Lesson Plan: Exploring the Chemistry of Oil and Acrylic Paints

FOR THE TEACHER

Summary
In this lesson students learn about the chemistry of oil and acrylic paints. They make their own paint, and complete an experiment to collect qualitative and quantitative data through a series of tests. Students will also apply the concepts of physical and chemical change to the results of this controlled experiment.

Grade Level
Middle School

NGSS Alignment
This lesson will help prepare your students to meet the performance expectations in the following standards:

- MS-ETS1-2: Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
- Science and Engineering Practice - Using Mathematics and Computational Thinking - Decide when to use qualitative vs. quantitative data.

Objectives
By the end of this lesson, students should be able to

- Complete a controlled experiment to make two different types of paint and complete a variety of tests on the samples
- Explain the difference between acrylic paint drying through evaporation (physical change) and oil paint drying through oxidation (chemical change).

Chemistry Topics
This lesson supports students’ understanding of

- Mixtures
- Physical Properties
- Chemical Properties
- Physical Change (Evaporation)
- Chemical Change (Oxidation)
- Scientific Method
- Polymers

Time
Teacher Preparation: 60 minutes
Lesson:

- Engage: 20 minutes
- Explore: 45 minutes
- Explain: 20 minutes
- Elaborate: 20 minutes
- Evaluate: 20 minutes

Materials

- Safety and Housekeeping:
  - Sealable, metal disposal can such as an old paint can for all oil containing waste
  - Table covers to prevent paint stains (old newspapers, cardboard, disposable table clothes)
Aprons or old clothing
Gloves (optional)

- Making paint (per group):
  - 4-5 gram (heaping teaspoon) Ultramarine blue pigment: available for purchased online and at art supply stores
    - Example 1
    - Example 2
  Note: Other pigments may also be used. Ultramarine blue was chosen because of its interesting history in painting and safety profile. If other pigments are selected, make sure they are safe for student use.
  - 3-4ml Refined flax seed oil (pure): available online and in health food stores (alternative: Safflower oil)
  - 4-5 gram (heaping teaspoon) Acrylic binder: emulsion of acrylic polymer and water, which forms a matrix holding the pigment in place.
    - Example 1
    - Example 2
  - 2 Plastic forks
  - 2 Plastic knives
  - 2 Plastic teaspoons
  - 1 Droppers
  - 2 Paper Plates topped with clear packing tape

- Testing the paint (per group):
  - 2 Identical paint brushes
  - 6 Cotton swabs
  - 1 Sheet of Canvas Paper
  - Scissors
  - Clock or stopwatches

Safety
- Always wear safety goggles when handling chemicals in the lab.
- Students should wash their hands thoroughly before leaving the lab.
- When students complete the lab, instruct them how to clean up their materials and dispose of any chemicals.
- We are using flax seed oil, which can be thought of as food grade linseed oil. Linseed oil is flammable, and flax seed oil should be treated with equal caution. Paper towels and rags used to clean up linseed oil often spontaneously combust. To dispose of paper towels and rags containing linseed oil, submerged them in water in a metal paint can and carefully seal the can. The can should then be disposed of at local hazardous waste disposal center. This article and news video review this danger, and can be used as a powerful tool to remind students of the importance of proper chemical disposal.
- Ultramarine blue pigment selected for use in this lesson has low toxicity. If you modify this activity, please research the health impacts and safety of any other pigments that are brought into the classroom. This website provides a list of some toxic pigments to avoid.
- Do not breathe in pigment powder.

Teacher Notes
- **Background:** Beginning painters are faced with the decision between purchasing oil or acrylic paints. Both paint types have advantages and disadvantages. This lesson teaches students about the chemistry of the two types of paint, asks them to mix their own oil and acrylic paint, and guides them through an experiment comparing the drying times of their paints.
- Oil paints consist of pigment particles suspended in a drying oil, like linseed oil. A drying oil hardens when its components react with oxygen in the air and polymerize to form a tough solid.
In this activity, flax seed oil is used as a drying oil. A thinner may be added to make the oil paint easier to store and spread, but will not be necessary in this activity.

- Oil paints do not change color when they dry, and can provide rich, deep colors. Solvents are required to clean oil paint off brushes once the paint has dried.
- Pure flax seed oil used in this lesson is very slow to dry. It should be possible to clean equipment and surfaces with soap and water, and not need any solvents.
- Acrylic paints consist of pigment particles suspended in an acrylic polymer emulsion. Acrylic paints dry quickly, but before they dry they are water soluble. This allows for simple cleanup.
- A comprehensive overview of the history of acrylic emulsions can be found at the American Chemical Society National Historic Chemical Landmarks website.
- Make sure that you do not tell the students about the difference in drying time between the two paints as they will discover this through their experiment.

