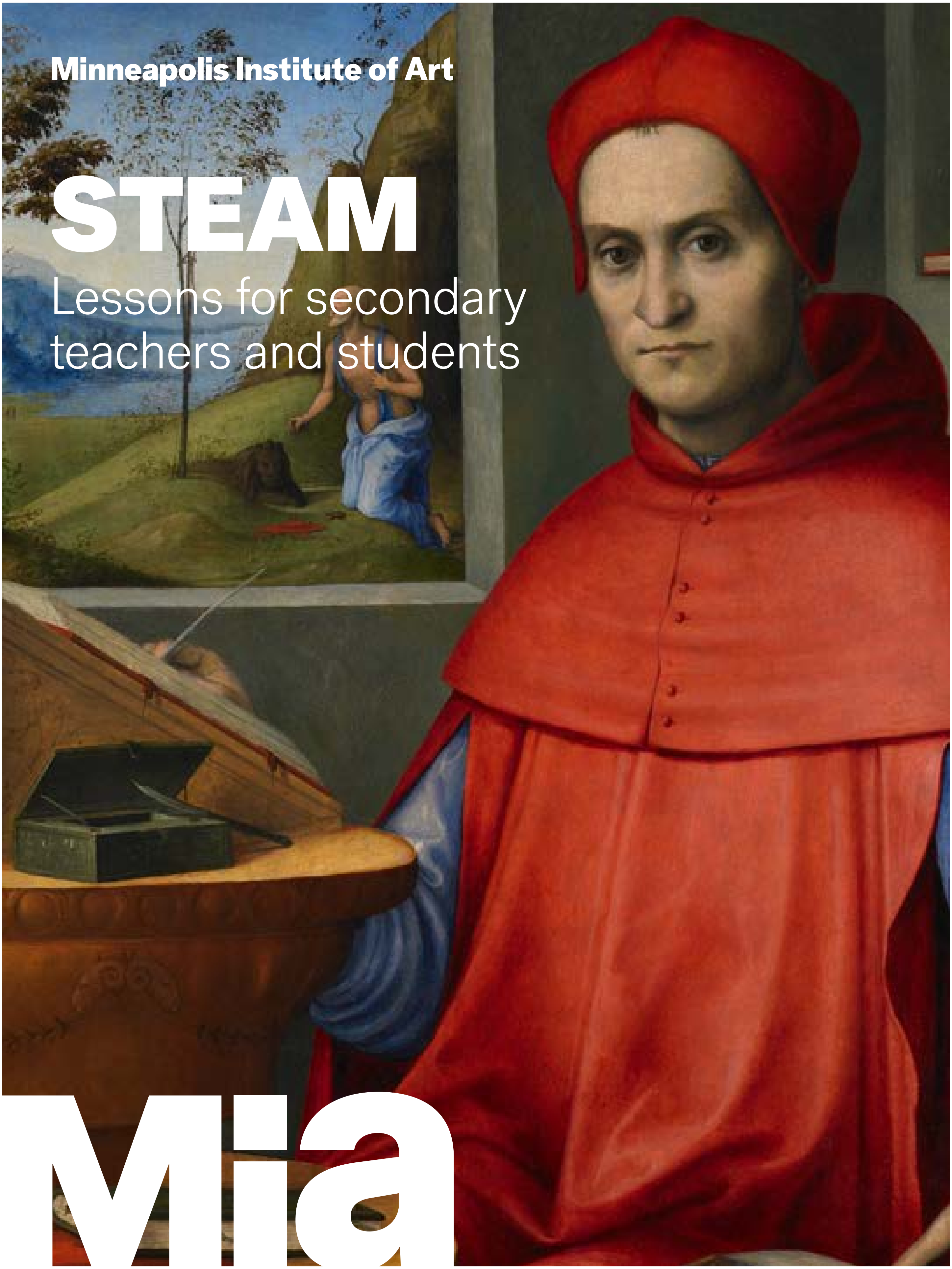
Minneapolis Institute of Art

STEAM

Lessons for secondary teachers and students



Mia

Introduction

The Minneapolis Institute of Art (Mia) Department of Student and Teacher Learning was fortunate to work with the 2013–14 cohort of the Twin Cities Teacher Collaborative (TC2), an urban teacher residency that prepares mathematics and science teachers for the 21st century.

What began as an invitation from Siri Anderson, associate professor and program director for online learning at St. Catherine University, to explore the value of introducing the Arts into STEM teaching turned into a true opportunity—a chance for TC2 residents to develop experimental lessons incorporating artworks from Mia's collection.

All of the lessons found here can be taught in your classroom; some can also be taught in Mia's galleries. Where relevant, the lessons include Minnesota academic standards and the benchmarks they support.

The five lessons, in alphabetical order:

- *Cephalopod Adaptations in Life and Art* by Kevin Tell
- *Chemistry and the Photographic Process* by Brady Jones, Caitlin Percy, and Ryan Wynn
- *Chemistry Colors Our World* by Heather Douglas and Jinjer Markley
- *Demonstration of 3-D Graphing on a Japanese Audience Hall* by Jeramy Wheeler with discussion and activity ideas by Dick Ploetz, Mia docent
- *Teaching Chemistry with Ancient Chinese Bronzes* by Matt Abbott, with art content by Dick Ploetz, Mia docent

Special thanks to Siri Anderson; the 2013–14 TC2 cohort; Dick Ploetz; and Diane Richard, editor.

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Cover: Lorenzo Costa, *Portrait of a Cardinal in His Study* (detail), c. 1510–20, oil and tempera on poplar panel, The John R. Van Derlip Fund and the William Hood Dunwoody Fund 70.17

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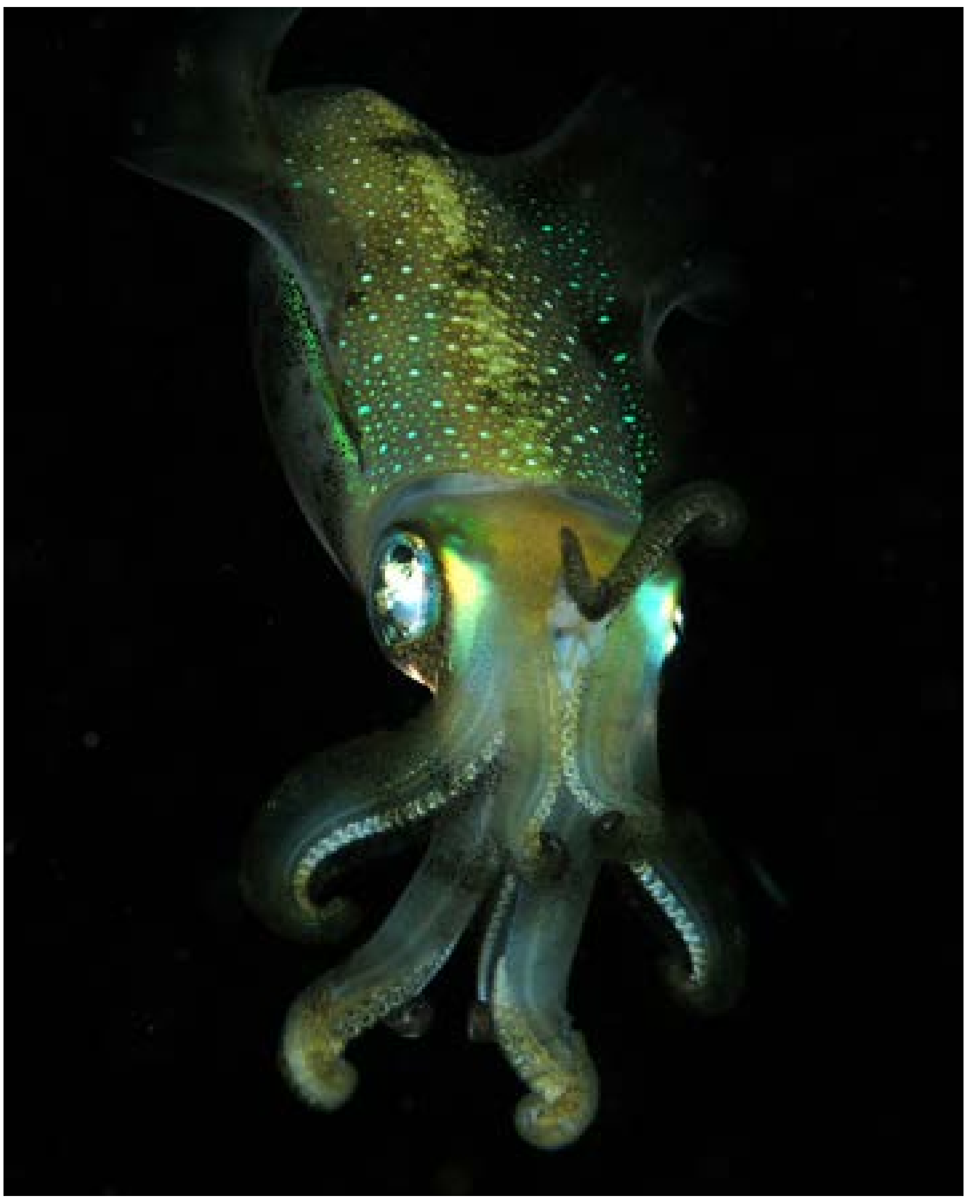
LESSON 1

