

Aligning Indigenous Knowledge with Montana's Middle School Physical Science Standards

Heidi Lyn Schuster

2026

Lesson Plan 2:

Chemistry in Natural Dyes and Pictographs

Date 6/29/26	Length of Lesson 8 days (50-minute class periods) + full-day field trip to Pictograph Cave State Park
Course 8th Grade Physical Science	Unit/Theme Chemical Reactions
Teacher Name Heidi Schuster	Standard(s) MS-PS1-2 analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred. MS-PS1-5 develop, use, and critique a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved.
Key Vocabulary Chemical reaction: atoms are rearranged to form new substances Physical change: change in matter that does not alter its chemical identity Matter: anything that has mass and takes up space Law of Conservation of Matter: matter cannot be created or destroyed; the total amount of matter is	Content Objective(s) ● I can identify evidence of chemical reactions. ● I can differentiate between physical changes and chemical reactions. ● I can explain that matter is conserved during chemical reactions. ● I can model how atoms rearrange during reactions. ● I can connect scientific observations to traditional knowledge and long-lasting pictographs. Essential Questions ● How can we tell when a chemical reaction has occurred? ● What evidence shows that matter is conserved during chemical changes?

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the same before and after a reaction Reactants: starting substances present before a chemical reaction. Products: new substances formed from a chemical reaction pH: scale used to specify the acidity or alkalinity of a solution Indicator: substance that changes color in response to a chemical reaction Pigment: material that changes the color of another substance Atoms: basic building blocks of all matter Molecules: groups of two or more atoms held together by chemical bonds Pictograph: an ancient image, symbol, or painting created on rock surfaces inside caves using natural pigments	• How were natural materials traditionally selected for paints and dyes? • Why have pictographs lasted for thousands of years? • How do science and observation help us understand materials in nature? Materials • Red cabbage pH indicator (or universal indicator) • Vinegar • Laundry Detergent • Images of pictographs from Pictograph Cave State Park • Cups/test tubes • Several liquids (Lemon juice, liquid soap, bleach, 7-Up, drain cleaner, tap water, Windex, milk, vinegar, baking soda, antacids, etc.) • Balloons • Baking Soda • Erlenmeyer Flasks • Hydrogen Peroxide • Yeast • Thermometers • Stirring rods • Vitamin C • Tincture of iodine (2%) • Measuring spoons • Measuring cup or Graduated cylinder • Liquid laundry starch • 1000 mg Vitamin C tablets • Empty plastic bottle (about 16 oz) • Dish soap
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	● Beakers ● Digital scale ● Calcium Chloride ● Sodium Carbonate ● Coffee filter ● Milk ● Hot plate ● Paper towels ● Strainer ● Foam cup ● Pen ● Goggles ● Rubber gloves ● Glass or metal bowl ● Acetone (nail polish remover) or gasoline ● Natural pigments (charcoal, soil, berries, turmeric, clay) ● Mortars/pestles ● Small bowls ● Brushes ● Red, yellow, brown, or white clay/soil ● Mortar and pestle or rocks ● Small bowls ● Binder (Egg yolk (tempera-style paint), Liquid starch, Flour paste, Gum arabic) ● Charcoal ● Dark berries (huckleberries, chokecherries, elderberries) ● Spoon
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	Resources Pictograph State Park: https://fwp.mt.gov/stateparks/pictograph-cave (Montana Fish, Wildlife & Parks, 2023) https://visitmt.com/listing/pictograph-cave-state-park-3107 (Visit Montana, 2026) https://www.pictographcave.com/ (Walker, 2026) Cabbage pH Color Change Comparison Sheet Chemistry in Natural Dyes and Pictographs: Claims, Evidence, Reasoning Background Knowledge Signs of a Chemical Reaction ● Change of Color ● Change of Odor ● Formation of Gas (Bubbles) ● Formation of a Precipitate ● Change of Temperature ● Formation of Light Types of Chemical Reactions ● Synthesis ($A + B \rightarrow AB$) ● Decomposition ($AB \rightarrow A + B$) ● Replacement ($AB + CD \rightarrow AD + CB$ or $AB + C \rightarrow AC + B$) ● Combustion ($A + O_2 \rightarrow B$)
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Day	Lesson Sequence	Notes
Day 1 20 min	Engage (Phenomena) Purpose Spark curiosity about changes in materials and introduce pictographs. Procedure 1. Display a pH indicator solution (red cabbage juice). 2. Add vinegar (acid) and allow students to observe color changes. 3. Add a laundry detergent (base) and observe additional changes. 4. Ask: ○ <i>What changed?</i> ○ <i>Did a new substance form?</i> ○ <i>Is color change evidence of a chemical reaction?</i> 5. Show pictograph images from Pictograph Cave State Park. 6. Ask: ○ <i>Why do these colors remain after thousands of years?</i> ○ <i>What materials may have been used?</i>	Materials: Red cabbage pH indicator (or universal indicator) Vinegar Laundry Detergent Pictograph State Park: https://fwp.mt.gov/stateparks/pictograph-cave (Montana Fish, Wildlife & Parks, 2023) https://visitmt.com/listing/pictograph-cave-state-park-3107 (Visit Montana, 2026) https://www.pictographcave.com/ (Walker, 2026) Modification suggestion: Try to find pictograph images from locations near the specific community.

