PROPERTIES
OF MATTER

Grade 5 - Physical Science

TRAINER GUIDE

CONTENT AND PEDAGOGY
PROFESSIONAL DEVELOPMENT

Smithsonian
Science Education Center

The **Smithsonian Science Education Center** (SSEC) is an education organization within the Smithsonian Institution. The SSEC's mission is to transform K–12 *Education Through Science*™ in collaboration with communities across the globe. The SSEC promotes authentic, interactive, inquiry-based K–12 STEM teaching and learning; ensures diversity, equity, accessibility, and inclusion in K–12 STEM education; and advances STEM education for sustainable development. The SSEC achieves its goals by developing exemplary curriculum materials and digital resources; supporting the professional growth of K–12 teachers and school leaders; and conducting outreach programs through LASER (Leadership and Assistance for Science Education Reform) to help schools, school districts, state education agencies, and ministries of education throughout the world implement inquiry-based science education programs.

The **Smithsonian Institution** was created by an Act of Congress in 1846 "for the increase and diffusion of knowledge . . ." This independent federal establishment is the world's largest museum, education, and research complex and is responsible for public and scholarly activities, exhibitions, and research projects nationwide and overseas. Among the objectives of the Smithsonian is the application of its unique resources to enhance elementary and secondary education.

Acknowledgments

Lead Trainer Guide Developer

Katherine Fancher

Division Director of Professional Services

Amy D'Amico, PhD, Principal Investigator, Smithsonian Science for North and South Carolina Classrooms

Assistant Division Director of Professional Services

Katie Gainsback, Project Manager, Smithsonian Science for North and South Carolina Classrooms

Addy Allred
Jacqueline Kolb
Shellie Pick
Katherine Blanchard
Dr. Hyunju Lee
Layla Sastry
Sherrell Williams
Katherine Fancher
Alexa Mogck
Ariel Waldman

Executive Director, Smithsonian Science Education Center

Dr. Carol O'Donnell, Co-PI, Smithsonian Science for North and South Carolina Classrooms

Smithsonian Science Education Center Staff

Executive Office

Kate Echevarria
Johnny F. McInerney

Advancement and Partnerships

Holly Glover, Division Director
Denise Anderson
Inola Walston

Finance and Administration

Lisa Rogers, Division Director
Allison Gamble
Jasmine Rogers

Curriculum, Digital Media, and Communications

Dr. Brian Mandell, Division Director
Sofia Elian
Heidi Gibson
Dr. Sarah J. Glassman
Carolina Gonzalez
Dr. Emily J. Harrison
Victor Lucena
Hannah Osborn
Andre Radloff
Melissa J.B. Rogers
Logan Schmidt
Dr. Mary E. Short
Khadijah Thibodeaux
Logan Werlinger
Raymond Williams, III

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Properties of Matter

Grade 5—Physical Science

Trainer Guide

INTRODUCTION

In 2019, the US Department of Education awarded the Smithsonian Science Education Center an early-phase Education Innovation and Research (EIR) grant to support the development, implementation, and initial evaluation of evidence-based innovations to improve student achievement. The project, called Smithsonian Science for North and South Carolina Classrooms (PR# U411C190055), took place between October 2019 and September 2024 in third-, fourth-, and fifth-grade classrooms in North and South Carolina.

Between 2020 and 2023, participating teachers in implementation schools received curriculum professional development tied to two Smithsonian Science for the Classroom curriculum modules and content and pedagogy professional development tied to the content of each module to implement in their classrooms. The Center for Research in Educational Policy (CREP) at the University of Memphis evaluated the impact of these modules and professional development on student achievement using standardized assessments, classroom observations, and teacher focus groups.

This guide was developed as a support for trainers leading content and pedagogy professional development for fifth grade teachers implementing the Smithsonian Science for the Classroom Physical Science module *How Can We Identify Materials Using Their Properties?*

HOW TO USE THIS TRAINER GUIDE

This guide shares important ideas and strategies for effectively delivering content and pedagogy professional development in connection with a Smithsonian Science for the Classroom module with educators. The professional development plan is outlined within a table on the following pages. The first column notes approximate timing for each activity and connections to standards or pedagogical strategies. The second column provides the trainer with additional directions in concise bullet points.

ROOM SETUP

To set up a classroom for this workshop:

1. Move tables or desks so groups of three or four can work together.
2. Locate the nearest restrooms and evacuation routes.
3. Make sure speakers are working.
4. Post a piece of chart paper labeled "Parking Lot" for participants to record questions and ideas for follow up later.
5. Place the eye wash bottle in an easily accessible area.

6. Set scales out on side tables for the groups to use. Check that the scales are working before starting for the day.
7. Set up the Section 1.1 testing trays for each group.
    - Portion cup with 50 mL water
    - Portion cup with 50 mL acetone
    - Thermometer
    - 2 pipets
    - 4 pH test strips
    - Coffee filter
    - 3-by-3-inch piece wax paper
    - Dropper of universal pH indicator
    - Portion cup with 1 tablespoon salt
8. Set up the Section 2.1 materials for each group.
    - Scenarios 1 and 2:
        - Portion cup with 1 tablespoon baking soda
        - 2 portion cups with water
        - Portion cup with 1 tablespoon drink mix
        - Toothpicks
    - Scenarios 5 and 6:
        - Portion cup with 1 tablespoon baking soda
        - Portion cup with 1 tablespoon calcium chloride (do not use the same spoon!)
        - Bag with a tight seal
        - Portion cup with a small amount of phenol red
        - Portion cup with 1 tablespoon sodium polyacrylate
        - Portion cup with 50 mL water
        - Pipet

WORKSHOP OVERVIEW

This trainer guide provides direction on facilitating the sessions highlighted in the table below.