Cephalopod Adaptions in Life and Art

by Kevin Tell



By Nhobgood
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Cephalopod Adaptions in Life and Art

This lesson explores cephalopods' reliance on camouflage as an adaptation for survival. Students study cephalopod adaptations and the artwork of artist Ryuta Nakajima to explore the interconnectedness of art and science.

Minnesota State Standards

Science 7.4.3.2.3/7.4.3.2.4
Individual organisms with certain traits in particular environments are more likely than others to survive and have offspring.

Science 7.1.3.4.1/7.1.3.4.2
Current and emerging technologies have enabled humans to develop and use models to understand and communicate how natural and designed systems work and interact.

Visual Arts 6.1.1.5.1 1.
Analyze how the elements of visual art including color, line, shape, value, form, texture, and space are used in the creation of, presentation of, or response to visual artworks.

Visual Arts 6.1.1.5.2 2.
Analyze how the principles of visual art, such as repetition, pattern, emphasis, contrast, and balance are used in the creation, presentation of, or response to visual artworks.

MPS District Learning Target

I can explain why some organisms are more likely to survive and have offspring.
(7.1.3.4.1, 7.1.3.4.2, 7.4.3.2.3, 7.4.3.2.4)

Objectives

Students will understand that cephalopods rely on camouflage as an adaptation for survival.

Students will be able to model their understanding of camouflage as an adaptation for survival by designing a cephalopod to match a specified environment.

Materials

- Access to a computer and projector
- "Cephalopod Camouflage" and "Cephalopod Chromatophore" images printed from the web
- Cephalopod Adaptations in Art and Life Response worksheet
- Markers, colored pencils, crayons, scissors
- Old magazines, preferably nature-related (for collages and/or inspiration)
- Tape or glue sticks
- Various other arts and crafts goods (e.g., pipe cleaners, googly eyes, fake fur, feathers, cardboard, etc.)

Lesson Plan

Anticipatory Set: (3–5 minutes)

This lesson should be introduced during a unit where students address the concept of adaptations as traits that help an organism grow, survive, and reproduce. As such, it is intended that students have some familiarity with these concepts before this lesson.

For this lesson, begin by linking to a set of images or doing a "cephalopod camouflage" image search. You could also search "cephalopod chromatophore." Print a selection of these images in color. Giving a picture to each pair of students, have them describe what they see in each picture with each other before performing a quick group share. During the group share, if any students happen to notice the cephalopod in the image, have them try to outline its shape using their finger, and discuss the ease or difficulty of doing so.

Direct Instruction Part 1
(10–12 minutes)

Next, have students watch the Science Friday video Where's The Octopus?

This 4½-minute video addresses the optical properties used by cephalopods, including octopi, squid, and cuttlefish, as camouflage to blend into their surroundings. Following the video, have students do a "Think, Pair, Share" or "Commit and Toss" to discuss what they saw in the videos. This could be followed by a short wholeclass discussion.

Possible discussion questions:

- What is one interesting or cool thing you saw in this video?
- How do cephalopods (octopi and cuttlefish) adapt to their environment?
- In what ways do cephalopods change their body appearance to blend into their environment?
- What about this particular adaptation allows cephalopods to survive in this particular environment?
- What is especially remarkable about these creatures' ability to blend into their environment?
- How does a squid's skin allow it to change color and create patterns to create texture?
- What does camouflage mean?

Direct Instruction Part 2
(15–20 minutes)

Before introducing the artwork of Ryuta Nakajima, have students watch another short video, "Can Cuttlefish Camouflage in a Living Room?"

After the video, ask students to consider what they saw in the video as they view cuttlefish artworks by Ryuta Nakajima in this PDF brochure that accompanied Nakajima's exhibition at Mia. After students have observed, described, and visually analyzed the artworks, have them read the essay "UMWELT Ryuta Nakajima" in the brochure. Continue the discussion using questions below or questions raised by the students.

Possible discussion questions:

- What do you notice about these sculptures by Ryuta Nakajima?
- What words would you use to describe these (as a group or individually)?
- How does the artist use color, line, shape, value, form, and/or texture in his artwork?
- How does Ryuta Nakajima's art model some of the adaptations cephalopods utilize to survive?
- Suppose you were going to make a 3-D cephalopod that would change based on its environment.
- What kinds of materials could you use to create the appearance of continuous change depending on the environment?
- How can natural phenomenon like camouflage be used to influence and inspire artistic endeavors?
- Specifically, how does the flexibility of cephalopod coloration and texture allow Nakajima to show them in creative and meaningful ways across various art mediums?
- What are some other ways you could take artistic license when depicting natural phenomena?
- How does technology help us better understand the adaptive abilities of cephalopods?

Independent Practice
(15 minutes)

Supplies needed: drawing paper, tools for coloring (colored pencils, crayons, paints, collage materials, etc.)

Have students model their understanding of cephalopod adaptations and how they could represent this concept artistically by having them design their own cephalopods within specified environments.

Assign each student an environment to which his or her cephalopod must adapt, or ask them to specify an environment for one another. Some environment options include various ecosystems like pond, forest, desert, ocean, arctic, or tropical rainforest; different galleries within Mia; or different parts of your classroom or school.

Encourage students to use their imaginations as they draw their cephalopods and their environments. The objective is to create a cephalopod that is not only adaptive, but also artistic; they should be as creative as possible with their designs and decisions.

As students create their own cephalopods, remind them of the following questions:

- How do these color schemes/patterns help the cephalopod blend into its environment?
- What other features might be useful to emphasize in order to ensure my cephalopod's survival?
- How do I balance making my picture both scientifically accurate while also artistic?

When students are done with their designs, have them complete the worksheet called *Cephalopod Adaptations in Life and Art Response* (see next page) as a post-activity reflection.

Cephalopod Adaptations in Life and Art Response

Name: ______________________________________ **Date:** ________________ **Hour:** ______________

Which cephalopod did you choose for this project?

____

Describe the environment in which you camouflaged this cephalopod including the ecosystem, important background features and possible predators.

____

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What important features of this environment did you choose to include in your cephalopod's camouflage to help it survive in that ecosystem (including colors, patterns and textures)?

____

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Describe your artistic process for designing your cephalopod. How did you represent these important features in a visually pleasing way? What artistic license did you take to make your cephalopod more creative?

