SUCCESS ACADEMY EDUCATION INSTITUTE

# Physical Science: Unit 1

# Separating Mixtures: Lessons

## Lesson 1: Dirty Water

**Lesson Objective: All of the substances on Earth are composed of unique combinations of atoms. Tap water, even bottled water, is a mixture of elements, compounds, and $H_2O$ molecules. To make clean water, we use filtration and other separation techniques.**

**Materials Needed**

- For the teacher: one bottle of water that contains more ingredients that just water, such as magnesium sulfate or potassium chloride (per section)
- For each group: 50 mL tap water, cup or beaker, paper towel, one copper water test strip, one iron water test strip, one lead testing strip
- For each scholar: computer

**Prep**

- Materials Prep:
    - Cut the lead testing paper into strips (two to three per sheet).
- Intellectual Prep:
    - Read "**That Tap Water Is Legal but May Be Unhealthy**" by The New York Times.
    - Watch the **Fluoride in Drinking Water Debate Continues Video** by FOX6 News Milwaukee (2 minutes, 45 seconds).

**What are scholars doing in this lesson?**

- Scholars test the water in their school water fountains for contaminants.

**Do Now**

- Follow the **Do Now plan**.

**Launch**

- Hold up a bottle of water.
    - What's in this bottle?
    - Ask for a volunteer to come up and take a sip.
        - Are water molecules the only things you can find in our tap water?
        - Reveal that the water from the bottle is <u>not</u> just water. Ask the scholar who drank from the water bottle to find and read the ingredients list to the class.
- Explain:
    - When we drink water, it isn't always just **pure** $H_2O$! Water, including our drinking water, often contains other ingredients. Some are safe, some are unsafe, and some are still up for debate in the scientific community.
    - During this unit, we will embark on a journey to learn more about the world's fresh water. We will learn about the global state of fresh water as well as the efforts by scientists to keep Earth's water clean. Through this lens, we can study what happens when unwanted substances get into our water supplyâ€"and how we can use science to clean up the mess!
    - Before we explore the globe, we'll start right in our own backyard.

**Experiment**

- Scholars work in groups of four to perform iron, copper, and lead tests on tap water.
    - Scholars conduct a copper test (i.e., dip strip in water for 20 seconds, let sit for 2 minutes, and take reading).
    - Scholars conduct an iron test (i.e., dip strip in water for 20 seconds, let sit for 2 minutes, and take reading).
    - Scholars conduct a lead test (i.e., hold strip in water for 2 minutes and take reading).
- Scholars determine the limits for iron, copper, and lead on the **EPA website**.
    - Using this research, they compare the results of their tests to the acceptable limits.
        - Note: The EPA imposes mandatory limits on lead and copper, a suggested limit for iron, and a stricter suggested limit for copper, which can be found in the Environmental Protection Agency's **Secondary Drinking Water Standards**.

- Scholars view he following videos and read the following article on their computers:
    - **Fluoride In Drinking Water Debate Continues Video** by FOX6 News Milwaukee (2 minutes, 45 seconds)
    - **Flint Water Crisis – How Do You Fix This Toxic Disaster Video** by Fusion (3 minutes, 39 seconds)
    - "**That Tap Water Is Legal but May Be Unhealthy**" by The New York Times
- As scholars are working, circulate and ensure all scholars are actively participating in their group discussion.

**Discourse  Debrief experiment:**

- Ask: How did your tests of the drinking water compare to the imposed and suggested limits by the EPA?
- Ask: Is most tap water composed of nothing but H2O molecules? Explain.

**Make broader connections:**

- Ask: If water is contaminated with a dangerous substance, what can we do to fix it?

**Accountability (Exit Ticket)**

1. How could we make clean water from water found at the beach? State and explain your claim simply and clearly.

We can use the water filtration system that is used for camping trips. The water from the beach will go into the filter and it will make the water clean.

**Scoring**  Award points as follows:

1. Score scholars on a 1–4 scale (below expectations through exceeding expectations). Do not penalize scholars for initial misconceptions about contentâ€” rate them on effort and writing.
    - Look for the following when scoring scholar responses:
        - A clear claim that answers the question
        - Specific evidence collected from the activity or their prior knowledge that supports the claim
        - Justification/reasoning that ties the evidence to the claim
        - High effort shown in writing, with complete sentences and proper grammar/ punctuation seen throughout the response

# Lesson 2: The Global State of Water

**Lesson Objective: Human activities have devastated much of the hydrosphere and, in turn, the biosphere. With much of Earth's accessible freshwater devastated by human activity, water pollution is responsible for millions of deaths annually. Materials Needed**

- For each scholar: computer

**Prep**

- Materials Prep:
    - Review the videos from the lesson and determine which you will assign to scholars.

**What are scholars doing in this lesson?**

- Scholars learn more about the current state of our planet's water, how it got that way, and what we can do about it.

**Do Now**

- Follow the **Do Now plan**.

**Launch**

- Scholars guess the answers to the following fill-in-the-blank questions in their Lab Notebooks:
    - Every day, _____ pounds of sewage and industrial and agricultural waste are discharged into the world's water.
        - (Answer: 4,000,000,000. Source: UN WWAP 2003)
    - Unsafe water causes _____ deaths each year.
        - (Answer: 2,200,000. Source: WHO and UNICEF 2000)
    - Most people who die from unsafe water are _____ years old.
        - (Answer: Younger than 5. Source: WHO and UNICEF 2000)
- Reveal the answers. Allow scholars to correct their answers.
    - Have scholars reflect and share on the answers to the activity.
- Say: As you can see, contaminated water is a shockingly widespread global problem. Today, you will conduct some research to better understand the problem.

**Research**

- Scholars watch the assigned videos from the following list:
    - **Pollution: Crash Course Ecology #11 Video** (9 minutes, 21 seconds)
    - **Move Over, Smog: China's Water Pollution Off the Charts Video** by LinkAsia (3 minutes, 45 seconds)
    - **10 of the Most Polluted Places on Earth Video** by Alltime10s (13 minutes, 51 seconds)
        - If using this video, remind scholars to focus on the water pollution, as this video covers land, air, and water pollution.
    - **Marine Pollution Video** by the U.S. Department of State (1 minute, 54 seconds)
        - If using this video, remind scholars to focus on the water pollution, as this video covers both air and water pollution.
- Scholars take notes in their Lab Notebook.
- As scholars are working, circulate and press them to connect their findings to what they learned about humans' impact on the environment in previous years' science classes.

**Discourse  Debrief activity:**

- Ask: How has human activity affected the Earth's **hydrosphere**?
- Ask: How has water pollution affected the **biosphere**?

[**Tip:** Consider completing a **KWL chart** (from **Peartreeedu**, **CC BY-SA 4.0**, via Wikimedia Commons) with your class so scholars can reflect on their prior knowledge and become invested in new questions to be answered throughout the unit.]

**Introduce the Essential Question:**

- Ask: How can scientists make poisonous water safe to drink?
- Explain to scholars that they will embark on a unit-long, hands-on search for answers to this question.

**Accountability (Exit Ticket)**

1. Should cleaning up polluted water on Earth be a priority for scientists? Explain and justify your response. [3]

I think that the cleanup of polluted water should be a priority for scientists. I think this because I know that water pollution has negative effects on the environment and many living things, including humans. For example, people need clean water to drink and bathe in, and without access to clean water, many people die each year.

**Scoring** Award points as follows:

1. Award one point for each of the following:

    - A reasonable claim that relates to their evidence
    - Evidence from class that supports their claim
    - A justification that explains their evidence

---

# Lesson 3: Removing Solid Particles

**Lesson Objective: Each pure substance has characteristic physical and chemical properties that can be used for their identification. Filtration is an effective method for separating solids from liquids. Strainers and filter paper separate mixtures based on their particle size. Understanding the properties of the materials in a mixture allows scientists to develop effective procedures for separating them. Materials Needed**

- For each group: cup of water containing sand and pebbles, strainer, plastic sandwich bag, heat lamp, plastic spoon, separatory funnel, filter paper, funnel, empty bowl, empty cup

**Prep**

- Materials Prep:
    - Prepare experimental cups using the following procedure:
        - Fill the cup approximately one quarter of the way with sand.
        - Add a large pinch of pebbles. (Note that pebbles that arrive dusty may need to be washed before use, as they should not cloud the water.)
        - Fill the remainder of the cup with water.
    - Read the **separatory funnel extraction procedure** by the University of South Florida. Ensure you feel confident using a separatory funnel before starting this activity.

