6^{th} Grade Unit 1–Water Chemistry and Beyond

Instructional Goals

1.1 Describing Water (Matter)
- Develop an understanding that matter comes in a variety of shapes, sizes, textures, states, etc.
- Different types of matter have different properties
- Observe and summarize evidence of some unique properties of water:
    - Droplets are attracted to other water droplets (cohesion)
    - Observe and summarize evidence that water droplets are sometimes attracted to other materials (adhesion).
    - Observe cases of water's surface acting like a skin or "protective" layer (surface tension -caused by water's cohesiveness).
    - Observe cases where water's attractive properties to itself and other materials (cohesion and adhesion) can work together to get water to move through tiny spaces (capillary action).

1.2 Particle Model of Water
- Visualize matter as composed of tiny BB-like particles (molecules).
- Use the model of water particles to build an understanding that particles are in constant motion.
- Extend the water particle model to matter in general.

1.3 States of Water (Matter)
- Explain the macroscopic properties of solids, liquids and gases using the particle model of matter.
- Relate observations regarding the addition of energy by warming to increased particle motion.
- Observe and explain that energy can be transferred into a liquid from warmer surroundings, causing its particles to speed up and break away to become a gas (evaporation).
- Observe and explain that when gas particles transfer their energy to cooler surroundings, they may slow down enough that their attraction to one another causes them to become a liquid (condensation).
- Observe and explain that when the particles of a liquid transfer their energy to something cooler, they slow down enough that their attractions cause them to arrange themselves into fixed positions as a solid (freezing).
- Observe and explain that when the particles of a solid speed up enough that the motion overcomes their attraction to one another, the particles can move past each other to become a liquid (melting).

1.4 Density
- Observe that liquids have a certain property that causes some liquids to float on top of others.
- Use an equal-arm or double-pan balance to compare amounts of matter.
- Define mass as a measure of the amount of particles in matter.

- Develop an operational definition for the *volume* – the amount of space an object (matter) takes up.
- Develop an operational definition of density as the amount of matter (mass) in a unit of space (volume)
- Use the particle model of matter to represent and explain differences in density.

Sequence

1.1 Properties of Water

Activity 1 –Investigating Water
Activity 2 – Sticky Liquids
Modal So Far
Quiz 1.1

1.2 Particle Model of Water

Activity 1 – Particles
Particles
Activity 2 – Particles in Motion
Model So Far
Quiz 1.2

1.3 States of Water (Matter)

Activity 1 –Heating Up
Activity 2 – Drying Out
Quiz 1.3A
Activity 3 – Cooling Off
Activity 4 – Freezing
PowerPoint on Energy Bar Charts
Worksheet - Energy Bar Charts
Activity 5 – Melting
Model So Far
Quiz 1.3B

1.4 Density

Activity 1 – Layering the Unknown
Activity 2 – Comparison of Objects
Activity 3 –Measuring Mass
Activity 4 –Defining Volume)
Activity 5—Mass and Volume of Liquids
Model So Far
Quiz 1.4
Unit 1 Test

Overview:

This unit begins with students observing the behavior and properties of "stuff" or matter, namely water. Once a set of common experiences are established and discussed the students will further develop and deepen their conceptual model of matter by thinking about what matter is like at the particle level.

Most middle school students do not have a mental model of matter as being composed of discrete particles. This unit develops the particle model of matter. Students begin to think of water and other matter being made up of little particles (molecules) that attract one another. This is important to develop early on as this conceptual model of particles carries over into the many branches of science and shouldn't just be taught in an isolated chemistry unit or class. The particle model is an important building block to understanding matter; and understanding the basic properties of matter is critical in any scientific field.

As unit 1 continues this model is further developed by describing phase changes, (solid, liquid, gas), at the microscopic level. These lessons allow students to observe and experiment with the various states of matter and changes in state. Energy and energy transfer is also brought in to address the physical changes that occur. Energy is another fundamental concept that often gets taught in isolation, instead of being an underlying theme in all sciences. AMTA's middle school units all address this energy, matter relationship in order to build a more fully developed conceptual model of these two critical concepts.

The unit progresses by investigating various liquids and observing that some liquids can float on other liquids, this seeds the idea of density. Students go on to develop this concept by first learning about mass, and that mass is a property of an object that tells how much matter (particles) is present in a substance. Once students have a good grasp of mass, they go on to learn that density is a special relationship between mass and volume. By the end of unit 1; students should have a foundation of some basic properties of matter, the building blocks for further developing the particle model of matter, and the beginnings of the energy conceptual model as being the culprit of change.

Instructional Notes

1.1 Properties of Water

Activity 1- Investigating Water (timing: 2-6 class periods)

(Inspired from: *Water Precious Water Book A*, Exploring our Fluid Earth, and Water Games

Note: that this is a series of four activities that explore some unique properties of water, applied in a method to engage students in the observation matter.

Apparatus:

Copies of Investigating Water Worksheet
Copies of Worksheet – Investigating Water Closure
For each pair or small group:
Initial Exploration:
Piece of wax paper

Piece of plastic wrap
Piece of paper towel
Small container of water + a pipette
Optional: Small container of oil + a pipette
How Water interacts with other objects at its surface:
Pepper (or something similar such as tiny pieces of a dried leaf)
2 petri dishes of water (shallow cups or bowls will also work)
Several paper clips
Small container of soapy water (1:2 detergent or liquid dish soap to water) + pipette

Water's capability to hold together:
Around a 100 pennies
Container (Petri dish, 100ml beaker, or small clear cup)
Water
Pipette
Toothpick
Liquid soap

Water's ability to climb
2-4 transparent straws of different diameters
Container of water (Petri dish, 100ml beaker, or small clear cup)
Optional (food coloring – to make it easier for students to observe)
Piece of paper towel
Marker
Pencil, pen, rod, or something similar
Two books, boxes or something similar
Piece of tape

Water's capability to stretch
Water Race worksheet
A piece of wax paper that can be laid on top of the worksheet
A small container of water + a pipette
Stopwatch or access to a clock with a second hand

Optional extension: Pouring water down a string
2-feet of cotton string (thicker than thread)
Two cups
Water

Pre-Activity discussion

- Ask students for some examples of "matter." It is likely that students will not have a clear picture of what the term matter encompasses so initially it is suggested to simplify the word matter to "stuff."
- Generate a list during a class brainstorm at the front of the room for students to share their ideas about matter (stuff).
    - Try to elicit a nice variety of items of different sizes shapes, states, textures, etc.
    - Then ask, "Do we all agree that this is a list of stuff? The students should agree. Now would be a good time to introduce the word matter, by simply explaining that there is a more scientific term to use besides this word stuff and that is matter. Explain to the class that from this point on they will try to use this new term "matter" which for now simply means stuff or things.
    - Continue by asking: "Why do we consider the items we have listed as matter? What characteristics does matter/stuff have"

        - Try to elicit key properties of matter such as: comes in a variety of shapes and materials, comes in different amounts (mass), takes up different amounts of space (volume), can be a solid, liquid, or gas, etc.

- Show a container of water, and initiate a discussion about a specific type of matter **->** water.
    - Is water matter? Why do we think so? Is one drop of water matter? Is a whole ocean of water matter?
    - Then guide the discussion to discuss some basic properties of liquid water. Allow students to share their ideas and record them on the board.
    - After a good list has been generated explain that this is just the start! In science we want to learn even more about water! Explain that water is just the starting place for our study of matter. Water is so important to Earth and life in general that it makes sense to start with water.
        - **Tip:** By pouring the water into another cup or pouring the water onto a piece of wax paper, you should be able to have students generate ideas such as the ability to flow, spread out, and take the shape of its container.

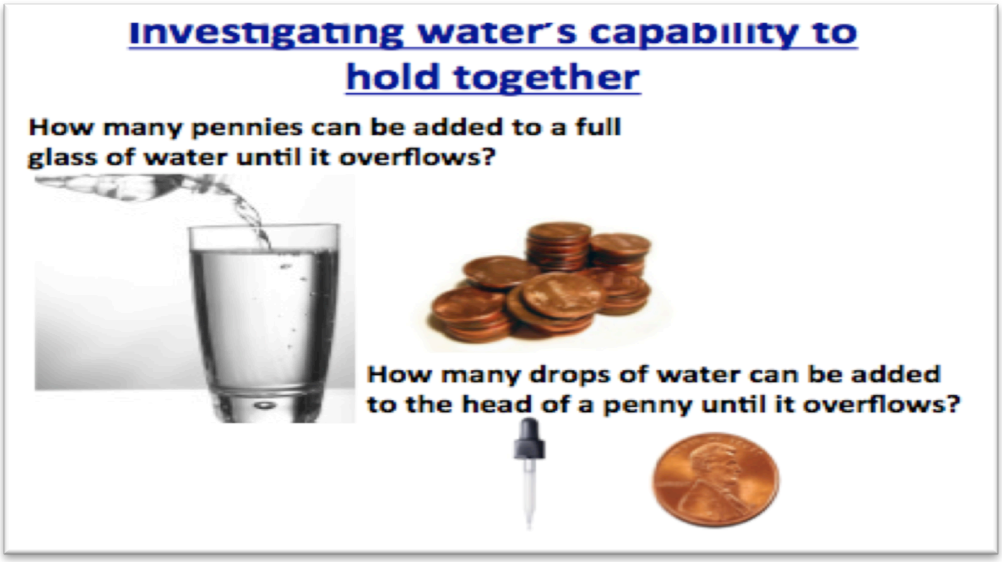
Performance notes

- Students will be investigating water by completing several short investigations where they will get a chance to observe some interesting behaviors and properties of liquid water. This paradigm investigation is designed to get students wondering, observing, predicting, and discussing evidence all in efforts to build a better understanding of water (a specific type of matter). As well as to get students thinking and wondering about why water (matter) has these unique properties.
- Do not be overly judgmental of student predictions or observations instead encourage and promote students to dialogue their thinking with you and the class. This will help build a safe, comfortable learning environment for young scientists to collaborate and develop their critical thinking skills.
- **Note:** DO NOT use technical vocabulary (such as cohesion and adhesion) to explain the phenomena that students observe as they complete the investigations. Instead emphasize that students should be explaining what is happening in their own words such as water tends to stick to itself and to other items. If desired the technical terms (cohesion, adhesion, surface tension, and capillary action) can be introduced during the post-lab discussion, in a later activity, or not at all. These terms are not at the core of building the particle model of matter they are simply descriptive terms.
- To warm-up and get students ready to make better observations begin by passing out the necessary apparatus for the initial exploration.
    - Once students have the materials begin by asking them to explore how drops of water behave when it comes into contact with each material.
        - Classroom Management Tip**:** Premise the activity with behavior expectations and be sure to set-up and reiterate proper procedures for open inquiry type investigations (some possibilities: use a timer, provide a short duration of open investigation time, hands off materials until explore time begins, when time is up hands off materials, and prepare an alternative assignment for students who misbehave for them to complete while the rest of the class continues to work as scientists)
    - Instruct students to make general observations, look for similarities, and differences. As students explore walk around encourage them to explore by asking probing questions such as: I wonder if you could use your pipette to drag that water droplet

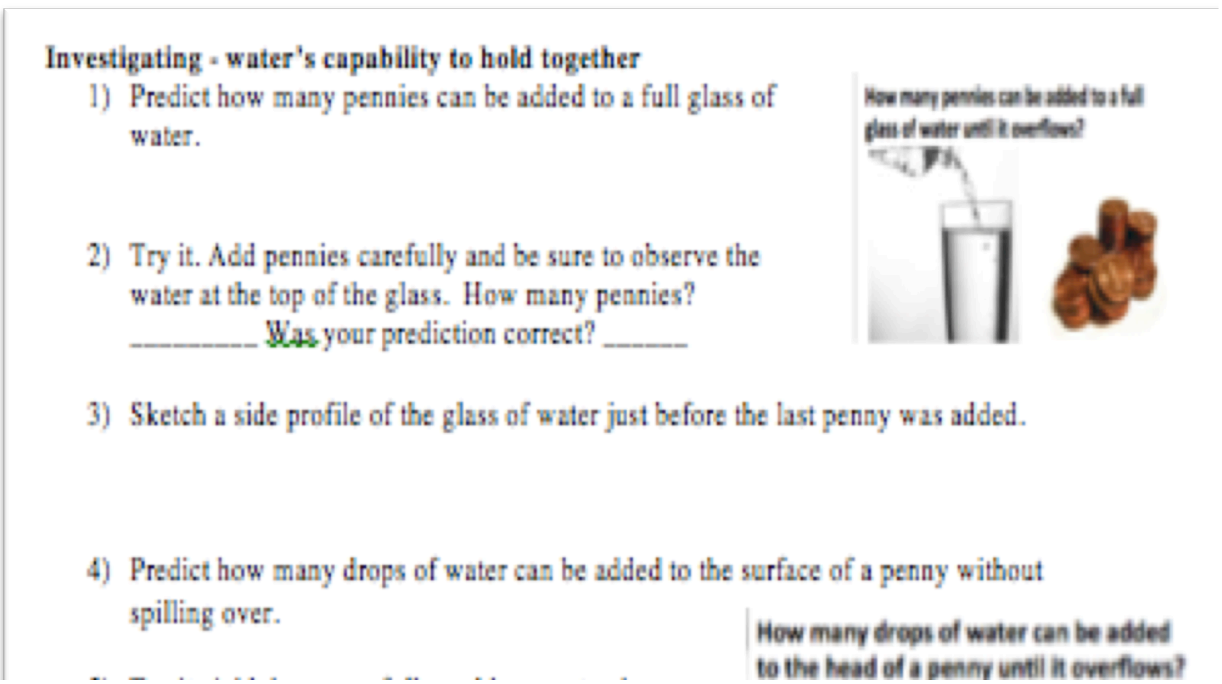
around on the wax paper? What about on the plastic wrap or paper towel? I wonder if you add another drop on top or next to that drop if the water will stay together?
    - Some examples of what students should notice include: water beads up into dome shaped drops, water beads up best on wax paper, water drops stay/stick together, water is absorbed by paper towel, and that water can be dragged or pushed fairly easily across wax paper.
  - After 2-5 minutes of exploring conduct a whole class share-out of their observations. Record their observations at the front of the room.
    - Optional: Conduct a comparison investigation with oil.
    - Optional: Have students add 1-2 drops of oil to one side of the plastic wrap and spread it around to form a thin coat of oil. Then add drops of water to both sides and compare. (Students should notice that the water forms tighter beads on the oily side.)
    - Optional: Have students add a drop of water to each and flip it upside down (students should see that the water holds onto the wax paper)
    - Note: some groups may need an additional piece of wax paper or paper towel at this point.
    - If any of the above optional extensions are done have students share out any new observations.
- Review their observation list and circle the ones that they will be looking into further. For example circle observations such as water beads up, water clings to the wax paper, etc. Explain to the students they will be given some more specific investigative tasks, where they will continue to observe water's unique properties.
  - Note: If desired there is a PowerPoint with some slides to aid in previewing the activities with the class. Screen shots from the PowerPoint are included periodically below in these teacher notes.
  - Note: Depending on the amount of class time and other factors the four activities could all be done in one class period (one at a time or divided up among stations), or even completed over the course of 2-4 class periods.
    - It is advisable that the teacher employs some kind of basic check for understanding for each investigation before students begin.
    - Also if activities are going to be done over multiple days it is recommended to incorporate some kind of short post discussion (ex. whiteboard session or group talk) after each day spent investigating to encourage deeper thought and analysis.
  - Note: If time is an issue some of the investigations could be cut and/or shortened. Just be sure to do enough of a variety for students to observe a couple of water's unique properties.
- Distribute copies of the Investigating Water worksheet.
  - Students will make predictions, follow instructions on the worksheet, complete each investigation, and record their observations/results.