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LESSON 2

Chemistry and the Photographic Process

by Brady Jones, Caitlin Percy, and Ryan Wynn

Chemistry and the Photographic Process

This lesson is designed to support teaching students in differentiating the five common types of chemical reactions. It incorporates hands-on activities that reinforce students' understanding of the chemical reactions, as well as the significance of chemical reactions in various photographic processes.

Minnesota State Standards

9C.2.1.3.1
Classify chemical reactions as double replacement, single replacement, synthesis, decomposition, or combustion.

9C.2.1.3.4
Balance chemical equations by applying the laws of conservation of mass and constant composition.

Objectives

- Students will learn to differentiate the five common types of chemical reactions (synthesis, decomposition, single replacement, double replacement, and combustion) through discussions of photographs and photographic processes.
- Students will understand how chemical reactions play a critical role in the art of photography.
- Students will be able to predict products of chemical reactions.

Vocabulary/Academic Language

- Chemical reaction: There are the five types: synthesis, decomposition, single replacement, double replacement, combustion. Learn more at this Web site.
- Albumen process: To make an albumen print, photographers float a thin piece of paper in a bath of egg white and salt, then coat it with silver nitrate. This light-sensitive paper is then placed against a glass plate negative and exposed to light to make a positive print. Subsequently, the prints are typically trimmed and glued to a card mount for support.
- Gelatin silver process: Introduced in the 1880s, this photographic process soon became the dominant black-and-white photographic print process. It includes various common developing-out papers that are difficult to distinguish by visual inspection (e.g., bromide, chloride or gaslight, and chloro-bromide) and one printing-out process.
- Chromogenic process: Also called "dye coupler prints," this term represents a majority of color prints made today. Part of the material that forms colored dyes upon development is included in the emulsion during manufacture. During development, the silver image is bleached out, leaving only the dye image.

Materials

- Student instruction sheet for activity
- Smartboard or projector for anticipatory set
- Silver nitrate solution
- Potassium chloride solution
- High quality, heavy-duty paper (watercolor paper)
- 2 small paint brushes per group
- Hairdryer per group
- UV light source
- 1 piece of plate glass per group
- 1 flat object (like a leaf) to be photographed per group

Classroom Environment

- Small groups of students (3–6 depending on space)

Lesson Plan

Anticipatory Set: (5–10 minutes)

1. Show images of photos by connecting to Mia Web site (artsmia.org) using links below. Discuss the chemical reactions of the older photographs.

The Great Pyramid and the Great Sphinx, 1858, by Francis Frith, albumen print https://collections.artsmia.org/art/89324/the-great-pyramid-and-the-great-sphinx-egypt-francis-frith

Migrant Mother, Nipomo, California, 1936, by Dorothea Lange, gelatin silver print https://collections.artsmia.org/art/4383/migrant-mother-nipomo-california-dorothea-lange

Charles, Vasa, Minnesota, 2002, by Alec Soth, chromogenic print https://collections.artsmia.org/art/105014/charles-vasa-minnesota-alec-william-soth

2. Have students discuss in "Think, Pair, Share" format the differences between the different photographs. Mention how two processes contain silver as a reactant.

Teacher-led Instruction Part 1
(50 minutes, if explaining lab on same day as completing it)

1. Describe the experiment the students will be completing ("Making a Photographic Print"). Teacher instructions are included in this lesson.
    - Safety reminder: Goggles and gloves must be worn! Silver nitrate and potassium nitrate are irritating to the skin; silver nitrate is light sensitive and will stain hands for several weeks.
    - The activity is similar in theory to the albumen process of photography that was common in the 1800s, which students saw in the Sphinx photograph. Review this article for a non chemistry–based description of some photographic processes including albumen prints.
2. Explain that the lab activity will be less fussy and less permanent than the traditional process of albumen photography.
3. Divide students into groups and provide each student with the activity handout at the back of this lesson.

These instructions are outlined on the handout:

1. Wear eye protection. Gloves should be worn to handle the silver nitrate and the coated paper. Silver nitrate stains your hands.
2. In a darkened room, take a piece of paper and paint one side of it with the potassium chloride solution. Dry the paper with a hairdryer.
3. Paint the dried paper, on the same side, with the silver nitrate solution. Dry the paper with a hairdryer.
4. Place your chosen object(s) on top of the paper and place under an ultraviolet light for 30 minutes.
5. Have the instructor place a piece of glass over your paper. This is optional; however it will reduce paper curling during exposure.
6. Switch off the ultraviolet light and remove the objects from the paper. Observe what has happened.

Notes: During the lab, the instructor should handle the glass sheets (not the students). The glass sheet is set atop the paper and the flat object. The glass sheet is optional, but it keeps the paper flat while drying. Remind students that a closure activity must still be completed. Provide a 5-minute warning to students before transitioning back to class.

Closure (7–10 minutes)

1. Transition back to classroom.
2. Have students form groups of 2–3.
3. Hand out a whiteboard, dry erase marker, and eraser (paper towel) to each group OR let students use a piece of note book paper and writing utensil.
4. Using flashcards, practice predicting products of double replacement reactions.
5. Show a flashcard to the class (you might need to write flashcard content on the board) and have each group respond to the question posted.
6. If time permits, go over additional flashcards for decomposition reactions.

Teacher Instructions MAKING A PHOTOGRAPHIC PRINT

Topic: Halogens, Alkali metals, balancing chemical equations, double replacement reactions, decomposition reactions

Minnesota State Standards

9C.2.1.3.1
Classify chemical reactions as double replacement, single replacement, synthesis, decomposition or combustion.

9C.2.1.3.4
Balance chemical equations by applying the laws of conservation of mass and constant composition.

Timing (40 minutes)

Apparatus & Equipment (per group)

- Paper
- 2 small brushes
- Hairdryer
- Ultraviolet light source
- Large glass sheet

Chemicals (per group)

- Silver nitrate solution (To prepare solution: add 1.3g of silver nitrate per 10mL of deionized water used.)
- Potassium chloride solution (To prepare solution: add 0.5g of potassium chloride per 10mL of deionized water used.)

Note: 10mL of each solution should be sufficient to produce 40 prints measuring 5cm x 5cm.

Teaching Tips

- Use a good quality paper such as watercolor paper.
- Any flat objects are ideal to place on the paper, including: Paper shapes; students can design their own dried leaves or pressed dried flowers
- A clean sheet of glass can be used to cover the prints during exposure to the light; this prevents the paper from curling during exposure.
- It is advisable to use a photographic fixer once the exposure is complete. The teacher (or a technician) should do this. Acufix is available from any photographic supplier. A 1:7 dilution with water at room temperature is adequate and enables the students to keep their prints (if desired and allowed).

Background

Silver chloride, silver bromide, and silver iodide (silver halides) are reduced to silver by the action of light, X-rays, and radiation from radioactive substances. They are used to make photographic film and photographic paper.

A solution of potassium chloride is put onto the paper and dried. A solution of silver nitrate is then used in the same way. The two compounds undergo a precipitation reaction, giving a slight creamy discoloration to the paper. Below is the chemical equation for this reaction.

$1\ KCl(aq) + 1\ AgNO_3(aq) \rightarrow 1\ AgCl + 1\ KNO_3$

The paper is then dried again. When the paper is exposed to light, X-rays, or radioactive substances, the silver chloride decomposes and the silver metal colors the paper. The areas of the paper that have been covered are not exposed to the energy source and remain unchanged. If a photographic negative is used, then the coloration occurs to varying degrees.

Safety

Wear eye protection. Gloves should be worn to handle the silver nitrate and the coated paper. Silver nitrate stains your hands.

