Lesson Plan: What Type of Mixture is Paint?

FOR THE TEACHER

Summary
In this lesson students will use simple laboratory tests to characterize differences between solutions, colloids, and suspensions. They will then apply those tests to paints to classify them as specific types of mixtures.

Grade Level
High School

NGSS Alignment
This lesson will help prepare your students to meet the performance expectations in the following standards:
- **HS-PS1-3**: Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.
- **HS-PS2-6**: Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.
- **Scientific and Engineering Practices**:
  - Analyzing and Interpreting Data
  - Planning and Carrying Out Investigations
  - Engaging in Argument from Evidence

Objectives
By the end of this lesson, students will be able to:
- Differentiate mixtures as solutions, colloids, or suspensions by particle size of the solute or dispersed phase.
- Correctly use the terms: dispersed phase, dispersing agent, colloid (or colloidal dispersion), and suspension.
- Identify solutions, colloids, and suspensions by results of simple laboratory tests.
- Explain how the properties of different mixtures can be used to design a product (paint).

Chemistry Topics
This lesson supports students’ understanding of:
- Mixtures
- Solutions
- Colloids
- Suspensions
- Tyndall Effect
- Separating Mixtures
- Molecular Structure

Time
Teacher Preparation:
- 60 minutes to label and prepare all samples for Part I.
- 20 minutes to label and prepare all samples for Part II.

Lesson:
The following times are valid if the optimal amount of equipment is available and the time-saving tips in the teacher notes are followed:
- Engage: 20 minutes
- Explore: 45 minutes
- Explain: 30 minutes (this may be completed as homework)
- Elaborate: 30 minutes
- Evaluate: 60 minutes (final writing may be completed as homework)

**Materials (Teacher Demo)**
- 2, 1-L graduated cylinders or beakers
- Penlight
- Index card, any size
- Tap water
- ~1 g Salt
- ~1 mL Milk (any %)

**Materials (Part I)**
See “Explore” section for possible alternative equipment/supplies.
- 1 lab centrifuge (if you have more, this will reduce waiting time)

For each group of four students:
- 18 medium-size, 15 x 150mm, test tubes w/ stoppers in 2 racks (choose tubes that fit your centrifuge)
- 7 funnels (you can use less, but it will take longer)
- 7 small flasks, any size, to hold funnels (alternatively, you may use a funnel rack)
- 7 Qualitative filter papers
- 1 Spatula
- 1 plastic pipet
- 1 Test tube holder (tongs)
- 1 Penlight (cell phone light can work, it is just less focused, so the beam will be more spread out)
- 1 Napkin or porous paper towel
- 1 Candle and match
- Tap water
- 1 Small container of each solid:
  - Salt
  - Mud
  - Unsweetened drink mix powder
  - Flour
- 1 Small bottle of each liquid w/ dropper:
  - Tap water
  - Food dye
  - Milk, any %
  - Oil

**Materials (Part II)**
- 1 lab centrifuge (if you have more, this will reduce waiting time)

For each group of four students:
- 16 medium-size, 15 x 150mm, test tubes w/ stoppers in 2 racks (choose tubes that fit your centrifuge)
- 7 funnels
- 7 small flasks, any size (to hold funnels)
- 2 spatulas
- 1 mortar and pestle (to mix the solid binder w/ solid pigment)
- 1 penlight
- 1 paintbrush
- 3 index cards
- 1 watch glass (for paint mixing)
- 1 glass stirring rod (for paint mixing)
- 1 small container of pigment*
- 1 small container of gum arabic
- 1 small dropper bottle of linseed oil**
- 1 small dropper bottle of citrus solvent***
- Tap water

*Pigments may be purchased or, if time is not a factor, you can have students use simple precipitation reactions to make their own pigments. Lead(II) iodide is a bright yellow pigment that is easy to make. There are many other possibilities, as well.

**Raw linseed oil, though considered superior by many artists, will take about 2 days to harden, while the boiled linseed oil will harden overnight (~12 hours). Additionally, the raw linseed oil shows the Tyndall effect when pure, and so will confuse the classification of anything with which it is mixed. Boiled linseed oil works...
better for this lab.

***Turpentine or paint thinner may be substituted for citrus solvent. The citrus solvent is NOT the same as citrus based cleansers. It is a pure extract from an orange peel and is less toxic and safer than the alternatives.

