SCOPE, SEQUENCE, and COORDINATION

A National Curriculum Project for High School Science Education

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National Science Education Standard—Physical Science
Structure and Properties of Matter
Solids, liquids, and gases differ in the distances and angles between molecules or atoms and therefore the energy that binds them together. In solids the structure is nearly rigid; in liquids molecules or atoms move around each other but do not move apart; and in gases molecules or atoms move almost independently of each other and are mostly far apart.

Teacher Materials

Learning Sequence Item:

909

Phase Changes of Water

September 1996
Adapted by: Glenda Burrus, Dorothy Gabel, Brett Pyle, and Linda W. Crow

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Solids, Liquids, and Gases: Empirical Laws and the Kinetic Theory. Students should observe phase changes in water, with measurements of mass, volume, density, and temperature (*Physics, A Framework for High School Science Education, p. 60*).

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This micro-unit was adapted by **Glenda Burrus** (Northside H.S., Pinetown, N.C.), **Dorothy Gabel** (Indiana Univ., Bloomington), **Brett Pyle** (Grady Middle School, Houston), and **Linda W. Crow** (Baylor College of Medicine, Houston)

909
Learning Sequence

Solids, Liquids, and Gases: Empirical Laws and the Kinetic Theory. Students should observe phase changes in water, with measurements of mass, volume, density, and temperature (*Physics, A Framework for High School Science Education, p. 60*).

Science as Inquiry	Science and Technology	Science in Personal and Social Perspectives	History and Nature of Science
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Suggested Sequence of Events

Event #1

Lab Activity

1. Water, Water Everywhere (1 hour)

Alternative or Additional Experiment

2. How Does the Density of Water Vary? (1 hour)

Event #2

Lab Activity

3. It's Just a Phase You're Going Through (45 minutes)

Event #3

Readings from Science as Inquiry, Science and Technology, Science in Personal and Social Perspectives, and History and Nature of Science

Suggested readings:

Ravven, W., "Biology on Ice," *Discover* Magazine, Vol. 15, No. 8, 1994, pp. 36–41.
"A Cold Drink of Fog," *Science World*, Vol. 49, No. 4, 1992, p. 5.

Assessment items are at the back of this volume.

Assessment Recommendations

This teacher materials packet contains a few items suggested for classroom assessment. Often, three types of items are included. Some have been tested and reviewed, but not all.

1. Multiple choice questions accompanied by short essays, called justification, that allow teachers to find out if students really understand their selections on the multiple choice.

2. Open-ended questions asking for essay responses.

3. Suggestions for performance tasks, usually including laboratory work, questions to be answered, data to be graphed and processed, and inferences to be made. Some tasks include proposals for student design of such tasks. These may sometimes closely resemble a good laboratory task, since the best types of laboratories are assessing student skills and performance at all times. Special assessment tasks will not be needed if measures such as questions, tabulations, graphs, calculations, etc., are incorporated into regular lab activities.

Teachers are encouraged to make changes in these items to suit their own classroom situations and to develop further items of their own, hopefully finding inspiration in the models we have provided. We hope you may consider adding your best items to our pool. We also will be very pleased to hear of proposed revisions to our items when you think they are needed.

Science as Inquiry

Water, Water Everywhere

How do the densities of ice and water differ?

Overview:

Students determine the mass, volume, and density of liquid water and ice.

Materials:

Per class:
ice chests with ice, 1–2 (refrigerator can be substituted)
graduated cylinders, 2 per ice chest
ethyl alcohol, ~100 mL

Per lab group:
bottle caps, 2
balance, digital or pan
ice cube

Procedure:

This lab consists of two parts, measurements of the mass, volume, and density of liquid water, followed by the same measurements for ice. For the liquid water have the students take the mass of an empty graduated cylinder and then fill it with an amount of water that they choose. They should measure and record the volume of the water as well as the mass. The mass is found by taking the total mass of the cylinder plus water and subtracting the mass of the empty graduated cylinder. From this data they should calculate the density in grams/cm^3.

