality plastic cup because the soap is basic when it is poured into the cup. The basic solution can cause a thin cup to deteriorate. Do not use paper or Styrofoam cups because these may leak. Also, it is preferable for the cup to be clear. If the cup is clear, students can see the soap form at the top of the salt solution.

**Note: The beaker does not have to be exactly 100mL. There just needs to be one small beaker and one large container.

Safety Guidelines

Students' soap may contain trace amounts of sodium hydroxide, which may irritate skin. For this reason, do not allow students to test their soap by applying it to their skin.

Safety guidelines from previous procedures apply here.

Differentiation Opportunities

Refer to IQWST Overview.

Lesson 14

How Does My Soap Compare or How Can I Improve My Soap?

TEACHING THE LESSON

Performance Expectation

Students will plan and carry out an investigation in which they compare soaps, or improve their own soap, as they apply what they have learned about properties and scientific investigation to a new problem-solving task.

Overview

Activity 14.1
Design and carry out investigations to compare student soap with commercially made soap.

Activity 14.2
Design and carry out a procedure for improving student soap.

Building Coherence

Students apply investigation skills they have developed to compare the soap they made with commercial soap, or to attempt to make a better soap than they did in their first effort. The concluding discussion summarizes what students have learned to answer the Driving Question.

Timeframe

3 Class Periods

⚠ Safety

Activity 14.1

- Students must wear gloves when handling their soap.
- Students must wear safety goggles when testing soaps.
- Students' soap should not be given to them to take home.

Activity 14.2

- Sodium hydroxide solution (NaOH) is caustic. Sodium hydroxide can cause severe burns. The sodium hydroxide solution should not come in contact with skin or eyes. If the sodium hydroxide solution touches the skin, the area should be immediately rinsed with water. If the sodium hydroxide solution contacts the eyes, they should be rinsed with water. In both instances, a school nurse or medical personnel should be notified.
- Students must wear goggles at all times.
- Students must wear gloves at all times.

- Students should be reminded that hot plates are like hot burners on a stove and that touching the surface of the plates could result in a serious burn. All plugs and cords should be kept away from the hot plates.
- To dispose of extra sodium hydroxide solution, dilute the solution further by pouring the solution into a beaker of ice water. After the sodium hydroxide is diluted, the solution can be poured down the drain.

Reading Follow Up

Have students compare their responses to the question posed in the reading. Make sure their comparisons address both what is similar and what is different.

Introducing the Lesson

Describe the investigations for students. Students do either Activity 14.1 or Activity 14.2.

Materials – Activity 14.1

For Each Group

Measuring Lather
- (1) broken-off piece of students' soap
- (1) broken-off piece of commercial brand soap
- (1) 100mL graduated cylinder
- plastic wrap or aluminum foil
- (1) rubber band

Testing How Well the Soaps Clean
- (1) broken-off piece of students' soap
- (1) broken-off piece of commercial brand soap
- (3) pieces of cloth*
- items to dirty the cloths (charcoal, dirt, markers)*

For Each Student
- Activity Sheet 14.1
- Reading 14.1

*This item is not included in the kit.

Activity 14.1 – How Does My Soap Compare with Commercial Brand Soap?

Plan and carry out an investigation to compare students' soap with commercial soap.

Discussion – Brainstorming

Suggested Prompts
- What criteria would you want to use to compare the soaps?
- What kind of tests could you conduct to compare the soaps?
- What qualities might you look for in soap that performs well? *(the ability of a soap to clean or remove dirt; bubbles or lather; fragrance; how soft it makes their skin or how non-drying it is)*

Have students predict whether their soap or the commercial soap would perform better.

- What type of test might you perform? *(lather, cleaning, and so on)*
- How could you test the soaps to make your comparisons?

Remind students that they cannot put the soap on their skin. Tell students that in this activity, they will design and conduct an investigation to compare their soap with commercial-brand soap.

- Anticipate that students will want to compare the soaps on lathering ability and cleaning power. In the preparation section of this lesson, materials for conducting tests that compare on those criteria are suggested. However, your students may suggest other comparisons. Allow other comparisons and tests that students come up with as long as these tests are safe.
- One strategy for helping students generate ideas for their comparison tests is to have them conduct an online Internet search.

Show students the materials available for their use in their comparison tests. Have students work in groups to design and carry out their test. Each group should draw and write their procedure on Activity Sheet 14.1.

Once groups have finished recording their procedures, have each group report to the class what their procedure will be. Provide feedback and encourage other groups to make suggestions. Then, have groups revise their initial procedure. Check each group's procedure before allowing them to start the investigation.

Prior to allowing groups to begin their soap testing, be sure that all students are wearing gloves and goggles. Students need to wear gloves because their soap might not have completely reacted and, as a result, may still contain trace amounts sodium hydroxide.

Materials – Activity 14.2

For Each Group

- (1) large plastic cup
- (1) 150mL beaker
- (2) stirring rods or plastic spoons
- (1) eye dropper or plastic pipette
- (1) hot plate
- (1) balance
- (1) graduated cylinder
- masking tape or label*
- (4) paper cups or other containers for the salt, water, fat, and rubbing alcohol
- (2) coffee filters or paper cups to mass the salt and fat
- 50g table salt* (sodium chloride)
- 175m water*
- 11g fat
- oils (coconut oil, olive oil)
- extracts (vanilla, peppermint)
- 20mL rubbing alcohol
- 20mL 6M sodium hydroxide solution
- (1) paper towel or paper plate*

For Each Student

- Activity Sheet 14.2
- Reading 14.1

*This item is not included in the kit.