### Safety
- When using centrifuge, samples must be in a balanced arrangement!
- Always wear safety goggles when handling chemicals in the lab.
- Do not consume lab solutions, even if they’re otherwise edible products.
- Open flames can cause burns. Liquid wax is hot and can burn the skin.
- When lighting the match, be cautious with the flame.
- 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.
- An operational fire extinguisher should be in the classroom.
- For Part II: Citrus solvent, and other solvents for oil paints, are organic. They often will interact with cheaper plastics, like a disposable plastic cup, and appear to melt or dissolve it. Do not substitute these plastics for the glassware when working with the oil paint.

### Teacher Notes
- Mixture Cards for the Engage Activity, as well as sample answers and results for Student Activity Part 1 and 2 can be found in the Appendix document.

**Teacher Background Information:**
- There is some disagreement in whether to classify colloids as homogeneous or heterogeneous. Many definitions describe them as macroscopically homogeneous, but microscopically heterogeneous. Students may be told, if needed, that heterogeneous means that you can see different parts, while homogeneous means that you can only see one part. This can then be further explained after the testing.

**Brief terminology:**
- The more abundant component in a solution is called the solvent. The more abundant component in a colloid or suspension is called the dispersing medium.
- The less abundant component in a solution is called the solute. The less abundant component in a colloid or suspension is called the dispersed phase.
- The term, “colloid” may be used to describe a mixture or its dispersed phase. “Colloidal” means that the particles are in the right range to make a colloid. A mixture may also be called a colloidal dispersion.
- The difference between solutions, colloids, and suspensions is in particle size of the dispersed particle.

<table>
<thead>
<tr>
<th></th>
<th>Size of dispersed particles</th>
<th>Macroscopic</th>
<th>Stability</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Solutions</strong></td>
<td>Individual atoms, ions, or molecules. In the range of picometers</td>
<td>Not visible in mixture Do not scatter light (no surface large enough to reflect light beams)</td>
<td>Particles remain dispersed indefinitely</td>
</tr>
<tr>
<td><strong>Colloids</strong></td>
<td>~1-100 nanometers Clusters of particles not large enough to be seen by naked eye</td>
<td>Not visible in mixture, but will scatter light (interface of particle and solvent is large enough to reflect light beams)</td>
<td>Particles remain dispersed indefinitely</td>
</tr>
<tr>
<td><strong>Suspensions</strong></td>
<td>About 1 micrometer or larger Visible to the naked eye</td>
<td>Visible in mixture Will reflect and scatter light</td>
<td>Will eventually settle out (no longer dispersed)</td>
</tr>
</tbody>
</table>
• The light-scattering effect described above is called the Tyndall effect and can be observed by shining a narrow beam of light through a sample. If the sample is transparent or translucent, a light beam will be visible inside a colloid sample and a suspension sample, but not inside a solution sample. If the mixture is opaque, the light will not make it to the inner part of the mixture, so the Tyndall effect is an invalid test for this type of mixture.

• Each possible combination of solid, liquid, and gas in a colloid has a subcategory. These subcategories are not addressed in this activity, but can be found in many textbooks.

• Paints are interesting mixtures. The job of the binder is to hold the pigments in place. The job of the solvent is to allow the paint to be spread. In some cases, the wet paint is a suspension, because it includes all three components, binder, pigment, and solvent, but must be mixed or shaken before using due to settling of the pigment. In other cases, the wet paint mixture does not need to be mixed because it does not settle over time, thus making it a colloid. Dried paint is typically considered to be a colloid, as the dispersed particles are indefinitely spread throughout the binder (dispersing medium). When paints are manufactured, the pigments are very finely ground, often with the binder, to create a particle size that is colloidal.

• Student pre-requisite knowledge:
  o Mixture vs pure substance
  o Homogeneous vs heterogeneous mixtures
  o Parts of a solution: solute and solvent
  o Particulate view of matter

Lesson
• **Engage:** At this point in the lesson, it is recommended that the teacher avoid any specific terms related to mixtures, as this may inadvertently sway the students’ grouping of the cards. Rather, introduce the lesson by saying that students will be exploring the differences between different types of mixtures.
  o Distribute “mixture” cards to groups of 2-4 students.
  o Tell students that each card contains a mixture that is familiar from daily life. Prompt them to think about each mixture and to sort them into groups with similar types of overall properties. (Note: try to avoid having them simply sort by whether the components are solid, liquid or gas.)
  o Next, students should write a brief description to justify each of their groupings.
  o Ask a few (or all) groups to share just the description for each group.
  o You may then further probe students’ thinking by asking questions such as, but not limited to:
    ▪ Did anyone put fog and mayonnaise into the same group?
    ▪ Did anyone put salt water and milk into the same group?
    ▪ Did anyone consider the phase of each substance of the mixture when determining grouping?
  o Ask students to record in their notebooks the descriptions and items in each grouping for review later in the lesson.