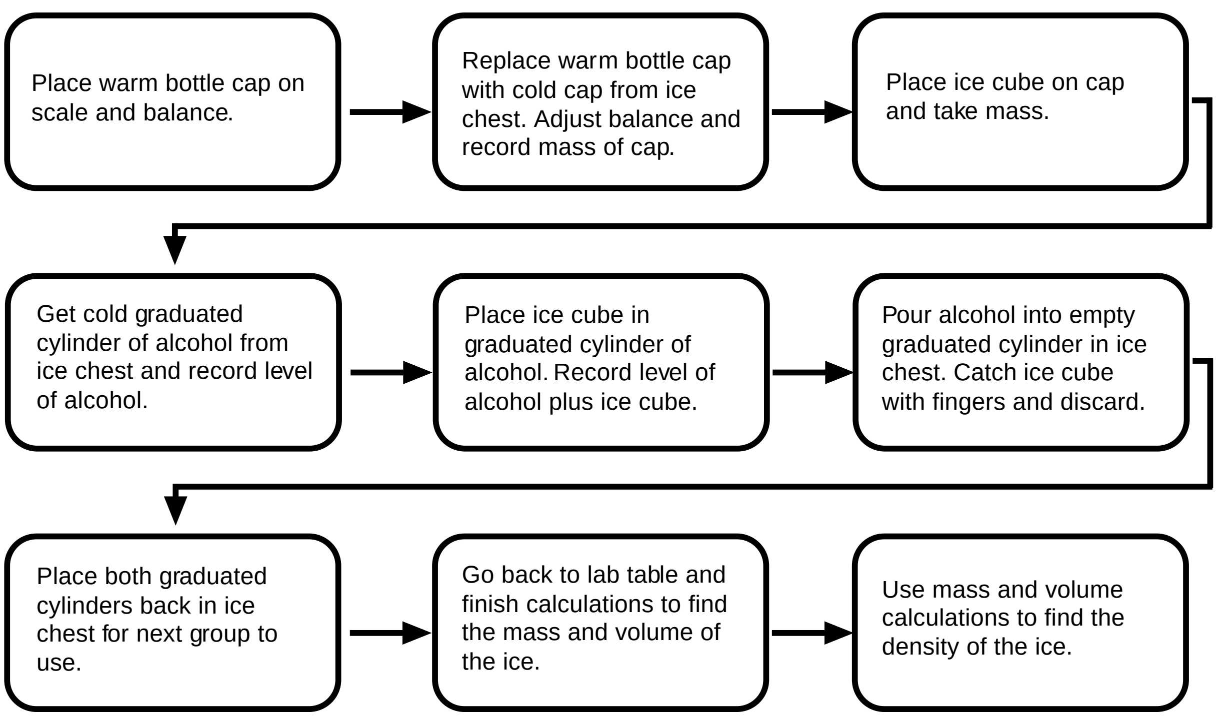
Next, students measure the mass and volume of a small ice cube and determine its density in grams/cm^3. They determine the mass first using a digital or pan balance. The volume is determined using the submersion method since the ice cube is an irregular solid. Finding the density of ice can be slightly tricky as the ice tends to start melting at room temperature. For this reason several accommodations must be made to keep the ice from melting during the mass and volume measurements. As the ice cube needs to fit into a graduated cylinder for the volume measurement, a small roundish ice cube works best. You will need to have one or two ice chests filled with ice set up in the lab. Inside each ice chest place several bottle caps and two graduated cylinders partially filled with ethyl alcohol.

When students take the mass of the ice cube they need to place the cube on a cold bottle cap to prevent it from melting while it is on the balance. If you are using pan balances students need to minimize the time the ice cube is on the balance. Supply each group with a room-temperature bottle cap and have them place it on the balance and balance it. Next they quickly get a cold bottle cap from the ice chest and exchange it with the warm one on the balance, making any fine adjustments to balance it. They record the mass of the empty cold cap, quickly place the cube on the cap, and take the mass of both. If digital scales are used, students should simply place the cold cap on the scale and read the mass and then quickly place the ice cube on the cap and record the mass of both together. At this point students should not do the math to figure out the mass of the ice alone. They must quickly do the volume measurement before melting begins.