The pigment chosen for this activity is ultramarine blue, a deep blue pigment. It was originally obtained by grinding the rock lapis lazuli into powder. It was the most expensive blue pigment, and painters reserved it for the most precious parts of their paintings. In the early 1800s, scientists devised a way to produce the same color artificially. Synthetic ultramarine is inexpensive and nontoxic. It is now used in many types of artist’s paints and wall paints, makeup, and even in laundry detergent as a “bluing” agent that brightens up faded whites.

- Artists typically mix on a glass plate. Watch glasses work, but must be cleaned while the paint is still wet, or else a solvent will be needed to remove the oil paint. A simple, disposable solution is to apply clear packing tape or plastic wrap to part of a paper plate and have students mix on top of the tape/plastic wrap. This will prevent the oil from soaking into the paper plate.

**Engage:** Ask the students to provide examples of when they have used paints (pre-lab question 1 from student handout), what they were painting, and what type of paint was used.

Next, read the following scenario:

- Frida and Andy enjoy painting at school. As a middle school graduation present, their uncle offers to buy them their own paints and painting supplies. Andy considers asking for acrylic paints, because he uses them in art class. Frida is interested in trying oil paints because many great masterpieces were created with oil paints.

Ask students if they know anything about acrylic and oil paints. Review the basic information about acrylic and oil paint from the student handout. "Do not mention drying time.

**Explore:** Students make oil and acrylic versions of ultramarine blue paint. The instructions in this activity create a paint that is good for immediate use, and does not store well. If you intended to store the paint for future use, stabilizers and binders need to be added.

- Each student group completes an experiment to compare the drying time of the two paints. Students define the independent variable (paint type), dependent variable (drying time), and controlled variables (type of paper, thickness of paint layer, temperature, humidity, convection).
- Students should complete this “Explore” section, which includes making and using the paint, in the same period, since the acrylic paint will dry by the next class period.
- The students have written directions for making and testing the paint, but it will be valuable to show them these images beforehand to help better prepare them for the lab experience.
• Photos: Left: Break apart pigment to make powder as fine as possible fine. Right: Oil added to pigment.

• Photos: Smooth paint samples created. Note that the Acrylic sample is more timing consuming to create.

• Photos: Sample tests prepared to compare drying times.

• **Explain:** Each group presents their qualitative and drying experiment results to the class, and summarizes their findings (Analysis question 1). The class collaborates to create a chart showing the advantages and disadvantages of each type of paint. Students take notes on class results to use in the Evaluate section.

<table>
<thead>
<tr>
<th>Property</th>
<th>Oil</th>
<th>Acrylic</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Paint Type</th>
<th>Property</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil</td>
<td></td>
</tr>
<tr>
<td>Acrylic</td>
<td></td>
</tr>
</tbody>
</table>
### Drying Time - Advantages

<table>
<thead>
<tr>
<th>Advantage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very slow to dry.</td>
<td>Allows artists to mix different colors on their pallet without drying out. Artist can make changes over a period of days.</td>
</tr>
<tr>
<td>Dries quickly.</td>
<td>Can finish a painting and transport it soon afterwards.</td>
</tr>
</tbody>
</table>

### Drying Time - Disadvantages

<table>
<thead>
<tr>
<th>Disadvantage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slow drying means that projects require longer to complete. Imagine waiting weeks for freshly painted walls to dry!</td>
<td>Dries so quickly that paint combinations mixed on a pallet must be used immediately or they will dry out. Mistakes on the canvas must be fixed in the moment.</td>
</tr>
<tr>
<td>If oil paint dries on surfaces like brushes or into fabrics, removing it requires solvents, which can be toxic</td>
<td>Water soluble, so brushes and other surfaces can be washed off with water, especially when the paint is still wet</td>
</tr>
</tbody>
</table>

### Clean Up

- Experimental results to help the teacher anticipate what the class will discover:

  ![Experimental Results Image]

  - The oil paint remains wet for days, although there are obvious changes in the first ten minutes. The pure flax seed oil used in this lesson is very slow to dry. Other versions of linseed oil have impurities that may speed drying time. The acrylic paint shows evidence of drying at 2 minutes. At 5 minutes it is mostly dry with only a few wisps of color rubbing off, and at 10 minutes it is dry. The class results vary, since each group uses different amounts of oil and acrylic binder, but the pattern is clear. When students report their results they should share how much oil and acrylic binder they used.

  - **Elaborate:** In questions 3 and 4 of the “Analysis” section, students learn that acrylic paint drying is a physical change, as water evaporates from the mixture quickly. They learn that oil paint “drying” is actually a chemical reaction that occurs as the oil is exposed to air, and this process takes longer.

  - **Evaluate:** Re-read the scenario from the “Engage” section. Students write a letter to Frida and Andy recommending one type of paint. They use all of the data collected by the class to explain their choice.