Chemistry of Photography Experiment

Name: ______________________________ **Date:** ________________ **Hour:** ______________

Introduction

Only a very small amount of energy is needed to break down silver halide compounds (compounds like silver chloride, silver bromide or silver iodide). This small amount of energy is available from many sources including light, x-rays and radiation from a radioactive substance. As a result, the above silver halides can be used to make photographic film and photographic paper. In this experiment, you will be producing a photographic print.

Background

Silver chloride, silver bromide and silver iodide (silver halides) are reduced to silver by the action of light, X-rays and radiation from radioactive substances. They are used to make photographic film and photographic paper.

A solution of potassium chloride is put onto the paper and dried. A solution of silver nitrate is then used in the same way. The two compounds undergo a precipitation reaction, giving a slight creamy discoloration to the paper. Below is the chemical equation for this reaction.

$KCl + AgNO_3 \rightarrow AgCl + KNO_3$

The paper is then dried again. When the paper is exposed to light, X-rays or radioactive substances, the silver chloride decomposes and the silver metal colors the paper. The areas of the paper that have been covered are not exposed to the energy source and remain unchanged. If a photographic negative is used, then the coloration occurs to varying degrees.

Materials List

- Paper (one per group)
- Two small paint brushes (per pair)
- Hair Dryer (per bench)
- Ultraviolet Light
- Large glass sheet
- Diluted Silver Nitrate solution (1.3 g in 10 mL deionized water)
- Diluted Potassium Chloride solution (0.5 g in 10 mL deionized water)
- Object(s) to photograph (flat objects like leaves work best)
- Safety goggles
- Nitrile gloves

Procedure

1. Wear eye protection. Gloves should be worn to handle the silver nitrate and the coated paper. Silver nitrate stains your hands.
2. In a darkened room, take a piece of paper and paint one side of it with the potassium chloride solution. Dry the paper with a hairdryer.
3. Paint the dried paper, on the same side, with the silver nitrate solution. Dry the paper with a hair dryer.
4. Place your chosen object(s) on top of the paper and place under an ultraviolet light for 30 minutes.
5. Have the instructor place a piece of glass over your paper. This is optional, however it will reduce paper curling during exposure.
6. Switch off the ultraviolet light and remove the objects from the top of the paper. Observe what has happened.

Observations:

Questions:

The chemical equation shown in the background section is incomplete, it may need to be balanced and it does need phases of the materials indicated. In the space below, write the equation making sure that these details are included.

What type of reaction is shown in the equation above?

What happens to the paper when it is exposed to the ultraviolet light source? Identify which of the five main types of chemical reactions is occurring.

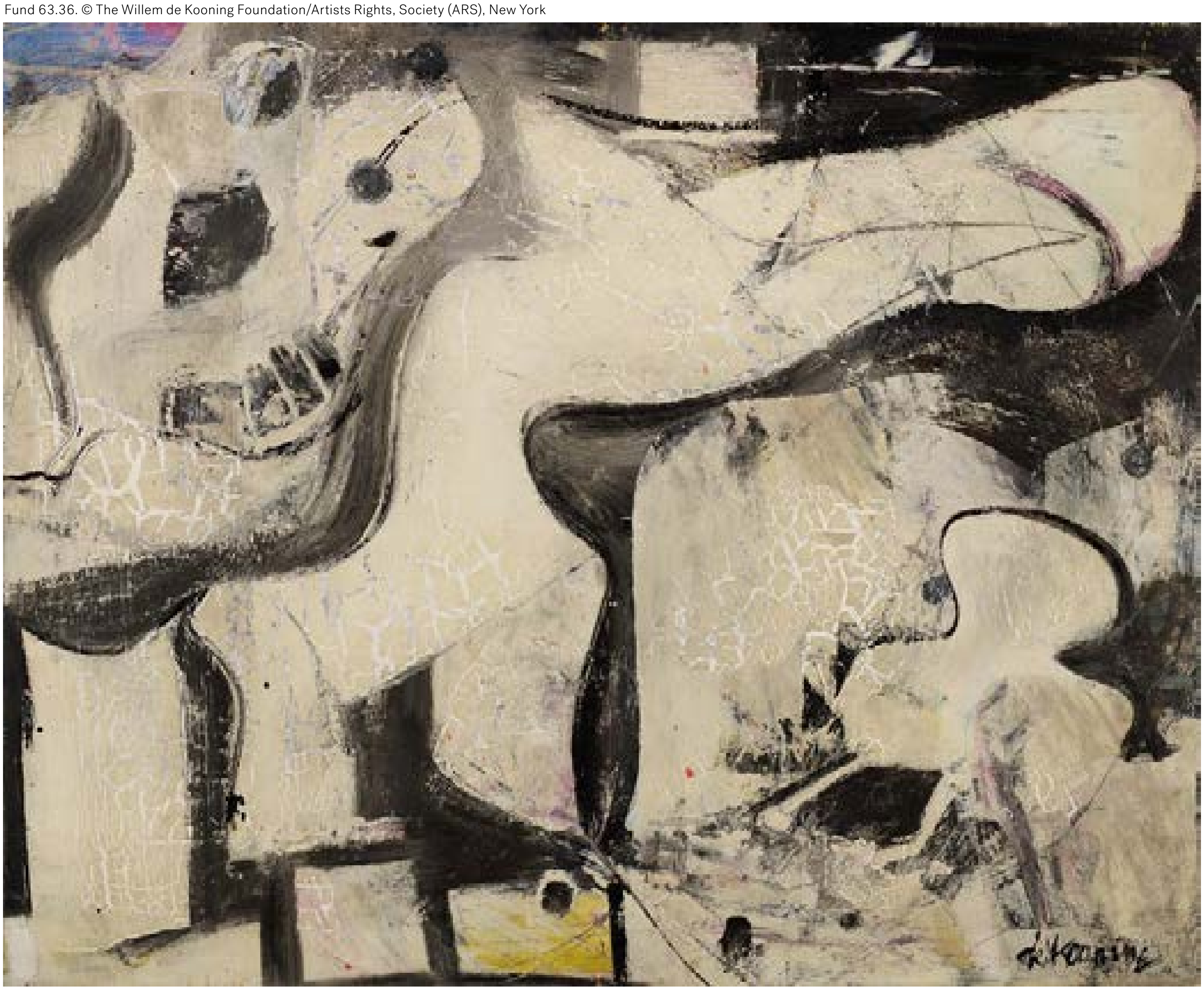
Why did we spend so much time on photography today?

LESSON 3

Chemistry Colors our World

by Heather Douglas and Jinjer Markley

Willem de Kooning, *Night*, 1948, oil on board, The John R. Van Derlip Fund and The Ethel Morrison Van Derlip Fund 63.36. © The Willem de Kooning Foundation/Artists Rights, Society (ARS), New York



Chemistry Colors our World

Big Ideas: Chemistry can help us understand and appreciate art. Though most metals are a dull gray in their elemental form, when bonded to other elements—particularly oxygen—they form brightly colored compounds that can be used as pigments in paint.

Minnesota State Standards

7.2.1.1.3 Recognize that a chemical equation describes a reaction where pure substances change to produce one or more pure substances whose properties are different from the original substance(s).

8.2.1.2.1 Identify evidence of chemical changes, including color change, generation of a gas, solid formation, and temperature change.

9.2.1.2.3 Describe a chemical reaction using words and symbolic equations.

9.2.1.1.3 Explain the arrangement of the elements on the Periodic Table, including the relationships among elements in a given column or row.

9C.2.1.2.1 Explain how elements combine to form compounds through ionic and covalent bonding.

9C.1.3.3.1 Explain the political, societal, economic and environmental impact of chemical products and technologies.

Assessments for Learning:

See *Chemistry Colors our World* worksheet included in this lesson.

Objectives

Students can describe a chemical reaction using a chemical equation.

Students can compare and contrast similar chemical reactions.