To find the volume of the ice cube students submerge it in a graduated cylinder of ethyl alcohol that is being kept cold in the ice chest. The ice will sink in the ethyl alcohol so a quick measurement can be made. Students should review and practice the process of determining volume by the submersion method ahead of time before doing it with the ice cubes when speed is vital. Once the volume is determined they should pour the alcohol into an empty graduated cylinder that also has been kept cold in the ice chest, catching the ice cube with fingers or a screen as it comes out of the graduated cylinder and disposing of it. The ice chest should be closed with both cylinders inside. The alcohol is now ready for the next group to use.

You will need to rehearse this process with students because once they start they will need to work rapidly through the mass and volume measurements before the cube melts. The flow chart below summarizes the process from start to finish.

Flow Chart to Find Density of Ice



After students have completed their calculations, have them complete the questions on the student sheet. You will want to discuss their findings and to ask them if their findings make sense based on what they know about ice and water (what happens when you put ice cubes in water?). You may also want to discuss the significance of ice floating and thus of ponds and lakes freezing from the top (see background in Activity 2).

Background:

If a refrigerator is present in the lab it can be substituted for the ice chests. Other materials, such as small pieces of Styrofoam, may be substituted for the bottle caps to provide insulation. Rubbing alcohol cannot be substituted for the ethyl alcohol as rubbing alcohol is mostly water and the ice cube will not sink in it.

The density of water is 1 g/cm^3. The density of ice is 0.92 g/cm^3. The density of ethyl alcohol is 0.79 g/cm^3.

Variations:

You can also have the students experimentally determine the density of the ethyl alcohol that is used in the experiment. The focus of the lab should remain, however, on the differences between the densities of ice and liquid water.

Adapted from: none

Science as Inquiry

How Does the Density of Water Vary?

How does the density of water vary in the liquid and solid states?
Is warm water more or less dense than cold water?

Overview:

This activity consists of four demonstrations on the density of water. Students make predictions and reach conclusions about each.

Materials:

Per class (demo):
beakers or clear glass/plastic jars (1000 mL), 2
bottle (2 liter), cut off (or additional 1000-mL jar)
vial, small with narrow neck and opening
ice cubes, 1 tray
ice chest
food coloring
tongs
metric measuring tape
graduated cylinder (1 liter) or graduated beaker (2 liter)
hot water
cold water

Procedure:

Students make predictions before each demonstration, observe the demonstration, and reach conclusions about the density of water.

Demonstration A

Ice cubes are placed in a large glass container and water is added to the rim. Students predict what will happen as the ice melts and explain in terms of the density of ice and water.

Demonstration B-1

A vial with a narrow rnouth is filled with hot water containing a vegetable dye. A large container is filled with ice water (with the cubes removed). Students predict what will happen when the vial is set at the bottom of the beaker of ice water and explain in terms of the density of hot and cold water.

Demonstration B-2

The same vial with a narrow mouth is filled with ice water and colored with vegetable dye. It is then placed in a container of hot water. Students predict what will happen when the vial is set at the bottom of the hot water container and explain in terms of the density of hot and cold water.

Demonstration C

In advance of the class, add some food coloring to water and freeze into ice cubes. In class, place one of the ice cubes in a container of hot water. Students predict what will happen as the ice cube melts and explain in terms of the density of ice, cold water, and hot water.

Background:

Water is a unique substance in that the solid has a density less than that of the liquid. This is due to the way the molecules are packed into the crystalline structure because of the presence of hydrogen bonding. Because ice floats and water in ponds freezes at the surface, ice remains on the top of the water, thus acting as insulation for the water below and preserving marine life in winter. The density of water also varies as a liquid. At 4 °C, water has its maximum density of 1.00 g/mL. Below this temperature liquid water decreases in density to 0.99987 g/mL at the freezing point and to 0.958 g/mL at the boiling point. The density of ice is 0.9168 g/mL at the freezing point.