Investigating - water's capability to hold together

- Provide students with the necessary apparatus
- Students will investigate how many pennies can be added to a full glass of water until it spills over. Then students will explore how many drops of water a penny can hold until it spills over.



See following screen clipping of student worksheet for additional information about this investigation.



Investigating - water's capability to hold together

1) Predict how many pennies can be added to a full glass of water.

2) Try it. Add pennies carefully and be sure to observe the water at the top of the glass. How many pennies? _________ Was your prediction correct? ______

3) Sketch a side profile of the glass of water just before the last penny was added.

4) Predict how many drops of water can be added to the surface of a penny without spilling over.

6) Sketch a side profile of the glass of water just before the last penny was added. How is this drawing similar to the one you drew for #3.

Re-add drops to two pennies until the water is almost ready to spill over.

7) Predict what you think will happen if you poke one penny's water with a wet toothpick?

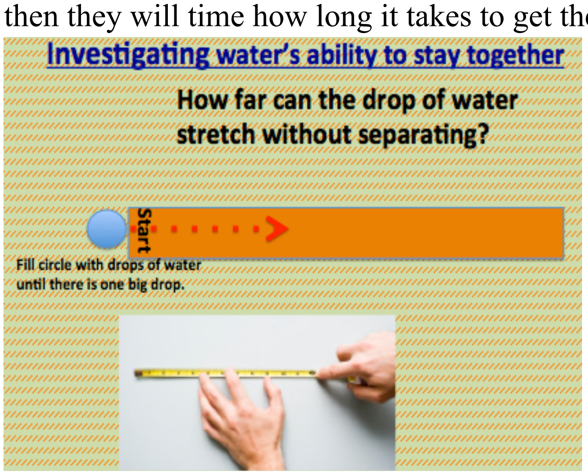
8) Try it. Observe the surface of the water especially as the toothpick enters the water. Record and sketch your observations

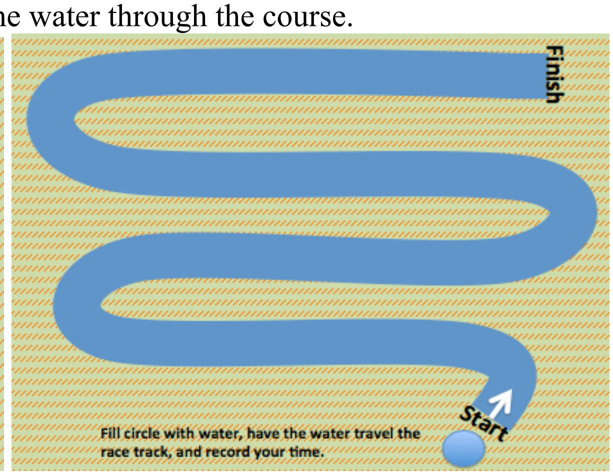
9) Predict what you think will happen to the second penny's water is poked by a toothpick dipped in soap.

10) Try it. Observe, record and sketch what happens.

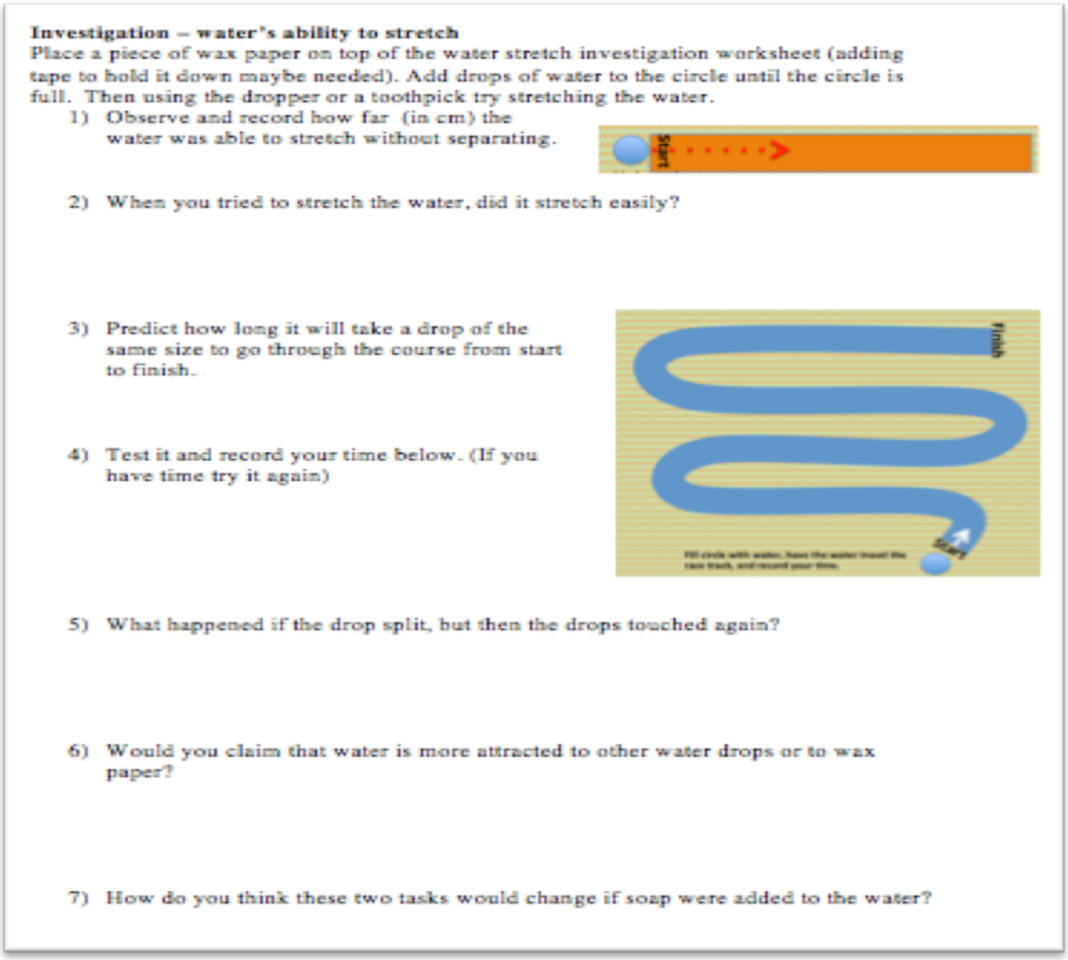
Investigating water's ability to stretch

- Provide students with the necessary apparatus.
- Instruct students to tape a piece of wax paper over the Water Race Worksheet before starting. They will begin by measuring how far they can get water to stretch before it separates, and then they will time how long it takes to get the water through the course.





- Walk around groups to observe their methods as they complete each investigation. Offer suggestions sparingly if groups are struggling with the procedures.
- See following screen clipping of student worksheet for additional information about this investigation.



Investigation – water's ability to stretch

Place a piece of wax paper on top of the water stretch investigation worksheet (adding tape to hold it down maybe needed). Add drops of water to the circle until the circle is full. Then using the dropper or a toothpick try stretching the water.

1) Observe and record how far (in cm) the water was able to stretch without separating.

Start

2) When you tried to stretch the water, did it stretch easily?

3) Predict how long it will take a drop of the same size to go through the course from start to finish.

Finish

Start

4) Test it and record your time below. (If you have time try it again)

5) What happened if the drop split, but then the drops touched again?

6) Would you claim that water is more attracted to other water drops or to wax paper?

7) How do you think these two tasks would change if soap were added to the water?

- Optional: After doing these two short stretch investigations have students observe the effect of adding soap to the water and trying the tasks again. Or possibly offer that task to groups or students who finish early.
    - Tip: If you teach multiple sections be sure to have extra wax paper because each group needs to start with a fresh piece of wax paper.

Investigating how water interacts with objects at its surface

- Provide students with the necessary apparatus
- Students will begin by making some predictions about whether a paperclip will float on water. They'll observe the paperclip sink and then be presented with the challenge of getting a paperclip to float by placing it very carefully on the water's surface.

- **Tip:** students may need the hint to bend one side up a little so that they can gently place the paperclip on the water without their fingers disrupting the water's surface.
- **Classroom Management/Differentiation Tip:** for students who figure it out early once they discover a method give them the additional challenge finding out the maximum number of paperclips they can get to float.
- **Option:** Have students repeat investigation with rubbing alcohol. This will help students see that this strength at its surface (surface tension) is not true for all liquids. Water has some unique properties!

- See following screen clipping of student worksheet for additional information about this investigation.

Investigating how water interacts with objects at its surface

1) Predict: What will happen when a paperclip is placed on top of the water?

2) Try it. Was your prediction correct?

Fill the dish with water and find a method to get the paperclip to float without adding any materials.

3) Record your method below.

Add one drop of soapy water next to the floating paperclip

4) Record what happened and your thoughts about why it happened.

Add one drop of soapy water next to the floating paperclip

4) Record what happened and your thoughts about why it happened.

Rinse out the dish and re-fill it with fresh tap water.

5) Predict what will happen if pepper is sprinkled on top of the water.

6) Try it. Was your prediction correct?

Add one drop of soapy water next to the pepper.

7) Record what happened and your thoughts about why it happened.

Investigating water's capability to climb

- Provide students with the necessary apparatus
- Students will begin by placing three different diameter straws in a dish of water. Students should observe water rising slightly in each straw, and that the straw with the smallest diameter straw experiences the highest water level.
    - Tip: Add food coloring to the water to make it easier to see.
- Students will continue this investigation by dipping the edge of piece of paper towel into a container of water and observe the water climb up the paper towel. Note that adding a scribble from a marker near the edge dipped in water makes the climbing process more visible due to chromatography.
- See following screen clipping of student worksheet for additional information about this investigation.

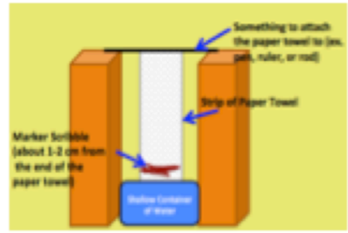
Investigating water's capability to climb

1) Place and hold the straws vertically in the dish of colored water. Observe then sketch what you see.

2) What do you notice? Be sure to include a comparison of the different diameter straws.

3) What do you think would happen if soap were added to the water?

4) Predict how water will behave if the edge of a piece of paper towel touches the surface of the water.



5) To make your observations easier add a thin scribble near the edge of the paper towel that will be placed in the water. Then attach your piece of paper towel to a pencil or other similar object and balance it between two books or something similar in order to create a stand. Then place the container under the paper towel, and allow the edge of the paper towel to hang in the water. Observe for about 2 minutes.

Record your observations and describe the water's behavior.

Post-Activity discussion

- After students have completed each investigation instruct each group of 3-4 students to create a whiteboard to illustrate and communicate their observations, results, and a list of properties they believe water to have. Encourage students to explain their thinking the best they can by utilizing diagrams, pictures, words, and any other way they find useful.
  - Note: Depending on how these investigations were implemented, one per day or all in one day, more whiteboarding and board meeting may be desired.
  - Circulate among the groups of students, encouraging them to discuss and to write down arguments and questions to share later during the whole class discussion. Don't offer answers to the students; instead use questioning strategies to get students to communicate their thinking to each other.
- Conduct a circle whiteboarding session where all or most groups display their whiteboards at the same time.
- Have students discuss. They could begin by discussing similarities among their boards. Then they could start asking particular groups questions or to ask them to explain something on their board. The goal is to get students to communicate scientific thinking and reasoning. This type of whole class sharing gets students to function as a scientific community where ideas are supported by evidence, and the contributions of all are respected and appreciated.
- The teacher's role ideally is to be more of a board-meeting guide where they encourage justifications, clarifications, and class conclusions based off evidence.
- This paradigm activity has two board meeting sessions. The first whiteboarding session's goal is to get students to communicate their observations and results of each activity. Students will hopefully be sharing similar observations and outcomes.
  - As needed ask questions to promote more discussion about the investigations:
    What did the water look like on the penny right before it spilled over? Did we all have similar results? What do these common observation tell us about water? How far did the water stretch? Did we all have similar results? What do these common observation tell us about water? How do your observations about water stretching versus the drops on the penny compare? Do both investigations tell similar stories or different stories about

water? What observations helped you decide that water holds together? How does soap affect water’s properties?
    - In addition depending upon their prior experience in science, this may be a good time to ask students about controls in each investigation and why they are important.
- After the conclusion of the board meeting distribute copies of the Water Investigation Closure Worksheet. This could be done as in class assignment or as a homework assignment.
- Below are the questions and sample answers for the Water Investigation Closure worksheet. Keep in mind some questions may elicit a variety of answers or ways of describing the same idea. These are just representing one possibility.

1. When you squeezed a drop of water out of the dropper, did the water break apart or did it hold together? What does that tell you about water’s attractiveness to itself? Draw a sketch to help explain your answer.