  - **Extend:** This lesson can easily be expanded to test the drying time of commercial or homemade tempera and watercolor paint. Students could also engage in an inquiry investigation of other variables, such as type of surface, method of application (brush, roller, sponge, spray), ratio of ingredients, and types of oil used.
FOR THE STUDENT

Exploring the Chemistry of Oil and Acrylic Paints

Background
Beginning painters are faced with the decision between purchasing oil or acrylic paints. Both paint types have advantages and disadvantages.

Oil paints consist of pigment particles suspended in a drying oil, like flax seed oil. A drying oil hardens when the oil molecules react with oxygen in the air and link together to form a tough solid. Oil paints do not change color when they dry, and can provide rich, deep colors. Solvents, like turpentine or mineral spirits, are required to clean dried oil paint off brushes once the oil has dried.

Acrylic paints consist of pigment particles suspended in a water-based acrylic polymer mixture. Polymers are large molecules made up of many repeating subunits. An acrylic polymer is a type of plastic. Acrylic paints dry as the water evaporates from the mixture. While acrylic paints remain wet, they can be washed away with water, allowing for simple cleanup. Latex house paint is one type of acrylic paint.

The pigment chosen for this activity is ultramarine blue, a deep blue pigment. It was originally obtained by grinding the rock lapis lazuli into powder. At one time it was the most expensive blue pigment, and painters reserved it for the most precious parts of their paintings. In the early 1800s, scientists devised a way to produce the same color artificially. Synthetic ultramarine is inexpensive and nontoxic. It is now used in many types of artist’s paints and wall paints, makeup, and even in laundry detergent as a “bluing” agent that brightens up faded whites.

Pre-lab Questions
1. List several situations where you have used paint. What surfaces were you painting? What type of paint did you use?
2. Both oil and acrylic paint are mixtures. Use the word bank to “fill” the paint cans with the correct components. Some words are used twice.

Word Bank:
- Water
- oil
- Pigment
- acrylic polymer

Objectives
In this activity you will:
- Learn about the chemistry of two types of paints.
• Make your own paints.
• Complete an experiment to compare the drying time of the two types of paint.

Materials
• Safety and Housekeeping:
  o Sealable, metal disposal can for all oil containing waste
  o Table covers to prevent paint stains
  o Gloves (optional)
  o Aprons or old clothing
• Making paint:
  o Ultramarine blue pigment
  o Refined flax seed oil
  o Acrylic binder
  o Plastic forks or knives
  o Plastic teaspoon
  o Surface for mixing paint (glass surface or clear packing tape on a paper plate)
  o Scale (optional)
• Testing the paint:
  o Paint brushes of the same size
  o Cotton swabs
  o Canvas Paper
  o Clock or stopwatch

Safety
• Always wear safety goggles when handling chemicals in the lab.
• Wash your hands thoroughly before leaving the lab.
• Follow the teacher’s instructions for cleanup of materials and disposal of chemicals.
  The flax seed oil in this activity is flammable, and any materials that absorb the oil must be placed in a water-filled container.

Procedure
Making Paint:
1. You will create your paints on mixing surfaces made of glass, or paper plates covered in packing tape or plastic wrap. Obtain two mixing surfaces from your teacher. Label one “oil” and the other “acrylic”.
2. Transfer approximately half a teaspoon of pigment powder to each mixing surface. For increased accuracy, a scale can also be used to measure about 1.5 grams of pigment powder for each paint type. Use a plastic knife or fork to break up any pigment clumps. Make the pigment powder as fine as possible with the equipment available.
3. Make the oil paint by adding oil, drop by drop, on top of the pigment pile. Keep track of how many drops of oil you use. Start by adding 20 drops of oil on to the pile, then mix the oil and paint together using a plastic fork/knife. Use the utensils to grind the pigments into the oil. Continue to add drops of oil, 5-10 drops at a time as needed, to achieve a smooth consistency, mixing and grinding well after each addition of oil. The paint should be a fluid, and apply smoothly on a brush.

Data: Making Oil Paint
4. Make the acrylic paint by adding a small amount of the white acrylic binder to the pigment powder labeled “acrylic.” Start with about half a teaspoon of the acrylic binder. Mix together using the plastic fork/knife. Grind the binder and pigment together. Add a little more acrylic binder if needed, and mix until a smooth paint is made.

<table>
<thead>
<tr>
<th>Data: Making Acrylic Paint</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount of pigment used</td>
</tr>
<tr>
<td>Number of drops of oil added</td>
</tr>
</tbody>
</table>

### Comparing the Drying Time of the Paint:

1. Cut one sheet of canvas paper into four rectangles.
2. Obtain two identical brushes from your teacher. Use one brush for the acrylic paint, and another for the oil paint. Do not mix brushes. Label the brushes with masking tape if necessary.
3. Your first goal is to qualitatively compare different properties of the two paint types. Using the brushes and one of the pieces of canvas paper, paint a few different shapes with oil and acrylic. Paint lines, circles, and words. Try to create areas that are darker and lighter. What do you notice about the two paints? In what ways are they the same and in what ways do they differ? How do they adhere to the paper? Do they look different? Record your observations below.