Day 1		Day 2	
10:00 a.m.	Welcome Session	**10:00 a.m**	Physical Science Content Session 2
11:00 a.m	Misconceptions and Student Work	**12:00 p.m.**	Lunch
12:00 p.m.	Lunch	**12:45 p.m.**	Reflections
12:45 p.m.	Misconceptions and Student Work, continued	**1:30 p.m.**	Break
1:30 p.m.	Break	**1:45 p.m.**	Concurrent Sessions: Planning Ahead and Principal’s Meeting
1:45 p.m.	Physical Science Content Session 1	**2:30 p.m.**	School Breakouts
3:45 p.m.	Wrap Up	**3:15 p.m.**	Closing Session
4:00 p.m.	Adjourn	**4:00 p.m.**	Adjourn

SCIENCE CONCEPTS AND STANDARDS

See Appendix 1 for the complete state standards listed here.

‡ SC/NGSS science standards refer to both NGSS and the most recent 2021 SC Science Standards.

Sessions	Science Concepts	Standards
Day 1: **Material Properties**	**1.1. Properties of Matter** Matter has a variety of properties that can be used to identify it. Some properties provide stronger evidence for identification, such as extensive properties and chemical properties, because they do not depend on the amount of the sample or recreating specific conditions.	**NC:** 5.P.2, 5.P.3 **SC/NGSS‡:** 5-PS1-3
	1.2. Reactions Predictions Predictions provide a look at current thinking and misconceptions to better focus instruction.	**NC:** 5.P.2, 5.P.3 **SC/NGSS:** 5-PS1-1, 5-PS1-2, 5-PS1-4

Day 2: **Chemical Reaction vs. Physical Changes**	**2.1. Physical vs. Chemical** When materials change, they can undergo physical or chemical changes, and some reactions involve both. The changes are categorized based on whether or not the chemical make-up changes. This can be difficult to determine, but a useful definition and examples can help.	**NC:** 5.P.2, 5.P.3 **SC/NGSS:** 5-PS1-1, 5-PS1-2, 5-PS1-4

MISCONCEPTIONS AND STUDENT WORK

Throughout this professional development, the trainer leads the sessions as a facilitator (modeling the teacher role) with teachers acting as learners. Though the content is designed for adult learners, the practices used by the facilitator may be used with grades 3-5 students.

SESSION GOALS

- Identify common misconceptions in student work.
- Increase understanding of where misconceptions come from and grow.
- Categorize student misconceptions based on their origin and impact on student learning.

AGENDA AND TIMING

Sections	Minutes	Materials/Notes
Housekeeping and Introductions	20 minutes	• Chart paper
Reflections	10 minutes	• Chart paper
Conceptual Change	30 minutes	• *Good Thinking!* video
Lunch	45 minutes	
Misconception identification	45 minutes	• Chart paper • Sticky notes • Colored dot stickers (5 colors) • Markers • "Misunderstanding Misconceptions" article

Timing	Key Points
Housekeeping and Introductions 20 minutes	**Introductions** Welcome participants to your session. Remind them that this professional learning workshop is meant to be an experience for adult learners to support their understanding of pedagogical content knowledge underlying a Smithsonian Science for the Classroom next page →

<table>
<tr><th>Timing</th><th>Key Points</th></tr>
<tr><td></td><td>module. Educators may feel some discomfort as they are confronted with the limits of their own content understanding just as their students do. Reassure them that this is part of the learning process and that it may help them build empathy for the students in their classrooms.

Icebreaker Activity

Participants introduce themselves through an icebreaker activity. Ask each participant to share what they remember about the last time they were taught this subject.

Housekeeping

Preview the agenda. Verify the safety protocols in the classroom and locate the nearest restrooms, fire exit, and tornado shelter.</td></tr>
<tr><td></td><td>Establish the Tone for the Day

Divide participants into small groups and ask them to think about what they want to achieve today. What norms do they think will encourage a positive learning environment?

Introduce group norm ideas:
Be brave
Be present
Ask questions
Be respectful
Have each small group discuss the suggested norms and add to the whole group list of norms. Once everyone has added their ideas, ask if there are any changes, additions, or modifications that need to be made.

Once the discussion is finished, this will be the social contract the group abides by for the next two days.</td></tr>
<tr><td>Reflections

10 minutes</td><td>Have participants turn to their shoulder partner and discuss their successes and challenges when teaching these units. Pairs can also discuss how they overcame challenges they faced. After partners have had time to talk, ask them to share their main points with the whole group. Record the main ideas on chart paper so everyone in the room can benefit from the shared learning.</td></tr>
</table>

Timing	Key Points
Conceptual Change 30 minutes	Ask participants to write down in their notebooks their ideas in response to the following questions: • How would you describe a scientific misconception? • How do you think student preconceptions can affect their understanding of new scientific concepts? Introduce the *Good Thinking!* Conceptual Change video. *Good Thinking!* is a video series created by the Smithsonian Science Education Center to support K–12 science educators through targeted short-format videos that explore common student ideas and misconceptions about a range of science topics such as energy, chemical reactions, and natural selection, as well as pedagogical subjects like student motivation and the myth of left- and right-brained people. Explain that the video we're about to watch is about conceptual change and explores the way students learn and develop new conceptual understanding, and shows how student misconceptions can be uncovered and addressed as part of effective learning. Show *Good Thinking!* Conceptual Change (run time: 6:26) https://s.si.edu/4dfqcQS Debrief the video by asking the participants to share how the video changed their definition of misconceptions and how preconceptions affect new learning. Have participants share anything else they found interesting or helpful. Before ending the session, let participants know that in the next session they will have a chance to explore student work and identify misconceptions. If your group is small and you're done before lunch, introduce the Keeley framework to allow more time for exploring student work after lunch.
Lunch 45 minutes	