The water held together, which tells me that water sticks to more water (attracted to each other)

2. Miguel asks: “Does a paperclip float on water?” Explain why this is not a simple ‘yes’ or ‘no’ answer.

It’s not an easy answer because it depends on how carefully the paperclip is placed in the water. The paperclip will usually sink unless it is placed in very carefully

3. What happened when a drop of soapy water was added next to the floating paperclip? Did the soap affect water-to-water attraction? Explain your thinking.

The paperclip sank once the soapy water was added. This happened because the soap weakened the water-to-water attraction.

4. You heard Julie compare the surface of water to the “skin” on pudding after it cools and the ghost armor one puts on a iPod screen). Do you agree with this comparison? Explain.

I agree because the surface of the water seems stronger than the water below.

5. How does the water behave differently with paper towels than with wax paper? Draw a sketch to help explain your answer.

Water is attracted to the paper towel so it soaks into the paper towel. Water is not attracted to the wax paper so it doesn’t absorb instead it just beads up on the surface of the wax paper.

6. **Summary**: Water is only one kind of matter. You now have a better understanding of water and some of its properties. Summarize and explain some of the new properties you've observed by answering questions ***a-c*** below. Use diagrams and words.

a. Do you think water droplets are *attracted to* or *repelled from* other water droplets? What is your evidence?

Attracted because if two drops are close enough they pull together to form one bigger droplet. This attraction can also be observed when drops of water are added to the top of a penny, the water holds together and doesn't just roll off.

b. Compare and contrast how water behaved with the different diameter straws to how it behaved with the paper towel. Would you say water was attracted more to the plastic straws or the paper towel? What is your evidence?

Water climbed up the straws and the paper towel, but the water climbed up much higher on the paper towel. I think that means that the water is more attracted to the paper towel.

c. Do you think water droplets are *attracted to* or *repelled from* wax paper? What is your evidence?

Water is repelled from wax paper because very little water sticks to the wax paper instead the water just balls up and stays on the surface.

- Upon the completion of the closure worksheet students should begin the second whiteboarding session. The goal of this second whiteboard session is to dig deeper into the properties of water and to come to a consensus about how the properties of water produced what they observed in each investigation. Have students in small groups discuss their answers then prepare a whiteboard to summarize and communicate their answers and reasoning for questions #5 and #6 a-c.
- Conduct a board meeting to discuss and come to a class consensus about the observed properties of water: stickiness or attraction of water to other materials and to itself.
- Try to guide students to a consensus by having them discuss their observations and evidence.
  - Note: If desired the concept of water drops *sticking together* can be defined as "cohesion." Likewise *sticking to other materials* as "adhesion." Water *sticking together at the surface* can be defined as "surface tension." Water particles *sticking to and climbing up* stuff can be defined as "capillary action."
- Initially one of the goals in this first activity is to help students realize that matter specifically water is sometimes attracted to other "stuff" and sometimes repelled. Later on in the unit these ideas will be further clarified as particles being "attracted to" or "repelled from" other particles.
- Two optional extensions to wrap up this activity.
  - Show They Walk on Water clip (2 min), which shows water insects such as the water strider moving around on water. After the video instruct students to discuss with a partner or in a small group. Have them try and explain using their new understanding why these insects are able to walk on water. Then share out and discuss as a class.

Students should be able to see the connection between water's attractive properties to how insects take advantage it.

- o Pouring water down a string challenge.

- Ask students to watch your demonstration of pouring water down a string. Ask them, if what you're doing is magic or science? Use a **wet** 2-foot long string segment. Place an empty cup on the table and hold one end of the string over the opening while lifting the second cup that is about half full of water and has the other end of the string in it. Then lift up the cup with water up, and tip it carefully toward the empty cup. The water should slowly travel down the string into the empty cup.
- If desired have student volunteers try it too, to help confirm that they are not witnessing "magic", have students try it at home, and/or have small groups of students try it in class.
- Tip: have some rags or paper towels handy since a little spilling is likely.
- Have students discuss with a partner or in a small group to see if they can apply what they learned about water to explain this phenomena.
- Note: This works because water is attracted to the cotton string (adhesion) and due to water's attraction to other water already soaked into the string it clings to the water (cohesion) already on the string therefore with a little help from gravity it travels downward into the other cup.

Activity 2 – Exploring Liquids

Adapted from TOPS Cohesion/Adhesion Book 13

Apparatus:

Copies of Exploring Liquids worksheet
Copies of Worksheet 2 – How Sticky
For each group:
4 Dropper bottles OR 4 jars in which to put solutions (can also use emptied water bottles)
Medicine Droppers (eyedroppers)
Rubbing alcohol (+ food coloring)
Tap water (+ food coloring)
Soapy water (~6 drops of liquid detergent mixed with 8 oz. water + food coloring)
Corn oil
4 Small graduated cylinders (~10 mL)
Wax paper
Paper towels
Scissors
Masking tape (to label bottles and for securing wax paper)
Large object to support a wax paper ramp
A stopwatch or access to a wall clock or watch with a second hand

Pre-Activity discussion

- Present students with samples of the 4 liquids (water, rubbing alcohol, soapy water, and corn oil). Ask them to describe initial observations. Record these observations in columns for each liquid at the front. Look for descriptions such as color, appearance, smell, and thickness.

Performance notes

- Distribute copies of the Exploring Liquids Worksheet and necessary apparatus.
- Describe the basic activities students will be performing with these sample liquids. Remind them of the properties of water they observed in the last activity.
- Instruct students to record observations and answer associated questions as they complete each task.
- For information about each task and see following screen clipping of student worksheet below:

1. Think Back: How many drops?

A. About how many drops of tap water can be added to the heads side of a penny before it spills over?

B. What property of water does the collection of water drops on a penny highlight. Explain your reasoning.

C. How does soap affect the "stickiness" of water?

2. Exploring multiple liquids volume

A. Place 1 drop of each of the 4 liquids on wax paper. Label and Draw a side view showing the relative height of each drop. In the space below.

Alcohol Oil Water Soapy Water

B. Carefully put 50 drops of each liquid into their own small graduated cylinder. Sketch and record the volume below.

Alcohol Oil Water Soapy Water

C. Compare your results from task A and task B. Do your drop shapes make sense to the volumes you recorded in task B? Explain your thinking.

D. Based off your observations of these liquids, which liquid held together (stuck to itself/attracted to itself) most strongly? What evidence do you have? What is your reasoning?

3. Wax Paper Slide

A. Tear off a piece of wax paper as wide as the roll, label each type of liquid along the top edge of the wax paper, tape it to a book or folder and then prop it up against something to create a fairly steep ramp.

Alcohol Oil Water Soapy Water

B. Place one drop of each liquid, one liquid at a time. Time how many seconds it takes for one drop of each liquid to move from the top of the ramp to the bottom. Record your times below.

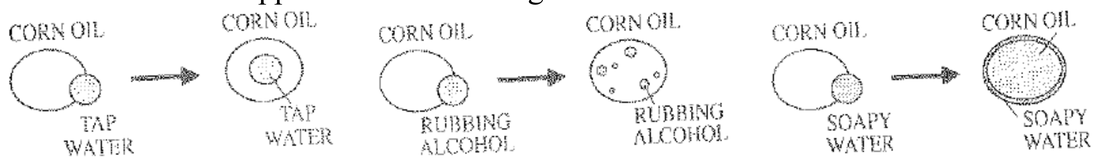
Alcohol Oil Water Soapy Water

C. Which liquid stuck to the wax paper the most? Which stuck the least? What is your evidence?

- Students will explore and observe each liquid by completing some simple tasks. Students will compare a drop of each liquid. Then they will add 50 drops of each liquid into a different graduated cylinder and compare the volume measurements. Students should notice that the drop shape and volume of the liquids are not identical.
  - **Tip:** Students may benefit from a review or mini lesson about how to accurately read a graduated cylinder.
- Next, students will put one drop of each liquid on a wax paper slide and time how long it takes for each drop to make it down the slide. Tap water should move the fastest while corn oil should move the slowest and rubbing alcohol and soapy water should move at about the same speed.
  - Explanation: the drop of corn oil "adheres" most strongly to wax paper as demonstrated by its slowest travel time. The drop of tap water "adheres" most weakly, slipping rapidly down the wax paper without breaking up.
  - When looking at paths left by the different liquids: the soapy water drop quickly soaks through the glossy waxed surface of the paper and turns it an opaque white. By weakening the cohesive bonds between water molecules, soap makes water *wetter*, allowing it to quickly saturate dirty laundry and carry away the dirt.
  - Following this, students will make 3 small puddles of oil and put 1 drop of each of the other liquids near one of the puddles.

- Tip: It would be beneficial to add food coloring to the tap water, rubbing alcohol, and soapy water to see how it spreads (or not) through the corn oil "puddle".

- Results should appear as the following:



  - Explanation: 1) Tap water adheres with greater force to the surface of corn oil than to wax paper. The stronger attraction to the oil pulls the drop onto the corn oil puddle, away from the wax paper. However, strong cohesive forces in the tap water prevent the drop from breaking apart as it is pulled along. 2) Rubbing alcohol adheres with greater force to the surface of corn oil than to wax paper. The stronger attraction to the oil pulls the drop onto the corn oil puddle, away from the wax paper. However rubbing alcohol's cohesiveness is too weak to prevent the drop from spreading out in the oil puddle. 3) Soapy water adheres with greater force to wax paper than to the surface of the oil. With only very weak cohesive forces holding it together, the soapy water spreads over the wax paper's surface and soon soaks in due its stronger adhesiveness with the wax paper.

Post-Activity discussion

- Instruct the students to whiteboard their findings. Have them create a whiteboard to illustrate their observations and findings about these liquids. Their boards should include multiple representations (pictures, diagrams, charts, graphs, units of measure, and phrases) to better communicate their ideas to their peers/scientific community.
- Circulate among the groups of students, encouraging them to discuss and to write down thoughts, arguments and questions to share later during the whole class discussion. Don't offer answers to the students instead use questioning strategies to get students to communicate their thinking to each other.
- Conduct a circle whiteboarding session where all or most groups display their whiteboards at the same time.
  - Have students discuss. They could discuss similarities and differences between boards. Ask particular groups questions or to explain their board. The goal is to get students to communicate scientific thinking and reasoning. As needed ask questions to promote more discussion such as:
    What observations helped you decide on how to draw that conclusion about rubbing alcohol? Why do you think each liquid is behaving differently? Do we have any evidence that would tell us one liquid is more strongly attracted to itself than another? Which liquid do we have evidence for to say it is the most attracted to the wax paper?
- After the board meeting show this brief water balloon slow-motion video.
- Distribute copies of the How Sticky worksheet. Have students work on in class or as homework.
- See following screen clipping of the student worksheet.

Watch the video at this link (in class or at home):
http://www.middleschoolchemistry.com/multimedia/chapter1/lesson1#water_balloon

1. Why do you think the water keeps its shape the moment the balloon is popped?

2. Imagine a drop of water hanging from your finger. How is this similar to the water staying together after the balloon is popped?

3. Trevor put one drop each of water and rubbing alcohol on a piece of wax paper and drew the results. Decide which of the diagrams shows the rubbing alcohol. How do you know?

4. *Cohesion* is the "sticking together of the *same* substance." Does rubbing alcohol or water demonstrate greater cohesion? How do you know?

5. *Adhesion* is the "sticking together of *different* substances." Should masking tape be described as "cohesive" or "adhesive"? Why?

- See following for some sample answers, note that these are just samples and that some questions may elicit a variety of answers or ways of describing the same idea.

1. Why do you think the water keeps its shape the moment the balloon is popped?
   The water in the balloon sticks together. The water is attracted to itself.

2. Imagine a drop of water hanging from your finger. How is this similar to the water staying together after the balloon is popped?
   This is similar because the water in the balloon is like a larger version of one drop. In both the water is attracted to itself, which keeps it together in a similar shape.

3. Trevor put one drop each of water and rubbing alcohol on a piece of wax paper and drew the results. Decide which of the diagrams shows the rubbing alcohol. How do you know?

A is rubbing alcohol and B is water because water is more attracted to itself. The stronger attraction gives it a more pronounced dome shape.

4. *Cohesion* is the "sticking together of the *same* substance." Does rubbing alcohol or water demonstrate greater cohesion? How do you know?

Water is more cohesive because it stays together better than rubbing alcohol.

5. *Adhesion* is the "sticking together of *different* substances." Should masking tape be described as "cohesive" or "adhesive"? Why?

Masking tape should be described as adhesive because it sticks to many other materials. It also sticks to itself so it could also be considered cohesive.

- Discuss and review the worksheet either as a class or go over the worksheet using the large whiteboards by having students form small groups where they share their thinking with each other in order to prepare a large whiteboard to illustrate their answers. Either have all groups of students put all their answers for 1-5 on their board, or divide up the questions among the groups.

Model so Far

- To wrap up the section, ask participants to prepare a whiteboard of the "Model so Far." This is basically a way for students to summarize the story, and the relevant parts of our s model up through this point. For the students, it's also a way for them to summarize the major concepts and find out what they may still struggle with or wonder about. For the instructor, this is a tool to see what the students think is important, what major ideas they feel comfortable with, and what concepts they may still be confused about.
- Have students create a large whiteboard to summarize what they now know about matter specifically the ones they spent time investigating tap water, oil, rubbing alcohol, and soapy water.
- Have students work in groups of 3-4 to create this board. Post the following somewhere in the room for a guide/reference:
  - Try to address on your whiteboard:
    - How does water behave when it is with other water? How does it behave when it comes into contact with soap? How does it behave when it comes into contact with materials like wax paper and paper towel? Compare and contrast the properties of the 4 liquids.? And whatever else you think is important?
    - Use diagrams, pictures, graphs, and words to demonstrate what you understand.
- Share the boards either in a whole class board meeting, select some groups to explain their boards, conduct a gallery walk where the students leave a sticky note comment or question, or some other method.

Quiz 1.1 – Give the Quiz

1.2 Particle Model of Water

Activity 1- Particles

Adapted from ACS Lesson 1.1

Apparatus:

Copies of Particles worksheet

For each group

- Whiteboard
- Cup of water
- Eye Dropper
- Food coloring (any color)

Optional: keep materials from earlier water investigations on hand for quick demos and review

Pre-Activity discussion

- Review with the class and record the known properties of water at the front of the room.
  - Water*: can flow easily, can change shape, clear, no odor, sticks together* "cohesion," *sticks to other things* "adhesion," etc.
- Ask each student in the group to draw a diagram of a drop of water on their large whiteboard. Once they've sketched a drop ask them to sketch next to it what they think the water would look like if they could put it under a super powerful microscope.
- Observe students as they prepare their diagrams. Do not be judgmental of their diagrams, rather, ask questions about why they are drawing or representing what they are drawing.
- Student representations are likely to be at the macroscopic level, including wavy lines, etc. This is typical of a "fluid" or continuous model of matter rather than a particle model of matter. This is okay at this point since we should be able to foster discussion and debate from these alternative models.