- When chemicals mix with O_2 in an oxidation reaction, the products (metal oxides) are colored. (Identify the movement of oxygen in chemical reaction.)
- Different metals create metal oxides of various colors.

Materials

This list is based on a class size of 18–36 students; 6 groups of 3–6 students will be formed. Adjust the number of supplies as needed.

- Samples of the following metals: copper and/or bronze, steel and/or iron, tin, aluminum, silver (optional)
- 6 small sliding-lock plastic bags to hold rusted objects for passing around
- Seven heavily rusted screws or other dull-edged objects
- 1 dry toothbrush for demonstration that rust is a powder. (Consumable)
- 6 8oz. jars with lids, each containing 4 oz. of white vinegar
- 30oz. of white vinegar 1 steel-wool cleaning pad
- 1 tube each of lead-tin yellow paint, firmly glued shut, red iron oxide (“mars red”) paint, and cobalt blue paint
- Sentence strips (at end of lesson)

Advance Preparation

1. Create Sentence strips using masters at the end of the lesson.

    a. Print 6 copies of Chemical Sentence Strips 1A-1D on white paper and cut on dotted lines:
    $Fe + O_2 \rightarrow Fe_2O_3$

    b. Print 6 copies of Chemical Sentence Strips 2A-2C on pale yellow paper and cut on dotted lines.
    $Sn + Pb + O_2 \rightarrow Pb_2SnO_4$

    c. Print 6 copies of Chemical Sentence Strips 3A-3C on pale blue paper and cut on dotted lines.
    $Co + Al + O_2 \rightarrow CoAl_2O_4$

    d. Glue or tape matching pieces together to eliminate extra spaces.

    e. Laminate the sentence strips.

2. Assemble supplies and arrange them for ease of passing when needed.

Lesson Plan

View rooster weathervanes in Mia galleries or use reproduction from an exhibition of the weathervanes included in this lesson.

A. Stimulate discussion:

- *What do you think the roosters are made of?* Students can also record responses on attached worksheet or in a notebook.
- *The roosters are made out of different kinds of metals. Some are made of brass or copper* (Pass out/show samples of brass and copper), *some are made of tin* (Pass out/show samples of tin), *and some are made of steel or iron* (Pass out/ show samples of steel and iron).
- *Why do you think the roosters don't look like these metals?* Anticipate the students might think the roosters were painted. Some students may know about rust, but may not make the connection. Follow up with, *What color is rust? What about the other colors?*

    1. Support observations that the colors are interesting and/or beautiful to look at, and that they would make good paint colors. We will return to this idea later.

    2. Explain: *Surprisingly, the roosters were NOT painted. Rather, the metal was exposed to oxygen. The metal and the oxygen combined to form a new substance with different properties, including color.*

B. Discuss how rusting is a chemical reaction. (Supplies: rusted screws in baggies and toothbrush)

- Pass out rusted screws in baggies.
- *Have you ever seen something metal that was left outside for a long time and changed color?* Ask for examples. *That's what happened to the rooster and these screws. A change that makes a new substance is called a chemical reaction.* Have students write this on worksheet or in notebook.
- Explain: *Not only is the new substance a different color, it is also a different texture. It is a powder.* Demonstrate that you can brush the powder off of the rusted screws with a clean toothbrush.

C. Demonstrate with steel wool and vinegar. (Supplies: steel wool, jars of vinegar)

- Explain: *We can watch a chemical reaction happen.* Pass steel wool around. *What do you think this is?* Guide students to the idea that the steel wool is made of very thin pieces of metal. If students do not identify the metal, mention it is steel.
- Pass jars of vinegar around. *This is vinegar. We will be using it to clean off the steel wool so that the iron inside the steel wool can combine with oxygen more quickly.*
- Allow students to write and draw their "before" descriptions on the worksheet or in a notebook. While they are doing so, combine steel wool and vinegar as described below.
- *While you were making your observations, I combined these two things. I'll show you what I did:*

    1. Tear off a quarter-sized piece of steel wool. Be careful not to ball it up too tightly.

    2. Place the steel wool into the 8oz. glass or clear plastic jar with a lid. The jar should already contain 4oz. of white vinegar.

    3. Soak 1–2 minutes.

    4. *After we add the two things together, what do you observe?* Have students record their observations.

- *Rust is the product of a chemical reaction. It is also called "red iron oxide."*

D. Explain what a chemical reaction is. (Supplies: iron oxide sentence strips)

Anticipate and discuss these common misconceptions about chemical equations in general, and rusting, in particular:

1. Misconception: Rust eats away at the metal. Metal and oxygen combine together, transforming into rust. Scientific conception: Although rust is "bigger" than the metal (because it also has oxygen in it), holes form where metal produces rust because rust can crumble into powder and fall off or get washed away.
2. Misconception: Rust is a mold or other living thing that grows on metal. Scientific conception: Rust is a non-living chemical.
3. Misconception: Chemical equations show what "ingredients" add together to make something. Scientific conception: Although the reactions we use today don't challenge this conception, it is misleading to support that idea. Chemical equations describe a chemical reaction; while some reactions put things together to make a more complicated substance, some reactions break complicated substances apart, and some recombine substances. The reactions we are describing today are called "synthesis reactions"
4. Misconception: Chemical equations are basically math equations. Scientific conception: Unlike mathematical equations, chemical equations cannot be turned around. A chemical equation represents an event. If you turn it around, it represents a very different event.

- Show the photo-based chemical sentence strip. This is a description of what we just saw happening. Remember, we used the vinegar just to clean off the steel so the iron inside it could react with oxygen more quickly. What do you notice about the format of this description?

  Lead students to notice that:
  - Photographs represent the different substances involved.
  - There are plus signs separating different substances.
  - The arrow separates what you had "before" and "after" you combined the substances.

- Show the word or formula-based chemical sentence strip, depending on the level of preparation of your group. You can also show the model-based equation. This is called a chemical equation. A chemical equation is a sentence that describes what is happening during a chemical reaction using symbols. Have students write this on worksheet or in notebook. The arrow shows the change that happened. Before the change, you had two substances: iron and oxygen. After the change, there was only one substance: rust.

  Common misconceptions about chemical equations:

  1. Misconception: All reactions show "ingredients" that add together to make something. Though the reactions we use today don't challenge this conception, it is misleading to support that idea. For advanced students, you can tell them that this type of reaction is called a synthesis reaction.
  2. Misconception: Chemical equations are basically math equations. Unlike mathematical equations, chemical equations cannot be turned around. They represent an event. If you turn it around, it represents a very different event.

E. Compare chemical reactions.

(Supplies: remaining sentence strips)

- Introduce chemical reaction sentence strips for other pigments, one at a time.
- Pass out sentence strips with photographs showing synthesis of lead-tin oxide. *Iron is not the only metal that can have chemical reactions. This sentence strip shows the story of lead and tin having a reaction.*
- Pass out equation (words or formulas depending on group). *This chemical equation describes the reaction. They are both on yellow paper so you know that they go together.*
- Pass out sentence strips with photographs showing synthesis of cobalt-aluminum oxide. *This sentence strip shows the story of cobalt and aluminum having a reaction.*
- Pass out equation (words or formulas depending on group). *This chemical equation describes the reaction. They are both on blue paper so you know that they go together.*
- Work with your group to compare and contrast all three of the reactions. After 3 minutes, you will share one thing you noticed.

  Students share their observations. If they do not mention the following, point them out:

  1. All of the reactions start with gray or silvery metal(s).
  2. All of the reactions start with oxygen.
  3. All of the reactions make an "oxide."
  4. All of the reactions make a powder.
  5. Each reaction makes a different colored powder.
  6. Each of the reactions starts with different metals.
  7. (Optional) All of the reactions start with elements.