Short demonstration – Tyndall Effect:
  o Darkening the room will make this effect a bit easier to see.
  o Before class, fill one large beaker or 1-L graduated cylinder with salt water and another one with any dilute colloid (water with a little milk is a good option). You should experiment with amounts for the colloid in order to ensure the light beam will be clearly visible to students. Place the two samples in an easily seen location and tell students that each contains a mixture.
  o Shine a penlight or laser light through each. This works best if the light source is placed
directly on the side of the container. (A square container works better because the curved surface can distort the light, but if you are careful in your aim, the effect is just as clearly shown in cylinders or beakers.) Show students how the beam goes through the mixture by holding an index card on the other side so the light hits it.

- Next, point out how the light beam is visible inside one sample, but not inside the other. Alternatively, you can ask the students what is different and elicit this response from them.
- Ask students for reasons why they might be able to see the light beam in one, but not the other. You may need to prompt them to remember that both are mixtures. Perhaps ask them if they can tell that each is a mixture just by looking at it.
- Eventually bring them to the understanding that the light is reflecting off the particles in one of the mixtures because they are bigger than those in the other mixture.
- Next, reveal the identity of each mixture and lead a brief discussion of what they already know about each mixture.
  - Students should know that salt water is a solution and that means that the salt is dissolved, which means broken down to a particle-level.
  - If milk in water is used, they may recognize the term “homogenized” and could be questioned about what that might mean.
- At this point, explain that the reason they see the light is that the particles in the milk/water (don’t say the word, colloid, yet!) are larger than individual atoms/molecules and therefore form interfaces with the liquid medium, creating tiny surfaces from which the light can be reflected. This could be simplified by simply saying that the particles are big enough to reflect the light.
- Last, tell students they will explore a variety of common mixtures by observing, testing for the light beam, and testing whether they can easily separate the parts.

**Explore**: Part I – Exploring Simple Mixtures on the student sheets

- You will need to prepare ahead of time (assuming 6 lab groups)
  - 6-Individual containers or dishes, each, of salt, mud, unsweetened drink powder, flour
  - 6-Individual dropper bottles, each, of milk, oil
  - 6-Individual bottles of food color (Color does not matter, but blue and green can get pretty dark and the light may not go through enough to see the beam. If diluted, these colors work just as well as the others.)
  - 6-Candles
  - 6-matchbooks or boxes of matches
- Ideally, all the following are available in your lab. If not, please see sub-bullets for alternate ways to manage the activity with less equipment.
  - Lab centrifuge
    - A mini-centrifuge (1.5 mL tubes) from the biology department can work, but it is difficult to see the light beam through the plastic tubes.
    - If no centrifuge is available, the samples could be left to settle overnight. Essentially, the centrifuge is just speeding up the settling, if it will happen.
  - Qualitative filter paper (42 papers)
    - Coffee filters could be used, but the mud sample will not be as well-separated. With the filter paper, only the colloidal portion goes through the filter paper and the particles large enough to settle stay in the paper.
    - 42 filtration set-ups (funnel + flask or graduated cylinder or test tube or funnel rack...)
      - You may need to consider having half of the class start with filtration while the other half starts with centrifugation.
      - It will take more time, but you can also give each group less funnels and just have them test the mixtures a few at a time.
- You may have a funnel rack that holds several funnels. In this case you just need some kind of container under the funnel.
- You could re-use test tubes after centrifugation to hold the funnels.
- **108 test tubes with stoppers that fit your centrifuge** (This procedure was written using a standard lab centrifuge borrowed from the physics department and 15x150mm tubes with #3 stoppers.)
  - 48 of the tubes could be replaced with beakers or cups, if needed (groups can pour the half of the sample to be filtered into a beaker instead of a tube).
  - Only 2 of the tubes truly need a stopper. If you need to reduce the number of stoppers, use them only on the “smoke+air” tubes.
  - One tube per group is simply the empty tube to balance the “smoke+air” tube. This can just be placed by the centrifuge and shared by the class.
  - Be careful to be consistent in using or not using a stopper when placing tubes in the centrifuge, as you want to ensure a balanced configuration.