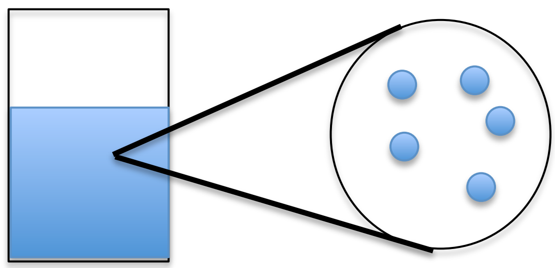
Performance notes

- Note: the objective here is NOT to come up with the technical composition of water as two hydrogen particles and one oxygen particle, but rather to start adding to the students' conceptual model of matter, that all matter is composed of small particles.
- Allow students to view representations of other groups. Then give them time to present and discuss their representations. Since it is likely that students still have not done much whiteboarding and discussion at this point, try to model clarifying questions for students to elaborate and explain their representations in a safe and open environment. No model is "wrong" as long as students can explain and provide reasoning. If students struggle, help them. Create a safe, engaging student-centered environment early on.

Post-Activity discussion

- Show Eureka Videos Molecules in Solids from the 1:00 minute time stamp to the 4:00 minute mark, and then show Molecules in Liquids. These videos emphasize a particle nature of matter that helps us account for the different observable properties of solids and liquids.
  - Note that sometimes these links become deactivated so that you need to search You Tube to get a more current link.
- Propose a particle model of water, BB's / "moles-cula" / molecules based on our observations of liquid water and the Molecules in Solids and Liquids Eureka videos.
- Then suggest students use their macroscopic pictures to construct particle-level diagrams. A common approach is to pick a point and "zoom in" to the particle level much like the "shrinking" person illustrated in the Eureka videos.

Macroscopic view: "Zoomed In" Particle Diagram:



-
- Then show the ACS animation.
- Ask students about why, in their water race game, the water seemed to form and stay in drops. Try to guide them to a consensus that the water particles must stick to each other and this is why the molecules stay together in observable drops. (Individual water particles or molecules are too small to see, but when many of them are "grouped" or "stuck" together, they make up a visible drop of water.)
- Note: At this point, we are not as worried about particle motion, as we are about using particles to represent matter. Evidence for particle motion will be considered and added to the model in later activities. If students want to include motion in their diagrams at this point, it would not have to be discouraged, as long as the students can explain their reasoning.
- Now let's see if we can use our model of water to explain some of the results of the other games:

For paper towel climb

1. We have already seen some examples of how water particles attract one another and that allows water to stay in "drops" or keep the foil from sinking between the water at the surface – with this in mind why would the water travel *up* the paper? What can we infer about water particles and paper towel particles?

The water is attracted to the dry paper towel. The water is filling in between paper towel particles. Students are not likely to extend the particle model proposed for water to paper towels. You may want to at this point guide students through a discussion and representation of the paper towel as particles, and that water can travel through the space between fibers of paper (strings of particles). The water particles must attract to the paper particles (students use unobservable model features to explain observed events).

- Distribute copies of the Particles worksheet
- Below are a couple sample of what students might include on their worksheet:

> 1. What evidence do you have that water that appears to be standing still is actually in motion?
> ***We have seen water "move" up a paper towel. We also know that water particles move aside when bubbles pop. Water can be poured into different shapes.***
> 2. Do you believe that tiny pieces of water are in motion even when they appear still? What evidence do you have that contradicts these views?
> ***Yes, but it still looks like its not moving when its in a glass or container.***

Activity 2- Particles in Motion

Adapted from ACS activity 1.2

Apparatus:

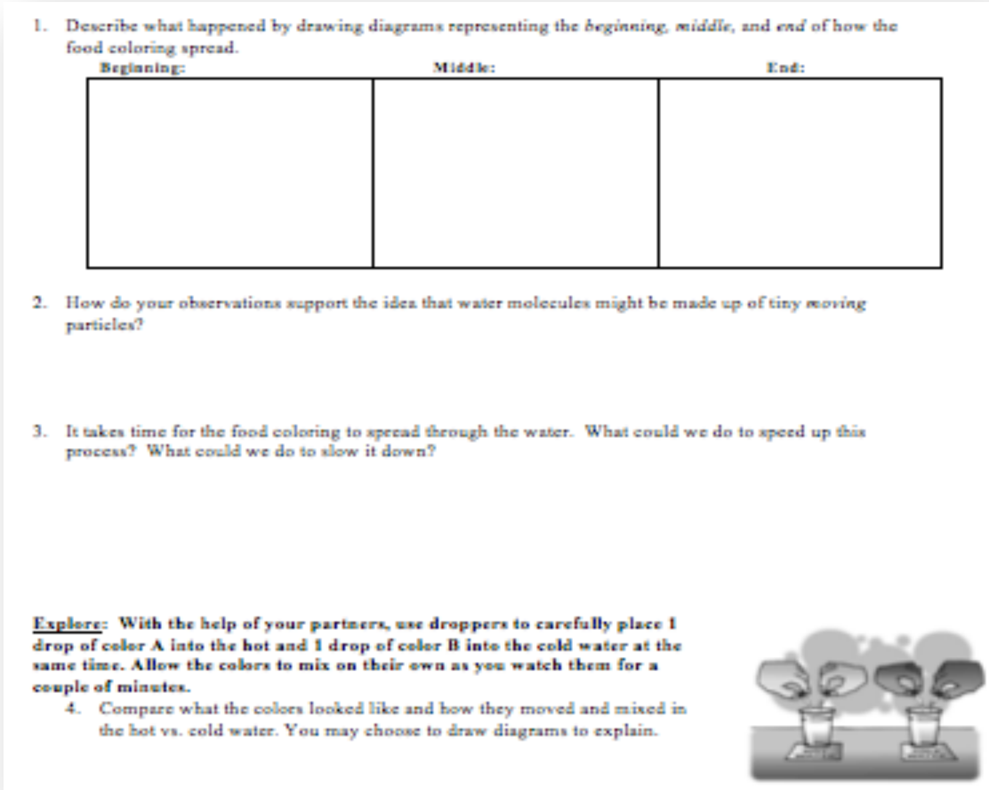
Cold Water (room temperature or less)
Hot Water (~50^{o}C)
Tall Clear Plastic Cups
White sheet(s) of paper
Food Coloring (red, blue, yellow, or green)
Copies of Activity 2 – Particles in Motion
Copies of Worksheet 2 – Hot and Cold

Pre-Activity discussion

- Show students a clear cup filled ¾ of the way with room-temperature tap water. Ask students to predict what will happen when a drop or two of food coloring is added to the water. Discuss predictions together.

Performance notes

- Distribute copies of the Particles in Motion worksheet.
- To the cup of room temperature water, add a drop or two of food coloring and have students record their observations of the diffusion process (not necessary to use the term diffusion). See screen clipping of student worksheet below.



1. Describe what happened by drawing diagrams representing the *beginning*, *middle*, and *end* of how the food coloring spread.

Beginning:	Middle:	End:

2. How do your observations support the idea that water molecules might be made up of tiny *moving* particles?

3. It takes time for the food coloring to spread through the water. What could we do to speed up this process? What could we do to slow it down?

Explore: With the help of your partners, use droppers to carefully place 1 drop of color A into the hot and 1 drop of color B into the cold water at the same time. Allow the colors to mix on their own as you watch them for a couple of minutes.

4. Compare what the colors looked like and how they moved and mixed in the hot vs. cold water. You may choose to draw diagrams to explain.

- The dye is not likely to spread very quickly in the cool water. If desired, ask students how the dye could be "spread" faster. The students are likely to suggest stirring. Test their prediction by stirring the mixture.
- If the students did not suggest heating up the water or using hot water, suggest that maybe using different temperature water might affect the results. Discuss with students how this could be tested in a controlled way. Guide students in designing a way to test the effects of temperature and the rate of dye movement.
  - Option: students can run a simultaneous test, adding drops of food coloring to cool and hot water at the same time. Suggest using different colors to keep track of hot vs. cold.
- Before running the test, ask students to make a prediction for the outcome based on their model of water, as they understand it at this point. The 'correctness' isn't important, just that the students commit to a prediction.
- After predictions are made allow student groups to run their test and observe the outcome.

Post-Activity discussion

- Ask students to describe what they saw macroscopically, and then explain their observations in terms of the particle model we have developed so far (small, separate particles in motion that move randomly by collision). The discussion should draw students to explain the observed behavior in terms of the effect that adding energy to the system of particles has on temperature and the speed of the particles.
- An important aspect of our model of matter that is being developed in this unit is that particles interact via collision to change motion and transfer energy from particle to particle. This feature of our model provides a mechanism for later understanding of energy transfer by both heating and working.

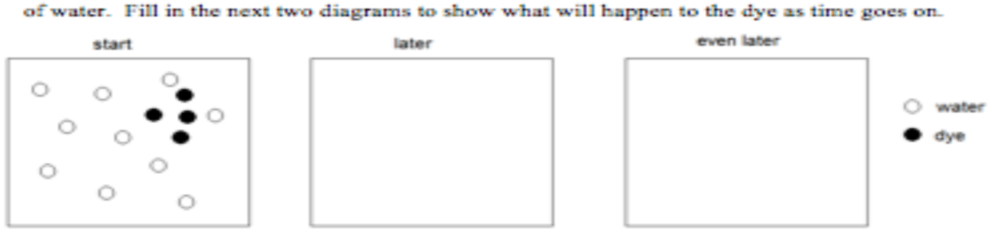
- This demonstration is followed up with the assignment to prepare two storyboard sequences o contrast the difference in rate, each storyboard sequence should contain the same number of frames at the same time intervals, one storyboard for each: the hot water and the cold water. These can be prepared individually as a homework assignment or, if preferred and class time allows, prepared in groups on whiteboards.
- Students often have difficulty with particle level representations at this point and will often draw continuous model pictures showing the dye and water as stringy lines. To help students, remind them they can start with a macro- level picture and then they can use zoom in circles to show their thinking of what is occurring at the particle level.
- Conduct a board meeting where all or most of the student whiteboards are displayed. Have students look for similarities among their boards. As needed re-focus discussion on the particle arrangements (particles are fairly close together, sticky water particles), and about particle behavior (particles must be *moving* to account for the ability of the water to flow and the ability of the dye and water to mix and spread).
- Option: Show the Diffusion simulation from Molecular Workbench—but only the very first animation is appropriate for this grade level!
  - Go to the web page http://mw.concord.org/modeler/
  - Find and run the simulation titled "Diffusion"
  - Choose the *Introduction* page
  - Scroll down to the "Simple Diffusion Example", add some dye to the water and watch what happens.
- Distribute the Hot and Cold worksheet and have students complete it in class or as homework. Be sure to review the worksheet together as a class, possibly in a board meeting style.
- Below is a screen clipping of the first portion of the worksheet:

1. During class discussion, it was proposed that water might be made out of very tiny particles that tend to stick to each other. How are these small particles similar to tiny magnets?

2. Think back to the when you touched a water droplet with a soapy toothpick. What happened? Did the water still behave like small magnets?

3. How does adding a droplet of food coloring or dye to a cup of water give evidence that water particles are moving? Explain.

4. The first frame below shows some food coloring (dye) "bbs" that have just been added to a cup of water. Fill in the next two diagrams to show what will happen to the dye as time goes on.



5. Based upon your observations, are particles moving faster in cold water or in hot water? How do you know?

Model so Far

- To wrap up the section, ask students to prepare a whiteboard of the "Model so Far." This is basically a way for students to summarize the story and the relevant parts of our scientific model up through this point. For the students, it's a way for them to summarize the major concepts and find out what they may still have struggles with or questions about. For the instructor, this is a tool to see what the students thought was important, what major ideas they feel comfortable with, and what concepts they may have missed.
- Have students create a large whiteboard to summarize what they now know about particles.
- Have students work in groups to create this board. Post the following somewhere in the room for a guide:
    - To address on your whiteboard:
        - What do you know about particles? How do particles behave?
        - Use diagrams, pictures, graphs, and words to demonstrate what you understand.
    - Observe the creation of these boards it will give you insights into how well they understand and what they think is important.
- Share the boards either in a whole class board meeting, select some groups to explain their boards, conduct a gallery walk where the students leave a sticky note comment or question, or some other method.

Unit 1.2 Quiz – Give the Quiz

1.3 States of Water/Matter

Activity 1- "Heating Up"

Adapted from ACS activity 2.1

Apparatus:

Materials for Each Group

Goggles for each student
2 sets of large metal washers on a string (or some other equal massed metal objects)
Styrofoam cup filled with hot water
Room-temperature water
2 thermometers (may also use Vernier temperature probes)
Graduated cylinder or beaker
Copies of Worksheet 1 – Conduction and Energy for each student

Materials for the Teacher

1 Styrofoam cup
Thermometer
Hot plate or coffee maker (Hang a set of washers for each student group in the hot water to keep them warm for the students until they are ready to perform experiment 2—probably more convenient to have two hot plates or to use a microwave to heat the water for experiment 1 while the washers are kept warm for experiment 2)
Large beaker or coffee pot

Pre-Activity discussion

- Discuss what happens when a spoon is placed in a hot liquid like soup or hot chocolate.
    - o Ask students if they ever put a metal spoon in hot soup or hot chocolate and then touch the spoon to their mouth? Ask what they think might be happening, between the particles in the soup and the particles in the spoon, to make the spoon get hot?
    - o It's not necessary for students to answer these questions completely at this time. It is more important that they begin to think that something is going on at the particle level that causes one substance to be able to make another hotter.
- Distribute the Conduction and Energy worksheet.
- Explain to students that they will be conducting two experiments to see what happens to the temperature of the solid (washers) and the temperature of the liquid (water) in both cases. (The teacher may choose to break this into two activities on separate days so students are not juggling too much information at one time.)
    - o Experiment 1: Placing Room Temperature Washers in Hot Water
    - o Experiment 2: Placing Hot Washers in Room Temperature Water
- The overall goal is for students to be able to describe and draw a model, on the molecular level, showing how energy is transferred from one substance to another through conduction.
    - o Negotiate with students on an appropriate procedure for them to collect information on both experiments described. Guide students , students must also collect a 'control' group of temperatures for a cup of water which has NO washers added to it.

