Oakland Schools Chemistry Resource Unit

Kinetic Molecular Theory & Phase Changes

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<u>Kinetic Molecular Theory</u>

Content Statements

C2.2 - Molecules in Motion
Molecules that compose matter are in constant motion (translational, rotational, and vibrational). Energy may be transferred from one object to another during collisions between molecules.

C3.3 Heating Impacts
Heating increases the kinetic (translational, rotational, and vibrational) energy of the atoms composing elements and the molecules or ions composing compounds. As the kinetic (translational) energy of the atoms, molecules, or ions increases, the temperature of the matter increases. Heating a sample of a crystalline solid increases the kinetic (vibrational) energy of the atoms, molecules, or ions. When the kinetic (vibrational) energy becomes great enough, the crystalline structure breaks down, and the solid melts.

C4.3 - Properties of Substances
Differences in the physical and chemical properties of substances are explained by the arrangement of the atoms, ions, or molecules of the substances and by the strength of the forces of attraction between the atoms, ions, or molecules.

C4.3x – Solids
Solids can be classified as metallic, ionic, covalent, or network covalent. These different types of solids have different properties that depend on the particles and forces found in the solid.

C5.4 - Phase/Change Diagrams
Changes of state require a transfer of energy. Water has unusually high-energy changes associated with its changes of state.

Content Expectations:

C2.2A - Describe conduction in terms of molecules bumping into each other to transfer energy. Explain why there is better conduction in solids and liquids than gases.

C2.2B - Describe the various states of matter in terms of the motion and arrangement of the molecules (atoms) making up the substance.

C2.2d - Explain convection and the difference in transfer of thermal energy for solids, liquids, and gases using evidence that molecules are in constant motion.

C3.3A - Describe how heat is conducted in a solid.

C4.3B - Recognize that solids have a more ordered, regular arrangement of their particles than liquids and that liquids are more ordered than gases.

C4.3h - Explain properties of various solids such as malleability, conductivity, and melting point in terms of solids structure and bonding.

Instructional Background Information

Structure of Matter

Matter is what makes up all substances, whether it is a solid, liquid or gas. Molecules, atoms and sub-atomic particles are all matter.

- The major properties of matter are that it takes up space, has mass and attracts other matter with gravity.
- All matter is made up of constantly jiggling atoms or molecules. The motion of these particles determines whether a substance is a solid, liquid, or a gas – the KINETIC THEORY OF MATTER!

States of Matter

1. Solid
2. Liquid
3. Gas
4. Plasma

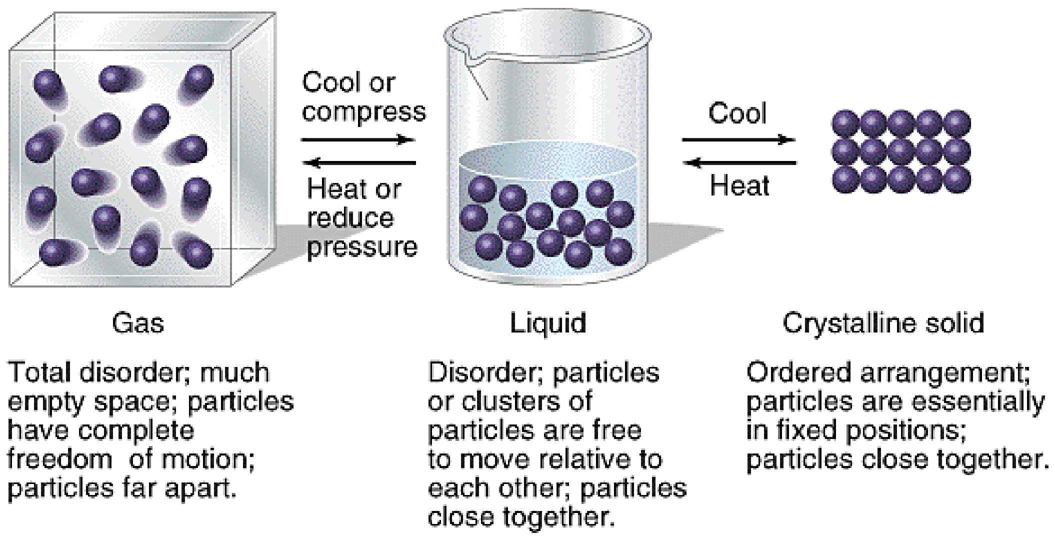
Each state of matter has different properties.