- *So now we can see why the roosters were so colorful. Different gray metals react with invisible oxygen gas to make different colored powders. Without chemical reactions, the world would be a dull gray color, but because the metals in rocks react with oxygen, there are beautiful, colorful rocks. Artists realized that they could use these colored powders. Artists call colored powders "pigments." They mix pigments with liquids to make paints.*
- Pass around tubes of "mars red," "lead-tin yellow," and "cobalt blue" paints.
- *Now we are going to go see a painting and ceramics that use the pigments we have just explored.*

  (If teaching at the museum, move to Lorenzo Costa's painting, *Portrait of a Cardinal in His Study* in the Renaissance galleries to explore "lead-tin yellow" paint.)

View Lorenzo Costa's *Portrait of a Cardinal in His Study* at Mia or use reproduction included in this lesson plan. Assign a student in each group to be responsible for the sentence strips.

- Point out the golden color in the trees in the background of the painting that are likely painted with "lead-tin yellow" based on art historical and chemical studies of other works by Costa.
- Ask: *What metal or metals reacted with oxygen to produce the pigment in that paint?* Allow time to think and look at the sentence strips as a group.
- Have students share out as a class. Ask them to explain their thinking.
- Higher-level question: *Do you think there are other metals that reacted with oxygen to produce paints used in this painting? If so, what metals do you think react and what parts of the painting have these pigments?*

[If teaching at the museum, move to Chinese ceramics installation that features blue and white objects to discuss "blue cobalt" pigment.]

View objects from the installation of Chinese ceramics decorated with "blue cobalt" in Mia galleries, or use the reproduction of a ceramic bowl included in this lesson plan.

- *What pigment do you think the artists in this room used to decorate their pottery?*

To remind students what "pigment" means, you can say: *The pigment we focused on in the last room was "lead-tin oxide."*

- *Artists call cobalt-aluminum oxide "cobalt blue." It was very popular with Chinese ceramic artists. It is still a popular pigment today.*

[If teaching at the museum, move to Willem de Kooning's painting, *Night*, in the Modern Art galleries for a discussion.]

View Willem de Kooning's *Night* at Mia or use the reproduction included in this lesson plan. Assign a student in each group to be responsible for the sentence strips.

- *What colors do you notice in this painting?*
- *How would the painting be different if the artist had used cobalt-aluminum oxide instead of the black pigment in this painting?*
- Follow-up questions: *How would this affect the mood of the painting? Would the painting tell a different story? Why do you think artists choose different colors?*
- This would also be a great place to talk about how the development of new pigments changed the look or feel of art through the ages.

Modifications

If students will complete this activity at the museum, have them write worksheet headings in a notebook or tape the worksheet into their notebook. You could also provide students with clipboards. These modifications will make it easier for students to record their observations and thoughts throughout the lesson.

If your class is learning about the periodic table, bring a portable periodic table, and have students find the elements they learned about. Do they see any patterns in where those elements are found?

Extension Activities

Middle School
This lesson can be extended in an art activity during which students paint a bookmark or paint with salad spinners using red iron oxide, black iron oxide, and/or yellow iron oxide mixed with white glue and water. These pigments are non-toxic, and are available at art or ceramics supply stores.

High School
Students complete a lab during which they make pigments. Search the Internet to find a lab that best fits your classroom.

Career & Technology Connections

Check out this blog by Joan Gorman, senior paintings conservator at the Midwest Arts Conservation Center. Gorman discusses and documents her progress on the restoration of a painting by Max Beckmann in Mia's collection.

Connections to Art

Art History
Learn about the history of pigments and paint production.

- Explore and discuss how pigments impact the works of art throughout history. http://www.webexhibits.org/pigments/intro/renaissance.html
- Timeline showing the connection between science and art in the production of paints and paint materials. http://www.winsornewton.com/na/heritage/our-history/

Recent Exhibition

Monica Haller https://new.artsmia.org/exhibition/america-beneath-the-soil/

Models
- cobalt aluminum oxide
- lead tin oxide
- photos
- aluminum
- lead
- tin
- cobalt aluminum oxide
- lead tin oxide

Installation view from the exhibition "Wind and Whimsy: Weathervanes and Whirligigs from Twin Cities Collections," Minneapolis Institute of Art

Lorenzo Costa, *Portrait of a Cardinal in His Study* (detail), c. 1510–20, oil and tempera on poplar panel, 32 1/4 x 30 in. (81.92 x 76.2 cm) (panel), The John R. Van Derlip Fund and the William Hood Dunwoody Fund 70.17

China, Bowl, 1522–66, porcelain with underglaze blue décor, 6 ¾ x 15 x 15 in. (17.15 x 38.1 x 38.1 cm),
Gift of Allan L. Rhoades 83.112.1

Willem de Kooning, *Night*, 1948, oil on board, 22 x 28 ¾in. (55.9 x 73cm) 28 x 34 x 1 1/2 in. (71.12 x 86.36 x 3.81 cm) (outer frame), The John R. Van Derlip Fund and The Ethel Morrison Van Derlip Fund 63.36. © The Willem de Kooning Foundation/ Artists Rights Society (ARS), New York

Chemistry Colors our World Student Activity Guide

Name: ____ **Date:** ________________

Rooster Weather Vanes: What do you think the roosters are made of? Why do you think this?

____

____

Chemical reaction	Chemical equation

Steel wool and Vinegar Observations: Draw a picture or write your observations of the steel wool before it was put in vinegar and after it was put in vinegar.

Before Combining Steel Wool and Vinegar	**After Combining Steel Wool and Vinegar**
Steel Wool	Steel Wool
Vinegar	Vinegar

Chemical Equations: After you completed the sentence strips for the iron, cooper, and tin. Using your sentence strips, fill in draw and write the chemical equation for iron rusting.

Iron Rusting

Drawings

	+		→	

Words

________________ + ________________ → ________________

Compare and contrast the sentence strips for the three chemical reactions. You can use words, sentences, pictures, or all three.

The three chemical equations are similar because...

The three chemical equations are different because...

Chinese Ceramics: What pigment do you think the artists used to decorate their pottery?

Willem de Kooning, *Night*: How would the painting be different if the artist had used cobalt-aluminum oxide instead of black pigment in this painting?

Chemical Sentence Strip 1A

$$\_\_\_Fe + \_\_\_O_2$$

$$\rightarrow \_\_\_Fe_2O_3$$

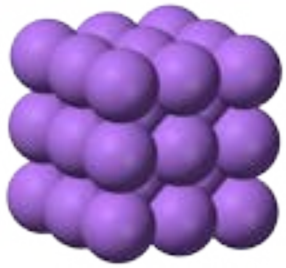
Chemical Sentence Strip 1B

iron + oxygen

→ red iron

oxide

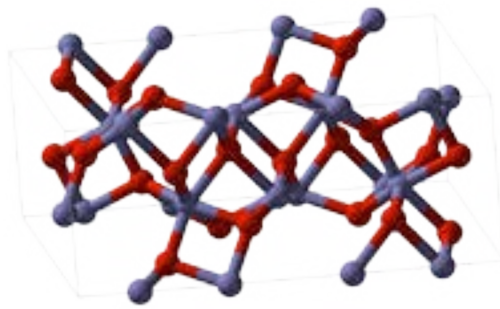
Chemical Sentence Strip 1C



+

+

→



All images are public domain

Chemical Sentence Strip 1D

+

→

Image credits:

Iron metal image is licensed under the Creative Commons Attribution-Share Alike 3.0 Unported license by: http://woelen.homescience.net/science/index.html
Water images is licensed under the Creative Commons Attribution-Share Alike 3.0 Unported license by: Walter J. Pilsak, Waldsassen, Germany
Oxygen image is public domain (A Sailor fills tanks with liquid oxygen on the flight deck aboard USS Harry S. Truman).
Rust image is public domain.