- Depending upon students/ reasoning level, the teacher should decide what information students should record and help them organize it into a data table:
    - o At a minimum, students should collect an initial temperature of the washers and water and a final temperature after the washers have been in the water for a while (for both experiments).
    - o Some students may also wish to collect time data, and take the temperature of the water/washer system at a few consistent time intervals. Allow them to do so if they wish, but help them to decide on time intervals (possibly every 1 to 3 minutes) and organize their data accordingly.
- Below is a possible data table. Note that these are NOT required—the teacher should alter this to add more or less information to fit the level of their students.

Experiment 1--Room Temperature Washers Placed in Hot Water			
Temperature of…	**Before**	**After**	**Change in Temperature**
Water in your cup			
Water in the control cup			
Metal Washers			

Experiment 2--Hot Washers Placed in Room Temperature Water			
Temperature of…	**Before**	**After**	**Change in Temperature**
Water in your cup			
Water in the control cup			
Metal Washers			

Performance notes

- Make sure you and your student wear goggles and are careful with the hot water.
- Use a string to tie 5 or 6 metal washers together as shown. Each group of students will need two sets of washers, each tied with a string.
- Hang one set of washers for each group in hot water on a hot plate or in water in a coffee maker so that the washers can get hot. These washers will need to remain hot until the second half of the activity.
- The other set should be left at room-temperature and may be distributed to students along with the materials for the activity.
- Immediately before the activity, fill the cup about half way with hot water (about 55 - 65°C) into a Styrofoam cup for each group.

<u>Experiment 1:</u>

- Tell students that they are going to see if the temperature of hot water changes as a result of placing room-temperature metal washers in the water. The only way to tell if the washers cause the temperature to change is to have a cup of hot water without washers. Explain that you will have this cup of hot water, which will be the control. (Alternatively, each group may have their own control cup).
- You will need to place your thermometer in the cup of hot water at the same time the students do. Have students record the initial temperature of the control in their charts along with the initial temperature of their own cup of hot water. The temperature of the two samples should be about the same.
- Have students place a thermometer in their cup to measure the initial temperature of the water. Record the temperature of the water in the "Before" column in the chart on the activity sheet. Be sure to also record the initial temperature of the water in the control cup.

- Have students use another thermometer or temperature probe to measure the temperature of the washers. Record this in the "Before" column. ***Note****: It is a little awkward to take the temperature of the washers with a regular thermometer because there is such a small point of contact between the bulb of the thermometer and the surface of the washers. The washers should be about room-temperature.*
- With the thermometer still in the water, hold the string and lower the metal washers all the way into the hot water.
- Observe any change in the temperature of the water. Leave the washers in the water until the temperature stops changing. Record the temperature of the water in each cup in the "After" column.

<u>Experiment 2:</u>

- Tell students that they are going to see if the temperature of room temperature water changes as a result of placing hot metal washers in the water. The only way to tell if the washers cause the temperature to change is to have a cup of water without washers. Explain that you will have this cup of water, which will be the control. (Alternatively, each group may have their own control cup).

- Pour about 30 milliliters of room-temperature water into the control cup. Place a thermometer in the cup and tell students the temperature of the water.
- Have each student pour about 30 milliliters of room-temperature water into their Styrofoam cup.
- Place a thermometer into the water and record its temperature. Be sure to also record the initial temperature of the water in the control cup.
- Remove the washers from the hot water where they have been heating and quickly use a thermometer to measure the temperature of the washers. Record this temperature.
- With the thermometer still in the water, hold the string and lower the hot metal washers all the way into the water.
- Observe any change in the temperature of the water. Leave the washers in the water until the temperature stops changing. Record the temperature of the water in your cup in the "After" column in the chart below. Also record the temperature of the water in the control cup.
- Remove the washers from the water. Take and record the temperature of the washers.

Post-Activity discussion

- Ask students to describe what they saw macroscopically, and then explain their observations in terms of the particle model we have developed so far (small, separate particles in motion that move randomly).
- Instruct the students to whiteboard their findings. Have them create a whiteboard to illustrate their observations and findings.
- Have students discuss. They could discuss similarities and differences between boards. Ask particular groups questions or to explain their board. The goal is to get students to communicate scientific thinking and reasoning. Focus discussion around the questions on the Conduction and Energy worksheet
- Below is a sample of what students might include on their worksheet

3. Scientists think of energy as the way to cause changes in a system. When you place room temperature washers into hot water, what changed about the water? What changed about the washers?

The temperature of the water and the washers changed. The water cooled and the washers became hotter.

4. When you place room temperature washers into hot water, scientists would think of that as a transfer of energy. Where do you think the energy transferred from? Where do you think the energy transferred to? Why?

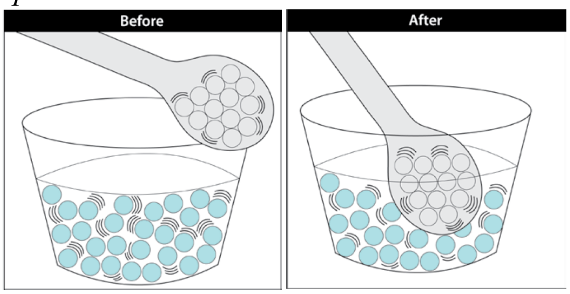
The energy transferred out of the water because the water got cooler. It transferred to the washers because they got hotter.

- If necessary, guide students' thinking about why the temperature of each changed by asking them which were probably moving faster, the atoms in the metal washers or the particles in the water. Tell students that the molecular model animation you will show next will show them why the temperature of both changed.
- Show the molecular model animation [Heated Spoon](http://www.middleschoolchemistry.com/multimedia/chapter2/lesson1#heated_spoon)
  http://www.middleschoolchemistry.com/multimedia/chapter2/lesson1#heated_spoon
    - Point out to students that the water particles in the hot water are moving faster than the atoms in the spoon. The water particles strike the atoms of the spoon and transfer some of their energy to these atoms. This is how the energy from the water is transferred to the spoon. This increases the motion of the particles in the spoon. Since the motion of the particles in the spoon increases, the temperature of the spoon increases.
    - It is not easy to notice, but when the fast-moving water particles hit the spoon and speed up the particles in the spoon, the water particles slow down a little. So when energy is transferred from the water to the spoon, the spoon gets warmer and the water gets cooler.
    - Explain to students that when fast-moving particles hit slower-moving particles and increase their speed, energy is transferred. The energy that is transferred is called heat. This energy transfer process is called conduction.
- Show the molecular model animation [Cooled Spoon](http://www.middleschoolchemistry.com/multimedia/chapter2/lesson1#cooled_spoon)
  http://www.middleschoolchemistry.com/multimedia/chapter2/lesson1#cooled_spoon
    - Point out to students that in this case, the particles in the spoon are moving faster than the water particles in the cold water. The faster-moving particles in the spoon transfer some of their energy to the water particles. This causes the water particles to move a little faster and the temperature of the water to increase. Since the particles in the spoon transfer some of their energy to the water particles, the particles in the spoon slow down a little. This causes the temperature of the spoon to decrease.
- Have students' whiteboard a particle diagram of what is happening in each of the following cases, using "tails or whooshies" or some kind of motion marks to represent how quickly particles are moving. At some point, define this as the process of *conduction* which caused the temperature of the washers and water to change in the activity.
- *Note: The change in speed of both the water particles and the particles in the spoon may be represented with different numbers of motion lines. Students may remember that when particles move faster, they tend to get further apart, and when they move slower, they tend to get closer together. For this activity, the change in distance between water particles or between particles in the spoon is not the focus, and therefore it is not necessary to show in the model. You could tell students that models can emphasize one feature over another, in order to help focus on the main point being represented.*
- **Room-temperature washers in hot water**
  When the room-temperature washers are placed in hot water, the faster-moving water particles hit the slower-moving metal atoms and make the atoms in the washers move a little faster. This causes the temperature of the washers to increase. Since some of the energy from the water was transferred to the metal to speed them up, the motion of the water particles decreases. This causes the temperature of the water to decrease.
- **Hot washers in room-temperature water**
  When the hot metal washers are placed in the room temperature water, the faster-moving metal particles hit the slower-moving water particles and make the water particles move a

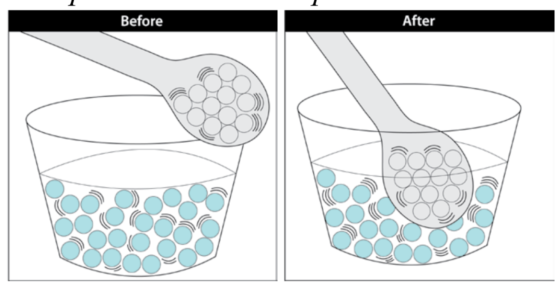
little faster. This causes the temperature of the water to increase. Since some of the energy from the metal particles was transferred to the water particles to speed them up, the motion of the metal atoms decreases. This causes the temperature of the washers to decrease.

- After students have experimented with creating their own particle diagrams, project the illustrations *Spoon in Hot Water Before* and *Spoon in Room Temperature Water Before & After* (also shown below).

Spoon in Hot Water:



Spoon in Room Temperature Water:



- Have students look at the motion lines in the "Before" picture on their activity sheet. Then ask students how the motion of the particles would change in the "After" picture. The activity sheet, along with the image you are projecting, does not have motion lines drawn in the "After" picture.
- Putting these in correctly is the students' task. Tell students to add motion lines to the "After" illustration and add descriptive words like "warmer" or "cooler" to describe the change in temperature of the water and the spoon.
- Show an animation *Temperature* to illustrate that temperature is the average kinetic energy of particles. The animation shows that at any temperature, the particles of a substance are moving at a variety of speeds. Some molecules are moving faster than others, some slower, but most are in-between.
  - This animation is from the Physics 2000 Project and is used with permission from the University of Colorado at Boulder. Place the temperature slider at about the middle of the range. Tell students that this animation shows the relationship between energy, molecular motion, and temperature.
  - To add energy, slowly move the slider about 2/3 of the way to the right. Ask students: What do you notice about the particles as energy is added? (As energy is added, more particles are moving faster. There are more pink and red particles, but there are still some slower-moving blue ones.)
  - To remove energy, slowly move the slider about 2/3 of the way to the left. Ask students: What do you notice about the particles as energy is removed? (As energy is removed, more particles are moving slower. There are more purple and blue particles, but a few still change to pink.)

Activity 2- Drying Out

Adapted from ACS activity 2.Evaporation

Apparatus: (for each group)

2 quart-size zip-closing plastic storage bags
Hot water
Room-temperature water
2 squares of brown paper towel
2 medicine droppers
Copies of Activity 2 – Drying Out

Pre-Activity discussion

- **Have students predict what might happen to a wet paper towel by the end of the class.** Show students two pieces of brown paper towel. Dampen one with water so that the color appears darker than the dry piece of paper towel. Select a student to feel the difference between the two paper towels now, and again at the end of the class period. Place both paper towels up in a prominent location.
- Ask students:
  - What do you think will happen to the paper towel by the end of class? How would this change if we placed a wet paper towel in the refrigerator? Outside in the sun?
  - It takes time for the paper towel to dry. What could we do to speed up this process? What could we do to slow it down?
  - Brainstorm with your group members: How could you test your predictions?
- Have class come to a consensus on describing a procedure they could follow to test their predictions given a supply of hot, cold, and room temperature water, as well as access to paper towels, plastic baggies, and ice.
- Have students investigate using the same procedure, or allow them to come up with a separate procedure in each group (recommended) to compare their ideas after investigation.
- Suggest to students that they will test the evaporation of just 1 drop of water on a brown paper towel so that they can see results quickly.
- Although the original activity has students place paper towel on both hot water and room temperature water baggies, some students may ask to also use a baggie of ice water to see the drying rate. Encourage this idea and let students investigate if it comes up in discussion.
- A possible procedure is listed below:

Procedure

1. Add room-temperature water to a zip-closing plastic bag until it is about ¼-filled. Get as much air out as possible, and seal the bag securely. Lay the bag down flat.
2. Add hot tap water to a different zip-closing plastic bag until it is about ¼-filled. Get as much air out as possible, and seal the bag securely. Lay the bag down flat. This bag will serve as an energy source. The bag with the room-temperature water will serve as the control.
3. Place 2 pieces of paper towel on your table. You and your partner should each use a dropper to place 1 drop of room-temperature water in the center of each piece of paper towel at the same time.

4. Allow the drops to spread for about 5–10 seconds until they don't seem to be spreading any more.
5. At the same time, place one paper towel on each bag.
6. Observe every few minutes. Compare the amount of water on each paper towel.

Performance notes

- Circulate as students negotiate and perform their investigations.
- Students will know that they should somehow heat the water on the paper towel.
- As you listen to students, help them realize that they will need to wet two paper towel samples but that only one will be heated. The unheated paper towel is the "control." If they wet two paper towels and heat one of them, they will be able to see whether adding energy affects the rate of evaporation.
- Expected results: The water mark on the brown paper lying on the hot water bag should disappear faster than the mark on the paper lying on the room-temperature water bag. This will take about 3–5 minutes.
- While waiting for water to evaporate, a good discussion of experimental design and controls can take place. This is a good place to introduce 6th grade students to these ideas in a hands on, more directly observable fashion.

Post-Activity discussion

- Ask students to prepare whiteboards of the water on the hot water bag versus the cool water bag. Have students be the source of the discussion. The teacher should provide prompts and clarifying questions, asking students to justify their models. In the end the discussion should focus on the difference in speed of the water particles, and that the process of evaporation involves the faster moving particles "breaking free" of those attractive/sticky forces at the surface of the liquid.
    - Only AFTER the 'drying out' process has been described and drawn at the particle level should the technical term "Evaporation" be given. To help with this, watch the Eureka episode on *Evaporation and Condensation*, https://www.youtube.com/watch?v=eWQuE0X-sTI&feature=youtu.be but only AFTER finishing Activity 3 Cooling Off.

Unit 1.3 Quiz A – Give the quiz A. Because of the length of this section there are two quizzes.