Timing	Key Points
Keeley Framework 10 minutes	Hand out the "Misunderstanding Misconceptions" article by Page Keeley. In the article, Keeley introduces a loose framework of five types of misconceptions: conceptual misunderstanding, factual misunderstanding, naïve idea, vernacular misconceptions, and fragmentary knowledge. These different types represent a misconception based on where it comes from, how it is expressed, and what impact it has on continued learning. Understanding which type of misconception students have can assist in determining where the misconception is coming from and what the impact on learning might be.
Exploring Student Work 30 minutes	To help prepare for content sessions and future implementation, have table groups read student work and mark misconceptions with colored dot stickers, indicating which type from the framework they think the misconception falls into. Each misconception could be multiple categories in the framework.
Wrap Up 5 minutes	Ask participants to write misconceptions they found and their category from the framework on sticky notes and post them on a piece of chart paper. Let the group know they will revisit these ideas tomorrow after they have completed the content sessions.
Trainer Note: Possible Misconceptions	Some misconceptions participants may identify include: • The word "materials" means fabric. • Solids are not made up of atoms, especially those without visible granularity. • If two materials share one property or many of the same properties, they are the same. • Color is not a characteristic property of a pure material. • Shape, length, weight, and width are characteristic properties of a material. next page →

Timing	Key Points
	• When matter evaporates or dissolves, it simply vanishes. • A chemical reaction occurs when a material dissolves, such as when making a powdered juice • A chemical reaction always happens when two materials are combined. • A chemical reaction occurs during a change of state • Chemical reactions involve liquids only or always result in the production of a gas. • All chemical reactions are inherently dangerous and must take place in a laboratory. • When a chemical reaction occurs, matter just disappears. When materials react to form a new material, the mass of the system decreases.

CONTENT SESSION 1:

Properties of Matter

SESSION GOALS

- Determine what types of properties provide the best evidence of a material's identity.

AGENDA AND TIMING

Sections	Minutes	Materials/Notes
1.1 Properties of Materials	90 minutes	• Water • Acetone • pH indicator • Portion cups • Scales • Pipets • Coffee filters • Chart paper • Eye wash • Thermometers • Piece of wax paper
1.2 Reaction Predictions	30 minutes	• Pictures of scenarios • Stickers • Chart paper • Sticky notes (yellow and blue)

1.1 Properties of Materials

90 minutes

Timing	Key Points
Introduction 10 minutes	1. As a starting point, have participants reflect on the physical science module *How Can We Identify Materials Based on Their Properties?* In the module, students are asked to identify properties of six solids that can be used to prove the material's identity from a list of possible options. 2. Examples of properties used in the module include color, consistency, smell, reaction with vinegar, reaction to heat, solubility, and reaction with iodine. 3. Some of the properties were unique to a material and were good evidence of the material's identity. Ask participants to share what those properties were. After collecting the participants' thoughts, ask what properties did not provide good evidence of a material's identity and/or were not helpful in this situation. 4. It is possible that not all properties will be mentioned, because some properties may not fall into either category. These "middle of the road" properties often require using multiple properties to identify a material.
Challenge Introduction 10 minutes	1. Similar to how the module asks students to identify materials, you have a materials challenge. There are two clear liquids: acetone and water. Over the next 20 to 30 minutes, your group will have a chance to identify properties of the two liquids, and to present a claim and evidence of which liquid is water and which is acetone. 2. Before handing out the materials, have groups discuss what properties might be helpful to look for, how you will record your findings, and what questions and concerns you have.

Timing	Key Points
Safety 5 minutes	Before handing out the materials, remind participants of the safety rules: • No eating, drinking, or tasting materials. • Do not huff the materials. Waft to smell. • If you get something in your eye, let the instructor know immediately and wash out your eyes with eye wash. • If you handle the materials, wash your hands before eating. • Pay attention as you move through the room.
Initial Investigation 10 minutes	1. Every group will receive 50mL of water, 50mL of acetone in a portion cup, and a testing tray. 2. Give the groups 10 to 15 minutes to explore the testing materials freely and make any observations or tests that they want.
Suggested Investigations 10 minutes	There are many properties that may be useful in identifying the liquids that the participants may not think of. Some tests to suggest might be: • Density: the ratio of volume to weight • Adhesion: how well the liquid sticks to the walls of the cups • Cohesion: how well the liquid sticks to itself • pH: the amount of hydrogen ions present • Solubility: how well salt dissolves in the liquid • Volatility: the tendency of a substance to evaporate at normal temperatures • Particle size: how large the molecule is
Making a Claim 20 minutes	1. Ask groups to share their observations about the liquids. What do they have in common and what is different? 2. After reviewing observations, ask the groups to make a claim about which liquid is water and which is acetone. Have them use their observations as supporting evidence. next page →

Timing	Key Points
	3. As the groups present, ask what evidence they believe is the strongest. Ask: • Which properties would be difficult to change? • Which are the most unique properties that would help eliminate other material options? • Which ones would still be good evidence if another clear liquid was introduced?
Water Is Weird 10 minutes	1. Adhesion, cohesion, and surface tension are less common in the discussion about properties, but they are mentioned here because water has high adhesion, cohesion, and surface tension, making these properties more useful in identifying water vs. acetone. Overall, water is unique, even though we use it as a standard example. 2. To make this explanation more interesting, show the YouTube video *Water—Liquid Awesome: Crash Course Biology #2*: https://youtu.be/HVT3Y3_gHGg (0-:40, 1:38-5:50, 7:45-11:16). 3. The video points out some interesting properties of water that can be useful for identification and everyday life, but there is still much that is unknown about water and why it behaves the way it does. There is not enough time in this professional development, but searching the web for water research or "Water Is Weird" will bring up plenty of articles and videos, for those who want to explore further. 4. The discussion about hydrogen bonds will be continued in Section 2.1.
What Evidence Is Used in the Module? 5 minutes	1. Looking back at the module and the student work, lead a discussion about what types of properties students identified and used for evidence. 2. Ask, "Was there stronger evidence they could have used to identify their materials?"
Session Reflection and Clean-Up 10 minutes	1. Address any questions from the group. If you do not know the answer, put the question in the parking lot until you can look the question up. 2. Everything used is safe for the drain or the trash can.