- **12 test tube racks**
- Alternatively, beakers can be used to hold the test tubes.

- **18 metal spatulas**
  - Each group can clean the spatula between samples, thus only needing 1 per group.

- **6 penlights**
  - A narrow beam is best. I used cheap penlights that are used for testing pupil dilation.
  - You can use laser pointers, but must be careful that the color is not absorbed by the food dye (blue and green will absorb the red of most laser pointers). If the dye is dilute enough, some of the light will still make it through the solution (the beam should not be visible, but it may be visible in more concentrated solutions)
  - I’ve seen cheap laser pointers sold for playing with cats (apparently, they like to chase the light).

- Time-saving hints are built into the student activity and include:
  - Students split the work of preparing the mixtures.
  - Half of the group performs the filtration while the other half performs the centrifugation. All tubes are then analyzed again by entire group.
  - For the filtrations, the directions say to set up all funnels and pour all solutions in, so they are filtering at the same time. In my experience, careful lab students will still attempt one at a time. You may want to reinforce this direction to ensure timeliness.
  - Some of the filtrations will appear to be very slow. In these cases, it is likely that the liquid portion remaining in the filter paper has particles that are too large to go through. Prepare students for this eventuality so they are not wasting time waiting for something that will not go through the filter. They just need to collect enough liquid at the bottom to be able to analyze it using the light beam.

- Students will perform some laboratory tests to find differences between different kinds of mixtures. Depending on lab experience, the following should be addressed before beginning the lab:
  - Instruction on using the centrifuge. Show students how to achieve a balanced configuration.
  - When centrifuging the “smoke + air” tube (w/ stopper), students should balance this with either an empty tube w/ stopper or with another group’s “smoke + air” tube.
  - Show students how to hold the penlight against the tube to get the best results for the Tyndall effect.
You may need to show an example of using a spatula to obtain a sample “the size of a grain of rice”.

If individual lab sets are not created, be sure to explain how you’d like students to obtain their materials.

- Expected results are included at the end of the Teacher section.

**Explain:**

- This occurs during the Analysis and Conclusion questions of Part I. Using the properties discovered in the lab, along with some given information, students will match an appropriate scientific name to each type of mixture.
- Teacher should discuss the answers to questions and the terminology before moving onto the next section.

**Elaborate:** Part II – Create Your Own Paint, Part A – Investigation of Paint Components on the student sheets.

- An introduction to the basic components of paints will set the tone for exploring a 3-component system and determining its mixture classification.
- Students will make dilute mixtures of each possible pair of paint components and will test them to decide what type of mixture is formed by each combination. They will then make and test a dilute mixture including all components of a given paint type and decide how the overall mixture should be classified.
- This part is designed as an open inquiry, where students design their own procedure. Depending on their experience with this, they may need some direction.
  - Guide them to use small amounts of the solids with larger amounts of the liquids, like what they did in Part I.
  - Remind them that they can use the same kinds of tests and observations as they did in Part I.
  - Coach them to write out the plan before enacting the plan.

**Evaluate:** Part B – Design Your Own Paint, in Part II

- Students will use what they have learned to determine how to mix the paint components to create a paint.
  - The goal is for students to consider how the substances interact to form solutions, suspensions, or colloids and to use the properties of each type of mixture to decide what proportions will be useful and how to put the components together. Prompt them to ask questions and think about whether amounts or order of mixing would affect the properties of the final paint mixture.
- After creating and analyzing their designed paint, students will answer the prompt, “How do the components of paint interact to give it the desired properties that make it useful?”
  - The goal is for students to make connections between properties of solutions, suspensions, and colloids and their role in manufacturing and applying a paint.
Lesson

Part I – Exploring Simple Mixtures

Background
There are a wide variety of materials in the world. Some are natural and some are man-made. Some are pure substances and others are mixtures. The properties of each type of material can be explained by the composition, interaction, and arrangement of the particles that make it up. In this investigation, you will perform a series of simple laboratory tests to classify different types of mixtures. To explain your observations, you will consider how the different parts of each type of mixture interact when mixed.