**What are scholars doing in this lesson?**

- Scholars design their own procedure to remove sand and rocks from a water sample.

**Do Now**

- Follow the **Do Now plan**.

**Launch**

- As we learned in our previous lessons, there are a number of other materials that make their way into our water supply. Throughout the next several lessons, we will explore a variety of common problems and develop our own solutions to learn more about how scientists make poisonous water safe to drink.

- In many areas, water from a large natural or man-made lake called a reservoir is used for drinking. However, these lakes often have rocky, sandy bottoms. No one wants to drink sand, so today, you will separate unwanted sand and rocks from water!
    - Aside from making the water taste bad, do you think there are other problems with drinking water that contains dirt?

**Experiment**

- Scholars devise and implement a procedure for removing sand and rocks from a water sample. Scholars must use the materials provided.
    - Note: Scholars should be given access to this **YouTube video** explaining how to use a separatory funnel. Scholars do not need separatory funnels to separate these materials, but in case a group decides to try using one, one teacher may want to be on hand to answer questions.
- As scholars are working, circulate and press scholars to explain parts of their procedure. Encourage scholars to write their procedures with as much detail as if someone else were to read and implement it.

[**Materials Management Tip:** Leave extra time for scholars to clean up at the end of this investigation.]

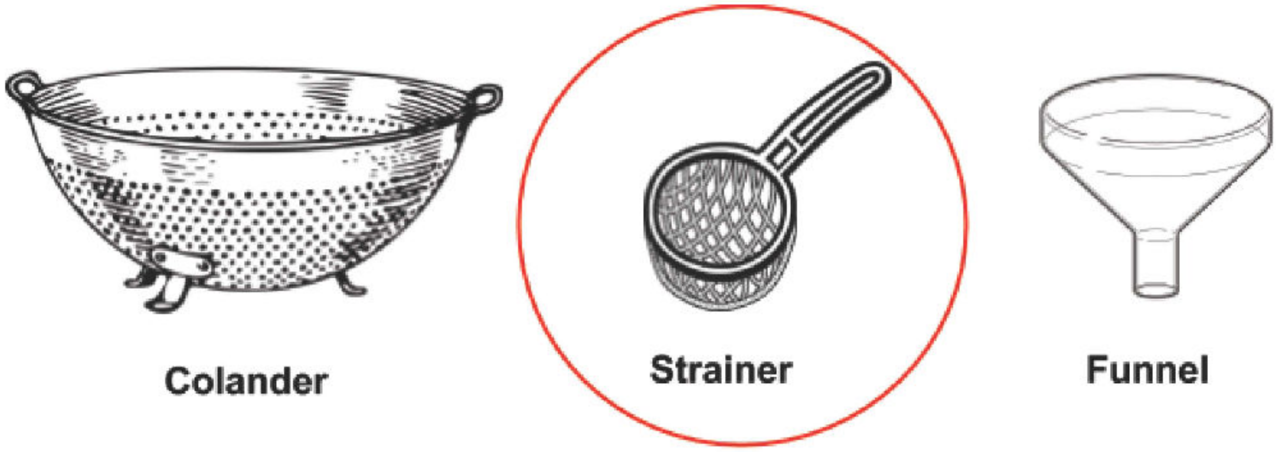
**Discourse  Debrief experiment:**

- Ask: What technique did you use to separate the rocks and sand from the water?
    - Define **filtration**.
    - Define **separation technique**.
    - Define **particle**.
- Ask: What properties of the rocks and sand led you to choose that technique?
    - Define **physical property**.
    - Define **mixture**.
- Ask: What other materials could be separated from water using the same technique?
    - Evaluate your group's procedure. Was it clearly written? Were you able to implement it successfully?

**Make connections to the Essential Question:**

- Ask: Based on today's activity, how can scientists make poisonous water safe to drink?

**Accountability (Exit Ticket)** Sahara has a mixture of 1,000 large and small paper clips. She has these following items in her kitchen:




1. Sahara decided to use a funnel to separate the large paper clips from the small paper clips. Explain why a funnel is not the best tool for separating the paper clip sizes. [1]

I think the funnel will not be the best tool for separating the paper clip sizes because the hole in the funnel is too big. The funnel will allow any size paper clip to go through the hole, so it will not separate the bigger ones from the smaller.

2. Circle the tool above that best separates the paper clips by size. [1]

**Scoring** Award points as follows:

1. Award one point for responses that demonstrate use of scientific reasoning that demonstrate understanding of effective separation procedures.
2. Award one point for responses that indicate the strainer is most expedient for separating large and small paper clips.

---

# Lesson 4: Removing Dissolved Particles

**Lesson Objective: Despite its apparent disappearance, a substance dissolved in a mixture often retains its chemical properties. Distillation can separate a dissolved solid from water. Materials Needed**

- For the teacher: one beaker (containing water and dissolved salt)
- For each group: one beaker (containing water and dissolved salt), small strainer, plastic sandwich bag, heat lamp, plastic spoon, separatory funnel, filter paper, funnel, cup (50 mL water), two empty cups

**Prep**

- Materials Prep:
    - Read the **separatory funnel extraction procedure** by the University of South Florida. Ensure you feel confident using a separatory funnel before starting this activity.
- Intellectual Prep:
    - Read **How to Separate Salt from Water** by WikiHow.

**What are scholars doing in this lesson?**

- Scholars are challenged to separate salt dissolved in water.

**Do Now**

- Follow the **Do Now plan**.

**Launch**

- Ask: So far, what types of mixtures do you know how to separate?
- Show a salt and water mixture to scholars. Present the lab challenge:
  - Separate salt dissolved in water.
- Return to the Essential Question. Explain that part of what makes scientists' jobs so difficult when cleaning contaminated water is that contaminants may already be dissolved in the water. Ask:
  - How can you remove something that you can't see?

**Experiment**

- Scholars design and implement a procedure to separate salt from the water it is dissolved in. Scholars must use the materials provided.
  - Note: Scholars should be given access to this **YouTube video** explaining how to use a separatory funnel.
- As scholars are working, circulate and press them to explain the reasoning behind their procedure.

**Discourse  Debrief experiment:**

- Ask: Why does filtration not work to separate these materials?
  - Scholars should remember discussion of physical properties from earlier in the unit; define here **chemical properties**.
  - What happens to the mixture when you add water?