Activity 3 – Cooling Off

(Adapted from ACS activity 2.3 Condensation)

Apparatus:

Copies of Activity 3 – Cooling Off
Copies of Worksheet 2 – Cooling Closure

Demonstration

- 2 clear plastic cups
- Room-temperature water
- Ice cubes
- Gallon-size zip-closing plastic bag

Student Tests

- 1 short wide-rimmed clear plastic cup
- 1 tall smaller-rimmed clear plastic cup
- Hot water (about 50 °C)
- Magnifier

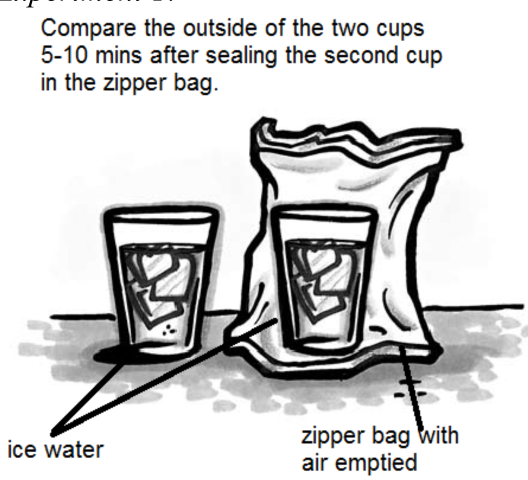
Pre-Activity discussion

- Ask students what they have noticed about the outside of a glass of ice water on a very humid day. They should recall that a layer of moisture often appears on the outside of the glass.
- Ask them what factors might affect the layer of moisture. They should list factors such as temperature, amount of time, and conditions in the surroundings such as humidity. (If they use the word humidity, be sure to have them explain what they mean by that to put it into words their classmates can understand.)
- Explain to students that they will be investigating different cases of systems, which are cooling. They will be given a picture and a brief description of each system, and should use the materials available to set up each system and record observations.
- Students should negotiate with group members to interpret the meaning of each case, and then ask other groups or the teacher if unsure about what to investigate.

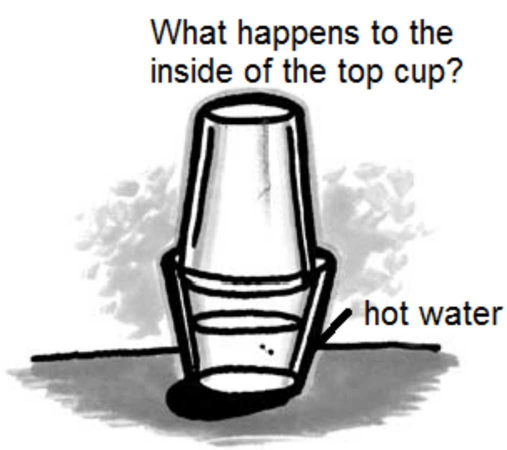
Performance Notes

- Try Experiment 1 before presenting it to your students because it will not work if the humidity is too low. You could instead show students the video Condensation on a Cold Cup. http://www.middleschoolchemistry.com/multimedia/chapter2/lesson3#condensation_cup The rest of the experiments will work no matter how dry or humid the air.
- Next to each diagram, students will briefly describe how they set up the experiment (including if/how they made sure to construct a "fair" test, and any considerations or concerns) and also observations.
- Remind students to record observations using multiple representations; they should use the method that makes sense for their group.
- Refer to the handout for Activity 3 for pictures of each situation (also listed below). See

Experiment 1:



Experiment 2:

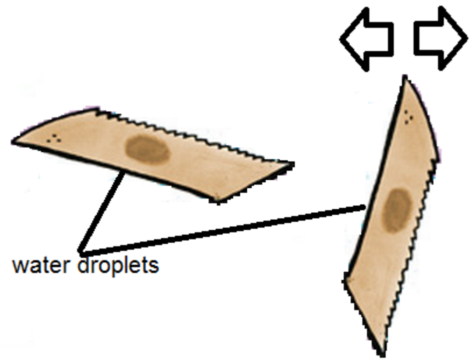


Experiment 3:

Experiment 4:

Compare the two top cups after 2-3 minutes. Wipe off any melted ice water from the first cup. It may help to have a magnifier.

Hold one paper towel still and wave the other back and forth for ~30 seconds. Observe the water spot. Is it the same for both paper towels?



Experiment 5:

Observe what happens in the top cup after ~1 to 3 minutes.

Post-Activity discussion

- Follow up by distributing the Cooling Closure worksheet.
- Below is are a couple sample answer of what students might include on their worksheet

The cup exposed to more air should have had more water on the outside.

1. Why do you think there was a difference (if you observed a difference)?

   The cup inside the baggie did not touch the air in the classroom. The baggie kept it closed up.

2. Where do you think the water on the outside of the cup came from – inside the cup? Outside the cup?

   It must have come from outside the cup, since the ice and water inside both cups was the same. Maybe it came from the air.

- Have students whiteboard a before and after picture of each activity, illustrating how the water vapor starts in the air and then ends up in drops of water on the cup.
- Conduct a board meeting where students share and discuss their boards. During the discussion ask where the condensation (water) came from. Look for misconception that the water came from the inside to the outside of the cup ("leaking" through) and how this experiment shows that the water does not leak or seep through the cup.
- Introduce the term for condensation. Elicit from students other sample of condensation that they have seen in everyday life. One common example is water that forms on the outside of a cold cup or the moisture that forms on car windows during a cool night. Other examples of condensation are dew, fog, clouds, and the fog you see when you breathe out on a cold day.
- Help students realize that the moisture on the window, and all of the examples of condensation they gave, comes from water vapor in the air, NOT by a process such as osmosis (they might falsely believe the moisture on the outside of their cold cup of water came from INSIDE the cup, going directly through the glass somehow.)
- Explain that the fast-moving particles of water vapor transfer their energy to the side of the cup, which is cooler. This causes the water vapor particles to slow down. When they slow down enough, their attractions overcome their speed and they stay together as liquid water on the inside surface of the cup.
- In later preparation for the Water Cycle, you might have students articulate that energy from the sun causes water to evaporate from the land and from bodies of water. As this water vapor moves high into the air, the surrounding air cools it, causing it to condense and form clouds. The tiny droplets of water in clouds collect on bits of dust in the air. When these drops of water become heavy enough, they fall to the ground as rain (or hail or snow). The rain flows over the land towards bodies of water, where it can evaporate again and continue the cycle.
- To help with this, watch the Eureka! Episode 18 Evaporation and Condensation: https://www.youtube.com/watch?v=M9gsOEF71bY

Activity 4- Freezing

Adapted from ACS activity 2.4

Apparatus:

PowerPoint on Energy Bar Graphs
Materials for each Group:

Empty clean metal soup can (use pliers and duct tape to protect edges)
Salt
Ice
Metal spoon or sturdy stick
Teaspoon
Paper towel
Copies of Activity 4 – Freezing
Copies of Worksheet 3 – Energy Bar Graph

Pre-Activity:

- Show students two identical bottles of water (or graduated cylinders), one of which is at room temperature and the other which has been placed in the freezer overnight. Emphasize that both water samples fill the container to exactly the *same* level before one was put in the freezer. Ask students to describe what they notice and then make a particle diagram of what they think is going on in the room temperature vs. the frozen water.
- Focus discussion on what happens to the *particles* of liquid water as they cool. This can be related back to the condensation idea. As the particles cool, they slow, and begin to stick together even more. If this idea is not brought up, the discussion can center more on the arrangement of particles in the liquid or gas (free moving) versus in the solid ("locked in place"). If the Eureka video on particles in solids has been shown, the latticework idea of vibrating particles can be mentioned again here.

Performance Notes

- The lead-in question is how can you make water vapor in air condense and then freeze?
- Discuss the basics of the methods with students. Try to get the students to suggest ideas as much as possible rather than telling them a procedure, but gently guide them to the procedure described on the Act 4 Freezing handout and as seen below:
    - Dry the outside of your can before you begin.
    - Place 3 heaping teaspoons of salt in the bottom of the can.
    - Fill the can about halfway with ice.
    - Add another 3 heaping teaspoons of salt.
    - Add more ice until the can is almost filled and add another 3 teaspoons of salt.
    - Hold the can securely and mix for about 1 minute.
    - Stop mixing and wait 3-5 minutes.
    - Answer the following questions about your observations.
- While waiting for water to condense and freeze, the students could be asked to draw particle diagrams for water and its journey from gas to liquid and solid water (liquid and gas should have been done during evaporation/condensation discussions).
- Allow students to explain and support their diagrams, but hold off on confirming or denying ideas until after further data collection.

Post-Activity discussion

- Discuss results of the activity. Ask questions about why the water froze, and even why all of it might not have frozen.

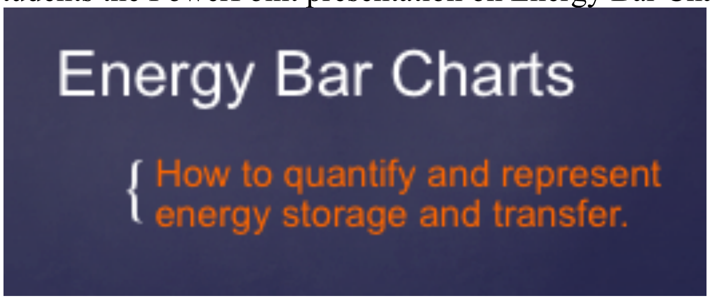
> ***Students should start to understand that water freezes and becomes a solid when energy leaves the system. Water has a freezing temperature and will turn to ice at that point. The can in the experiment cannot be kept at 0 C so all of the water may not freeze.***

- Give student groups time to use their particle diagram whiteboards they started during the activity to tell the story of the water molecules from the gas state near the can to the solid state on the can.
- Allow students to present and discuss their whiteboards, and what is happening to the particles of water in this activity.

- Animations can be shown ([Phet: States of Matter](http://phet.colorado.edu/en/simulation/states-of-matter-basics)) http://phet.colorado.edu/en/simulation/states-of-matter-basics that are great for illustrating particle motion and the **role of energy** in these processes.

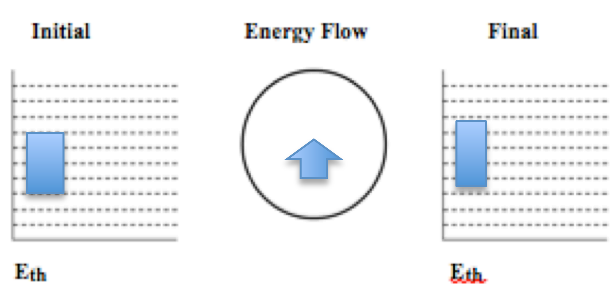
Energy Bar Charts Introduction and Worksheet

- Show students the PowerPoint presentation on Energy Bar Charts.



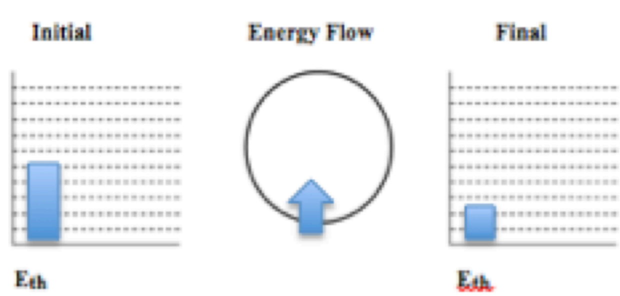
- These bar charts provide a great approach to help students develop a better conceptual understanding of energy storage and transfer by adding a visual and quantitative technique to represent energy. These bar charts will be utilized throughout the middle school units as a method to tie in the energy theme.
- After this presentation, have students complete the Energy Bar Chart worksheet.
- Circulate among the groups of students, encouraging them to discuss questions and/or disagreements and to write them down to share later during the whole class discussion
- Below is a sample of what students might include on their worksheet. Keep in mind answers may vary; as interpretations may vary.

2. A can of cold soda warms as it is left on the counter.



Thermal Energy increases a little as it warms. So a little energy enters the system and the final bar is a little larger

3. A tray of water (20 °C) is placed in the freezer and turns into ice cubes (- 8 °C)

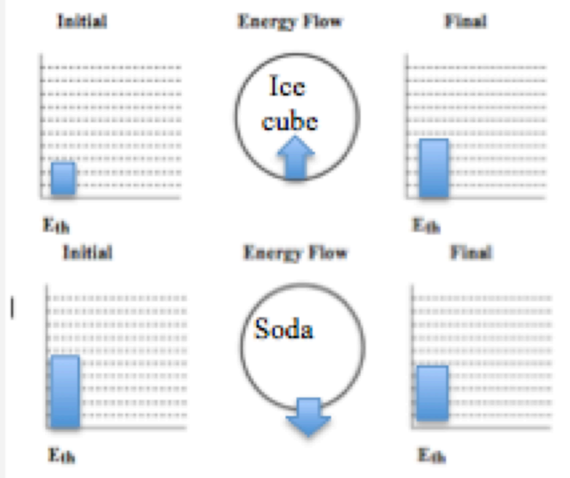


Thermal Energy decreases as energy leaves the system causing the water to change from its liquid form to its solid form.

4. Where does the energy that leaves the system in #3 go?
   Into the surroundings (the freezer)

Students will not know this, but for your own personal information the freezer has a mechanism that does work to force the energy to leave the freezer.

5. One of the ice cubes described in #3 is placed in a glass of room temperature (25 °C) soft drink. Do separate bar charts for the ice cube and the soft drink.



Describe how the arrangement and the motion of the particles in each system change from the initial to the final state.

The ice cubes particles are compact and just jiggling in place. Then when placed in the soda the particles begin to jiggle more and more as energy is transferred in and it begins to melt. Conversely, the sodas particles are jiggling and moving around, then when the ice is placed in energy from the soda is transferred to the cold ice.

6. Suppose someone in your class said that when water freezes, it is because the molecules get cold and turn hard. Provide a better explanation for this in terms of the motion of molecules and the attractions between them.
It's not because the molecules get cold and hard – it's because the particles lose energy, which causes the particles to move less thus they get closer together (more compact). This compactness is what makes it "feel" hard.

- Instruct the students to whiteboard their answers. You may want to just focus on a couple at a time, or assign each group a different question to whiteboard.