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Day 2 50 min	Elder Purpose An Elder shares how natural materials were traditionally tested and selected for dyes and paints, connecting traditional knowledge to material science and observation. Procedure Invite an Elder or cultural knowledge keeper to discuss: • Traditional paint and dye materials • Testing plants/minerals for color and durability • Respectful harvesting practices • Observations of natural changes	Modification suggestion: Try to find pictograph images from locations near the specific community.
Day 3-4 100 min	Explore Purpose Investigate evidence of chemical reactions through hands-on stations. Station 1: pH Color, Thermal Energy, and Odor Changes Procedure 1. Test several liquids with a pH indicator. (Lemon juice, liquid soap, bleach, 7-Up, drain cleaner, tap water, Windex, milk, vinegar, baking soda, antacids, etc.) 2. Record original and final colors. 3. Record original and final temperature. 4. Make observations about any changes in odor 5. Determine whether evidence suggests a chemical change. Evidence Collected • Color change	<i>To make your own pH indicator, shred ½ of a red cabbage and boil it in one gallon of water. Strain the cabbage from the juice.</i> Materials Station 1 pH indicator Test tubes Test tube rack Household liquids (Lemon juice, liquid soap, bleach, 7-Up, drain cleaner, tap water, Windex, milk, vinegar, baking soda, antacids, etc.)

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	Station 2: Gas Production Procedure 1. Add baking soda to a balloon. 2. Pour vinegar into an Erlenmeyer flask and attach the balloon, making sure the baking soda does not fall into the flask. 3. Once the balloon is attached, lift it up so the baking soda drops into the flask. 4. Observe balloon inflation. 5. Touch the outside of the flask and observe changes in temperature. Evidence Collected ● Gas formation ● Temperature change ● Questions ○ <i>How do you know a reaction occurred?</i> ○ <i>If the equation for this reaction is:</i> $\text{CH}_3\text{COOH} + \text{NaHCO}_3 \rightarrow \text{H}_2\text{O} + \text{CO}_2 + \text{Na},$<i>what type of chemical reaction is this?</i> ○ <i>How do you know?</i> ○ <i>What is the gas in the balloon?</i> Station 3: Production of Heat Procedure: 1. Pour 1/4 cup of hydrogen peroxide into a beaker and place the thermometer in the liquid. Let it sit for a few minutes until the temperature has stabilized. 2. Record this starting temperature. 3. Pour in 1 tsp yeast and stir. 4. Record the ending temperature.	Cabbage pH Color Change Comparison Sheet Station 2 Erlenmeyer Flask Balloon Vinegar Baking soda Funnel Station 3 Beaker 3% Hydrogen Peroxide Yeast
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Chemistry in Natural Dyes and Pictographs