<table>
<thead>
<tr>
<th>Data: Qualitative Comparison of Paint Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observations</td>
</tr>
<tr>
<td>Oil</td>
</tr>
<tr>
<td>Acrylic</td>
</tr>
</tbody>
</table>

4. The second goal is to quantitatively compare the drying time of the two paints. Take the second piece of canvas paper. Label one side “oil”, and the other “acrylic”. On one side label “1 minute” and “2 minutes”, as shown in the data table below.

<table>
<thead>
<tr>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil</td>
</tr>
<tr>
<td>Acrylic</td>
</tr>
</tbody>
</table>

5. Under “Oil” and across from “1 minute” quickly paint a smooth line of even thickness. Switch to the acrylic paint and brush and do the same next to “1 minute.” Begin timing 1 minute with your stopwatch ready as soon as the second line is painted.

6. After one minute has passed, use one side of a cotton swab and press firmly onto the page near the oil line. Apply strong and even pressure and push the cotton swab through the oil line, and going back and forth down the line in an “S” or zigzag pattern. Repeat for the acrylic line, using the clean side of the cotton swab.
7. Repeat these steps for the 2 minute trial. Use a clean cotton swab for each test.

8. After you complete the experiment, record your observations below.

<table>
<thead>
<tr>
<th>Data: Quantitative Comparison of Paint Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil</td>
</tr>
<tr>
<td>1 minute</td>
</tr>
<tr>
<td>2 minutes</td>
</tr>
</tbody>
</table>

9. On the third piece of canvas paper create labels for “5 minutes” and “10 minutes” much like you did previously.

10. For these longer test times, create multiple oil lines and multiple acrylic lines and then start the clock.

11. Complete the cotton swab test after 5 minutes and 10 minutes is reached.

12. After you complete the experiment, record your observations below.

<table>
<thead>
<tr>
<th>Data: Quantitative Comparison of Paint Samples</th>
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<tbody>
<tr>
<td>Oil</td>
</tr>
<tr>
<td>5 minutes</td>
</tr>
<tr>
<td>10 minutes</td>
</tr>
</tbody>
</table>

13. On the final piece of canvas paper create labels for “1 day” and “2 days” much like you did for the previous tests.

14. Again, create multiple oil lines and multiple acrylic lines. Note the day and time this test started in the data table below.

15. Put the paper at a safe location in the classroom, and repeat the cotton swab test again roughly 1 day and 2 days later.

16. After you complete the experiment, record your observations below.

<table>
<thead>
<tr>
<th>Data: Quantitative Comparison of Paint Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil</td>
</tr>
<tr>
<td>Date/Time started:</td>
</tr>
<tr>
<td>Date/Time started:</td>
</tr>
</tbody>
</table>

Data Analysis
Summarize drying time results from each of your comparison tests below. Also include your observations. For example, how much did each paint smear on the page?

**Analysis Questions**

1. As each group presents their results to the class, take notes on drying times and other observations discussed.

2. Complete this chart describing the advantages and disadvantages of each type of paint. Include examples where oil paints are advantageous, where acrylic paints are advantageous, and the opposite.

<table>
<thead>
<tr>
<th>Paint Type</th>
<th>Property</th>
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<th>Acrylic</th>
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<tbody>
<tr>
<td><strong>Drying Time: Advantages</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Drying Time: Disadvantages</strong></td>
<td></td>
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<tr>
<td><strong>Clean-Up</strong></td>
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</tr>
</tbody>
</table>

3. Acrylic and oil paints dry through two very different processes, as described below. Draw models below each description to represent each process. Use images, labels, symbols, arrows as needed.

<table>
<thead>
<tr>
<th>Acrylic paints dry as water evaporates from the pigment-polymer-water mixture:</th>
<th>Oil paints dry as molecules of oil react with oxygen in the air and form longer chains that turn into a hard solid:</th>
</tr>
</thead>
</table>

4. Physical changes occur when the form of a chemical substance changes, but the chemical composition (the molecules involved) remain the same. Which drying process is a physical change? How do you know?

5. Chemical changes, or chemical reactions, occur when existing atoms and molecules rearrange in new ways to form different molecules. Which drying process is a chemical change? How do you know?

**Conclusion**

Your teacher read you a scenario of two students trying to decide on what paint to buy. Write a letter recommending one type of paint. Use the data collected by the class on
drying time, as well as your qualitative observations to explain your choice.