Adapted from:
Operation Chemistry. Washington, D.C.: American Chemical Society, 1994.

Science as Inquiry

It's Just a Phase You're Going Through

What is the temperature of water when it freezes?
When it boils?

Overview:

In this activity, students examine the temperature of water during phase changes.

Caution students not to move or twist the thermometer once the water begins to freeze. The thermometer can be broken this way. When working with boiling water, students may need an oven mitt or pot holder to hold the thermometer in place.

Materials:

Per lab group:

test tube
beaker, 500 mL
thermometer
Styrofoam™ cup
ice
rock salt
water
hot plate
oven mitt
graph paper

Procedure:

Have students place 5–8 mL of water in the test tube and insert the thermometer. They should wait one minute and record the starting temperature of the water. They then place the test tube in the Styrofoam cup and surround it with ice and rock salt. Have them take the temperature of the water every 30 seconds until the water completely freezes in the test tube, continuing to record temperatures until the temperature no longer drops. After the data have been collected, students should carefully remove the test tube and run cool water over it to melt the ice and recover the thermometer.

Next, students measure 200 mL of water into the beaker. They place the thermometer in the beaker, wait one minute, and record the initial water temperature. They then turn on the hot plate and record the temperature every 30 seconds until the water boils. They should continue to record the temperature for two minutes after the water has begun to boil.

After collecting the data, students should plot both parts of the experiment on a line graph of time vs. temperature.

Background:

In this lab students should focus on the temperature of the water, particularly during the times when the water is partially frozen and when it is boiling. The temperature of the water will remain at 0 °C until it is solid ice. At this point the temperature will begin to drop again until it levels out at ~10 °C. The boiling water will remain at 100 °C and not go higher. The boiling curve will look slightly different than the cooling curve because we are measuring the temperature of the liquid water and this will not go above 100 °C. We cannot accurately measure the steam temperature in this experiment. When the water freezes into ice the temperature can then drop and we are then measuring the temperature of the solid state of water. This temperature can drop as low as the surrounding temperature drops.

At a phase change a substance will continue to absorb (or lose) heat until all of the material has changed phase. During this time the temperature will not change, remaining at the boiling point (or freezing point) temperature. When enough energy is absorbed (or released) to complete the phase change, then the temperature of the substance in its new phase will rise (or fall) again until it reaches equilibrium with its surroundings.

Adapted from:

Crow, L., *Hot Stuff*. Houston: Baylor College of Medicine, 1994.

Science as Inquiry

Melting Ice

Item:

Water in the solid state forms a uniform crystal of ice. Melting of the ice shows all of the following *except:*

A. The water becomes more dense in the liquid state.
B. The energy of the water molecules increases as the ice melts.
C. The mass of the water is less than the mass of the ice that melts.
D. The molecules in liquid water are packed tighter than those in the same amount of water in the ice crystal form.

Justification:

Explain what happens to the water molecules during melting of the ice.

Answer:

The correct choice is C. The mass of the water is the same as the mass of the ice that melts. Ice melts due to the absorption of the energy by the water molecules, which allows them to overcome and break the bonds that hold them in the crystalline formation. There is no addition of molecules. As the water molecules begin to move freely about they occupy less total space, and since the volume of the water decreases while the mass remains the same, the water becomes more dense than the ice from which it was formed.

Science as Inquiry

Sunlight and Water

Item:

When sunlight hits a puddle of water, the water is observed to disappear slowly. This is because:

A. Water molecules are attracted to the soil particles and repelled by sunlight, so they soak into the ground.

B. Water is attracted to sunlight.

C. Water molecules gain energy from sunlight, which enables them to escape the surface.

D. Water molecules have surface tension forces that pull them from the surface as the sunlight is absorbed.

Justification:

The same volume of water is added to two beakers standing on the sidewalk in the hot sunlight. The water from one beaker is poured onto the sidewalk. That water is seen to evaporate faster than the water in the other beaker. Explain why.