Station 4

1000 mg Vitamin C

Plastic sandwich bag

Spoon or weight

3 cups

Graduated cylinder

Measuring spoons

Tincture Iodine

3% Hydrogen Peroxide

Liquid Starch

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	Procedure: 1. Place a few drops of food coloring into the bottles with $\frac{1}{2}$ cup of hydrogen peroxide. 2. Add a squirt of dish soap and swirl the bottle to mix. 3. In the cup, mix $\frac{1}{4}$ cup of warm water with one package of yeast, then stir for a few seconds to combine. 4. In the sink or outside, pour the yeast mixture into the bottle with the hydrogen peroxide. Evidence collected: • <i>What did you see happen when you combined the yeast?</i> • <i>What do you notice when you touch it?</i> • <i>How do you know a chemical reaction occurred?</i> Station 6: Formation of a Precipitate Procedure: 1. Dissolve 3 grams of calcium chloride in 20 mL of water. (Stir until the solute is all dissolved.) 2. Dissolve 6 grams of sodium carbonate in 20 mL of water. (Stir until dissolved.) 3. Combine the solutions and stir them for a minute or so 4. Fold filter paper into fourths. Make a cone with three sides together and one side separated. Place a filter paper into the funnel. 5. Pour the mixture from the beaker into the funnel. Place a beaker underneath to collect the liquid. The white solid chalk, or CaCO_3, collects on the filter paper in the funnel; this is the precipitate. The salt, or sodium chloride, dissolves in the water and passes through the filter paper; this is the filtrate.	Station 5 16 oz Plastic bottle Food coloring 3% Hydrogen Peroxide Dish soap Beaker Yeast Stirring Rod Station 6 Beakers Digital scale Calcium Chloride Stirring Rods Sodium Carbonate Graduated cylinder Coffee filter Funnel Water
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	6. Repeat the filtering process several times to collect the most precipitate. Allow the filter paper to dry until the next class. Evidence Collected ● Question: What evidence did you see that a reaction occurred when you combined the calcium chloride and sodium carbonate? ● Equation: $\text{CaCl}_2 + \text{Na}_2\text{CO}_3 \rightarrow 2\text{NaCl} + \text{CaCO}_3$ calcium chloride + sodium carbonate = sodium chloride + calcium carbonate Station 7: Formation of a Precipitate Procedure: 1. Heat up the milk on the hot plate for 1-2 minutes. 2. Add vinegar to the milk. Start with 4 tablespoons of vinegar for 1 cup of milk. Keep adding until you see mostly curd in the mixture. 3. Place a paper towel on the strainer before straining the mixture. 4. Once you've removed most of the liquid, transfer the curds onto a fresh piece of paper towel. 5. Press and squeeze the curds until most of the liquid is out. 6. Shape the curd puddle like you would with Play-Doh. Let it dry for 2-3 days. Evidence Collected ● Questions: ○ <i>Put a dab of the mixture on your tongue to taste. Do you like it? Does it taste like buttermilk, yogurt, or cheese?</i> ○ <i>How do you know a reaction occurred?</i>	Station 7 Beaker Milk Hot plate Vinegar Paper towels Strainer
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	● In 2-3 days, when the curd is completely dry, it becomes hard and will not dissolve in water. The resulting substance is organic plastic. We don't usually associate milk with plastic, since modern plastic is synthetic and made from petroleum. Before the invention of synthetic plastic, acid casein was used to manufacture buttons because dried casein is hard, strong, and insoluble in water. Mixing milk and vinegar creates a plastic that feels almost as strong as stone. ● While milk plastic isn't an Indigenous invention, Indigenous Americans did discover how to make natural rubber. They figured out how to tap the latex from rubber trees and mix it with Morning Glory vine juice to create bouncing balls and waterproof materials long before Europeans arrived in the 1500s. (Schreiber, 2025) Station 8: Physical Change Purpose: Determine physical or chemical change. Safety: ● Wear goggles to keep acetone away from your eyes. ● Wear rubber gloves to protect your hands. ● Do not use a plastic bowl. ● This activity needs good air circulation. Procedure: 1. Draw a picture of a wicked witch on an upside-down foam cup. 2. Wearing rubber gloves, pour acetone into the bowl so it is about 1/2 inch deep. 3. Put the witch into the acetone, feet first. Then watch as the witch melts.	Station 8 Foam cup Pen Goggles Rubber gloves Glass or metal bowl Acetone (nail polish remover) or gasoline
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	4. When the witch has totally melted, reach into the acetone (with the rubber gloves still on) and pull out the goo. 5. Mold the goo into any shape – when it dries, you will have a statue. Evidence Collected • Questions ○ <i>Melting is a change in thermal energy. Does this experiment cause Styrofoam to melt?</i> ○ <i>Why is there such a small amount of goo after the cup dissolves?</i> ○ <i>How do you know a reaction occurred?</i> ○ <i>This change is actually a physical change. Can you think of a reason for the bubbles if they are not part of a chemical reaction?</i>	
Day 5 Full Day	Environment Students travel to Pictograph Cave State Park to observe the cave drawings that have been there for thousands of years. Purpose Observe long-lasting pigments and evidence of material durability in the environment. Procedure 1. Students observe pictographs and surrounding rock formations. 2. Students sketch patterns and colors observed. 3. Discuss: ○ Why have these pigments lasted? ○ What reactions may have occurred between minerals and rock surfaces?	Modification suggestion: Visit a location that has pictograph paintings near the specific community.