Activity 14.2 – How Can I Improve My Soap?

Discussion – Brainstorming

Purpose

Encourage students to think about how they could improve their soap.

Suggested Prompts

- If you were going to make soap again, what could you do to make a better soap?
- Think about soap that you use to wash your hands. What would you want to be in that soap?
- Why would that make it better? *(add fragrance or add a different ingredient to make the soap better for cleaning dirt)*

- One way to support students' thinking about how to improve their soaps is to have them explore different soap-making websites. A web search may lead them to consider other reactants that may be used in their soap making. If students do find new procedures on the web, check them to make sure they are feasible in the classroom and not dangerous. Limit the reactants students can use for this experiment.
- Students might want to try different types of fats to see if they can make soap. For instance, can they make soap using olive oil instead of vegetable shortening as the fat?

Students should review the procedure from Lesson 11. Share the different ways that they might change the procedure. Remind students that they only want to change one variable in the procedure so they can compare whether altering that variable changed the quality of their soap.

Students may suggest some of the following possibilities:

- substitute an oil (coconut or olive oil) for the vegetable shortening
- use a combination of an oil and vegetable shortening
- add a scent (vanilla, peppermint) to the existing procedure
- increase or decrease the heating time
- increase or decrease the amount of rubbing alcohol

Why is it important to change only one variable at a time? *(If we change more than one variable, we will not be able to tell which of the changes is responsible for the change of properties.)*

Show students the extracts and oils available. Explain that there are two things that you do not want them to change because of safety issues. First, since sodium hydroxide is a potentially harmful chemical, they may not increase the amount of sodium hydroxide. And second, they may not increase the temperature of the hot plate because it could cause the solution to bubble or splash out of the beaker.

Refer to Activity Sheet 14.2. Have each group choose one variable to change. Then have them revise their procedure from Lesson 11 to write their new procedure. You may want to check each group's procedure before they begin to make sure the procedure is feasible and safe.

Review the procedure, and provide each group with the appropriate materials. Review Safety Guidelines with students. Remind students that sodium hydroxide solution is a caustic chemical. They must wear gloves and goggles while making soap. Emphasize that if sodium hydroxide spills or splashes on their body or clothes they need to flush with water and notify you immediately.

The chemical reaction to make soap takes an entire class period. Students will need to work quickly and efficiently to complete the reaction in one period. If you are concerned that students will take a while to select oils and collect and mass the materials, you may want to split the reaction over two days. Have students decide on what oils and extracts they will use and measure the water, rubbing alcohol, salt, fats, and oils on Day 1. Then on Day 2 they could complete the soap-making activity.

Explain that their soap needs to continue reacting overnight. Tomorrow they will be able to remove a bar of soft soap from the salt water, just as before.

The soap-making reaction will take about a week to reach completion. At that time, you may want to do a comparison between students' new soap and their old soap, or between their new soap and commercially-made soap. Activity 14.1 provides guidelines for comparison testing of soaps. Refer to Lesson 13 for measuring and comparing properties.

Wrapping Up the Lesson

Discussion – Summarizing

Purpose

Synthesize learning and answer the Driving Question: How can I make new substances (stuff) from old substances (stuff)?

Suggested Prompts

- What specific concepts did you learn in this unit? *(concepts: substance, property, chemical reaction, atoms, molecules, conservation of mass)*
- What does each of them mean?
  - o Substances are made of one type of atom/molecule throughout.
  - o Properties are characteristics of substances used to describe substances that do not change in the same environmental conditions. Different substances have different properties.
  - o A chemical reaction is a process in which one substance breaks down, or two or more substances interact, to form new substances. The atoms combine into new molecules to form new substances with properties different from the old substances. The new substances are made of the same atoms as the old substances, but the atoms are arranged in new ways.

- A closed system is a volume that is sealed so that no molecules or atoms leave or enter it. Molecules have mass because atoms have mass.
- The mass of a closed system does not change in a chemical reaction because no atoms leave or enter it.

- What scientific principles did we learn from the investigations in this unit?
- How do these concepts and principles help us answer the Driving Question?
- What scientific practices have we experienced? (*data gathering and analysis, modeling, explanations and argumentation, designing investigation)*
- How have these concepts allowed us to explain other phenomena, not just making soap from fat?
- How do these concepts connect to our daily lives? Have students provide examples they remember from reading materials and class discussions.
- Why do you think learning about making new stuff from old stuff might be of interest or use to us? *(Responses will vary and the discussion could go in any number of directions. You may want to focus discussion on what students learned and enjoyed about the unit, or direct students' thinking toward how what they learned may be useful beyond this classroom and this school year.)*

Discussion could also address why scientists might be interested in the Driving Question, or how society benefits from chemical reactions in general.

You may want to discuss some of the practical benefits of chemical reactions, like how chemical reactions are used in the making of new stuff like soaps, plastics, and bread; in photography to make pictures; in burning and rusting; and even when a banana ripens.

Introducing Reading 14.1 – The Science behind *Rumpelstiltskin*

This is less a reading than a culminating activity that gives students an opportunity to bring their understandings to bear on a situation they have encountered before: turning straw into gold. Options for using this reading include the following.

- Create a rubric to give to students ahead of time.
- Create a rubric with the students.
- Encourage them to be as detailed as they can in their responses.

Use their response to the reading to see what they have learned about chemical reactions, substances and properties, and open and closed systems.