To characterize each mixture, you will look for the following:

- What does it look like?
  - Visual observations can be very informative. Be sure to record everything that you see.
- Will it settle over time?
  - You will use a centrifuge to speed up any settling that might occur if we let it sit overnight.
- Can the parts be separated easily?
  - You will attempt to filter the mixture through filter paper to see if the particles are different enough in size to be filtered.
    - Atoms are about $10^{-12}$ meters in size
    - Small molecules are about $10^{-11}$ meters in size
    - The pore size on the filter paper is about $10^{-6}$ meters wide
    - The smallest size a human eye can perceive is about $10^{-4}$ meters
- How big are the particles?
  - Light can be absorbed, transmitted, or reflected. We will focus only on reflection of light
  - If light simply passes through a sample, then none of the particles were large enough to change the direction of the light. You will see the light come out the other side, but will not see it inside the sample.
  - If particles in a mixture are very large, the light reflects off the particles and you see the particles.
  - If particles are of an intermediate size, they will not be visible, but will scatter the light because they are large enough, at least 1 nm ($10^{-9}$ meters), to have a surface that the light can bounce from. In this case, you will see a beam of scattered light inside the mixture.

Pre-lab Questions
Define the following:

- Homogeneous mixture
- Heterogeneous mixture
- Solution
- Solute
- Solvent

Objective
To classify mixtures based on the results of simple laboratory tests.
Materials

- 18 medium-size test tubes w/ stoppers in 2 racks
- 7 funnels
- 7 small flasks (or other container to hold funnels during filtration)
- 7 filter papers
- 1 Spatula
- 1 plastic pipet
- 1 Test tube tongs
- 1 Penlight
- 1 Napkin or porous paper towel
- 1 Candle and match
- Centrifuge (in a central location)
- Tap water
- Small container of each solid:
  - Salt
  - Mud
  - Drink mix powder
  - Flour
- Small container of each liquid w/ dropper:
  - Tap water
  - Food dye
  - Milk
  - Oil

Safety

- **When using centrifuge, samples must be in a balanced arrangement!**
- Always wear safety goggles when handling chemicals in the lab.
- Do not consume lab solutions, even if they’re otherwise edible products.
  - Always be aware of an open flame. Do not reach over it, tie back hair, and secure loose clothing.
  - When lighting the match and wooden splint, be cautious with the flame.
  - Open flames can cause burns. Liquid wax is hot and can burn the skin.
  - Wash your hands thoroughly before leaving the lab.
  - Follow the teacher’s instructions for cleanup of materials and disposal of chemicals.

Procedure

You will be working in groups of four.

1. Label 1 rack the “Filtration” rack and the other one the “Centrifuge” rack.
2. Assign each group member to create two of the mixtures in the chart below using the following directions:
   a. Label 2 test tubes for each mixture. Place one tube in each rack.
   b. Use the directions in the chart to create your assigned mixture in the “Filtration” tube and then place the tube with mixture back in the rack to be tested. (The “Centrifuge” tubes should remain empty)
   c. For the “smoke + air” tube, repeat the procedure for BOTH tubes (“Filtration” and “Centrifuge”) and set one each rack.

<table>
<thead>
<tr>
<th>Directions for creating mixtures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salt + water</td>
</tr>
<tr>
<td>Fill about ¾ of the test tube with water. Use a spatula to collect a sample of salt about the size of a grain of rice. Add this to the tube. Put a stopper on the tube and shake it until mixed.</td>
</tr>
<tr>
<td>Food dye + water</td>
</tr>
<tr>
<td>Fill about ¾ of the test tube with water. Add one drop of food coloring. Put a stopper on the tube and invert it a few times until mixed.</td>
</tr>
<tr>
<td>Substance</td>
</tr>
<tr>
<td>--------------------</td>
</tr>
<tr>
<td>Milk + water</td>
</tr>
<tr>
<td>Mud + water</td>
</tr>
<tr>
<td>Drink powder + water</td>
</tr>
<tr>
<td>Smoke + air</td>
</tr>
<tr>
<td>Salt + oil</td>
</tr>
<tr>
<td>Flour + water</td>
</tr>
</tbody>
</table>

3. After mixing the contents of each tube, allow the tubes to settle for about a minute. You will not be analyzing any “leftover” solids that collect at the bottom quickly. This just means that too much solid was added to the system.

4. Closely observe the mixed portion of each tube. In the “Initial” Visual Observations column of your data table, write down observations about what you see. Pay close attention to whether or not you can see “parts” of each mixture. Be as descriptive as you can.

5. Shine the beam of a penlight through each sample. In the “Initial” Beam? column, record whether you can see the beam inside the sample, along with any other observations.