Answer:

C. Energy is transferred from light, by absorption, to kinetic energy of water molecules, which speeds evaporation from the surface.

The justification answer should include the idea that more efficient energy transfer can occur over the larger surface area exposed to sunlight in the case of the puddle.

Science as Inquiry

Changes in Temperature

Item:

You need to demonstrate to a middle school class that heating a substance at a steady rate does not necessarily mean that its temperature increases at a steady rate. You also plan to show them something about phase changes and why adding heat makes a difference.

Design and carry out a demonstration where you measure temperature changes using a thermometer, as water changes from solid to liquid to gas. You will have the use of a Bunsen burner, test tubes, and test tube holders, as well as the thermometer and some way to support the thermometer. You will need to have a device that measures time in seconds and minutes. Graph the results and identify where there are major changes in temperature. Analyze these results and write explanations for major changes that occur on the graph.

Answers:

Students should design an experiment that deals with one variable, in this case the change in temperature causing a change in phase of the water. The thermometer should be suspended in the water, not touching the test tube. Their graphs should shows change in temperature vs. time and should identify what happens as water nears each phase change. They should be able to interpret regions and patterns on the graph, as well as explain some inconsistencies that may occur in the data.

Misconceptions:

As with any designed experiment, students may try to change more than one variable at a time. Graphs may not identify the correct variables, or they may have inappropriate scales and therefore be useless. Students may not see changes in slope as implying something about the different phases and their heat capacities or they may identify flat regions as phase changes. In particular, students may think change only occurs at the intersection point between flat and sloped portions of the graph.

Science as Inquiry

Condensation

Item:

When water vapor condenses onto a cold surface to form drops of liquid water:

A. Water molecules gain kinetic energy from the surface, which helps them to stick to the surface.
B. Water molecules are more attracted to the surface then they are to each other.
C. The surface gets cooler because of the latent heat of water being released.
D. Water molecules lose kinetic energy to the surface, which becomes warmer.

Justification:

Orange growers in Florida sometimes spray their tree orchards with water during the night to stop oranges from freezing if the nighttime temperature is expected to drop below 0 °C. Explain how this works to protect the fruit.

Answer:

D. Energy is transferred from higher-energy water vapor molecules to the surface, which thus becomes warmer.

Justification answer should include the same idea: the fruit will be kept warmer by condensing water vapor.

Science as Inquiry

Melting Ice

Item:

Freeze a thermometer in water in a test tube for 24 hours. Remove the test tube to room temperature and plot and record the temperature each minute once melting begins. Do this until half the ice has melted.

1. Why didn't the ice begin melting once exposed to room temperature?
2. Why didn’t the temperature change once the ice began to melt?

Answer:

1. The temperature of the ice was below the melting point. The internal temperature was the same as the external temperature. There was an interaction between the warm air and the cold test tube.
2. Energy was used to melt the remaining ice rather than to heat the resulting water.

Science as Inquiry

Ice Floats

Item:

Devise and carry out an experiment that would help you determine the percentage of a floating ice cube that is above the water. Does the shape of the ice cube make a difference? Explain.

Does it matter whether the measurements are of mass or volume?

How would the numbers be different if a large iceberg was considered rather than a small ice cube?

Materials:

Per class:

beakers (small)
graduated cylinder (small, that might or might not be large enough to hold the ice cube)
plastic rulers (small)
water
ice cubes of various shapes
tape and string for markers
modeling clay (smart students might think of modeling parts above and below and then measuring the model, since it won't melt)
balance

Answer:

Students should measure the displacement of the ice cube or experiment with ways to measure dimensions of the parts above and below water and calculate volumes.

Since the cube has uniform density, it shouldn't matter whether percentage by mass or by volume is determined or what the overall shape is.

The percentage for an iceberg should be the same as that for an ice cube.