- Have students discuss. They could discuss similarities and differences between boards. Ask particular groups questions or to explain their board. The goal is to get students to communicate their thinking about energy transfer and to quantify energy. As needed ask questions to promote more discussion such as: What helped you decide the energy is leaving the system? If energy enters the system how is that represented on the energy bar graph?

Activity 5- Melting

Adapted from ACS activity 2.5

Apparatus:

Copies of Worksheet 4 – More Bar Graphs
Copies of 1.3 Act 5 Reading (optional)
For melting demonstration

- Ice
- Metal surface (ex. tinfoil)
- Plastic surface

For student testing:

- 2 small pieces of ice
- 2 small clear plastic cups
- Water

For dry ice demo:

- Ice
- Dry ice
- Brown paper towel
- Cold water
- Hot water

Pre-Activity discussion

- Conduct a melting demonstration. Show ice melting on plastic and aluminum foil or show the video linked in the ACS Activity. http://www.middleschoolchemistry.com/multimedia/chapter2/lesson5#ice_melting_on_different_surfaces
- Get student observations and comment on what they observe from this demonstration or video clip.
- Ask the students about the role of energy in this process. (*In melting, particle attractions need to be broken, which takes energy, therefore energy must be added*).
- Ask students to suggest why they think melting occurred faster on the foil rather than the plastic. Hopefully students will address the idea of energy *transfer* here and that the metal must be better at transferring energy to the ice than the plastic.

Performance Notes

- Introduce a question for students to investigate: How can you make ice melt faster?
- Help students plan and conduct their experiment by asking:
    - How could you set up an experiment to test your method? Students might suggest breathing on the ice, holding it in their hand, or placing the ice in room temperature or warm water. Any of these methods are fine, but try to have students think about including a control as part of the experiment. In each case, they would need two similar size pieces of ice—one that they warm in some way and one that they don't.
    - Here is one method students could try.
        - Question to investigate Will placing ice in water make ice melt faster? Materials 2 small pieces of ice • 2 small clear plastic cups • Water

        - Procedure 1. Add room-temperature water to a cup until it is about ½-full. 2. Place a small piece of ice in the water and another small piece of ice in a cup without water.
- After conducting their mini-experiment have students present their findings on a large whiteboard to share.
- Circulate among the groups of students, encouraging them to discuss any disagreements fully and to write down arguments and questions to share later during the whole class discussion. Also encourage students to explain their thinking the best they can using diagrams, pictures, words, and any other way they find useful.
- Suggest drawing particle diagrams of a sample of ice in air and a sample of ice in water. (*Since many more water particles are in contact with the ice cube, the energy can transfer easier through collisions.)* Make sure to connect these ideas to other substances so that the discussion is not limited to water.
- Conduct a board meeting where all groups display their whiteboards at the same time.
- Have students discuss. They could discuss similarities and differences between boards. Ask particular groups questions or to explain their board. The goal is to get students to communicate scientific thinking and reasoning. As needed ask questions to promote more discussion such as: What observations helped you decide to draw your particles that way. What evidence do you have that energy is entering the system?
    - Again we are building a model of energy storage and transfer early on through readily observable and accessible phenomena.

Optional Demonstration: Dry Ice vs. Water

- A cool comparison of water vs. dry ice. This allows students to see a different phase change.
- If you do not have dry ice available to demonstrate show students this dry ice http://www.middleschoolchemistry.com/multimedia/chapter2/lesson5#dry_ice video instead.
- Suggestion: Have students draw before and after pictures for both solid water and dry ice. This should allow students to use their models to illustrate the solid-liquid change for water and the solid-gas change for dry ice.
- Ask students what they can infer about the "stickiness" or attractions between dry ice (carbon dioxide particles) as compared to water. Hopefully students can be guided to verbalize that the dry ice particles must be much less sticky, since they can be observed going directly from solid to gas at room temperature!

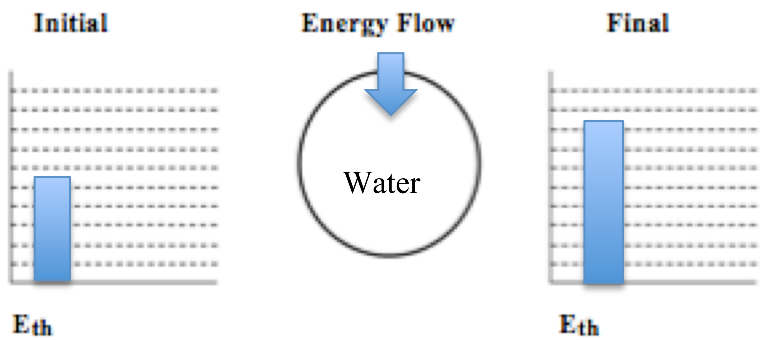
Optional Reading Assignment

- 1.3 Act 5 reading from ACS. This would be a good to read together as a class or take home after the concepts have been observed, discussed, and defined in class (then discussed as a class the following day). If you or the students prefer to read it online here is the link: http://www.middleschoolchemistry.com/lessonplans/chapter2

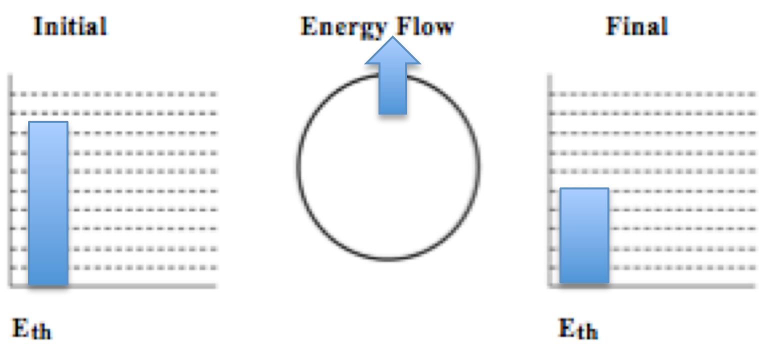
Post-Activity Discussion

- Distribute copies of 1.3 Act 5 More Energy Bar Charts.
- Have students complete it with a partner then have two groups of partners meet to review their answers and create a large whiteboard to share with the class.
- Below is a sample of what students might include on their worksheet. Keep in mind answers may vary as interpretations may vary.

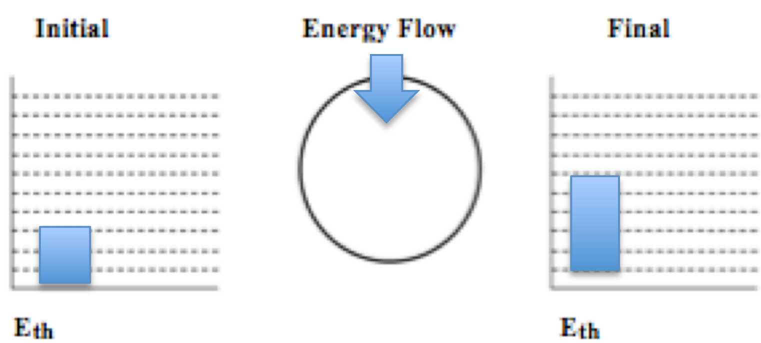
1. Some of the water you spilled on your shirt evaporates.



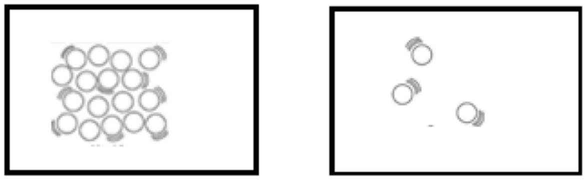
2. Water vapor in the room condenses on a cold surface



3. A solid bar of lead is heated until it melts completely.



4. During boiling, bubbles appear in the liquid water. In the boxes below represent the arrangement of molecules inside the liquid water and inside a bubble



liquid water bubble

What is inside the bubble? Why do you think so?

Gas – water vapor because the liquid water has had enough energy transferred into it to cause it to turn to its gaseous state.

5. In what ways are liquid water and water vapor the same? How are they different?

They are both made of water particles. They are different because they have different amounts of energy because they are in different states. The gas particles move more and move freely.

6. You decide to boil water to cook noodles. You place the pan of water on the stove and turn on the burner.

a. How does the behavior of the water molecules change as the pan of water is heated?

The water particles begin to vibrate/jiggle more as the pan is heated by the stove. It begins near the heat source and continues to transfer energy throughout the liquid. Over time as energy is continually transferred into the water all the particles begin to move faster.

b. What about your answer to (a) would change if there were more water in the pan?

The same would occur it just would take more time for enough energy to transfer into the system.

Model so Far

- To wrap up the section, ask participants to prepare a large whiteboard to summarize what they now know about particles, energy, states, state changes and the effects of energy entering and leaving a system.
- Have students work in groups to create this board. Post the following somewhere in the room for a guide:
  - To address on your whiteboard:
    - Describe/show particles in a solid, liquid, and gas, What are some interesting properties about water, How does energy entering or leaving a system affect particles, how does energy play a crucial role in the states of matter?
    - Use diagrams, pictures, graphs, and words to demonstrate what you understand.
  - Observe the creation of these boards it will give you insights into how well they understand and what they think is important.
- Share the boards in either a whole class board meeting, select some groups to explain their boards, conduct a gallery walk where the students leave a sticky note comment or question, or some other method.

Unit 1.3 Quiz B – Give the quiz

1.4 Density

Activity 1- Layering the Unknown

Adapted from GEMS *Discovering Density*

Apparatus:

1 potato and knife to cut it (any type—used to stick straw into so liquids don't leak out – test tubes or graduated cylinders also work well)
6 Clear plastic straws (in lieu of potato and clear straw test tubes or narrow plastic cups will work as well)
4 different food colors to add to each different liquid
Water tinted with yellow food coloring
Salt water (~5T of salt to ~16 ounces of tap water (saturate the solution)) tinted with green food coloring
Isopropyl or denatured alcohol tinted with red food coloring
Glycerin tinted with blue food coloring—or possibly Karo syrup or some other thick liquid
Medicine Droppers/pipette (eyedroppers)
Old plastic container for waste
Copies of 1.4 Act 1 – Layering the Unknown
Copies of 1.4 WS 1 – Comparing Objects

Pre-Activity discussion

- Tell the students that today they will attempt to layer 4 unknown liquids in the same straw so that none of the colored liquids mix or blend (run through another).
- Caution students to NOT taste any of the unknown liquids.
- Demo as you explain: Insert the straw into the potato at a 45-degree angle. Explain that the reason the straw is placed at this angle is so the liquid can run down the inside of the straw. If the straw is not pushed into the potato far enough or all the way through, the liquids will leak out. Food coloring stains, so it is important to set the straw correctly.
- Demo as you explain: Remind students of proper pipette technique: Squeeze the bulb and insert the tip into the liquid. Release the bulb so the liquid is drawn up into the pipette. Carefully squeeze the bulb so that liquid slowly flows into the straw one drop at a time (shooting the liquid forcefully will ruin the results).
- Remind students to replace pipettes in the proper liquid container so as to NOT contaminate the liquids.
- Students will use the Act 1 Handout on Layering the Unknown to write their predictions of how to layer and record their successes.
- Students will insert a new straw into their potato for each new layering experiment.
- Remind students not to yell out the correct sequence.

Activity Performance Notes

- This activity challenges students to layer 4 different colored liquids (of different densities) in a clear straw. Through trial and error, students keep track of their successes and make predictions as to the correct order. Most teams come up with the correct layering after about 15 minutes.
- Circulate the class as students attempt to layer the liquids.
- As you circulate, students may complain that the blue liquid (glycerin) is too thick and won't move down the straw. Tell them it will move down the straw, just slowly. It helps to add only one drop at a time and not "force" the blue liquid into the straw.
- As students finish, have them repeat their experiment, carefully layering the liquids in the expected order to see if they can get very clear separations between the layers.

Post-Activity Discussion

- Draw several large columns on the board like those on the data sheets. Ask the students to report how they ordered the layers, starting with the bottom layer. Sometimes, one or two students will find another order that worked. If so, list those results as well.
- Ask the students if they can guess what some of the liquids are. Reveal the identity of the liquids to the students. Write the names of the liquids alongside one of the columns on the board.
- Ask the students why they think the liquids layered the way they did. Be careful of the words "heavy" or "light" – use their words for now.
- Some students may mention that some of the liquids were thicker. Others might mention differences in density. If they do use "density" ask them to explain what they mean by it. Encourage alternative explanations and argumentation about the differences between the liquids are and why they layer that way.
- Remember to refrain from defining density yourself at this time ~ probably the most difficult part in all of this!

- If teams have different results, ask the students why they think different teams came up with different ways to layer the liquids.

Activity 2- Comparison of objects

Apparatus

Copies of Comparing Objects worksheet

<u>For each group</u>

Pan balance
6 glass marbles
6 steel marbles (or choose to other objects of the same shape and volume but different mass)
Containers
Sand
Water

Pre-lab discussion

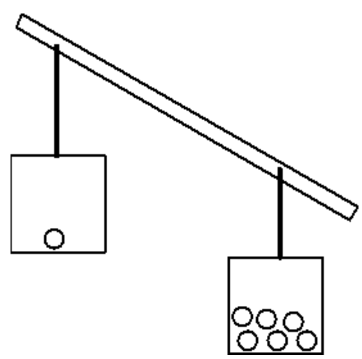
- In this activity students will learn that mass is the quantity of matter. A series of demonstrations will have students define mass as the amount of particles a substance contains..

- If a pan balance is not available, one can be made by hanging a string from the ceiling and attaching a meter stick to the middle. Cups can be hung from both ends of the meter stick to hold the objects. Be sure the cups are clear so students can see inside them. Instead of a class demonstration, students may also complete this activity in small groups with a class discussion at the end.
  Note: you will have to prepare in advance to find a combination of marbles and steel spheres that will have the same mass.

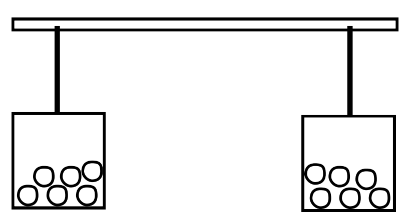
Performance notes

- The following diagrams are examples of the situations that students should observe and discuss. The observations can be recorded on Worksheet 1- Comparing Objects.