6. Use a pipet to transfer about half of the mixed portion of each sample into the corresponding empty tube in the Centrifuge rack (except “smoke + air” because that should already have the smoke.) Two people should centrifuge the samples in the Centrifuge rack while the other two filter the samples in the Filtration rack.
   a. Centrifuge: Place the tubes in a balanced arrangement in the centrifuge. Set the timer to spin at full speed for 2 minutes. Then, return the tubes to the rack and bring them back to your table. Be sure to handle the tubes gently, so they do not re-mix after centrifuging.
      i. When centrifuging the “smoke+air” tube, be sure to balance it in the centrifuge with either an empty tube w/ stopper or with another group’s “smoke+air” tube.
   b. Filtration: Set up 7 funnels with filter paper for filtration. Carefully pour only the mixed portion of each of the liquid samples into one of the funnels.
      i. To filter the smoke, take a plastic pipet and suction some smoke from the smoke tube into the pipet.
      ii. Wrap a napkin or porous paper towel around the tip and then expel the contents through the paper towel and into the empty test tube. Repeat this until you think you transferred all of the smoke. Stopper
the new tube.

1. In steps 6a and 6b, you will use this new tube to observe and test with the penlight.

7. When all tubes have been centrifuged and filtered;
   a. Record observations in the appropriate columns of the data table. Be sure to note any changes from the initial observations.
   b. Shine light through each sample again and record results in the data table.

8. Discard into the trash can all substances on filter papers.

9. Check with your teacher before pouring liquid samples down the drain.

10. Wash all tubes and spatulas with soap and water and return them as designated by your teacher.
## Observations and Results

<table>
<thead>
<tr>
<th>Sample</th>
<th>Initial</th>
<th>After Filtration</th>
<th>After Centrifugation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salt + water</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food dye + water</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Milk + water</td>
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<td></td>
<td></td>
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<tr>
<td>Mud + water</td>
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<tr>
<td>Drink powder + water</td>
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<tr>
<td>smoke + air</td>
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<td></td>
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<tr>
<td>Salt + oil</td>
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<tr>
<td>Flour + water</td>
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</tbody>
</table>
Analysis

1. Consider the observations and results you obtained for your samples. Categorize the eight samples into three groups, based on your observations and testing. Give each group a heading that indicates how that group is different from the others.

2. Each mixture was a combination of two things, with one being more abundant and the other being less abundant
   a. Which of your groups had the largest particle size for the less abundant part of the mixture? What is your evidence?

   b. In which of your groups were the particles of the two parts of the mixture the most attracted to each other? What is your evidence?

3. Think about the mud + water mixture. In a stream or a pond, there is a lot of muddy water. Some of the mud stays at the bottom, while some of it stays in the water.
   a. If the water from the stream could settle overnight without movement, would any of the mud stay mixed in the water? Use evidence from your exploration to justify your answer.

4. The Background stated that, “The properties of each type of material can be explained by the composition, interaction, and arrangement of the particles that make it up.” Using evidence from the exploration, discuss how the composition, interaction, and arrangement of particles caused different properties for each of your three groupings from question 1.

Conclusion
Read the information on the following page, then answer the questions that follow.

Information
You may have noticed during your mixture exploration that the distinction between heterogeneous and homogeneous matter is not always easy to make. Below are some definitions to help clarify what you observed:

- **Solution** – a solute is dissolved in a solvent. The solute is broken down to a molecular level and is evenly spread throughout the more abundant solvent, making a homogeneous mixture. The solutes and solvents may be any combination of solid, liquid, and gas.
  o Examples:
    ▪ Air (Nitrogen would be the solvent, as it is the most abundant. All other gases are the solutes.)
    ▪ Brewed iced tea (Water is the solvent. Molecules from within the tea leaf that give color and flavor are the solutes.)
    ▪ Some alloys (One metal is often present in greater abundance. If the alloy is a true solution, then the individual metal atoms of the solute are spread evenly throughout the metal atoms of the solvent.)

- **Suspension** – A mixture that has visible pieces of one substance well-mixed throughout another substance. This is heterogeneous, because the parts are visible, but is different from something like fruit salad because the parts are
dispersed throughout. This mixture will eventually settle and become two distinct phases. The more abundant substance is called the “dispersing medium”, and the less abundant substance is called the “dispersed phase”.