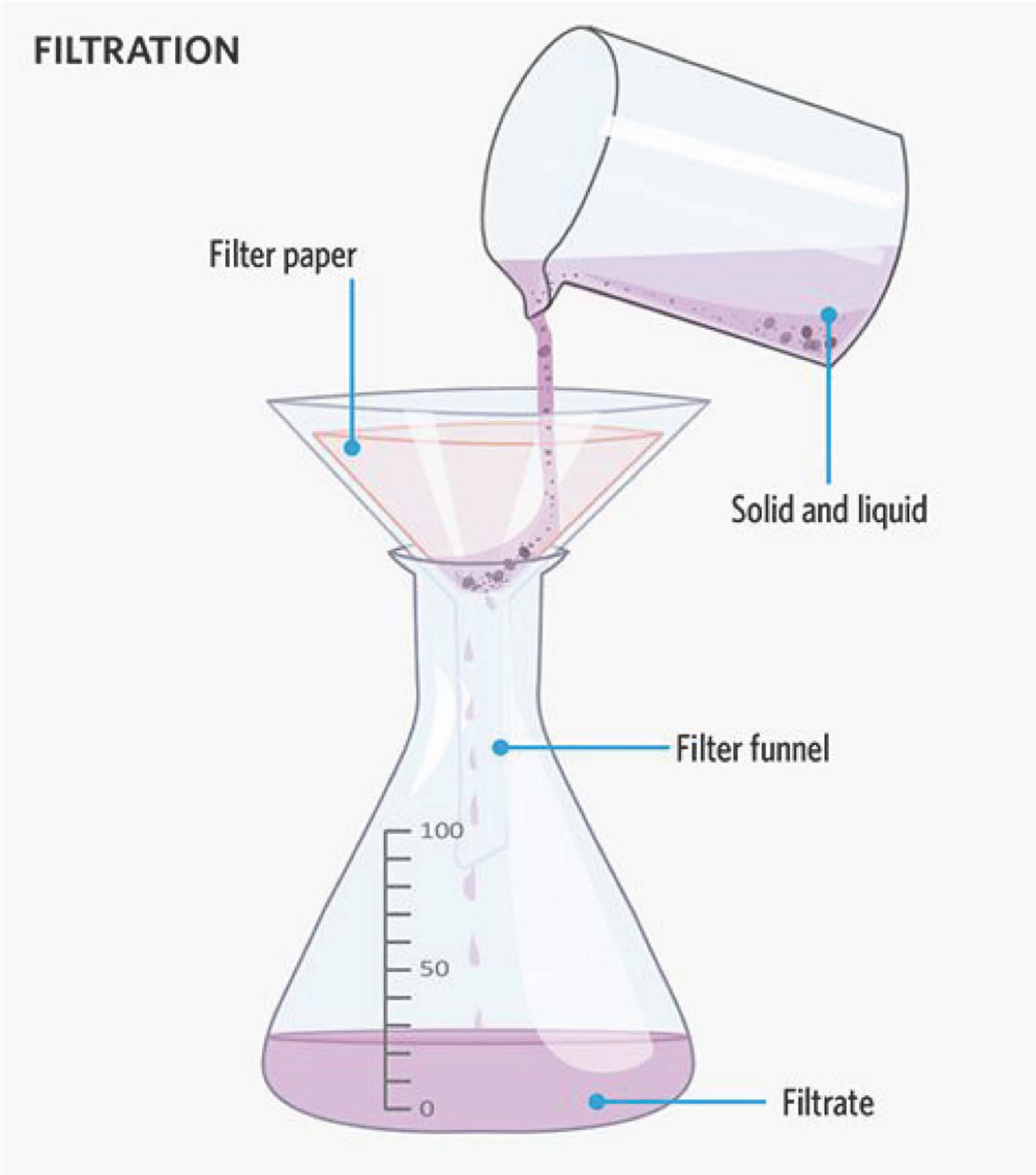
**Make connections to the Essential Question:**

- Ask: How can you separate the salt from the water? Could scientists apply this method to remove other dissolved particles? Would this make poisonous water safer to drink?
- Show scholars this **YouTube video** explaining and defining **distillation** (show the first 45 seconds).

**Make broader connections:**

- Ask: How might distillation be used for other practical purposes?

**Accountability (Exit Ticket) Directions:** The picture shows an experimental setup to separate a salt, sand, and water mixture by filtration.




1. Salt and sand are approximately the same size. Will the experimental setup shown above separate the solutes (sand and salt) from the solvent (water)? Put an X on the statement you agree with most. [1]

☐ Filtration will separate both salt and sand from the water.

✓ Filtration is not enough to separate both sand and salt from the water.

2. Why or why not? Explain your choice. In your explanation, address both the sand and the salt. [2]

Filtration will be able to separate sand from the salt and water because the sand is too big to pass through the filter. The sand does not dissolve in water, but salt does. The water carries the dissolved salt through the filter; therefore, filtration is not able to separate both salt and sand from the water.

3. Identify the components in the filtrate that would be present after pouring the mixture through the filter. [1]

Salt dissolved in water.

Salt and water.

**Scoring** Award points as follows:

1. Award one point for responses that indicate filtration is not enough to separate both sand and salt from the water.
2. Award two points for scientific reasoning that indicates salt dissolves in water, but sand does not. Therefore filtration is able to separate sand from water because the sand cannot pass through the filter.
3. Award one point for correctly identifying that salt and water are in the filtrate.

---

# Lesson 5: Removing Other Liquids

**Lesson Objective: Some liquids can be separated through the process of decantation because of their different densities. Oil and water are immiscible and instead form layers. Once immiscible liquids settle in a separatory funnel, liquids layer from least dense (top) to most dense (bottom).**
**Materials Needed**

- For each group: cup of vegetable oil and water mixed (50 mL each), small strainer, plastic sandwich bag, heat lamp, plastic spoon, separatory funnel, filter paper, funnel, cup (50 mL water), two empty cups

**Prep**

- Materials Prep:
    - Read the **separatory funnel extraction procedure** by the University of South Florida. Ensure you feel confident using a separatory funnel before starting this activity.

**What are scholars doing in this lesson?**

- Scholars design and implement a procedure to separate two liquids from each other.

**Do Now**

- Follow the **Do Now plan**.

**Launch**

- Say: In addition to the many solid particles that end up in our water, liquids often end up there, too. People have dumped hazardous chemicals and other material into our waterways for centuries. Now, polluting fresh water is illegal almost everywhere, but despite global efforts to prevent it, accidents still happen and people still sometimes choose to break the laws.
  - When scientists attempt to clean contaminated water, they must consider whether other liquids have made their way into it.
- Show **Yellowstone River Oil Spill Contaminates Water Supply Video** by NBC Nightly News (2 minutes, 12 seconds).
  - Ask: How can we separate two liquids?

**Experiment**

- Scholars design and implement a procedure to separate oil from water.
  - Note: Scholars should be given access to this **YouTube video** explaining how to use a separatory funnel.
- Sample procedure:
  - Scholars pour mixture into a separatory funnel.
  - Scholars allow water and oil to settle.
  - Scholars place a cup underneath the funnel.
  - Scholars conduct a slow turn of the valve on the funnel to drain water into the cup.
  - Scholars close the valve once all water is drained.
  - Scholars empty the remaining liquid in the funnel into a new cup.
- As scholars are working, circulate and take note of the scholars who are struggling to explain the connection between their procedure and the physical properties of the substances being separated. Create a plan to follow up with these scholars.

**Discourse  Debrief experiment:**

- Ask: What technique did you use to separate the mixture and **isolate** the water?
  - Define **decantation**.
- Ask: What properties of oil and water does this technique rely on?
- Ask: Which liquid dropped through the funnel first? Why?

**Make connections to the Essential Question:**

- Ask: How does the ability to separate multiple liquids help scientists clean polluted water?

**Make broader connections:**

- Ask: If there was an oil spill in a lake that poisoned the water, could we use this method to separate the oil and water? Why?

**Accountability (Exit Ticket) Directions:** The cup pictured below contains a mixture of the following three immiscible liquids: honey, dyed green water, and blue dish soap. Table 1 lists the physical properties of those substances.

**Table 1**

| Substance | Mass (g) | Color | State of Matter | Density (g/ml) |
|---|---|---|---|---|
| **Honey** | 11.36 | Gold | Liquid | 1.42 |
| **Dyed Water** | 30.00 | Green | Liquid | 1.00 |
| **Dish Soap** | 28.40 | Blue | Liquid | 1.06 |

1. Which layer would you expect to find each substance in the cup? [1]

| Layer | Substance |
|---|---|
| Top | Dyed water |
| Middle | Dish soap |
| Bottom | Honey |

2. If the liquids were not immiscible, could you use decantation to separate this mixture? Circle the most correct explanation. [2]
    1. You could not use decantation to separate this mixture. If the liquids were not immiscible, each liquid would have an identical density.
    2. You could use decantation since the liquids would still retain their individual densities.
    3. You could not use decantation to separate this mixture. If the liquids were not immiscible, they would all mix together.