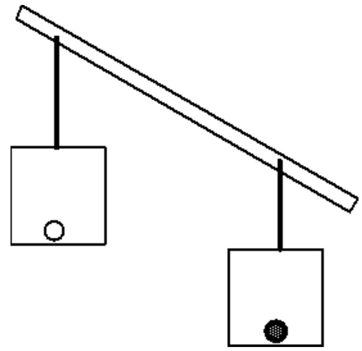
<u>Situation 1</u> Place six marbles in one cup and one marble in the other. Have students discuss ideas why this happens. Put ideas on the board.



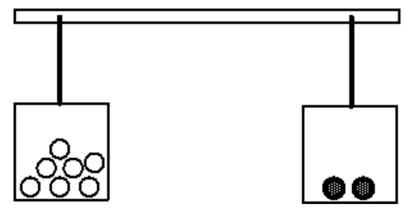
<u>Situation 2</u> Ask students what would balance it. Try their suggestions until you find a workable solution. Add 5 additional marbles to one cup to balance the setup. Why is it balanced? Is it equal numbers of objects?



Situation 3 Now place a steel ball in one pan and compare its mass to that of the marble. What is it about the steel ball that makes the system unbalanced?



Situation 4   Ask the students what it would take to balance the system. Adjust the contents of the pans by adding as many marbles and steel balls as needed so that that the balance is level.



Post-lab discussion

- Conduct a class discussion and make a heading on the board of Similarities and Differences. Have students give you their ideas while you record them. Next ask them which is the "biggest" difference and the "biggest" similarity. Guide them to the mass and volume as the answers. Although they are likely to use the term "weight" (instead of mass), do not dwell on this issue now.

- Follow up on answering the question "Why is one heavier* than the other if they are the same size?" Likely one or more students will mention the difference in the material that make-up each object. At this point, guide connection between matter to the term mass - the amount of particles that makes up the materials.
  **Realizing that 'heavy' refers to weight it may be best to start out using their familiar terms and then switch to 'more massive' after introducing mass.*

- Now pose the question: "In what ways could the particles differ between the two objects?" List the hypotheses on the board. Two on target possibilities that students might suggest are:
  1. the heavier substance has heavier particles than the other (Fig 1a)
  2. the heavier substance has particles that are more tightly packed than the other (Fig 1b)

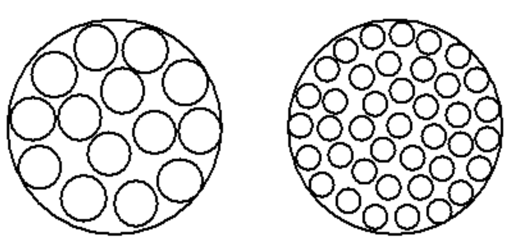


Fig 1a

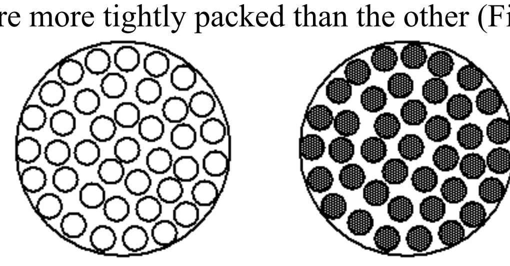


Fig 1b

- For closure, go back to the objects. The main point to emphasize is: while the volumes are the same the amount of matter in each is different. Matter is the 'stuff' making up the materials and this stuff is made of particles. Particles in different materials may be different in arrangement and /or have different masses. Mass is a measure of the amount of matter. Mass is measured in grams, kilograms, etc.

Activity 3: Measuring mass

Apparatus

Balances (triple beam or equal arm)
Items for massing (pencils, paper clips, coins, paper, etc.)
Copies of Mass of Objects

Pre-lab discussion

- This activity is for students to practice using balances and using the units (g and kg) for mass.
- Students may need a discussion on the techniques of using the balance including zeroing and recording values to the appropriate degree of precision.
- Students need to construct their own data table with appropriate titles and units.

Performance notes

- Demonstrate to the students the proper use of a balance.
- Each member of a lab group should find the mass of the same set of objects independently, then compare their results to see how close their values are to each other.

Post-lab discussion

- When students white board their lab results, they should find that they do not all obtain the same mass for the common objects. Ask the following questions
  - o What could have caused these variations? (Mistakes, scales weren't calibrated correctly, etc.)
  - What should we do with the data so we can report a more accurate mass for each object - Students will most certainly suggest using some type of average (mode, median or mean). If needed guide them to this understanding. It also might be necessary to have theAsk if they should average all the values. That is, are some data not as reliable as others? Once these are discarded and averages are found, how far below and how far above are the minimum and maximum values?

If the situation does not arise, ask the students what they would do with the following data.

Group	Mass (g)
1	6.35
2	6.37
3	6.18
4	6.36
5	6.39

- The average of all five values is 6.33 g. Suggest that this is not best way to report the mass of the object. If the third trial were dropped, then the average mass would be 6.37 g with the range of values ± 0.02 g from the average.

- Distribute copies of the Mass of Objects worksheet
- Following is a sample of what students might include on their worksheet:

1. Suppose that one lab group reported the following results for the mass of the same object they measured several times.

trial	mass (g)
1	13.54
2	13.56
3	13.55
4	13.54

Is there a problem with the balance? Explain. What is the best way to report the mass of the object?

School balances are not exact to 1/100 of a gram and human error is possible.

The best way to report the mass would be to average the 4 trials.

2. A lab group found the mass of a ball of clay to be 15.20 g. They carefully flattened the ball of clay into a pancake, then put the clay on the pan of the balance. What mass should they expect for the piece of clay? Explain.

   The mass should be the same. The amount of matter did not change.

Activity 4 - Defining volume

Apparatus

Lots of 1 cm unit cubes
Several cardboard boxes (some small - ex. tea bag box, some larger - ex. Cereal box
Centimeter rulers
Copies of How much Space?

Pre-lab discussion

- Note that this activity can be skipped our shortened if your students are already comfortable with the concept of volume.
- Hold up a sample box and ask how many unit blocks do they think would fill up one of the small boxes?
- Distribute one smaller box to each pair of students. Have students predict how many unit cubes fit into the small box.

Performance notes

- Distribute the student worksheet and have each group follow and complete question 1 and 2.
    - Tip: You may want to number the boxes and create a volume answer key.

1. Fill up the small box with the 1-cm cubes.

a. How many 1-cm cubes does it take to fill up/make up the length of the box? _____

b. How many 1-cm cubes does it take to fill up/make up the width of the box? _____

c. How many 1-cm cubes does it take to fill up/make up one full layer across the bottom? _____

d. How many 1-cm cubes does it take to fill up/make up the height of the box? _____

e. Determine the number of 1-cm cubes it takes to fill the box. Write down the total number of cubes and describe how you came to this total.

2. Determine a method for solving how many 1cm blocks would be needed to fill up the larger box. Draw a picture and describe your method in the space below.

- Once they have completed finding the volume of the smaller box give them a larger box (a box large enough for which there are not enough unit blocks to fill the space but at least enough to fill the longest side.

Post-lab discussion

- Have students prepare a large whiteboard to display their answers and methods for determining their answers.
- During the board meeting have students discuss their methods. Guide the discussion and thinking as needed to transition from counting each individual block to utilizing the number of blocks for length, width, and height.
    - Hopefully, students will come up with the idea that they can count how many cubes in an individual layer, and then add the number of layers up to get total number of cubes.
    - Help them take it a step further and point out that number of blocks can be determined by multiplying length times width times height.
        - Let them confirm that it works by using their boxes information
        - Explain how this results in the 'typical' volume formula (that only works for rectangular solids) of $V = l \cdot w \cdot h$.
        - Be sure to ask and discuss why this method of checking works
    - Also introduce the term volume during the discuss (if it hasn't already come up)
        - How much space an object (matter) takes up is called volume

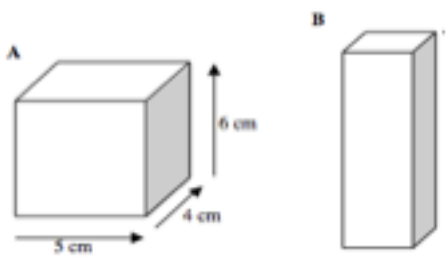
- Then have students complete the remaining portions of the worksheet (Questions 3, 4 and 5)

3. How many 1 cm volume cubes would fit into the 3cm x 4cm x 10cm shape below?

4. List 3 possible combinations of length, width, and height that will give a volume of 24 cm^3. Calculate the area of the topside. Then sketch the object.

	Sketch	Length	Width	Height	Volume
Example		2 cm	3 cm	4 cm	24 cm^3
		______	______	______	______
		______	______	______	______
		______	______	______	______

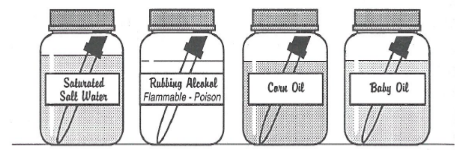
5. Object A is reshaped into object B; would the same number of 1cm blocks fit into object B? Explain your thinking



Activity 5 – Mass and Volume of Liquids
Adapted from TOPS Floating and Sinking Book 9

Apparatus:
Mass and Volume of Water:
- A 10 mL capacity graduated cylinder (larger 100 mL graduated cylinders do not measure volume with enough accuracy
- A source of water
- A gram balance

Density of Other Liquids:
- A 10 mL graduated cylinder
- A gram balance
- Saturated salt water: add 1 part table salt to 5 parts water and shake vigorously for at least 1 minute; let it settle overnight and pour off clear liquid into another clean jar as salt water for this activity
- 70% isopropyl rubbing alcohol
- 100% corn oil
- Baby oil (mineral oil)
- Dispensing containers for each group (baby food jars work well
- Soap and water to clean the graduated cylinder of oil residue
- Paper towels and masking tape to make rolled towels to clean out graduated cylinder



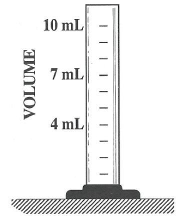
Copies of Mass and Volume of Liquids worksheet

Pre-Activity discussion
- Ask students to explain in their own words the difference between volume and mass. Have them articulate especially how each of these quantities are *measured* differently.
- Ask students if they believe the volume and mass of a particular substance (such as water) are related to one another. Ask them *how* they might be related; getting them to express that a greater volume of any substance should have a greater mass.
- Explain that they are going to find the relationship between the mass and volume of water (Part 1 on handout). Brainstorm with them how they can measure each of these quantities for a particular sample of water and record their results. Make sure they realize that, in order to get the mass of the water only, they will need to subtract the mass of the graduated cylinder.
- Present students with samples of the other liquids to be used in cups or beakers (that will be used in Part 2: Salt Water, Corn Oil, Rubbing Alcohol, and Baby Oil). Ask them to describe initial observations. Record these observations in columns for each liquid at the front. Look for descriptions such as color, appearance, smell, thickness?
- Ask them if a 10 mL sample of these other liquids will have the same mass as a 10 mL sample of water. Have them predict which will have the greatest and the least mass.
- Remind students to record observations and answer questions as they complete each activity.

Performance notes
- Part 1: Mass and Volume of Water:
    - o Teacher may choose to draw an enlarged view of a graduated cylinder being used to emphasize how it is divided into different increments, and also to explain the water meniscus.
    - o Review with students how to read the volume in a graduated cylinder.

- Review with students how to calculate the mass of the water only in the graduated cylinder.
- Sample Data: Mass of empty graduated cylinder = 28.7 g

Volume of Water (______) **Label the appropriate units!**	Total Mass (______) **Water + Graduated Cylinder Label the appropriate units!**	Mass of Water (______) **Label the appropriate units!**
4.0 mL	32.6 g	3.9 g
7.0 mL	35.8 g	7.1 g
10.0 mL	38.7 g	10.0 g



- Note that students will be using proportional reasoning to predict the mass or volume of water in question 5—do NOT emphasize a formal 'proportion' at this point.
- Encourage students to make predictions based upon their own reasoning using charts or diagrams that make sense to them.
- The actual density of water is 1 gram for every 1 mL, or 1 g/mL. Note that a mL is the same volume as 1 cubic centimeter, so this can also be reported as a density of 1g/cm^3

- Part 2: Density of Other Liquids
  - Circulate to ensure students are measuring mass and volume properly.
  - It is important that the students thoroughly clean the graduated cylinder between each different liquid type trial.
  - Help students label and organize the data table in a manner similar to the data table for part 1.
  - Sample Results:
    - Density salt water = 11.8 g/10.0 mL = 1.18 g/mL
    - Density rubbing alcohol = 8.7 g/10.0 mL = 0.85 g/mL
    - Density corn oil = 9.1 g/10.0 mL = 0.91 g/mL
    - Density baby oil = 8.3 g/10.0 mL = 0.83 g/mL
    - Ordering of density: MOST DENSE salt water, fresh water, corn oil, rubbing alcohol, baby oil LEAST DENSE

Post-Activity discussion

- Students should whiteboard their results for the activities. Activities can be divided amongst groups. Groups present results up front – this could be done as individual whiteboard presentations or having all groups in the class whiteboard the results of part 1 and doing a "circle" board meeting. This would be followed by the entire class whiteboarding and comparing results to parts 2.
- The students might represent the particle diagrams in different ways:
  - They may choose to display particles of the same *size*, with higher density substances being packed together *more closely* than lower density substances (this might be the case for the same substance such as chocolate, but in different phases of solid, liquid, gas)
    - Note that in MOST substances, the solid phase is *most* dense, with liquid being less dense than the solid, and gas being the least dense
    - However, water is peculiar in that it is actually *less* dense in its solid phase than its liquid phase, which is why ice floats in water
    - You may choose to display the diagrams of liquid and solid water from U 1.3 Activity 5 on melting to emphasize this peculiarity of water, which will

        - become increasingly important as they study the Water Cycle and Weather in later units
        - Note also that salt water is *more* dense that fresh water, which will also be important in later units.
    - Alternatively, they may choose to display particles of different *size*, with the same *number* of particles in each box, but the more dense substance having particles that are *larger* (this might be the case for different substances whose particles would not all appear the same)
- End by showing this video so students can formalize the difference between mass, volume, and density: Eureka! Episode 25 Volume and Density https://www.youtube.com/watch?v=OXMscU5qJfY
- Have students complete U 1.4 WS 4 to assess their understanding of the proportional reasoning involved with density

Quiz 1.4 – Give the Quiz

Unit 1 Test – Give the Test