1. <u>Solids</u>
   - Have definite shape.
   - Have definite volume
   - Highest mass per unit of volume
     - The solid state of matter is when the material has a definite volume or size and distinct shape at a given temperature.
     - In a solid, the particles are so close that the forces of attraction confine the material to create the specific shape.
     - In solids, the motion of the particles is severely constrained to a small area, in order for the solid to maintain its shape.
     - Ex. A piece of iron at room temperature has a shape and size that does not change

2. Liquids
    - Have definite volume.
    - Takes the shape of the container
    - More mass per unit of volume than a gas, but less than a solid.
        - In a liquid, the particles are farther apart, but they are still close enough that attractive forces confine the material to the shape of its container.
        - In liquids, the movement is somewhat constrained by the volume of the liquid
        - Ex. If you pour water into a cup or container, it will take the shape of that container. If you put water in a balloon, the water will take the shape of the balloon, no matter how you change the shape of the balloon.

3. Gases
    - Has no definite shape
    - Has no definite volume
        - In a gas, the separation between particles is very large compared to their size, such that there are no attractive or repulsive forces between the molecules.
        - In gases, the movement of the particles is assumed to be random and free.
        - The volume of a quantity of gas is dependent on its temperature and the surrounding pressure.

4. Plasma
    - Similar to a gas, but charged particles with extremely high energy
    - Exists at very high temperatures
    - Rare on earth, but found in universe in stars
        - Ex. Northern lights, solar flares, fluorescent lamps



Conduction

If you have ever left a silver spoon in very hot soup, you will notice that the whole spoon gets hot. Thermal energy is transferred from the hot end of the spoon through the entire length, its called conduction.

- Particles often collide with each other. When this happens, energy is transferred from the faster (hotter) moving particle to the slower (cooler) moving particle. This makes the slower moving particles increase in speed.
- When molecules in a substance are made to move faster, they get warmer. The warmer an object gets, the more kinetic energy and therefore, thermal energy it contains:
    - Kinetic energy is the energy of motion
    - Thermal energy is the total energy of the atoms.
        - ❖ The Law of Conservation of Energy states that energy cannot be created or destroyed. Following this rule we assume no energy is lost in these collisions.

- In solids (especially metals), electrons in atoms collide with each other inside the object being heated.
    - Good conductors of heat are metals with loose electrons – silver, copper, iron, etc.
    - Poor conductors are called insulators. These don't have loose electrons – wool, wood, paper, Styrofoam, etc.
    - Air is a poor conductor of heat, so things with air spaces in them are sometimes used as insulators.
- The rate at which the kinetic or thermal energy is transferred from one particle to another depends on the separation of the particles and their freedom to move.
    - In a gas, the particles are allowed to move freely, but their separation distance is great, so heat or energy transfer is slow.
    - In a liquid, the heat transfer by conduction is faster because the particles are closer together.
    - In a solid, the molecules are constrained into a specific location within the material, which can make for quick conduction. Although the particles are closer together than in liquids, the constraints in some materials actually prevent the transfer of heat energy. A good example of that is in wood.

Convection

- Convection is the transfer of heat by motion of a fluid (a fluid is a liquid or a gas), or by currents.
- Convection works in fluids in the following way:
    - Fluid is heated from below and the molecules on the bottom start moving faster.
    - The molecules on the bottom spread apart and become less dense.
    - The less dense molecules move up to the top, as the denser, cooler fluid moves to the bottom.
    - The convection current will keep stirring this way. The warmer fluid will always move away from the heat source and the colder will move towards it.
- Sometimes convection works in gases like it does in fluids:
    - Warm air expands and therefore becomes less dense.
    - This less dense air rises through the surrounding cooler air.
    - Once the warm air reaches air with the same density, it stops rising.
        - As air expands, it cools.
        - As it is compressed, it gets hotter.