1.2 Reaction Predictions

30 minutes

<table>
<tr><th>Timing</th><th>Key Points</th></tr>
<tr><td>Curriculum Review
5 minutes</td><td>1. Introduce the topic and science concepts that will be covered in this section.

2. In the module, students are given the opportunity to combine materials to determine changes in properties.

3. Ask, "What test options do they have? What could they learn from this? How does the curriculum address a physical change vs. a chemical reaction?"</td></tr>
<tr><td>Introduce Reactions
10 minutes</td><td>In the next section of this professional development, you will look at six scenarios:
1. Baking soda combined with water
2. Drink mix combined with water
3. Hydrogen peroxide in an open container
4. Dry ice in an open container
5. Sodium polyacrylate combined with water
6. Calcium chloride and baking soda combined with indicator phenol red and combined with each other

Have individuals place stickers on a piece of chart paper to indicate whether they predict the reaction will be a physical reaction or a chemical change.</td></tr>
<tr><td>Small Group Thinking
15 minutes</td><td>Have small groups discuss what they chose and their thinking behind it. They should also predict what they think will happen and what property changes they will be looking for.</td></tr>
<tr><td>Reflection
5 minutes</td><td>Address any questions from the group. If you do not know the answer, put the question in the parking lot until you can look the question up.

next page →</td></tr>
</table>

Timing	Key Points
	Learner Reflection Wrap up the session by having a general conversation to debrief the session as learners. Ask questions such as: • Any questions about the content covered in the session? • What new learning did you encounter today? • What misconceptions did you debunk today? Teacher Reflection Wrap up the session by having a general conversation to debrief the session as teachers. Ask questions such as: • Where can you tie these concepts back to the curriculum module? Address content and practices. • Any misconceptions that teachers may expect from their students on the science concepts covered in the session? Exit Ticket Ask participants to record their "sunshines and blues" for the day on yellow (sunshines) and blue (blues) sticky notes and add them to a piece of chart paper before leaving for the day.

CONTENT SESSION 2:

Chemical vs. Physical

SESSION GOALS

- Collaboratively develop a working explanation/definition for chemical reactions and how they are different than physical changes.

AGENDA AND TIMING

Sections	Minutes	Materials/Notes
2.1 Can We Predict Chemical Reactions vs. Physical Changes?	120 minutes	• Sample definitions (Appendix 2) • Pictures of scenarios • Chart paper • Baking soda • Drink mix • Sodium polyacrylate • Zip top bags • Calcium chloride • Rulers • Scales • Phenol red • Toothpicks • Pipets • Portion cups • Tablespoon

2.1 Can We Predict Chemical Reactions vs. Physical Changes?

120 minutes

Timing	Key Points
Introduction	Introduce the topic and science concepts that will be covered in this section. Address any daily needs or updates before starting the content.
Initial Definitions 10 minutes	1. In the last session, we reviewed how the module addresses physical changes and chemical reactions. 2. Have the participants take a few minutes to write down definitions of physical changes and chemical reactions. 3. To help participants get started, hand out the example definitions, Appendix 2, and example indicators of reactions. Participants will hold on to these definitions to adjust throughout the training.
Physical Changes 10 minutes	1. A physical change is any change to how a material appears, without changing its chemical makeup. 2. The module asks students to create a model of this type of change in Focus Question 2, where sugar is dissolved in water. The molecules of sugar and water do not change to become a new molecule; they remain sugar and water. The sugar is simply broken into smaller pieces and spread farther apart, so it is no longer visible within the water. 3. Have participants discuss in small groups how to illustrate one of the examples of a physical change on a molecular level. Examples include: • Dissolving • Melting • Cutting • Freezing • Boiling

Timing	Key Points
Experiments Part 1, Scenarios 1–2 15 minutes	1. Give each group a portion cup with 1 tablespoon of baking soda, a portion cup of water, a portion cup with 1 tablespoon of drink mix, and some toothpicks. 2. For the first scenario, groups will mix the baking soda and half the portion cup of water. When they are done mixing, they should make observations about the mixture. The baking soda should fully dissolve and the mixture should decrease in temperature. 3. For the second scenario, the groups should mix the drink mix with the rest of the water and observe the mixture. The mixture should turn yellow and remain the same temperature as the water. 4. Ask the groups what they observed and what type of change/reaction they think occurred. 5. The baking soda and water is a chemical reaction, where the baking soda and water switch ions to create sodium hydroxide and carbonic acid. $NaHCO_3 + H_2O \longrightarrow NaOH + H_2CO_3$ 6. The drink mix is just dissolving sugar and artificial flavor into water. Each component is still the same as when it started, just spread out much more. This example is similar to the Sugar Simulation in Lesson 5 of the Grade 5 Physical Science module. Participants can play with that simulation to visualize what is occurring (https://ssec.si.edu/sugar-simulation).
Indicators of a Chemical Reaction 10 minutes	1. It can be difficult to predict when the combination of materials will result in a chemical reaction. It is possible to predict by looking at bonding and the elements involved, but a faster way is to look for indicators. 2. Depending on the book being referenced, there are many possible indicators of a chemical reaction. next page →