**Scoring** Award points as follows:

1. Award one point for all substances listed in the correct layers.
2. Award two points for answer C.

---

# Lesson 6: Physical Properties

**Lesson Objective: Multiple techniques must be used to separate more complex mixtures. To separate a mixture efficiently, you must understand the physical properties of its ingredients. Filtration and decantation rely on differences in physical properties. Filtering uses particle size to separate materials, while decanting relies on differences in densities. Materials Needed**

- For each group: cup of "motor oil" (vegetable oil and 2 tbsp cocoa powder mixed to simulate motor oil), coffee beans, and water mixed; small strainer; plastic sandwich bag; heat lamp; plastic spoon; separatory funnel; filter paper; funnel; cup (50 mL water); two empty cups

**Prep**

- Materials Prep:
    - Create each experimental cup by combining one part "motor oil," one part coffee beans, and two parts water.

- Intellectual Prep:
    - Watch **Physical vs Chemical Properties - Explained Video** by Chem Academy (6 minutes, 25 seconds).

**What are scholars doing in this lesson?**

- Scholars work to solve a real-world scenario by cleaning water with several contaminants.

**Do Now**

- Follow the **Do Now plan**.

**Launch**

- Explain that physical properties are properties you can measure without changing the chemical makeup of the material.
    - Have scholars make a list of the physical properties of water in their Lab Notebooks.
- Ask: Is density a physical property?
- Say: You now understand several methods for separating mixtures. However, in the real world, water often contains several contaminants, not just one! Read the scenario in your Lab Notebook and develop a solution to clean the water.
    - Scenario: An accident at a plant that produces flavored coffee resulted in some of the ingredients and oil used to operate the factory's machines being dumped into a nearby reservoir! Unfortunately, that reservoir houses the town's supply of drinking water. Help the company clean the water so the townspeople can use it again.

**Experiment**

- Scholars create a procedure for separating the components of the mixture.
- As scholars are working, circulate and ask them to cite specific evidence from previous experiments that have led them to their new procedure.

**Discourse  Debrief experiment:**

- Ask: Which separation techniques did you rely on to separate the parts of the mixture?
- Ask; What properties of each ingredient led you to make these decisions?

**Make connections to the Essential Question:**

- Ask: How did this experience mimic the real experience of a scientist trying to clean polluted water?
- Ask: What other challenges do you think scientists might face when cleaning contaminated water in the real world?

**Accountability (Exit Ticket)**

1. José has a mixture of marshmallows, sugar, and water. The sugar has dissolved into the water. List two materials José would need to separate his mixture. [2]

Sieve for filtration

Pot for distillation

2. Explain why he would need both of these materials. [2]

The solid marshmallows can be easily removed using filtration, but the dissolved sugar will need to be removed through distillation. Using these materials will ensure that Jose is able to separate all three ingredients from the mixture.

3. Identify two substances that you think could be separated using decantation. Explain your reasoning. [2]

I think oil and vinegar could be separated using decantation. If left to sit out, the oil would settle on the top, leaving the vinegar on the bottom. Then, the oil could be poured off. I chose these two liquids because I believe they have different densities.

**Scoring** Award points as follows:

1. Award one point for each of the following:
    - Naming two materials that can be used to separate substances in the mixture (filter paper, pot, etc.)
2. Award one point for each of the following:
    - Explains how material 1 would be used to separate
    - Explains how material 2 would be used to separate
3. Award one point for each of the following:
    - Identifies two substances that could reasonably be separated using decantation (score this holistically given their current level of understanding and their reasoning)
    - Explains how the substances could be separated

---

# Lesson 7: Solubility

**Lesson Objective: You cannot just combine any two materials to create a solution. Only certain materials are able to dissolve in others because of their polarity. Polarity affects attraction between molecules, which affects solubility. In most cases, like dissolves like: polar dissolves polar, and nonpolar dissolves nonpolar. An example of an excellent polar solvent is water. When an object dissolves, the molecules are still there but are dispersed within the solvent, making them impossible to see. Materials Needed**

- For each group: lauric acid, copper sulfate, cornstarch, salt, oil, ethanol, water, 12 soufflé cups (with lids), dump bucket

### Prep

- Intellectual Prep:
    - Watch **Polar Bonds and Molecules Video** by Teacher's Pet (3 minutes, 35 seconds).

### What are scholars doing in this lesson?

- Scholars learn more about solubility of substances by testing their ability to create a solution when mixed.

### Do Now

- Follow the **Do Now plan**.

### Launch

- Ask: Why doesn't sand **dissolve** in water like salt does?
    - Explain that the property of being able to dissolve is called **solubility**.
        - One factor that affects solubility is a property called molecular **polarity**, which is based on the distribution of charge within a molecule.
- Show diagrams of polar, nonpolar, and ionic compounds.
    - Explain the distribution of charge and its effect on intermolecular forces for each type of compound.
- Ask: How might understanding molecular polarity help a scientist who is trying to clean the world's water?
- Say: To help us solidify our understanding of solubility, we will test several substances to see whether or not they create a **solution** when mixed.
    - Define **solvent**, **solute**, **soluble**, and **insoluble**.

### Experiment

- Scholars test the solubility of four solutes in three solvents.
    - Scholars compare their findings to the molecular structures of each pairing to determine trends.
    - Sample lab procedure:
        - Scholars create a 3 × 4 grid with the soufflé cups.
        - Scholars put one scoop of cornstarch in each cup in row 1.
        - Scholars put one scoop of salt in each cup in row 2.
        - Scholars put one scoop of lauric acid in each cup in row 3.

- Scholars put one scoop of copper sulfate in each cup in row 4.
- Scholars fill each cup halfway with water in column 1.
- Scholars fill each cup halfway with oil in column 2.
- Scholars fill each cup halfway with ethanol in column 3.
- Scholars put lids on all cups.
- Scholars gently shake individual cups and observe.
- Scholars record whether powder is visible and note any detectable changes.
- Scholars empty all used soufflé cups into a dump bucket.

**Discourse Debrief experiment:**

- Have scholars share out their results. Ask:
  - What molecules had similar solubility?
  - How did the molecular structures connect to the substances' ability to create a solution?

**Make connections to the Essential Question:**

- Ask: How could this knowledge help scientists clean poisoned water?

**Accountability (Exit Ticket) Directions:** The following table lists the physical properties of the following substances. Use the following information, Table 1, and your knowledge of science to answer the question below.

**Table 1: Physical Properties of Substances in Water**

| Substances | Polar or Nonpolar? | Soluble in water? |
|---|---|---|
| **Ethanol** | Polar | Yes |
| **Vegetable oil** | Nonpolar | No |
| **Salt** | Polar | Yes |
| **Sugar** | Polar | Yes |

1. Which compounds are polar, nonpolar, and soluble/not soluble in water? Fill in the blanks in Table 1. [3]

**Scoring** Award points as follows:

1. Award three points for all four correct responses.
   - Award partial credit as follows:
     - Two points for three correct responses
     - One point for two correct responses
     - Zero points for less than two correct responses

# Lesson 8: Changing Solubility

**Lesson Objective: It is possible to change the speed at which a solute dissolves. Increasing temperature and agitation both increase the rate of solubility.  Materials Needed**

- For each group: hot plate, stirring sticks, sugar, water, plastic-coated ice cubes

**Prep**

- Materials Prep:
    - Review the unit safety note regarding hot plates and plan to review safety cautions and expectations on how to use hot plates with your class before the activity.

**What are scholars doing in this lesson?**

- Scholars use sugar as a model “pollutant” and devise a procedure to determine the factors that affect the rate at which sugar dissolves in water.

**Do Now**

- Follow the **Do Now plan**.