Properties of Solids

- Solids can be classified as metallic, ionic, covalent or network covalent. These different types of solids have different properties that depend on the particles and forces found in the solid.
  - Metallic solid – Matter that consists of closely packed cations surrounded by mobile valence electrons.
    - Metals are malleable. When pounded with a hammer, we can shape them due to the metallic bonding that takes place. The cations easily slide by one another in the sea of loose electrons and this allows us to pound the metal into thin sheets.
    - Metals are also ductile, which means they can be drawn into thin wires. Again, their structure accounts for this property.
    - These are good conductors of electricity due to the loose electron structure.
  - Ionic solid- Matter that consists of a metal and a nonmetal or a cation and an anion in a crystalline structure. Each ion is attracted strongly to each of its neighbors and repulsions are minimized.
    - Ionic compounds would shatter due to their crystalline structures and are therefore not malleable. If we were to strike a crystal with a hammer, the like ions would be driven nearer to each other and they would repel causing the crystal to shatter.
    - Ionic solids have higher melting points than covalent solids due to the strength of attraction between particles.
    - Ionic solids will conduct electricity.
  - Covalent solid – Matter that contains bonds that exist between 2 nonmetals where electrons are shared.
    - To melt this solid, enough energy must be given to the molecules to allow them to overcome the force of attraction holding them in fixed positions. This force is weak in a covalent solid and so it is easily melted.
    - In fact most covalent substances are liquids or gases at room temperature and the solid ones have low melting points. Covalent compounds are non-electrolytes and usually dissolve best in organic solvents (such as cyclohexane).

- Network covalent solid- There is a class of solids called network solids in which the bonding is essentially due to a network of covalent bonds that extends throughout the solid.
    - Such solids are hard and rigid, or not malleable.
    - They have high melting points because the crystal is like one enormous molecule. The most well-known example of a network solid is diamond.

Kinetic Molecular Theory
Terms and Concepts

Ionic Bonds	Covalent Bonds	Metallic bonds
Conduction	Malleability	Convection
Kinetic molecular model	Solids	Liquids
Gases	Melting point	Boiling Point

Kinetic Molecular Theory

Instructional Resources

The following website contains simulations to help students understand phase change and the difference between chemical and physical changes.

http://www.bbc.co.uk/schools/scienceclips/ages/9_10/changing_state.shtml

The following website is information and is geared toward student learning and contains excellent visuals regarding states of matter, as well as phase changes.

http://www.chem4kids.com/files/matter_intro.html

KINETIC MOLECULAR THEORY

Activity #1—Molecules in Motion-Eureka!!

Questions to be investigated:

What are conduction and convection? What are the motion and arrangement of molecules in various states of matter? What are the properties of various solids?

Objectives:

C2.2B - Describe the various states of matter in terms of the motion and arrangement of the molecules (atoms) making up the substance.

C4.3B - Recognize that solids have a more ordered, regular arrangement of their particles than liquids and that liquids are more ordered than gases.

C2.2A - Describe conduction in terms of molecules bumping into each other to transfer energy. Explain why there is better conduction in solids and liquids than gases.

C3.3A - Describe how heat is conducted in a solid.

C2.2d - Explain convection and the difference in transfer of thermal energy for solids, liquids, and gases using evidence that molecules are in constant motion.

Teacher notes:

This activity is based on simulations found on youtube.com. To locate these simulations, go to the link found beneath each heading.

Materials:

Computers with internet access—make sure students can access youtube.com from school computers!

Source:

http://www.youtube.com/
Search term "Eureka Science Videos."

Questions developed by OSMTech Project Group.

Real-world connections:

Students will understand how heat is conducted in everyday real world interactions.

Description of Lesson:

This lesson allows students to solidify their understanding of kinetic molecular theory using a video series (Eureka) that is posted on youtube.com.

The lesson is grouped into sections based on various video clips and each clip has corresponding questions.

Molecules in a Solid

http://youtube.com/watch?v=AhBGMdhJ4nA

1. What are the three states of matter?
2. Give an example of each of the three states of matter.
3. What is the difference in motion in the states of matter?
4. Describe the motion of the particles in a solid.

Molecules in a Liquid

http://youtube.com/watch?v=hxqEUy9Dusk

1. Explain the shape of liquids.
2. Why does the sun melt the chocolate rabbit?
3. Which state of matter has more energy, solids or liquids?