Timing	Key Points
	3. Here are some examples of indicators. While indicators may point to changes, they do not guarantee that a chemical change is taking place. As with other human-derived categories, some reactions do not fit clearly into a chemical reaction vs. a physical change. It is best to have multiple points of evidence, such as: • Change in color: A sudden color change; not additive, like black plus white creating gray, and not from a pH indicator. While change in pH can indicate a chemical reaction, it is the pH change, not the color change, that is important when using pH indicators. • Formation of a gas: Formation of a new gas, not changing the current material into a gas form. • Formation of a precipitate: A precipitate is a solid material that forms in a solution by chemical reaction and settles to the bottom of the container or emerges from the liquid. This is not to be confused with a material freezing or becoming solid, where the colder parts solidify and sink first. • Change in odor: The odor may not actually be different; it might simply be stronger or become more noticeable. This is also a more dangerous indicator to use, as odor can be a sign of dangerous vapors. • Change in temperature: This refers to a change in temperature without a change in the environment or adding energy to the system. It can be an increase or decrease in temperature. • Burning: Not so much an indicator as a process, but burning is definitely a chemical reaction. • Light is produced: Light bulbs creating heat and light are still physical changes, because this does not change the chemical makeup of the gases or metals in the light bulb, but a firefly lighting up or a glow stick is a chemical reaction. • Change in volume: Change in phase can also cause a change in volume. • Change in conductivity: Adding salt to water increases conductivity, but is considered a physical change. next page →

Timing	Key Points
	4. Ask participants to look at the list of indicators and discuss: • Which ones they think provide the strongest evidence of a chemical reaction • Examples of when an indicator is helpful • Examples of when an indicator might be misleading
Experiments Part 2, Scenarios 3-4 10 minutes	1. For the next two scenarios, groups will not need any materials. Instead, they will observe videos. 2. The third scenario is the decomposition of hydrogen peroxide. This decomposition takes a while, so the video shows hydrogen peroxide plus a catalyst to speed up the reaction. Remember, the catalyst does not change a reaction; it simply increases the speed at which it occurs. 3. Show the YouTube video *Decomposition of hydrogen peroxide with manganese dioxide* (https://youtu.be/hd92QQeGVHA) and stop at around 0:49 to avoid showing the equation. 4. Scenario 4 is the sublimation of dry ice. Dry ice is carbon dioxide that has been cooled below its freezing temperature (-78.4°C/-109.2°F). 5. Show the YouTube video *Dry Ice Sublimating* (https://www.youtube.com/watch?v=8Gj8dr6AsYg). 6. Ask groups what they observed and what type of change/reaction they think occurred. What gas do they think is present in each scenario? 7. Decomposition of hydrogen peroxide is a chemical reaction. The chemical formula for hydrogen peroxide is H_2O_2, which breaks down into the more stable hydrogen gas and water. 8. Sublimation describes when a solid changes into a gas without first becoming a liquid. This is an example of phase change, which is a physical change.

Timing	Key Points
Chemical Bonding 20 minutes	1. By looking at the chemical equations of the materials involved, you get an accurate prediction of whether a phenomenon is a chemical reaction or a physical change. 2. This requires some understanding of the structure of atoms (including subatomic particles such as protons and electrons), as well as the types of bonds that may be formed between atoms. An important factor in bonding is the electrons that are part of an atom. Electrons are negatively charged particles around an atom's nucleus. The number of electrons in a given atom is represented by the atom's atomic number on the periodic table. 3. Electronegativity is an atom's ability to attract electrons. Generally, electronegativity increases toward the left and to the top of the periodic table. Oxygen and fluorine have the strongest pull on electrons because they are relatively small atoms that cause the protons (positively charged subatomic particles in the nucleus) to play a larger role in attracting the negatively charged electrons. 4. Hand out the electronegativity table, Appendix 3, for participants to review. 5. The difference in electronegativity between two atoms can help determine whether molecules are held together by ionic or covalent bonds. In ionic bonds, there is a large difference in electronegativity, and the less electronegative atoms give up an electron to the atom they are bonded to. Covalent bonds occur between atoms that have more similar electronegativities, and atoms are shared. 6. Ionic bonds have differences in electronegativity of 1.7 and higher. Polar-covalent bonds have differences in electronegativity of between 1.7 and 0.4. Covalent bonds have differences in electronegativity of 0.4 or lower. next page →

Timing	Key Points
	7. Hydrogen bonds are unique bonds that occurs when a hydrogen atom bonds to a highly electronegative atom with an unshared pair of electrons. Most hydrogen bonds are relatively weak. An example of hydrogen bonds are the bonds that occur between two water molecules. In water molecules the larger oxygen atom holds more closely to the extra electron from the hydrogen atom, resulting in a slightly negative charge of the oxygen and a slightly positive charge of the hydrogen. This allows for the hydrogen on one water molecule to be drawn to the oxygen of another water molecule, resulting in the hydrogen bond. These bonds are what give water a lot of interesting properties, as we saw in the session yesterday. 8. Let's use the example of a reaction we just watched on the video—the decomposition of hydrogen peroxide—to talk about what is happening with the atoms. Hydrogen peroxide = H_2O_2 9. When oxygen is covalently bonded to another oxygen atom, it is called a peroxide bond. The simplest form of a peroxide molecule is when it is bound to two hydrogen atoms, which is called hydrogen peroxide. Peroxide bonds are highly unstable because each oxygen atom has a set of unpaired electrons (with a negative charge) that repel each other. When two hydrogen peroxide molecules are aligned in a specific manner (there is movement around bonds), the molecules will spontaneously decompose to form water and oxygen gas. 10. Oxygen gas is comprised of two oxygen atoms, just as peroxide is, so you may think that the resulting molecule is also unstable. But the opposite is true! Why? next page →