**Launch**

- Ask: When an oil spill or other source of pollution is identified in a body of water, why do you think scientists want to clean it up as fast as possible?
- Show pictures of the negative results of water pollution on the biosphere, such as these:

Image Credit: “A dead bird covered in oil from the Deepwater Horizon oil spill in the Gulf of Mexico, East Grand Terre Island, Louisiana, June 2010,” Charlie Riedelâ€”AP/Shutterstock.com via **Encyclopedia Britannica**

Image Credit: “Pollution in the Lachine Canal, in Montreal,” **Aarchiba**, public domain, via Wikimedia Commons

Image Credit: “Coral colony in the Gulf of Mexico affected by the 2010 oil spill,” **Lophelia II 2010 Expedition, NOAA-OER/BOEMRE)**, public domain, via Wikimedia Commons

- Say: Some pollutants, such as the oil shown earlier, are immiscible, meaning they do not mix with the water. But because of their polarity, other substances will begin to dissolve into the water right away.
    - Scientists who clean up pollution care about how quickly water-soluble pollutants dissolve in water because it affects how fast and how far they will spread. It also determines the likelihood of the contaminated water being consumed by living organisms.
    - Ask: What factors do you think affect the rate of how fast a substance dissolves into solution?

**Experiment**

- Considering the available materials, scholars design a procedure to test the effects of various factors (such as temperature or agitation) on solubility.
    - If scholars are stuck, encourage them to think about real-life scenarios in which materials dissolve.
        - Ask: What makes ice melt into a beverage?
        - Ask: How do they get a powdered drink mix to dissolve into water faster?
- As scholars are working, ask them to explain the background knowledge that led to their experimental design and their hypotheses.
    - Ensure that their experimental designs are valid and only have one independent variable (i.e., they are not leaving one cold beaker of sugar water sitting still while they stir the hot beaker).

**Discourse  Debrief experiment:**

- Have scholars share out their procedures and results.
    - Ask: What factors affected the sugar's solubility? How?

**Make connections to the Essential Question:**

- Ask: Under which conditions do you think a pollutant would dissolve fastest in a lake?
    - Scholars should consider weather conditions as well as organisms living in the water that may lead to agitation.
- Ask: How could understanding this help scientists who are trying to clean up the Earth's water?

**Accountability (Exit Ticket)**  Kyra is experimenting with hot chocolate mix at home. She places the mix into a cup of water.

1. Identify two things Kyra could do to make the hot chocolate mix dissolve faster. Explain your response. [3]

Krya could stir the mix or place the mixture of hot chocolate mix and water in the microwave. Heating and agitation both increase the rate of solubility.

**Scoring**  Award points as follows:

1. Award one point for each of the following:
    - One method that describes increasing the temperature of the mixture
    - A second method that describes increasing the agitation of the mixture
    - Relevant explanation that relates the methods to increased agitation and temperature to increased solubility

---

# Lesson 9: Graphing Solubility

**Lesson Objective: The changes in solubility that occur with variations in temperature or pressure can be described and predicted. Temperature can have modest or drastic impacts on solubility depending on the substance. Solubility curves tell us how temperature affects solubility, how much solute we would expect to be dissolved or not dissolved, and the relative polarity of molecules.  Materials Needed**

- For each scholar: extra graph paper (optional)

**Prep**

- Intellectual Prep:
    - Watch the **Solubility Curves Video** by FuseSchool (4 minutes, 23 seconds).

**What are scholars doing in this lesson?**

- Scholars learn how scientists communicate their data about solubility using two examples that are known pollutants to fresh water.

**Do Now**

- Follow the **Do Now plan**.

**Launch**

- Show the **Sweet Peach Iced Tea Recipe Video** by I Heart Recipes (1 minute, 16 seconds).
    - Ask: Why does she mix in the sugar when the tea is still hot?
- Explain that solubility is impacted by temperature, but it has different effects depending on the solute.
    - Say: Today, you will consider why scientists who are working to clean polluted, poisoned water would care about graphing their data.
        - Define **quantitative** and **qualitative** data. Ask scholars to consider whether they are using quantitative or qualitative data when they graph solubility.

**Activity**

- Scholars individually create a graph using the solubility data in their Lab Notebooks for sodium chloride and copper sulfate.
    - Scholars complete analysis questions using their graph.
- As scholars are working, circulate and look for scholars with a model graph that can be displayed during discourse.

**Discourse  Debrief activity:**

- Display two model graphs. Ask:
    - How does temperature affect the solubility of these two solutes? How can you tell?
    - What information can we get from interpreting solubility curves?

**Make connections to the Essential Question:**

- Ask: How can this data help scientists who are working to clean polluted water?
    - Why might they want to share their data with other scientists?

**Accountability (Exit Ticket)** Scholars were studying the solubility of four substances using the graph shown. Use the image below to answer questions one through three.

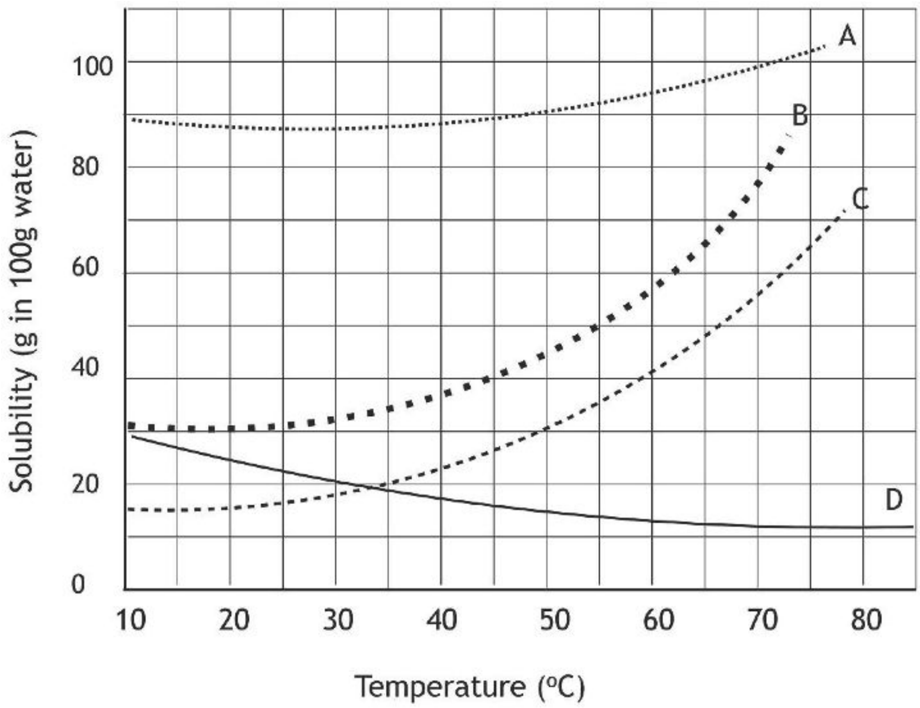
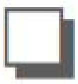


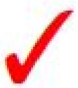

Image Credit: [Brightyellowjeans](), [CC BY-SA 4.0](), via Wikimedia Commons

1. At which temperature was approximately 20 g of Substance C and Substance D dissolved? [1]
    1. 10â„ƒ
    2. 27â„ƒ
    3. 33â„ƒ
    4. 42â„ƒ

Rafael is trying to dissolve 100 g of Substance A in Beaker 1 and 100 g of Substance B in Beaker 2 at room temperature (23â„ƒ) but only some of each compound dissolves.

2. Which compound would benefit the most with an increase in temperature? [1]


Substance A


Substance B

3. How do you know? Explain why. [1]

Possible Exemplars:

Substance B has the steepest curve on the graph, which indicates temperature affects Substance B solubility greatly.

Substance B is most affected by a change in temperature. This dramatic change was represented by the steepest curve on the graph.

**Scoring** Award points as follows:

1. Award one point for answer C.
2. Award one point for selecting Substance B.
3. Award one point for responses that give scientific reasoning that correctly interprets solubility curves. The steeper the curve, the more temperature plays a factor in modulating solubility. The more gradual the curve, the less temperature plays a factor in modulating solubility.

---

# Lesson 10: Panning for Gold

**Lesson Objective: When confronted with an unfamiliar mixture, scholars should study the physical properties of the ingredients to help determine the best method of separating them.**
**Materials Needed**

- For each group: sample of pay dirt, gold pan, strainer, beaker of water, plastic sandwich bag, hot plate, plastic spoon, separatory funnel, filter paper, funnel, empty bowl, empty cup

**Prep**

- Materials Prep:
    - Review the unit safety note regarding hot plates and plan to review safety cautions and expectations on how to use hot plates with your class before the activity.
- Intellectual Prep:
    - Read the **Beginner's Corner: Gold Panning Instructions** from ICMJ's Prospecting and Mining Journal.