Students who have not mastered density, mass, and volume concepts may reveal misconceptions in doing this item. This investigation is also a good way to have students think about design, since it should not involve elaborate equipment but it does offer a few small challenges.

Science in Personal and
Social Perspectives

Pipe Burst in Winter

Item:

Why does a water pipe burst when it freezes? What steps might you take to prevent this from happening?

Answer:

A pipe bursts because of the difference in space occupied by liquid and solid water. Prevention includes emptying pipes before freezing, warming them above freezing, and developing a flexible kind of pipe.

Science in Personal and
Social Perspectives

Expansion of Freezing Water

Item:

In cold climates cement sidewalks sometimes upheave when the temperatures are well below the freezing point of water. Explain why this happens.

Answer:

Upheavals result from the difference in space occupied by liquid and solid water. The water in the earth below the cement is expanding as it changes to a solid.

Science in Personal and Social Perspectives

Snow Melt

Item:

A lot of snow fell near where you live in the mountains. On a warm, cloudless, sunny day in spring, the snow starts melting, but some also seems to be disappearing without melting. Explain the phase changes and how these could be related to what is occurring at the molecular level.

Answers:

Ideas that may be found in student answers:

When the snow melts, it changes from a solid form to a liquid form. When it changes from solid to liquid, the velocity of the molecules increases and they move farther apart. As the spring days heat up, the liquid water may start the process of evaporation as it turns to steam. Molecules will move even faster and move further apart. Solid-phase molecules may go directly into the vapor phase as they gain energy from the sun's radiation, especially at times of low atmospheric humidity.

Concepts that may be misunderstood:

Students may have little idea about what is going on at the molecular level. They may misidentify the closeness of the molecules and the velocity component.

Science as Inquiry

Changes in Volume

Item:

Water is placed in a measuring cup and put in a freezer. Just before it starts to freeze, the volume of liquid water, measured at 1°C, is 100 mL. When it freezes to solid ice, which of the following correctly describes what occurred?

A. The solid has a smaller volume than 100 mL.
B. The solid at 0 °C may have a smaller volume than 100 mL, but if the temperature is less than 0°C the volume will increase to larger than 100 mL.
C. The solid has a larger volume than 100 mL.
D. The solid has a volume of exactly 100 mL.

Justification:

Describe what happens when water collects in the crevice of a rock and the temperature falls below 0 °C during the night. What does this have to do with erosion of rocks?

Answer:

C. Water expands by about 10% of its volume when it freezes. This expansion exerts a tremendous force on the walls of a rock crevice. The freezing water wedges the rock apart, breaking off small and large pieces.

Science as Inquiry

Sublimation of Ice

Item:

A student carefully and quickly measures the dimensions of an ice cube and returns it to the freezer. Several days later, the measurement is repeated but the ice cube seems to have become smaller. Which of the following is most likely to have happened?

A. The freezer was too warm, some of the ice cube melted, and water was lost.

B. The ice cube gets smaller as the temperature is reduced. The second measurement must have been at a lower temperature than the first.

C. Water is condensing from other items in the freezer onto the cube, but since this condensation has a smaller volume than the liquid, the cube is smaller.

D. Solid ice slowly turns to water vapor (gas) on the surface so some water is lost over time.

Justification:

You hang some clothes to dry on the line outside. The temperature is below freezing. The next day you remove the clothes because they are dry. Explain.

Answer:

D. The frozen water will sublime over a period of time to the vapor state. This happens on the clothes. Some students may reveal the misconception that water can be in only a single phase at a single temperature. Except at the triple point, water can be in equilibrium at two phases at any temperature.

Science as Inquiry

Absorption and Release of Thermal Energy

Item:

Are boiling point and condensation point of a substance the same? Explain.
Are freezing point and melting point the same? Explain.

Answer:

In order for a phase change to occur, thermal energy is absorbed or released. When heat is absorbed or given off, the same amount of thermal energy is needed to cause changes in the intermolecular forces. At the boiling point, thermal energy is added to overcome the attractive forces and move the molecules further apart. At the condensation point, thermal energy is released as the forces interact between molecules as they come closer together. The amount of thermal energy in each case is equal. Each process is the reverse of the other.