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	○ How does the environment affect preservation? Optional Student Activities ● Observation sheet ● Sketches ● Reflection paragraph													
Day 6-7 100 min	Explain Students create paints from natural pigments. Many Indigenous people throughout North America created paints from locally available minerals, plants, charcoal, and clays. The specific materials varied by region and nation, so it is important to emphasize that there is not one single Indigenous paint-making tradition. When teaching students, focus on how Indigenous people carefully observed their environment and tested natural materials to find pigments that were durable and meaningful. <table><tr><th colspan="2">Common Natural Pigments</th></tr><tr><td rowspan="2">Red Pigments Red, reddish-brown, rust</td><td>Red ochre (iron-rich clay or soil)</td></tr><tr><td>Hematite (iron oxide mineral)</td></tr><tr><td rowspan="3">Yellow Pigments Yellow to golden yellow</td><td>Yellow ochre</td></tr><tr><td>Certain yellow clays</td></tr><tr><td>Turmeric (for classroom use, though not traditionally used by most North American tribes)</td></tr><tr><td rowspan="2">Black Pigments Black to dark gray</td><td>Charcoal from burned wood</td></tr><tr><td>Soot from fires</td></tr></table>	Common Natural Pigments		Red Pigments Red, reddish-brown, rust	Red ochre (iron-rich clay or soil)	Hematite (iron oxide mineral)	Yellow Pigments Yellow to golden yellow	Yellow ochre	Certain yellow clays	Turmeric (for classroom use, though not traditionally used by most North American tribes)	Black Pigments Black to dark gray	Charcoal from burned wood	Soot from fires	
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		Burned plant material		
	White Pigments White to light gray	White clay		
		Kaolin clay		
		Crushed limestone or chalk		
	Brown Pigments Brown shades	Brown clay		
		Iron-rich soil		
		Ground tree bark		
	Green Pigments Green (often less permanent than mineral pigments)	Crushed leaves		
		Mosses		
		Copper-containing minerals (historically in some regions)		
	Classroom-Friendly Paint Making			
	Method 1: Mineral Pigment Paint			
	Procedure			
	1. Collect dry clay or colored soil.			
	2. Remove sticks, roots, and debris.			
3. Crush into a fine powder.				
4. Sift through a strainer.				
5. Place powder in a bowl.				
6. Add small amounts of water until a paint-like consistency forms.				
7. Add a binder if desired.				
Materials				
Method 1				
Red, yellow, brown, or white clay/soil				
Mortar and pestle or rocks				
Fine mesh strainer				
Small bowls				
Water				
Binder (optional)				