Timing	Key Points
	11. Oxygen gas is a highly stable molecule because it has a double bond between the two oxygen atoms. This means there are two pairs of shared electrons. 12. Let's take a look at a couple more scenarios to see if we can apply what we know to predict whether a chemical reaction or a physical change is occurring.
Experiments Part 3, Scenarios 5–6 15 minutes	1. In this section, participants will complete the last two hands-on scenarios. Scenario 5 will be simply mixing water and an absorbent polymer. Scenario 6 is the final scenario and is the most complicated. The materials will be mixed in a plastic bag to trap the gas created, to show another example of conservation of mass. 2. There is no prescribed method for weighing and tracking the materials; instead, groups are asked to determine their own plan. 3. For these two scenarios, groups will need 1 tablespoon of baking soda, 1 tablespoon of calcium chloride (do not use the same spoon!), a bag with a tight seal, a portion cup with phenol red, a portion cup of sodium polyacrylate, a portion cup of water, and a pipet. Groups will also need access to a weighing station. 4. For scenario 5, groups will add water to the sodium polyacrylate. The water will be absorbed. The resulting gel can be handled and is safe to dispose in the trash. This is the same absorbent powder that is used in diapers. 5. Ask the groups what they observed and what type of change/reaction they think occurred. 6. This is an example of a physical change, as the water is simply being held in the polymer. Neither the polymer nor the water has had changes in bonds or chemical composition. next page →

Timing	Key Points
	7. Scenario 6 is made up of many steps that need to be carried out carefully to see the full reaction. Additionally, this scenario will be used to discuss conservation of mass, so groups will need access to a scale at a weighing station. Based on time, groups may also predict chemical changes based on the bonds present in the different substances. 8. In this scenario, groups will be combining baking soda, calcium chloride, and phenol red in a bag with a good seal. Before giving each group their materials, they will need to make a plan about how they will weigh the materials and in what order they need to tare the scale. 9. After every group has made a plan for weighing, walk the groups through the following steps, while leaving time for groups to follow their weighing plan. • Open the bag and pinch the bag in a way that separates the left side from the right side. • Dump the baking soda in one side of the bag while keeping it out of the other side. • Dump the calcium chloride in the other side of the bag. • Use the pipet to add phenol red to both sides until both sides are moist. • Keeping the sides separate, close the bag tightly. Then mix the two sides together. 10. Start the discussion by asking what the groups observed and what they think happened at each step of the process. Also ask about the weight changes between the steps. Did the weight change throughout the experiment? If so, why? If not, why not? next page →

Timing	Key Points

	11. There are multiple reactions in this scenario and they are all chemical reactions:
	• Reaction 1: Baking soda + phenol red
	  • Phenol red is a water-based indicator, so it is the same reaction as in scenario 1.
	• Reaction 2: Calcium chloride + phenol red
	  • Phenol red is a water-based indicator. Combined with calcium chloride, there is an exothermic reaction that results in caustic lime and hydrochloric acid. But the pH remains high enough that the mixture is still a base and does not get an indicator change.
	
	$CaCl_2 + 2H_2O \longrightarrow Ca(OH)_2 + 2HCl$
	
	• Reaction 3: $NaOH + H_2CO_3 + Ca(OH)_2 + 2HCl$
	  • Reaction 3 combines the outcomes of the first two reactions and creates carbon dioxide, salt, and chalk. The carbon dioxide is the gas that fills the bag and is also dissolved in the water. The carbon dioxide is what causes the pH to drop and become acidic enough for the phenol red to turn yellow. This scenario has gas creation, a pH change, and creation of a precipitate.
	
	$NaOH + H_2CO_3 + Ca(OH)_2 + 2HCl \longrightarrow CaCO_3 + 2NaCl + CO_2 + H_2O$
	
	12. Using the reaction diagrams the group creates together, look at the atoms that are part of the reaction on the left-hand side of the reaction (reactants) and the right-hand side of the reaction (products). Are there any new atoms? Is the number of atoms equal? What does this tell you about the weight of the reaction before and after?

Reworking Definitions 10 minutes	Give participants time to work with their small group or individually to adjust their definitions/explanations of chemical reactions and indicators that are helpful in identifying those reactions.

Timing	Key Points
Share Out 10 minutes	1. Have participants share their definitions/explanations of what a chemical reaction is and what indicators help in identifying chemical reactions. 2. Big takeaways from the scenarios: • It is difficult to predict whether a phenomenon is a chemical reaction or a physical change from observation alone. So why do we do it? Because a lot of the time observation is accurate! Honing observation skills is an important part of developing critical thinking skills. Also, these observations will become the foundation of understanding and questioning chemistry that are central to middle school and high school chemistry, where students begin to better understand atoms and chemical bonding. • Conservation of mass—this becomes more apparent when using reaction diagrams, but having concrete examples makes it "real." 3. Science is undergirded by uncertainty. There may have been times in this training where participants felt uncomfortable because they didn't know the "right" answer. This is what students feel all the time! It is also the foundation of science. There are bounds to our collective knowledge, and scientific research continues because we are constantly learning
Reflection 5 minutes	Address any questions from the group. If you do not know the answer, put the question in the parking lot until you can look the question up. Learner Reflection Wrap up the session by having a general conversation to debrief the session as learners. Ask questions such as: • Any questions about the content covered in the session? • What new learning did you encounter today? • What misconceptions did you debunk today? next page →

Timing	Key Points
	Teacher Reflection Wrap up the session by having a general conversation to debrief the session as teachers. Ask questions such as: • How confident are you feeling about the science concepts underlying the module *How Can We Identify Materials Based on Their Properties?* • Where can you tie these concepts back to the curriculum module? Address content and practices. • Any misconceptions that teachers may expect from their students on the science concepts covered in the session? • Any other general questions?