Science as Inquiry

Density of Water

Item:

Not everyone knows how the density of water varies over a range of temperatures from –10 °C to 30 °C. Design and carry out a procedure to determine the density of liquid and solid water over this temperature range. Given a 100-mL graduated cylinder, a balance, a thermometer, a beaker, and a supply of hot water and ice cubes (and/or access to a freezer), determine the density of ice and of liquid water. Plastic measuring cups might work well, too.

Comment on how accurate your results are. What could have been done to give better accuracy? If possible, combine notes with others in the class.

What do your results show about how the density of water changes with temperature?

How best can you show such results?

Prepare a brief report on the class results for a parent meeting.

Answer:

This should be an open-ended exercise with little guidance. Students can be judged on how well their procedure could be followed by another student and how well they collaborate to get the full range effectively covered. Also, they should graph results for presentation purposes.

Science as Inquiry

Dew Point

Item:

The dew point of the atmosphere is the temperature at which water condenses from the atmosphere. What properties of the atmosphere do you think will change the dew point?

Carry out the following experiment to find the dew point in your classroom.

Fill a glass about 2/3 full of water. Place a thermometer in the water at room temperature. Add ice a little at a time while stirring the water. At the first indication of condensation on the outside of the glass record the temperature

At what room temperature did condensation begin? What conditions of the atmosphere should you record? If possible repeat this experiment on a different day when the weather is very different. Predict whether you would expect a higher, lower, or the same dew point, and explain your prediction before doing the experiment. Were your predictions validated? Why or why not?

Dew would never form unless a cool surface forms. Dew is often seen on the leaves of grass. How do grass leaves that form dew become cooler than the air around them?

Answer:

The amount of water vapor in the atmosphere (humidity) is the main factor. Temperature is not a factor, since dew point fixes the temperature by definition. Wind currents may be factors. Local variations can be significant. For example, humidities inside and outside the classroom may be different.

The final question leads students to consider differential heating and cooling rates as a function of heat capacity and radiation phenomena. This may not be covered until later, but this experiment may be a good lead-in to further investigations.

Science as Inquiry

Heat Input and Phase Transition

Item:

Students investigate how the input of heat drives the phase transition of water from a solid to a liquid to a gas.

Materials:

thermometer
hot plate w/wire gauze
crushed ice and water
beaker w/stirring rod, 250 mL
timing device
cardboard
scissors
tape

Procedure:

Cut cardboard in the shape of a disk to cover the mouth of the beaker. Poke a small hole in the center of the cardboard disk with the scissors or a sharpened pencil. Ease thermometer into the hole in the cardboard disk so that when the disk rests on the rim of the beaker, the bulb of the thermometer is suspended inside of the beaker. Tape thermometer in this position. Make a table to record temperature readings.

Fill beaker half full of water. Add enough crushed ice to fill beaker. Stir ice and water.

Position the cardboard disk so it rests on the rim of the beaker, making sure the thermometer is in the middle of the water/ice mixture. Place the wire gauze on the *cold* hot plate and place the beaker on the wire gauze. Set hot plate control to medium-high heat. Record the temperature of the mixture in the beaker and the time.

Take a temperature reading every minute until the ice is melted and the water is boiling with steam evaporating. For each temperature reading, note the phase of the material—solid, liquid, or gas. If more than one phase is present at a given time, use fractions to indicate how much of each phase is present. For example, 1/2 water, 1/2 ice. Periodically remove the cardboard disk for a few seconds and stir the ice and water mixture.

Plot your data on a graph showing temperature versus time.

Questions:

1. How does solid water (ice) respond to heat input?

2. Consider your graph. How does the temperature change with heat input? Is the temperature change linear throughout the phase transition from solid to gas, or does your graph show bursts of temperature increase and zones of little change?