**What are scholars doing in this lesson?**

- Scholars devise a method to pan for real gold with their group.

**Do Now**

- Follow the **Do Now plan**.

**Launch**

- Say: Scientists use their knowledge of physical properties to separate mixtures in many ways. This knowledge is not just reserved for cleaning up water pollution! Over the next two classes, we will explore other contexts in which scientists apply this information.

- Watch **American the Story of Us: Gold Rush Video** by History (2 minutes, 32 seconds).
    - Say: Using your knowledge of separating mixtures, how would you look for gold?
        - Today, you have a chance to see if your method would really work!

[**Behavior Management Tip:** Set clear behavioral expectations for this investigation.]

**Experiment**

- Scholars develop and execute a procedure to pan for gold in pay dirt using the materials provided.
    - Scholars may choose to research the properties of gold on their computers while planning their procedure.
- Sample procedure:
    - Scholars place pay dirt in gold pan.
    - Scholars pour water into the pan and swish the pan.
    - Scholars decant liquid and floating pieces out of the pan.
    - Scholars continue pouring water and decanting until gold flakes are visible.
- As scholars are working, ask them to explain how their knowledge of the properties of gold led them to devise their procedure.

**Discourse  Debrief experiment:**

- Ask: What separation techniques did you use?
- Ask: What are the physical properties that allow you to isolate the gold?

**Make connections to the Essential Question:**

- Ask: How was panning for gold similar to cleaning dirty water? How was it different?

**Make broader connections:**

- Ask: Besides cleaning dirty water for drinking uses, how might separation techniques help scientists or people in the real world?

**Accountability (Lab Notebook)**

1. What properties of gold allowed you to isolate it? Explain. [3]

Density allowed us to separate the gold. Gold is denser than the dirt, sand, and rocks with which it is mixed. It sinks to the bottom because it is denser, so we can decant the other materials.

**Scoring** Award points as follows:

1. Award one point for each of the following:
    - An accurate claim that identifies a property used to isolate the gold
    - Evidence from class to support their claim
    - A relevant justification/reasoning to explain their evidence

---

# Lesson 11: Fizz, Fizz, Pop!

**Lesson Objective: Gases, like solids, can also be dissolved in liquids. Gases can be separated via changes in temperature, the solubility of gases decrease as temperature increases. The changes of state that occur with variations in temperature or pressure can be modeled and predicted.**
**Materials Needed**

- For each group: 100 mL seltzer, four clear plastic cups, cold water, hot water

**Prep**

- Materials Prep:
    - Keep a kettle of hot water boiling to refresh/reheat the hot water baths.
- Intellectual Prep:
    - Watch the **Science: Love Seltzer, Champagne, or Soda? We Explain Carbonation & Bubbles in Fizzy Beverages Video** by America's Test Kitchen (4 minutes, 31 seconds).

**What are scholars doing in this lesson?**

- Scholars observe how gases and liquids separate by testing the effect of temperature on seltzer.

**Do Now**

- Follow the **Do Now plan**.

**Launch**

- Show the **Macro Polar Seltzer Bubbles video** from Matty Stevenson (23 seconds).
    - Explain that the bubbles in your soda are dissolved carbon dioxide gas.
        - Gases dissolve in water under different conditions than solids do.

- Ask: What happens to the dissolved COâ‚‚ when you open a can of soda?
    - How do you think temperature affects the separation of the mixture?

**Activity**

- Scholars observe seltzer in cold and hot water baths using the following procedure:
    - Scholars pour an inch of hot water into a clear plastic cup.
    - Scholars pour seltzer into a second clear plastic cup and place it inside the hot water cup.
    - Scholars pour an inch of cold tap water into a new clear plastic cup.
    - Scholars pour seltzer into a second clear plastic cup and place it inside the cold water cup.
    - Scholars observe the two mixtures.
- As scholars are working, ask them to connect what they know about solubility of solids and liquids to gases.

**Discourse  Debrief activity:**

- Ask: What was the difference between the hot and cold cups?
- Ask: What does this tell us about the solubility of gases?
- Ask: What does this tell us about the molecules in the mixture?
- Ask: Why do you think soda is usually served cold?
- Show the following solubility curves below:

- Ask: Which curve could represent the solubility of COâ‚‚ in water?

**Make connections to the Essential Question:**

- Show the following image:

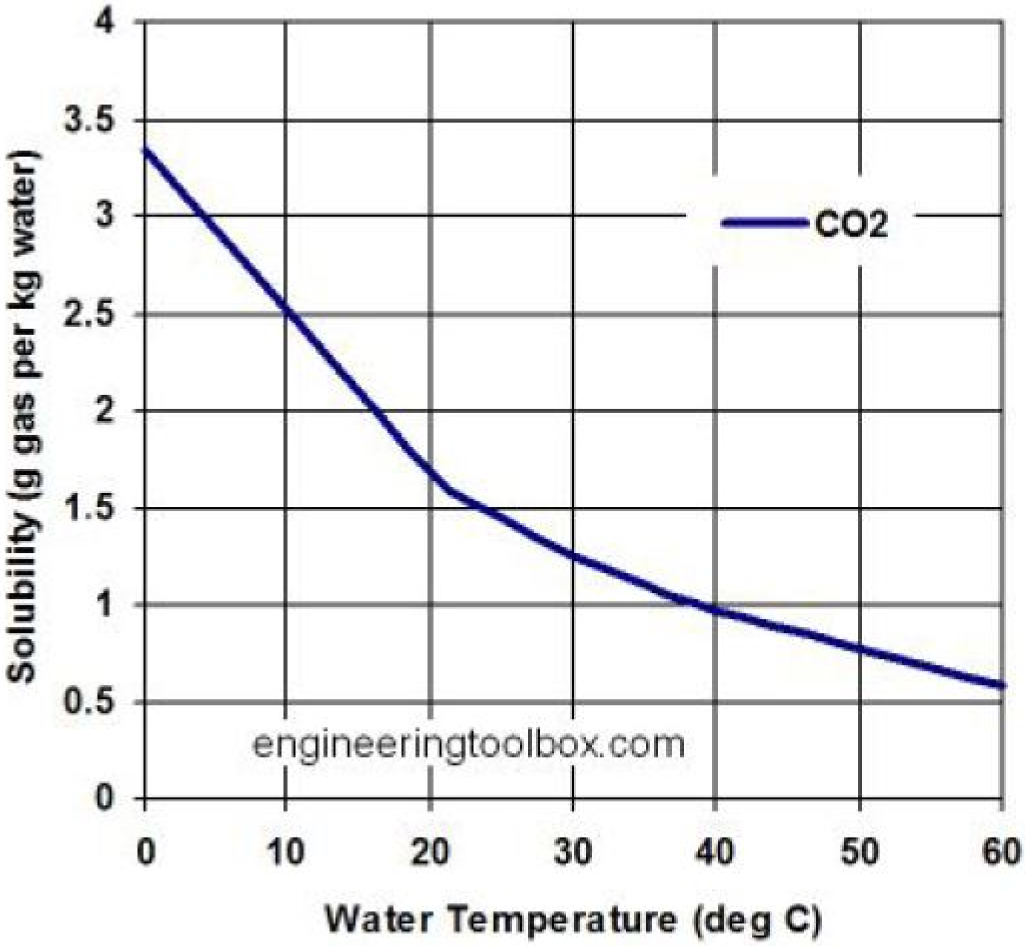



Image Credit: “Solubility of CO2 in water” from **The Engineering Toolbox (multiple authors)**, Public domain, via Wikimedia Commons

- Ask: How could scientists who are cleaning polluted water apply this knowledge?