Chemical Sentence Strip 2A

$$\_\_\_Pb + \_\_\_$$

$$Sn + \_\_\_O_2$$

$$\rightarrow \_\_\_Pb_2SnO_4$$

Note: Lead-Tin Yellow is generally produced by a chemical reaction between a lead oxide and a tin oxide, but for educational simplicity, it has been presented here as a synthesis reaction. For advanced students, groups, a more authentic equation could be used. For example: Pb3O4 + SnO2 --> Pb_2SnO_4

Chemical Sentence Strip 2B

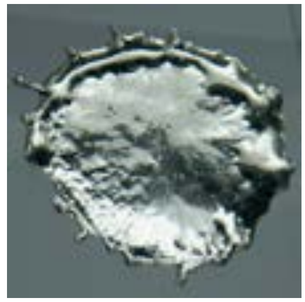
lead + tin +

oxygen

➔ lead-tin oxide

Note: Lead-Tin Yellow is generally produced by a chemical reaction between a lead oxide and a tin oxide, but for educational simplicity, it has been presented here as a synthesis reaction. For advanced students, groups, a more authentic equation could be used. For example: Pb3O4 + SnO2 --> Pb_2SnO_4

Chemical Sentence Strip 2C

 +  +

 → 

Image Credits:
Lead: *Creative Commons 'Attribution-NonCommercial-NonDerivative 3.0 {No facebook] by* Alchemist-hp ***Tin:*** Creative Commons Attribution 3.0 Unported license created by Jurii - http://images-of-elements.com/tin.php ***oxygen:*** public domain. ***lead-tin oxide:*** actually a different pigment, but the color is so similar, it doesn't matter. copyright free: http://commons.wikimedia.org/wiki/File:Pigment_Yellow_53.jpg

Chemical Sentence Strip 3A

$$\_\_\_ Co + \_\_\_ Al +$$

$$\_\_\_ O_2 \rightarrow$$

$$\_\_\_ CoAl_2O_4$$

Note:Cobalt Blue is generally produced by a chemical reaction between a cobalt oxide and an aluminum oxide, but for educational simplicity, it has been presented here as a synthesis reaction. For advanced students, groups, a more authentic equation could be used. For example: $CoO + Al_2O_3 \text{-->} CoAl_2O_4$

cobalt +

aluminum +

oxygen

➔ cobalt-

aluminum oxide

Note:Cobalt Blue is generally produced by a chemical reaction between a cobalt oxide and an aluminum oxide, but for educational simplicity, it has been presented here as a synthesis reaction. For advanced students, groups, a more authentic equation could be used. For example: $CoO + Al_2O_3 \text{-->} CoAl_2O_4$

Chemical Sentence Strip 3C

+

+

→

Photo credits:
cobalt: Creative Commons Attribution 1.0 Generic license. available at http://images-of-elements.com/
aluminum: Creative Commons Attribution 3.0 Unported license created by Materialscientist
oxygen and cobalt blue : public domain

LESSON 4

Demonstration of 3-D Graphing on a Japanese Audience Hall

by Jeramy Wheeler, with discussion and activity ideas by Dick Ploetz, MIA docent

Japan, Formal Audience Hall. Constructed 2001, Yasuimoku Komuten Company Ltd.,
Gift of the Roberta Mann Foundation in memory of Ted Mann 2001.204.2

3-D Graphing

This is a brief video demonstration of how to make a 3-D graph. By modeling 3-D graphing on a replica of a 17th-century Japanese audience hall, you can introduce students to the interrelatedness of art and math. You can extend the experience with a discussion of the Japanese audience hall on view at the Minneapolis Institute of Art (Mia).

Objectives

- Students will understand how to create a 3-D graph.
- Students will understand the importance of geometry to Japanese architectural design.
- Video demonstration of 3-D graphing (6 minutes)
- View the video to learn how to do 3-D graphing.

Discussion & Activities (10–30 minutes)

After viewing the video demonstration of 3-D graphing, engage students in a discussion about the Audience Hall and the architects' use of geometry. An image of the room is included at the back of this lesson. Time permitting, use these questions and/or activities, or questions generated by the students.

1. The video shows the process of 3-D graphing using x, y, and z axis and illustrates the result by overlaying the drawing on a corner of a Japanese Audience Hall at Mia. How have the architects created symmetry in the room? Where do you see asymmetrical design elements? Notice all of the straight lines and right angles. How many geometric forms can you see? What is the effect of the rectangular shapes on the walls? How does the arrangement of the rectangular forms in the room affect its "feel"?

   Where do you see non-angular elements in the room? What are their overall relationships to the room? Another element of art, besides line and shape, is color. How does color play a role in the overall composition of the hall?

2. This room is a replica of a 17th-century Japanese audience hall located in a temple of a Zen monastery in Japan. Elegant rooms such as these are called shoin, which means study or writing hall, even thoughvthey are used as reception rooms. The room is filled with decorative details, such as lightweight paper sliding doors embellished in gold and beautiful images painted on some of the paper walls. What other details do you notice? What do you wonder about this room? Where might you search to find out more about the room?

3. The floor is covered with ***tatami*** mats, made of soft woven grasses. The edges on the long sides of the ***tatami*** are finished with a brocade or plain cloth. The Japanese traditionally sit on these mats, eliminating the need for much of the furniture found in a western home. Tatami mats differ slightly in size across Japan but always have a length three times longer than their width. Even though homes in Japan seldom have ***tatami*** mat floors today, the common unit of room measurement uses ***tatami*** mats as a reference.

   A *tatami* mat measures approximately 6 feet by 3 feet. Based on the picture you see, can you calculate the square footage of the hall?

4. Artists wrestle with the depiction of 3-D spaces on 2-D materials, such as paper or canvas. Artists of the Renaissance era discovered the vanishing point—the point at which parallel lines converge to a single point in the distance. Some paintings have one, two, or three vanishing points, which give the image reality and depth. Where can you see the principle of the vanishing point demonstrated in the photograph of the floor in the audience hall? What geometric figures are created when this technique is used on a 2-D surface like a painting or a photograph?

To see a modern artist's play on perspective, see René Magritte's *The Promenades of Euclid,* 1955. To learn more about it, visit this Teaching the Arts feature on Math and Art.

René Magritte, Belgium, 1898–1967, *The Promenades of Euclid*, 1955, oil on canvas, The William Hood Dunwoody Fund, 68.3, © C. Herscovici / Artists Rights Society (ARS), New York

LESSON 5

Bronze: Teaching Chemistry with Ancient Chinese Bronzes

by Matt Abbott, with art content by Dick Ploetz, Mia docent

China, Covered Ding (Ritual Food Vessel), 600–222 BCE, bronze, Bequest of Alfred F. Pillsbury 50.46.38a,b

Ancient Chinese Bronzes

Scientists and artists are not all that different. Both are interested in understanding the world around them. While scientists use the scientific method, chemical analysis, and mathematics to define their world, artists use materials (paint, stone, metal, fiber) and imagination in unique ways to express their feelings and thoughts about their world. Both scientists and artists work hard to develop their particular skills and master those skills through discipline and practice.

Overview

This set of lessons covers 13 benchmarks across various grade levels as defined by the 2009 Minnesota Department of Education K–12 Standards.

The set of lessons is broken into three parts:

Part 1: Materials (for elementary and junior high students; this could also serve as an introduction for high school students)

Part 2: Atomic Conservation (for junior high and high school students)

Part 3: Unit Analysis (for high school students)

These lessons are designed to take place in the Minneapolis Institute of Art's (Mia) gallery featuring ancient Chinese bronze vessels. They can also be completed using images from the Mia Web site artsmia.org.

To view images of bronze objects in Gallery 214, follow this link.

Introduction

Scientists and artists are not all that different. Both are interested in understanding the world around them. While scientists use the scientific method, chemical analysis, and mathematics to define their world, artists use materials (paint, stone, metal, fiber) and imagination in unique ways to express their feelings and thoughts about their world. Both scientists and artists work hard to develop their particular skills and master those skills through discipline and practice.