Evaporation & Condensation

http://youtube.com/watch?v=yyxc-81JDbo

1. How do molecules escape from a liquid?
2. What is the process called?
3. Why does warmer water evaporate quicker than cold water?
4. Why can't he see the goldfish when taken out of the fridge?
5. What is this process called?

Conduction

http://youtube.com/watch?v=77R4arwD8G8

1. What happens to a metal ladle vs. a wooden ladle?
2. Why does this happen?
3. Give examples of some good conductors and bad conductors.
4. What's the secret to metals being good conductors?
5. When the metal gets hot, what happens to the free electrons?
6. Relate a game of pinball to what happens in metals.

Convection

http://youtube.com/watch?v=5pG-tkbQgMo

1. What would happen if you had the furnace on the top floor?
2. How does a radiator work?
3. What happens when water is heated?
4. Why does a hot air balloon expand?
5. Why does a system that uses water work the same as a system that uses gas?
6. What is included in the term "fluids"?
7. Draw the convection cycle below:

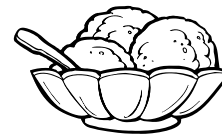
COLD FLUID	**HOT FLUID**

Molecules in Motion

http://youtube.com/watch?v=EH5v54dmb5U

Enjoy!!!!!

KINETIC MOLECULAR THEORY



Activity #2--Homemade Ice Cream Lab

Questions to be investigated:

Is freezing an exothermic or endothermic reaction?

Objectives:

C2.2B Describe the various states of matter in terms of the motion and arrangement of the molecules (atoms) making up the substance.

C4.3B Recognize that solids have a more ordered, regular arrangement of their particles than liquids and that liquids are more ordered than gases.

C5.4d Explain why freezing is an exothermic change of state.

Teacher Notes:

Ice Cream is simply a tasty way to observe scientific principles. The first concept is a phase change or the movement from one state of matter to another. The three primary states of matter we study are solids, liquids, and gases. Solids are tightly packed atoms that have rigid bonds that do not flow. Solids have a fixed volume and shape. Liquids are bound together, but not as tightly packed and their bonds are more flexible allowing them to flow. Liquids have a fixed volume, but their shape is the same as their container. Gases are loosely packed molecules that flow freely. Gases have an indefinite volume and shape because they take the volume and shape of their container.

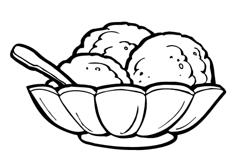
The second principle observed in the ice cream lab is the transfer of heat in a system. The two types of heat transfer are endothermic and exothermic reactions. Endothermic reactions remove heat from the surrounding environment into the primary system.

Exothermic reactions remove heat from the primary system and transfer it to the surrounding environment. In either case, the Law of Conservation of Energy is applied. Heat is a form of energy and it is neither created nor destroyed in a reaction, it merely changes form or location.

Materials: (per group):

1-gal Ziploc bag or plastic container	(4) 1-qt Ziploc bags
5 cups ice	1 cup rock salt
3 cups milk (3/4 cup/person)	16 tsp sugar (4 tsp/person)
4 tsp vanilla (1 tsp/person)	4 spoons (1/person)

Source: Chemistry: Chapter 16--Homemade Ice Cream Lab:



http://www.mvhs.fuhsd.org/mia_onodera/chemistry%20documents/labs%202007-2008/lab%2028%20chapter%2016-%20Ice%20Cream%20Lab%2008.doc

Ice Cream Lab, Adapted from UVA Physics Department:
http://www.school.cdfarmsite.com/labs/icecreamlab0506.doc

Procedure:

1. Wash your hands.
2. Obtain a small Ziploc bag and write your name on it.
3. Fill your small Ziploc bag with 3/4 cup of milk and 4 tsp sugar and 1 tsp vanilla. Add milk last.
4. Carefully "zip" your bag with the ice cream mixture. Check the seal, or you will end up with salty ice cream!
5. For your group, obtain a 1-gal Ziploc bag. Put five cups of ice and one cup of salt in the bag.
6. Place the small bags of the ice cream mixture in the salt-ice mixture.
7. Gently shake the large container until the contents of the small bags freeze.
8. Before opening your small Ziploc bag, rinse it in the sink so the salt does not go inside.
9. Enjoy!