**Accountability (Exit Ticket) Directions:** Use the graph below to answer the question that follows.

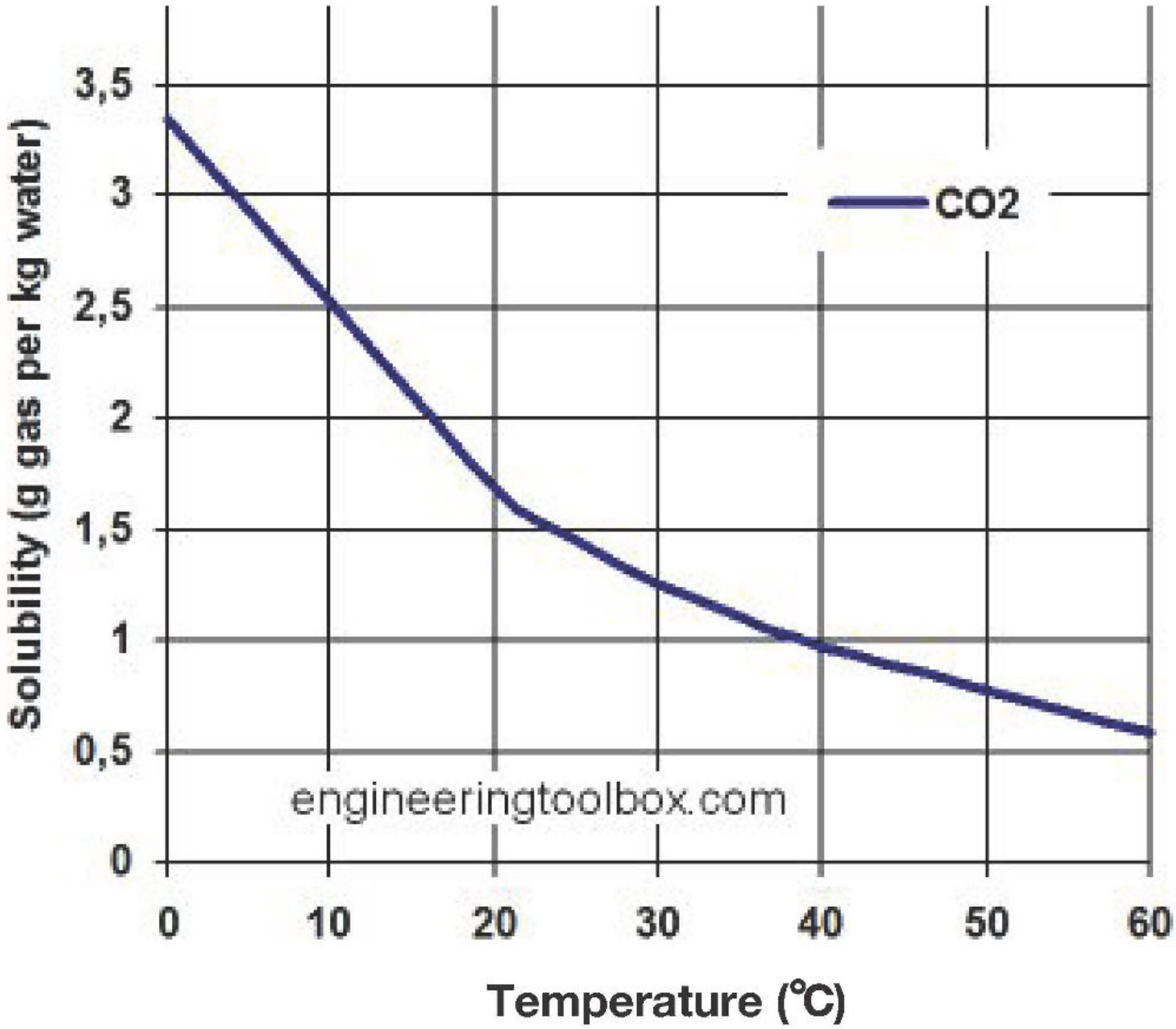



Image Credit: "Solubility of CO2 in water," **The Engineering Toolbox (multiple authors)**, public domain, via Wikimedia Commons

1. When making your own soda, circle the best strategy to maximize the number of bubbles in your soda without adding more COâ‚‚. [2]
    1. Agitate the solution.
    2. Increase the temperature of the solution.
    3. Decrease the temperature of the solution.
    4. Increase the amount of COâ‚‚ in the solution.
    5. Decrease the amount of COâ‚‚ in the solution.

**Scoring** Award points as follows:

1. Award two points for answer C.

# Lesson 12: The Dirty Water Design Challenge — Introduction and Planning (Two Days)

**Lesson Objective: Researching the properties of materials provides scientists with more information to plan a multistep solution to a complex problem. Engineered designs should be justifiable using science.  Materials Needed**

- For the teacher: plastic cups, plastic spoon, funnels, beakers, cotton balls, gauze pads, coffee filters, gravel, paper towels, tulle, separatory funnels, oil, peppercorns, wood shavings, soil, salt, **Dirty Water Challenge Resource**
- For each group: 100 mL sample of "dirty water," two plastic cups, one plastic spoon, funnel, two beakers, $10 credit voucher and optional materials price list from the **Dirty Water Challenge Resource**

**Prep**

- Materials Prep (directions for entire challenge):
    - Create the dirty water by combining the following in a 5-gallon bucket:
        - 6 L water
        - 1 L oil
        - 16 oz whole peppercorns
        - two cups wood shavings
        - 1 L soil
        - one cup salt
    - Construction materials (prepare for each lab group):
        - two beakers
        - two plastic cups
        - one plastic funnel
        - one plastic spoon
        - Print and cut out the materials from the **Dirty Water Challenge Resource** ($10 credit voucher and optional materials price list)
    - Optional materials:
        - Coffee filters
        - Cotton balls
        - Gauze squares
        - Tulle
        - Gravel
        - Paper towels

**What are scholars doing in this lesson?**

- Scholars plan and design a method for cleaning a complex sample of polluted water using both provided materials and optional additionally priced materials using a limited supply of credit.

---

# Day One

**Do Now**

- Follow the **Do Now plan**.

**Launch**

- Say: Today you will begin the unit's final challenge!
    - For your final challenge, you will put yourself in the shoes of a real environmental engineer and devise a method for cleaning the most complex sample of polluted water you've received yet.
- Say: As you work, consider all that you've learned throughout the unit to help you answer the Essential Question: How do scientists make poisonous water safe to drink?

**Activity**

- Scholars receive a small sample of the dirty water to study. They discuss possible procedures for isolating each ingredient from the mixture and record them in their Lab Notebooks.
    - Explain that some of the pollutants are known, but some are unknown. Reveal the identity of three of the pollutants.
- Scholars conduct research on the known pollutants to help them design their plan.
- As scholars are working, ask them to connect what they know about solubility to their research of the known pollutants.
    - How does your research of each pollutant connect to your plan?
    - What about the unknown pollutants?

**Discourse  Debrief activity:**

- Ask: Why do we need to examine the water sample, conduct research, and discuss our plans before designing our solution?
- Ask: What type of information is helpful to find out about the different pollutants?
    - Have scholars share how their research influenced their plans.
- Ask: How do you plan for a solution when there are still unknown pollutants in the mixture?

**Accountability (Exit Ticket)**

1. Identify two ingredients in the dirty water mixture and explain how your group plans to remove them. Justify your response. [2]

Our group plans to remove the peppercorns by using a filter. Because the peppercorns are solid and did not dissolve in the water, we think we can remove those with a strainer. Additionally, our group plans to use a separatory funnel to remove the oil from the water. Because they have different densities and are layered, we think we can separate the oil to remove it. We are confident in these methods because of our understanding of physical properties.

**Scoring** Award points as follows:

1. Award two points for each of the following:

    - Identifies one ingredient and describes an accurate method for removing it
    - Identifies the second ingredient and describes an accurate method for removing it

---

# Day Two

**Do Now**

- Follow the **Do Now plan**.

**Launch**

- Why do you think engineers create sketches of their work before building?
    - Explain that engineers create sketches as well as prototypes to simulate their design and make adjustments before the design's production.
- Show examples of engineering sketches such as this filtration system.