REFLECTIONS

Before this session, consolidate the misconceptions from the first day into a number appropriate for your group.

SESSION GOALS

- Identify common misconceptions in student work.
- Increase understanding of where misconceptions come from and grow.
- Categorize student misconceptions based on their origin and impact on student learning.

Timing	Key Points
Addressing Misconceptions 30 minutes	1. Refer back to the misconceptions that were collected in the first session. 2. Break into small groups and have each group select a misconception to work on. 3. Give the groups time to discuss the misconceptions, what factors are part of the misconception, and how they might address it in the classroom, based on their experiences during the content sessions or other resources they may have access to. Ideally, groups are leveraging activities from their Smithsonian Science for the Classroom modules. 4. Have groups share out.
Grade Level Planning 15 minutes	Discuss what the next school year looks like, including when teachers might implement the lessons, what testing is upcoming, if there are any interesting resources available, etc.
Exit Ticket	Ask participants to record their "sunshines and blues" for the day on yellow (sunshines) and blue (blues) sticky notes and add them to a chart paper before leaving for the day.

APPENDIX 1: SCIENCE STANDARDS

NORTH CAROLINA SCIENCE ESSENTIAL STANDARDS

5.P.2 Understand the interactions of matter and energy and the changes that occur.

5.P.2.2 Compare the weight of an object to the sum of the weight of its parts before and after an interaction.

5.P.2.3 Summarize properties of original materials, and the new material(s) formed, to demonstrate that a change has occurred.

5.P.3 Explain how the properties of some materials change as a result of heating and cooling.

5.P.3.2 Explain how heating and cooling affect some materials and how this relates to their purpose and practical applications.

SOUTH CAROLINA COLLEGE- AND CAREER-READY SCIENCE STANDARDS 2021 / NEXT GENERATION SCIENCE STANDARDS (NGSS) ‡

‡ *SC/NGSS science standards refer to both NGSS and the South Carolina College- and Career-Ready Science Standards 2021.*

5-PS1-1 Develop a model to describe that matter is made of particles too small to be seen.

5-PS1-2 Measure and graph quantities to provide evidence that regardless of the type of change that occurs when heating, cooling, or mixing substances, the total weight of matter is conserved.

5-PS1-3 Make observations and measurements to identify materials based on their properties.

5-PS1-4 Conduct an investigation to determine whether the mixing of two or more substances results in new substances.

APPENDIX 2: SAMPLE DEFINITIONS

DEFINING PHYSICAL CHANGE AND CHEMICAL REACTION

***Chemical Change Definition & meaning*. Dictionary.com. Retrieved from https://www.dictionary.com/browse/chemical-change**

A usually irreversible chemical reaction involving the rearrangement of the atoms of one or more substances and a change in their chemical properties or composition, resulting in the formation of at least one new substance.

Davis, R. E. (2004). *Modern Chemistry*. Holt, Rinehart and Winston.

Chemical change - a change in which one or more substances are converted into different substances Indicators of reaction:

- Evolution of heat or light
- Production of a gas
- Formation of a precipitate
- Color change

Evidence of a Chemical Reaction. (2023, April 6). Retrieved from https://chem.libretexts.org/@go/page/289394

To identify a chemical reaction, we look for a chemical change. A chemical change always produces one or more types of matter that differ from the matter present before the change. The formation of rust is a chemical change because rust is a different kind of matter than the iron, oxygen, and water present before the rust formed. The explosion of nitroglycerin is a chemical change because the gases produced are very different kinds of matter from the original substance.

Various signs of a chemical reaction include:

1. Change in Color
2. Formation of a Gas
3. Formation of a Precipitate
4. Change in Odor
5. Change in Temperature
6. Something is Burning
7. Light is Being Produced

McKinsey, M. (2023, January 12). *Chemical change: Definition, properties, types & examples*. Tutors.com. Retrieved from https://tutors.com/lesson/chemical-change-definition-properties-examples

A chemical change is a reaction that alters the chemical composition of a pure substance. They occur when a pure substance becomes one or more different pure substances.

- Indicators of reaction:
- Production of heat, light, or sound
- Production of gas not present in the reactants
- A permanent change in color
- Production of a precipitate
- Change in odor or taste
- Change in density
- Change in temperature

Science and Technology Concepts Middle School (STCMS) *Matter and Its Interactions*. (2017). Carolina Biological Supply Company.

Chemical changes (also called chemical reactions) involve either the rearrangement/reorganization of atoms or ions and/or the transfer of electrons. For middle school, the scope is limited to changes at the atomic level. When a chemical change occurs, the atoms in a substance are rearranged to form a new substance (or substances) that can be distinguished from the original ones. Even when the substances involved are unknown, some macroscopic observations suggest a chemical change:

- Production of a gas
- Production of a precipitate
- Production of light
- Production or absorption of heat
- A color change that cannot be explained by simple addition of colors (e.g., two colorless chemicals that form a white compound)

Smithsonian Science Stories *"What's Cooking?"* (2019). Smithsonian Institution.