Assessment:

Answer the following in the conclusion of your lab report:

1. What state of matter was the milk when you began?
2. What state of matter was the milk when you were done?
3. In order to change the phase of the milk, what had to be removed?
4. What happened to the heat energy that left the milk?
5. Why was the salt added to the ice?
6. If you did not add sugar would the ice cream have frozen faster? Why?
7. Why did the outside of the bag get wet? (Assume that your bag did not spring a leak.) What states of matter were involved in this process?

Kinetic Molecular Theory

Activity #3 – States of Matter Skits

Questions to be investigated:

What does the motion of particles look like in different states of matter?

Objectives:

C2.2B - Describe the various states of matter in terms of the motion and arrangement of the molecules (atoms) making up the substance.

C4.3B - Recognize that solids have a more ordered, regular arrangement of their particles than liquids and that liquids are more ordered than gases.

C2.2A - Describe conduction in terms of molecules bumping into each other to transfer energy. Explain why there is better conduction in solids and liquids than gases.

C3.3A - Describe how heat is conducted in a solid.

C2.2d - Explain convection and the difference in transfer of thermal energy for solids, liquids, and gases using evidence that molecules are in constant motion.

Teacher Notes:

This activity uses short and simple demonstrations that will get students involved in the states of matter. It may require more classroom space, as students will be physically acting out the motion of the particles. This could involve the entire class or a group of 5 or more students.

Sources:

Young Scientist Program Chemistry Teaching Team:

www.wustlysp.pbwiki.com/f/**States**+of+**Matter**-+Liquids+and+Gases.doc

Procedure/Description of Lesson:

Have the students assemble in a large space between the demonstration tables. Tell them they are all currently small molecules in the solid state, such as water molecules, and that they must stand still in a rigid shape (let's say a rectangle). Tell them that you, the experimenter "outside the system", are increasing the temperature. You may take a minute to ask them how exactly one could add energy to a system.

As it gets hotter, the "molecules" have more energy and move faster. When a sufficient amount of energy has been added, the water molecules are moving too vigorously to be a solid, and the transition from solid to liquid occurs. Point out that the more vigorously the "molecules" move, the more space they require. Keep adding energy until the students are acting as gas molecules.

Explain that in general, addition of energy to a group of molecules increases the molecules' kinetic energy, which is expended as random molecular movement, which in turn requires more space for any given number of molecules. Once the molecules' kinetic energy reaches a certain threshold, a state change occurs.

Assessment Ideas:

Have students describe what took place in the activity in terms of energy and states of matter.

KINETIC MOLECULAR THEORY

Activity #4--The CHEMISTRY of Ice Cream/Inquiry Based

Questions to be investigated: Is freezing an exothermic or endothermic reaction?

Objectives:
C2.2B - Describe the various states of matter in terms of the motion and arrangement of the molecules (atoms) making up the substance.
C4.3B - Recognize that solids have a more ordered, regular arrangement of their particles than liquids and that liquids are more ordered than gases.
C5.4d - Explain why freezing is an exothermic change of state.

Teacher Notes:
Don't give students the recipe; make your students use their brains. But you should guide their brains before they start.... Here are some sample questions to ask them to make them think about their recipes:

-Which of the 5 ingredients do you want IN the ice cream? (milk, sugar, vanilla)

-Which of the 5 ingredients should NOT be in? (ice, salt)

-Why are there 2 bags? (one for the "wanted" stuff, one for the other stuff)

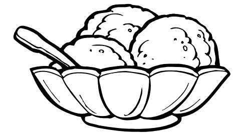
-How much of each ingredient goes into the ice cream? (I only put out the proper size cups so they have to figure out that its 1 cup milk, 1/3 c. sugar, ½ tsp. vanilla.)

Here's the actual recipe to refer to:

1. Place 1 c. milk, 1/3 c. sugar, and ½ tsp. Vanilla in small bag. Seal the small bag.
2. Fill large bag half full with ice and add a scoop of salt. Put the small bag inside the larger bag. Seal the large bag.
3. Shake and flip the large bag for a minimum of 10 minutes.
4. Check for solidification. If it's done- clean up, get a spoon, and enjoy! Be careful not to get the salt/ice mixture into your ice cream.