**Activity**

- Scholars sketch their designs and gather the needed materials for building.
- The credit voucher and the list of available additional material prices should be given to each group from the **Dirty Water Challenge Resource**.
    - Assign scholars a budget for "purchasing" additional materials from the list.
- As scholars are working, circulate and ask them to explain how they are incorporating their notes from yesterday into today's design.

**Discourse Debrief activity:**

- Ask: How confident are you in your ability to clean the dirty water? Why?

- Ask: How did you use your notes from the last class to create your design?
- Ask: What are the features of your design? How do they work?
- Ask: Will you be collecting quantitative or qualitative data to measure the success of your design?

**Make connections to the Essential Question:**

- Ask: How does your experience mimic that of a real environmental engineer? How is it different?
    - What is challenging about designing a solution to a real world problem?

**Accountability (Lab Notebook)**

- Grade scholar designs in their Lab Notebooks. Look for evidence of scholars engaging in the engineering design cycle by creating an engineering design plan.

**Scoring** Award points as follows:

- Award one point for each of the following:
    - All parts of the design are neatly drawn (up to two points)
    - All parts of the design are labeled (up to two points)
    - The design includes a relevant title
    - A plan that addresses each ingredient that must be removed from the water (up to five points)

---

# Lesson 13: The Dirty Water Design Challenge — Implementation and Reflection (Two Days)

**Lesson Objective: Performance of a design can be optimized by prioritizing criteria, making tradeoffs, testing, revising, and retesting. By studying the physical properties of a substance, scientists can choose a successful method for isolation. Materials Needed**

- For the teacher: plastic cups, plastic spoon, funnel, beakers, cotton balls, gauze pads, coffee filters, gravel, paper towels, tulle, separatory funnels, oil, peppercorns, wood shavings, soil, salt, **Dirty Water Challenge Resource**
- For each group: 100 mL sample of “dirty water,” two plastic cups, one plastic spoon, funnel, two beakers, $10 credit voucher and optional materials price list from the **Dirty Water Challenge Resource**

### Prep

- Materials Prep (directions for entire challenge):
    - Create the dirty water by combining the following in a 5-gallon bucket:
        - 6 L water
        - 1 L oil
        - 16 oz whole peppercorns
        - two cups wood shavings
        - 1 L soil
        - one cup salt
    - Construction materials (each lab group receives):
        - two beakers
        - two plastic cups
        - one plastic funnel
        - one plastic spoon
        - Print and cut out the materials from the **Dirty Water Challenge Resource** ($10 credit voucher and optional materials price list)
    - Optional materials:
        - Coffee filters
        - Cotton balls
        - Gauze squares
        - Tulle
        - Gravel
        - Paper towels

### What are scholars doing in this lesson?

- Scholars bring their design solutions to life by building, testing, and modifying their filtration devices.

---

# Day One

### Do Now

- Follow the **Do Now plan**.

**Launch**

- Show **Facing Failure: What It Takes to Be Good at Science Video** by the University of Bristol (2 minutes, 38 seconds).
    - Ask: Why is failure an important part of the scientific and engineering processes?
    - Ask: Why is revision and improvement necessary for an environmental engineer trying to clean poisoned water?
        - Ask: What are the consequences of cleaning the water improperly?

**Activity**

- Scholars build, test, and modify their filtration devices.

[**Materials Management Tip:** Leave ample time for cleanup, as scholars will need extra time to ensure their tables are clean and wiped down after this investigation.]

- As scholars are working, circulate and look for groups who can share their successes or failures with the class during discourse.

**Discourse  Debrief activity:**

- Ask: What about your design worked? What didn't work? Why?
- Ask: How did you approach this challenge differently for the known ingredients versus the unknown ingredients?
- Ask: How would you approach this challenge differently if you could create a new design tomorrow?

**Make connections to the Essential Question:**

- Ask: How did this experiment teach you about the way scientists must devise solutions to clean polluted water?

**Accountability (Exit Ticket)**

1. Explain one revision you want to make to your group's design when you have the opportunity tomorrow. Justify your response. [3]

Tomorrow, we want to use tulle to filter the mixture. Today, we only used a strainer, which has larger holes; it was not able to effectively remove all the smallest particles. Swapping the strainer for the tulle allows us to further isolate the solid particles from the water.

**Scoring**  Award points as follows:

- Award one point for each of the following:
    - A claim identifying one reasonable change to the design
    - Evidence explaining why that change would benefit the design

    - Justification/reasoning to explain their evidence

---

# Day Two

**Do Now**

- Follow the **Do Now plan**.

**Launch**

- Ask: What parts of your design failed yesterday? How do you plan to revise them?

**Activity**

- Scholars continue to test and modify their filtration devices.
- As scholars are working, circulate and ensure they are recording their revisions in their Lab Notebooks.
- Scholars discuss the unit Essential Question with lab group partners.

**Discourse  Debrief activity:**

- Ask: In the end, how effective was your final design? Do you have quantitative or qualitative evidence for your design's success?
- Ask: How did your design change over the course of testing? Why?

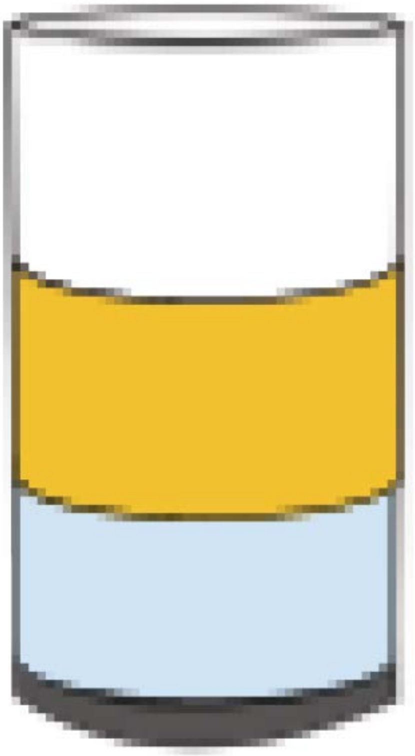
**Make connections to the Essential Question:**

- Ask: How can scientists make poisonous water safe to drink?

**Accountability (Exit Ticket)**

1. List the method the household items can be separated by on the line below its picture: distillation, decantation, and/or filtration. [4]

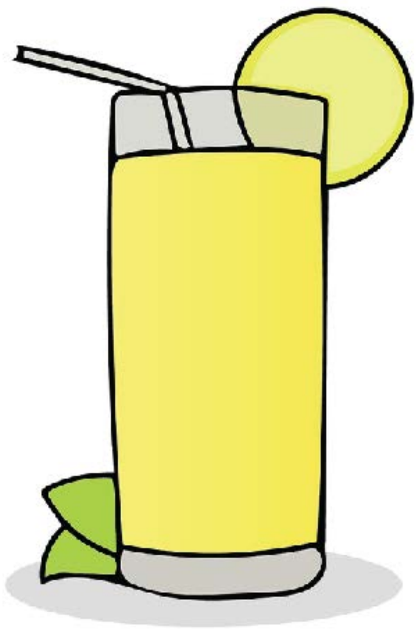
**Oil and Water Mixture** **Salted Water**



Separation Technique: Decantation

Separation Technique: *Distillation*

**Lemonade Powder Drink**



Separation Technique: **Distillation**

**Coffee Grounds and Coffee**

Separation Technique: *Filtration*

**Scoring** Award points as follows:

1. Award one point for each correct answer. Other scientifically correct answers may be acceptable as well.

# Unit Vocabulary

**Vocabulary List**

- **hydrosphere**
- **biosphere**
- **pure**
- **mixture**
- **physical property**
- **separation techniques**
- **filtration**
- **particle**
- **qualitative data**
- **quantitative data**
- **distillation**
- **decantation**
- **density**
- **isolate**
- **chemical property**
- **dissolve**
- **solubility**
- **polarity**
- **solution**
- **solvent**
- **solute**
- **soluble**
- **insoluble**