Chemical reaction: Something that occurs when two or more materials combine to make something new. Indicators of reaction:

- Bubbles
- Color change

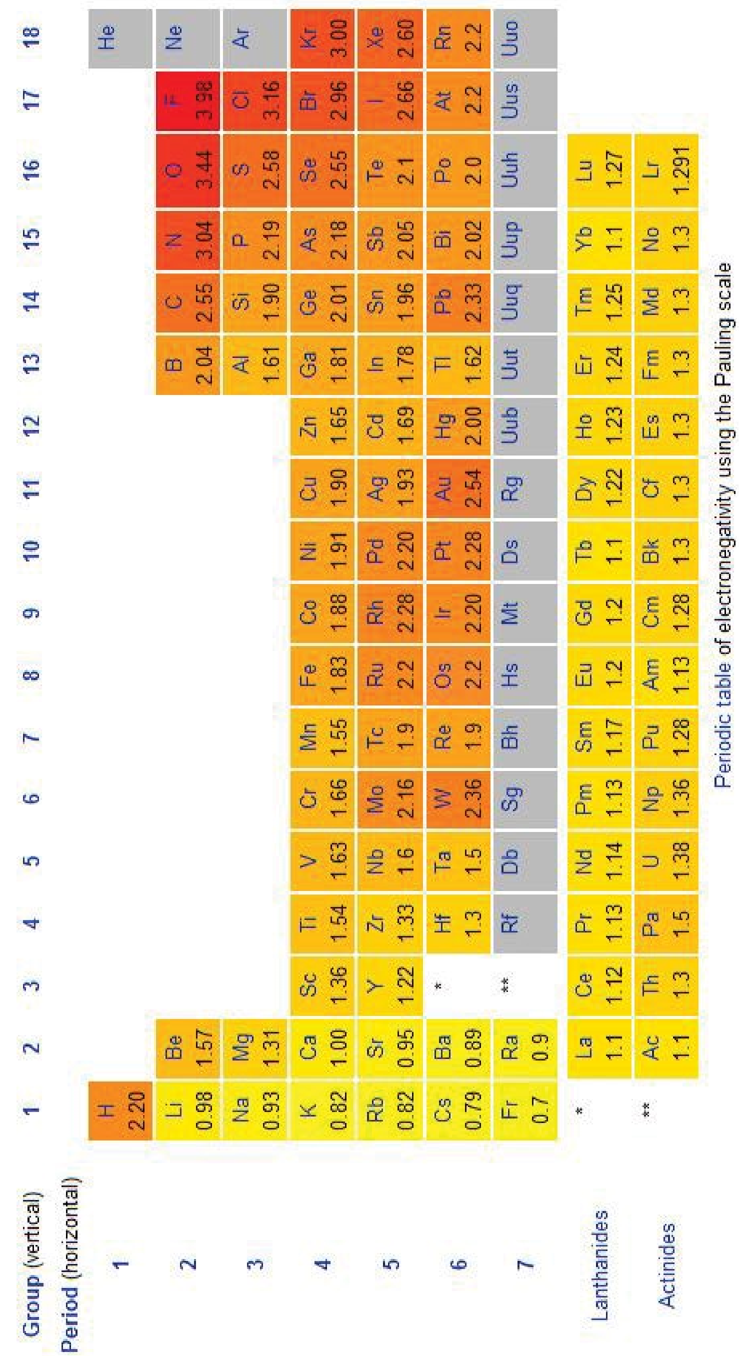
Swanson, J., & Pearce, C. (2020). *Everything you need to Ace Chemistry in one big fat notebook: The complete high school study guide*. Workman Publishing.

Two or more substances interact and their atomic bonds are broken and new bonds are created, forming new substances. Indicators of reaction:

- Change in color
- Creation of a solid
- Release of light
- Formation of gas
- Change in temperature

APPENDIX 3: ELECTRONEGATIVITY

Adblocker (2013, March 23). *Periodic table of electronegativity using the Pauling scale.* Licensed under CC BY-SA 3.0 via Wikimedia Commons. Retrieved from https://commons.wikimedia.org/wiki/File:Electronegative.jpg



Group (vertical) / Period (horizontal)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	H 2.20																	He
2	Li 0.98	Be 1.57											B 2.04	C 2.55	N 3.04	O 3.44	F 3.98	Ne
3	Na 0.93	Mg 1.31											Al 1.61	Si 1.90	P 2.19	S 2.58	Cl 3.16	Ar
4	K 0.82	Ca 1.00	Sc 1.36	Ti 1.54	V 1.63	Cr 1.66	Mn 1.55	Fe 1.83	Co 1.88	Ni 1.91	Cu 1.90	Zn 1.65	Ga 1.81	Ge 2.01	As 2.18	Se 2.55	Br 2.96	Kr 3.00
5	Rb 0.82	Sr 0.95	Y 1.22	Zr 1.33	Nb 1.6	Mo 2.16	Tc 1.9	Ru 2.2	Rh 2.28	Pd 2.20	Ag 1.93	Cd 1.69	In 1.78	Sn 1.96	Sb 2.05	Te 2.1	I 2.66	Xe 2.60
6	Cs 0.79	Ba 0.89	*	Hf 1.3	Ta 1.5	W 2.36	Re 1.9	Os 2.2	Ir 2.20	Pt 2.28	Au 2.54	Hg 2.00	Tl 1.62	Pb 2.33	Bi 2.02	Po 2.0	At 2.2	Rn 2.2
7	Fr 0.7	Ra 0.9	**	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Uub	Uut	Uuq	Uup	Uuh	Uus	Uuo
Lanthanides	*	La 1.1	Ce 1.12	Pr 1.13	Nd 1.14	Pm 1.13	Sm 1.17	Eu 1.2	Gd 1.2	Tb 1.1	Dy 1.22	Ho 1.23	Er 1.24	Tm 1.25	Yb 1.1	Lu 1.27		
Actinides	**	Ac 1.1	Th 1.3	Pa 1.5	U 1.38	Np 1.36	Pu 1.28	Am 1.13	Cm 1.28	Bk 1.3	Cf 1.3	Es 1.3	Fm 1.3	Md 1.3	No 1.3	Lr 1.291		

Periodic table of electronegativity using the Pauling scale

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