Materials:
Ice
Salt
Sugar
Milk
Vanilla extract

Source:



Chemistry: Chapter 16--Homemade Ice Cream Lab:

http://www.mvhs.fuhsd.org/mia_onodera/chemistry%20documents/labs%2020
07-2008/lab%2028%20chapter%2016-%20Ice%20Cream%20Lab%2008.doc

Ice Cream Lab, Adapted from UVA Physics Department:

http://www.school.cdfarmsite.com/labs/icecreamlab0506.doc

The Chemistry of Ice Cream:
http://www.scienceteacherprogram.org/chemistry/seeleyworksheet06.html

Procedure:

Who knew chemistry could be so tasty! Today we will be investigating colligative properties and how they affect freezing points, and some yummy results of energy changes.

I will not give you the recipe; you must use your brain. Here are some questions to guide your brain before you start

-Which of the 5 ingredients do you want IN the ice cream?

-Which of the 5 ingredients should NOT be in?

-Why are there 2 bags?

-How much of each ingredient goes into the ice cream?

Ingredients available for your recipe:

Ice
Salt
Sugar
Milk
Vanilla extract

Write your final recipe here. It must be approved by the teacher before you begin.

Assessment:

After you have successfully made your ice cream, describe the entire process using the following terms: solid, liquid, gas, exothermic, endothermic, freezing, energy flow, and phase change.

KINETIC MOLECULAR THEORY

Activity #5 – Demo - Comparing Heat Transfer by Convection and Conduction

Questions to be investigated:

How are conduction and convection affected by temperature?

Objectives:

C2.2B - Describe the various states of matter in terms of the motion and arrangement of the molecules (atoms) making up the substance.

C4.3B - Recognize that solids have a more ordered, regular arrangement of their particles than liquids and that liquids are more ordered than gases.

C2.2A - Describe conduction in terms of molecules bumping into each other to transfer energy. Explain why there is better conduction in solids and liquids than gases.

C3.3A - Describe how heat is conducted in a solid.

C2.2d - Explain convection and the difference in transfer of thermal energy for solids, liquids, and gases using evidence that molecules are in constant motion.

Teacher Notes:

This lab is designed to be a demonstration.

Materials:

Two tall cylindrical beakers
Water
food coloring
2 salsa containers
short piece of metal chain

Real World Connections:

methods of heat transfer in the atmosphere

Source:

Comparing Heat Transfer by Convection and Conduction:

http://www.atmos.washington.edu/~durrand/demos/convection_conduction.htm

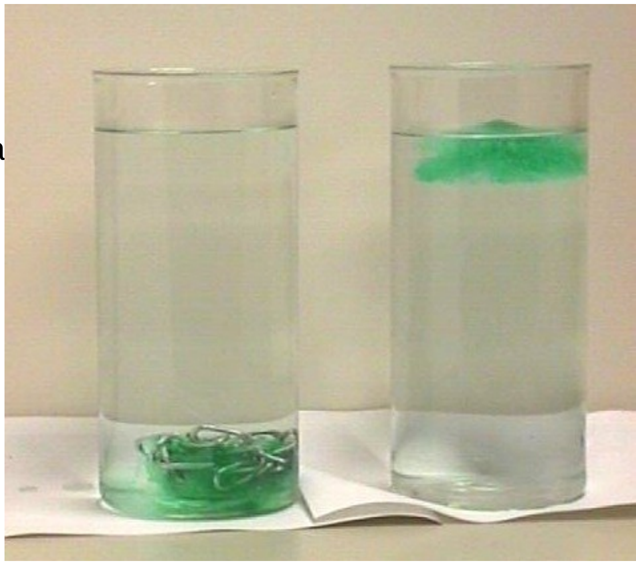
Procedure:

Before beginning demonstration explain the lab setup and have students make predictions.

Early Preparation - The metal chain is placed in one salsa container. Subsequently both salsa containers are filled with equal amounts of water dyed by food coloring and placed in the freezer until the water is frozen.