- Examples:
  - A snow globe (The solid “snow” is the dispersed phase inside the liquid dispersing medium. This is only a suspension for a little while, as the snow eventually settles.)
  - Dust in the air (The dust is very fine and is spread throughout the air, but it will eventually settle onto a surface, due to gravity.)
  - Latex paint (If you’ve ever bought a can of paint to paint your bedroom walls, you may have noticed that the store puts it on a shaker before giving it to you. That is because some of the particles will settle over time.)

- **Colloid** – A mixture with particles that are too large to dissolve, but too small to settle out. The particles are not broken down all the way to molecule-size, and stay in clusters. In some cases, the particles may actually be very large molecules (macromolecules, like proteins). The interaction between the molecules of the dispersed phase and those of the dispersing medium stabilize the arrangement and allow it to remain homogeneous on a macroscopic level. If observed at a particle-level, this type of mixture is heterogeneous.

- Examples:
  - Milk (A heterogeneous mixture of water and butterfat, which is shaken with a certain protein that allows it to stay homogeneous, thus being classified as a colloid.)
  - Clouds (Water particles are the dispersed phase, while air is the dispersing medium. Note that if the particles were individual molecules it would just be water vapor, and thus, a solution.)
  - Whipped cream (Air particles are the dispersed phase and cream is the dispersing medium.)

**Conclusion Questions**

1. Using the information above, classify each of the studied mixtures as either a solution, a suspension, or a colloid. For each mixture, identify the **solute** and **solvent** or the **dispersed phase** and the **dispersing medium**.

<table>
<thead>
<tr>
<th>Solution</th>
<th>Suspension</th>
<th>Colloid</th>
</tr>
</thead>
</table>

2. Compare your classifications to the way that you grouped the mixtures in the analysis (Analysis Question 1). Comment on any differences in your groupings and state the evidence that allows you to classify it as you did in the above table.
FOR THE STUDENT

Lesson

Part II – Exploring Paint as a Mixture

Background
You are probably familiar with some different kinds of paints. As a child, you may have used finger paints. In school classes, you may have used watercolor, acrylic, or oil paints. At home, you may have seen walls being painted with latex paint. Each different kind of paint is made of different kinds of components. In general, there are three required components needed to create any paint.

- **Pigment**: Gives the paint color and hides the surface it is painted upon.
- **Binder**: A medium to hold the pigment particles together and stick to the surface being painted.
- **Solvent**: Allows paint to be spread onto a surface. This evaporates after applying the paint.

Commercial paints may have a variety of other components added to them to give the paints specific properties, like fade-resistance or durability. In this exploration, we will only consider the three basic components of paints.

In the following activity, you will explore the components of two common types of paints, watercolor paint and oil paint. The components of these two paint types differ, and you will note that the paints also have very different properties. You should use these differences to think about how the varying interactions between substances lead to different properties for the paint mixtures.

- Pigments exist in many forms, both organic and inorganic in nature. Many of these pigments are universal and can be used in several different types of paint. You will be experimenting with a set of inorganic pigments primarily composed of various metal oxide compounds to make your paints.

- Binders are the main component that differentiates types of paint. The two you will explore in this lab are:
  - Gum Arabic – This is the binder for watercolor paints.
  - Linseed Oil – This is one of a few different types of binders used in oil paints.

- The solvent is the component of paint that allows it to be spreadable. The solvent will evaporate as the paint is drying. In some cases, the solvent evaporation is the only step in the drying process. In other cases, the solvent evaporates and then the binder reacts with oxygen in the air to chemically change and harden into a solid.
  - For the watercolor paint, we will use water as a solvent.
  - For the oil paint, we will use an extract from orange peels as a solvent.

Pre-lab Questions
1. Give a definition in your own words for each of the following types of mixtures:
   - Solution
   - Suspension
   - Colloid
2. Consider the classification of mixtures as solutions, suspensions, or colloids.
   a. Are visual observations enough to make the classification? Explain.
   b. What information can be provided by the light beam to assist the classification?
   c. What information can be provided by the centrifugation to assist the classification?
   d. What information can be provided by the filtration to assist the classification?

3. Using the information learned from exploring simple mixtures, predict how you think each of the following would be classified (solution, suspension, colloid). Give at least one reason for your prediction.
   a. Wet Paint
   b. Dried Paint

Objective
How do the components of paints interact to give paint mixtures the desired properties that make them useful and desirable?