Learning Activity 1: Materials

(elementary, junior high, introduction for high school)

1. Science allows us to learn about the world around us, as do objects from the past. For example, this ancient vessel is over 2,500 years old. What is it made of? An ancient artist made it out of bronze. What two elements are in bronze? Bronze is an alloy made out of more than one type of metal atom. Alloys are metals made out of more than one type of metal.

   Science 7.2.1.1.2 Describe the differences between elements and compounds in terms of atoms and molecules.

2. Copper and tin are fairly soft by themselves. (Distribute samples of the two metals to the students.)But when they are melted together, they create hard bronze. (Distribute bronze sample.

   Science 7.2.1.1.3 Recognize that a chemical equation describes a reaction where pure substances change to produce one or more pure substances whose properties are different from the original substance(s).

3. Why does this sample of bronze look different from the bronze in the Chinese ritual food vessel, called a ding?

   Science 9.2.1.2.3 Describe a chemical reaction using words and symbolic equations. For example: The reaction of hydrogen gas with oxygen can be written: 2H2 + O2 2H2O.

4. Right now this ding has been cast into a very specific shape. How could they have taken a solid hunk of bronze and changed it into this shape?

   Science 4.2.1.2.1 Distinguish solids, liquids, and gases in terms of shape and volume.

5. This shape and design have been created by melting the bronze. How do you melt (or smelt) a metal?

   Science 4.2.1.2.2 Describe how the states of matter change as result of heating and cooling.

To prepare for this lesson, watch: YouTube video on the history and evolution of bronze-casting. Use the information below to integrate a discussion of the art of Chinese bronzes into the science lesson.

1. Early Chinese craftsmen made serving vessels from fire-hardened clay. These objects were practical, durable, and often beautifully finished. The discovery that copper and tin could be smelted into bronze opened new avenues of expression for the artist. Bronze, with its golden color, durability, and malleability, led to complex, finely crafted vessels. By 1200 BCE, these vessels were prized and collected by the Chinese aristocracy, who often had them placed in their graves for use in the afterlife.

   Bronze proved to be a perfect medium for the artist's imagination. Elaborate ritual vessels intended to serve food, water, and wine were sometimes even fashioned in the shapes of animals. Many had the intricate faces of dragons inscribed on them, and all were elaborately decorated with intricate images and geometric designs.

2. Chinese artists produced bronze alloys in kilns that reached temperatures of 1000 degrees Fahrenheit. But first the artist had to fashion it in clay. Once the clay model was made and hardened, the artist placed another layer of clay over the outside of the model. When this outer layer was still soft and leathery, the artist took this outer layer of the mold and carved the vessel design on its inner surface. This second layer of clay was then carefully placed—separated slightly by supporting pins of clay—over the original clay model. Molten bronze was then poured between the two layers of clay and allowed to harden. When the bronze was ready, the clay mold was broken and the cast bronze vessel was revealed. Since the mold was destroyed and no other pieces could be made from it, this method was called piece casting.

3. Artists need to know their materials well. Ancient Chinese artists may not have known the principles of chemistry that created bronze, but they were expert in the processes of mixing the elements (copper and tin) of bronze, the temperatures and conditions required for melting it, and the making of the mold.

   These techniques—based on the science of materials —enabled artists to achieve their vision. Their mastery created the complex designs we see today.

Learning Activity 2: Atomic Conservation (high school)

1. What happens with the copper and tin atoms in bronze as it melts?

   Science 6.2.1.2.3 Use the relationship between heat and the motion and arrangement of particles in solids, liquids and gases to explain melting, freezing, condensation, and evaporation.

   Science 9C.2.1.4.1 Use kinetic molecular theory to explain how changes in energy content affect the state of matter (solid, liquid, and gaseous phases).

2. We can measure this bronze in different ways, including mass, volume, and density. Mass is the amount of something. In science, we can measure mass in grams (g). For example, there are 33g of sugar in a can of cola.

   Science 6.2.2.2.4 Distinguish between mass and weight.

3. Volume is the amount of space something takes up. In science, we measure volume in milliliters (ml). For example, there are 355ml of cola in a cola can.

4. When we combine mass and volume, we get density, or how dense something is. Density is measured in grams per milliliter (g/mL).

5. So how many milliliters of melted bronze did it take to make this sculpture? How could we find out?

   Science 6.2.1.2.2 Describe how mass is conserved during a physical change in closed system. For example: The mass of an ice cube does not change when it melts.

   Science 8.2.1.2.3 Use the particle model of matter to explain how mass is conserved during physical and chemical changes in a closed system.

Use the information below to integrate a discussion of the art of Chinese bronzes into the science lesson.

As artists developed greater skills in working with bronze, they grew more creative and experimental in their techniques. Some objects became more delicate; others larger in scale. Some bronzes are 5 feet tall and weigh over 2 tons!

Vessels were made for secular and religious purposes. Perfectly tuned bell ensembles could perform complex musical compositions. Later on, artists began to incorporate other metals into their creations by inlaying those metals and/or semi-precious stones into the surface of the bronze vessel. The sudden explosion of varieties in form (volume), size (mass), and design demonstrate the continued experimentation achieved by the bronze artists of China.

The *ding*, a ritual food vessel, in Gallery 214, is an excellent example of this innovation. Dating to the 4th or 3th century BCE, it represents a new vessel design and is beautifully decorated with silver inlay.

See the following YouTube link for a two-minute recording of a Chinese bell ensemble concert.

Learning Activity 3: Unit Analysis

(high school)

Show the *ding* referenced above for this activity. Based on measurements taken of similar vessels, we can use a mass of 3.2kg and a capacity of 2205ml. for this exercise.

Melting this ding would destroy it. We can use dimensional analysis to find the volume of liquid bronze that was poured over 2,200 years ago to create it.

Science 9.1.3.4.5 Demonstrate how unit consistency and dimensional analysis can guide the calculation of quantitative solutions and verification of results.

1. This ding has a mass of 3.2kg. Modern bronze has the density of about 8.5g/ml. Using these dimensions, what was the mass of the liquid bronze used to cast this piece?

   Example using mass of 1.44kg

   1.445kg × 1000g × 1ml = 144500ml = 1700ml

   1 kg   8.5g   8.5

2. This *ding* can hold 2.5 liters. If we poured 2.5 liters of melted bronze into the ding, how many copper atoms will it hold? How many tin atoms? How many atoms total?

   Example using 17.5 liters

   Let's say the bronze is 75% copper and 25% tin by mass.

   17.5L bronze × 1000ml × 1ml × 75g copper × 1mol copper × 6.02×1023 atoms = 1.5×1025 copper atoms

   1L   8.5g   100g bronze   63.546g copper   1mol

   17.5L bronze × 1000ml × 1ml × 25g tin × 1mol tin × 6.02×1023 atoms = 2.6×1024 tin atoms

   1L   8.5g   100g bronze   118.71g tin   1mol

3. How else could you express these results?

Example based on calculations from previous example.

1.5×1025 copper atoms		15. ×1024 copper atoms
+ 2.6×1024 tin atoms	because	2.6×1024 tin atoms
1.8×1026 total atoms		17.6×1024 total atoms

17.6×1024 atoms rounds up to 1.8×1025 atoms (two significant figures)

That is close to 20,000,000,000,000,000,000,00 0,000

... a 2 followed by 25 zeros

... 20 thousand million

... 20 septillion

... atoms.

Math 8.1.1.5 Express approximations of very large and very small numbers using scientific notation; understand how calculators display numbers in scientific notation. Multiply and divide numbers expressed in scientific notation, express the answer in scientific notation, using the correct number of significant digits when physical measurements are involved.