3. How could you explain the variation you saw?

Answer:

Students might be asked to do this experiment with little direction if they have done similar experiments before. If so, they should be asked to submit their designs for teacher approval before starting. Otherwise it can be seen as an assessment in following directions and in plotting and interpreting graphs.

Science as Inquiry

Transfer of Heat Energy

Item:

Students investigate phase changes and transfer of heat energy. Skills assessed are reading a thermometer, analyzing data, and drawing inferences.

Materials:

graduated cylinder, 50 mL or larger
Styrofoam™ cups, 2
thermometers, 2
aluminum foil (10-cm square), 2 pieces
eye protection
graph paper, 1–2 sheets
colored pencils, 2 different colors
hot water supply
ice water supply

Procedure:

Measure 50 mL of ice water and pour into a Styrofoam cup, covering it with a piece of aluminum foil. Make a hole with a pencil or pen in the center of the foil piece to allow a thermometer to pass through and measure the temperature.

Measure the temperature of 50 mL of tap water. Carefully remove the foil from the ice water and pour the tap water into the cup and re-cover with foil. Take temperature readings every minute for a total of five minutes. Record your observations in the form of a table/chart.

Wearing eye protection, carefully measure and pour 50 mL of hot water into another Styrofoam cup and cover with a piece of aluminum foil. Make a hole in the center of the foil piece to allow a thermometer to pass through to measure the temperature.

Measure the temperature of another 50 mL of tap water. Carefully removing the foil, pour the tap water into the cup of hot water and re-cover. Take temperature readings every minute for a total of five minutes. Record your observations in the form of a table/chart.

Use the data you have collected to make a line graph. Use one colored pencil to denote the slope for ice water and a different pencil for the slope of hot water.

Questions:

1. What was the starting temperature of ice water?

2. What was the starting temperature of hot water?

3. What was the starting temperature of tap water?

4. What was the final temperature of the ice water?

5. What was the final temperature of the hot water?

6. How do the two slopes of the graph compare?

7. What was one common thing that happened in the two cups of water? Use the term “heat” in your answer.

Answer:

This is a simpler alternative to Assessment 15 and could be used in a similar way. The response to question seven should indicate that heat flows from objects at a higher temperature level to those at lower temperature levels.

This item bridges the gap between qualitative observations of heat involved in phase changes and quantitative observations. If used for the latter, students can be asked to predict and measure mixtures of hot and cold water at different temperatures and quantities to assess their understanding of the relationships.

Consumables

Item	Quantity per lab group	Activity
bottle caps	2	1
ethyl alcohol	~100 mL	1
food coloring	— per class (demo)	2*
graph paper	—	3
ice	—	3
ice cube	1	1
ice cubes	1 tray per class (demo)	2*
rock salt	—	3
Styrofoam™ cup	1	3
water, cold	— per class (demo)	2*
water, hot	— per class (demo)	2*

Nonconsumables

Item	Quantity per lab group	Activity
balance, digital or pan	1	1
beaker, 500 mL	1	3
beakers or clear plastic/glass jars, 1000 mL	2 per class (demo)	2*
bottle (2 liter), cut off (or 1000-mL jar)	1 per class (demo)	2*
graduated cylinder (1 liter) or graduated beaker (2 liter)	1 per class (demo)	2*
graduated cylinders	2–4 (1–2 per ice chest)	1
hot plate	1	3
ice chest	1 per class (demo)	2*
ice chests with ice (or refrigerator)	1–2 (per class)	1
metric measuring tape	1 per class (demo)	2*
oven mitt	1	3
test tube	1	3
thermometer	1	3
tongs	1 per class (demo)	2*
vial, small with narrow neck and opening	1 per class (demo)	2*

*denotes alternate or additional activity

Key to activities:
1. Water, Water Everywhere
2. How Does the Density of Water Vary?
3. It's Just a Phase You're Going Through

Activity Sources

Crow, L.W., *Hot Stuff.* Houston: Baylor College of Medicine, 1994.
Operation Chemistry, Washington, D.C.: American Chemical Society, 1994.