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	Simple Binder Options • Egg yolk (tempera-style paint) • Liquid starch • Flour paste • Gum arabic Method 2: Charcoal Paint Procedure 1. Grind charcoal into a fine powder. 2. Add a few drops of water. 3. Mix into a thick paste. 4. Add a small amount of binder for durability. Produces deep black paint similar to some traditional pictograph pigments. Method 3: Berry Pigments Procedure 1. Crush berries thoroughly. 2. Strain out solids. 3. Use juice as paint. Note: Berry pigments produce beautiful colors but often fade quickly, providing an excellent opportunity to discuss why mineral pigments were often preferred for long-lasting artwork. Traditional Binders Many Indigenous people mixed pigments with substances that helped paint adhere to rock, hide, wood, or other surfaces. Depending on the culture and region, binders could include: • Animal fat or grease	Method 2 Charcoal Mortar and pestle Water Small bowl Method 3 Dark berries (huckleberries, chokecherries, elderberries) Small bowl Spoon
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	● Plant oils ● Tree sap ● Egg ● Blood (in some historical contexts) ● Water For classroom use, flour paste, liquid starch, or egg yolk is a safer and easier alternative. Connection to Pictograph Cave If students visit Pictograph Cave State Park, discuss why many pictographs have survived for thousands of years. Students often discover that: ● Mineral pigments are more stable than plant pigments. ● Iron oxides (ochres) do not fade easily. ● Dry cave environments help preserve artwork. ● Careful selection and testing of materials contributed to the longevity of the paintings.	
Day 8 30 min	Elaborate Students create pictographs using their paints and model chemical reactions to show how atoms rearrange while matter is conserved. Investigation Idea Have students use the paints they created using: 1. Red clay 2. Charcoal 3. Berry juice Paint identical symbols on paper or small stones. Place them in sunlight for several days and record which pigment lasts longest. This mirrors the careful observation and testing that Indigenous people used when selecting materials.	

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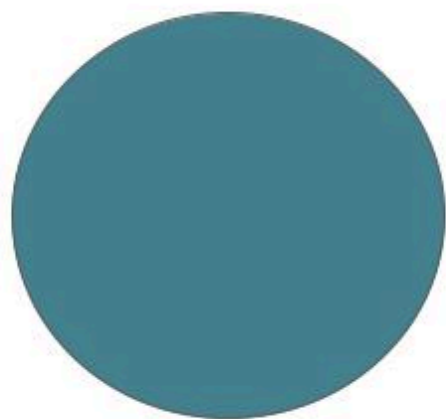
	1. Grind natural pigments. 2. Mix with water or binder. 3. Test paint on paper/rock-like surface. 4. Observe texture, color, and durability. Evidence Collected ● Physical mixing ● Color stability ● Material changes Student Data Table Students record: ● Materials used ● Observations ● Evidence of reaction ● Physical or chemical change?	
Day 8 30 min	Evaluate Using the Claims, Evidence, Reasoning (CER) format, students explain how chemical reactions were used to create pictographs. 1. Give the students the following guiding question: <i>How do we know that a chemical reaction has occurred in pictographs?</i> 2. Give the students the following statement to use as the Claim: <i>We know chemical reactions have occurred when substances change color, change odor, form a precipitate, form bubbles, change temperature, or give off light.</i> 3. Using all of the information gained from this lesson, students write a statement of Evidence. They may use the sketch part of the CER to illustrate their evidence.	Resources Chemistry in Natural Dyes and Pictographs: Claims, Evidence, Reasoning

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	4. Using all the information gained from this lesson and critical thinking, students will write their Reasoning, illustrating their ideas with a drawing.	
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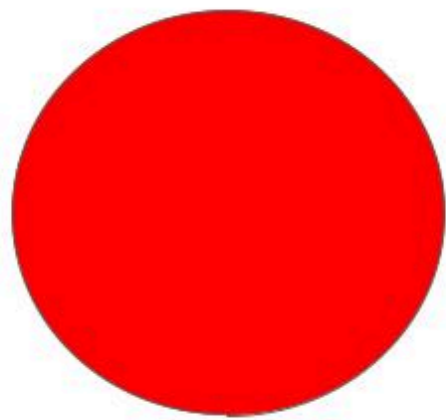
Lesson Plan 2:
Chemistry in Natural Dyes and Pictographs - Resources
Cabbage pH Color Comparison



Bases



Neutral



Acids

Acids			Bases		
2	4	6	8	10	12
Red	Orange	Yellow	Green	Teal	Blue

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Chemistry in Natural Dyes and Pictographs - Resources

Claims, Evidence, and Reasoning Graphic Organizer

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