Materials
- 1 lab centrifuge (in a central location)
- 16 medium-size test tubes w/ stoppers in 2 racks
- 7 funnels
- 7 small flasks, (or other container to hold funnels during filtration)
- 2 spatulas
- 1 mortar and pestle
- 1 penlight
- 1 paintbrush
- 3 index cards (or other painting surface)
- 1 watchglass (for mixing paint)
- 1 glass stirring rod (for mixing paint)
- 1 small container of pigment
- 1 small container of gum arabic
- 1 small dropper bottle of linseed oil
- 1 small dropper bottle of citrus solvent
- Tap water

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.
- Citrus solvent, and other solvents for oil paints, are organic. They often will interact with cheaper plastics, like a disposable plastic cup, and appear to melt or dissolve it. Do not substitute these plastics for the glassware when working with the oil paint.
Part A – Investigation of paint components

Procedure
1. As in Part I, split up the work of creating the mixtures, but be sure that each group member takes part in all observations and testing.

2. For each type of paint, you will test all possible 2-component mixtures, as well as the mixture of all three components. Each of these mixtures will be separately classified as being a solution, suspension, or colloid.

3. Set up a data table to collect all results from these mixtures.

**Investigate Watercolor Paint:**
- Pigment: Choose any color
- Binder: Gum Arabic
- Solvent: Tap Water

*Note, in the watercolor paint, one of the mixtures will be solid with solid. In this case, blend the two in a mortar and pestle and simply make observations. The other procedures will not be useful for this combination.

**Investigate Oil Paint:**
- Pigment: Choose any color
- Binder: Linseed Oil
- Solvent: Citrus Solvent

**Suggested amounts for your test mixtures:**
- 2 liquids: equal amounts
- 2 solids: equal amounts
- Solid + liquid: Size of a grain of rice for solid, ~ ½ - ¾ of a test tube for liquid

Results
Create your data table on the next page. Be sure to consider all possible combinations and all observations and tests you can do to characterize each mixture. Also make sure to leave enough room in your table to record your results. You may use additional pages, if needed.

Data Table
Analysis

1. Which combinations of two components were solutions? For each, use evidence to justify your claim.

2. Which combinations of two components were suspensions? For each, use evidence to justify your claim.

3. Which combinations of two components were colloids? For each, use evidence to justify your claim.

4. Consider the entire mixture of “watercolor paint”. How would you classify that mixture? Justify your claim with evidence.

5. Consider the entire mixture of “oil paint”. How would you classify that mixture? Justify your claim with evidence.

Part B – Design Your Own Paint

Procedure

1. Choose either watercolor paint or oil paint. You will create your own formulation of the ingredients to paint a small picture of your choice on an index card.

2. Use your observations and results from the above investigation to plan an experimental procedure to determine a good formulation for paint. This may NOT be completed by trial and error.
   a. You must document all your work.
   b. You are only allowed TWO test mixtures before making your final paint, so you should carefully consider the interactions between substances and use what you’ve learned to decide how much of each to use, if the order of mixing matters, and if there is anything you want to do to aid the mixing.
   c. You must be able to explain WHY you made each of your test mixtures, based on previous observations and results.
   d. You will justify the quality of your final design based on the nature of the mixtures and on the results of your test mixtures.
   e. You will evaluate your final results and use the properties observed throughout this lesson to analyze successes and deficiencies in your product.
   f. Each test mixture will be painted onto an index card for observations. The index cards should be labeled so you can look at them later, if needed. Hint: Painting on the lined side will help you to evaluate how opaque the paint is.

3. In the space below, write out the plan you will use to create and test your two test paint mixtures. After testing the two mixtures, use the results to determine what your final formulation should contain. Record all justifications and results in the table in the Results section.

YOUR PLAN
Results

<table>
<thead>
<tr>
<th>Formulation for mixture</th>
<th>Justify the design of this formulation with previous evidence</th>
<th>Record results of your test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test Mixture #1:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test Mixture #2:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final Mixture:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Analysis
Before creating your own paint, you learned about how the particles in various types of mixtures interact to give them different properties. For each mixture above, consider the interactions of particles in the paint mixtures and explain how those interactions led to each of the results you observed.

| Test Mixture #1         |                                                               |
| Test Mixture #2         |                                                               |
| Final Mixture           |                                                               |

Conclusion
In 2-3 paragraphs, write a complete answer to the following question:

**How do paint manufacturers make use of the interactions of individual components to create paints with desired properties?**

- Your answer should include an evaluation of your test paints as evidence for your answer.
- Your answer should include proper use of the following terms:
  - solution, suspension, colloid, wet, dry, particles, attraction, particle size