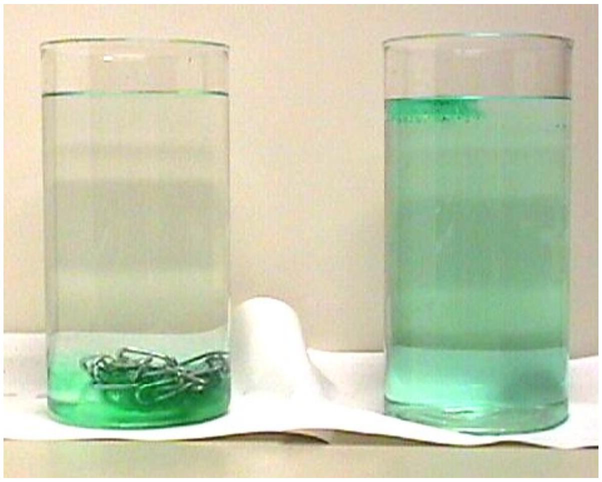
1) Two tall beakers, A and B, are filled with hot water (3/4 full only).

2) Ice chunks are taken out of the salsa containers and carefully placed in the tall beakers: The ice with chain in Beaker A; the ice without chain in Beaker B.



Immediately:

- The ice without chain floats near the surface of Beaker B
- The ice with chain sinks to the bottom of Beaker A



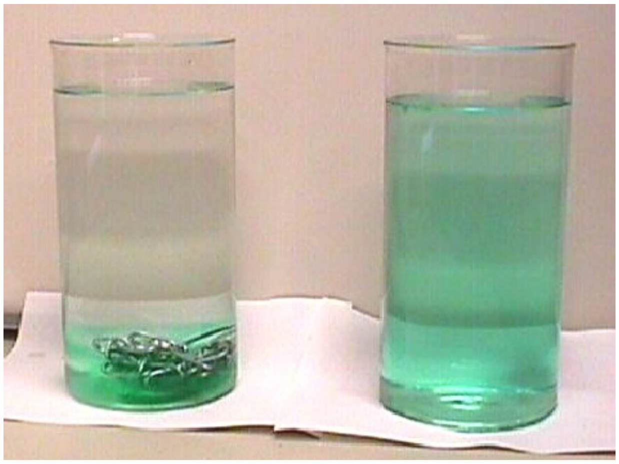
After few minutes:

- In Beaker A, the cold, colored water remains near the bottom of the beaker, and hot clear water stays near the top.

- In Beaker B, the dyed water melted from the ice quickly starts sinking down and warmer water from the bottom of the beaker rises to replace it

After 30 minutes:

- The ice is still largely un-melted at the bottom of the beaker A. Just above the surface of the ice, there is a small layer of colored water. Above that level, the water is clear and much warmer than the ice (at a temperature fairly close to its initial temperature).
- In Beaker B, all ice has melted, and all of the water in the beaker is of uniform temperature and color



Assessment:

Have students pair and share to discuss the results of the demonstration. Their discussion should include the concepts of conduction, convection, density, and heat transfer.

Explanation for teacher:

Warm water is more buoyant than cold water. Since warm water is below the ice and cold water in Beaker B, the warm water rises, whereas the cold water sinks. This is convection in action!

In Beaker A, on the other hand, the warm buoyant water overlays the cold ice. This is a very stable arrangement, and convection does not occur. Heat transfer only occurs through conduction in this case.

In fluids, such as water and air, convection is a much more efficient method of heat transfer than conduction. This difference in efficiency produced the dramatic difference in the time required to melt the ice. Although conduction was at work in both cases, it transferred much less heat than convection.

Kinetic Molecular Theory

Activity #6 – Ionic Compounds vs. Covalent Molecules.

Questions to be investigated:

Which materials around you are ionic? Which are covalent? Is your body made up of mostly ionic or mostly covalent materials? What about our classroom? What about our community? How can you tell ionic compounds and covalent molecules apart?

Objectives:

C4.3h Explain properties of various solids such as malleability, conductivity, and melting point in terms of solids structure and bonding.
C4.3i Explain why ionic solids have higher melting points than covalent solids (for example, NaF has a melting point of 995°C, while water has a melting point of 0°C).
C5.4e Compare the melting point of covalent compounds based on the strength of IMF (intermolecular forces).

Materials:

NaCl, coarse grain
Sugar (sucrose)
Hammer
Crucible
Conductivity indicator
Distilled water
NaCl, fine grain
Roll sulfur
Microscope
Hot plate
100mL beaker

Safety Concerns:

- Goggles must be worn at all times.
- Be careful with hot objects. They will not appear hot.
- Do not touch or taste any of the chemicals formed in lab.
- Do not touch both electrodes of the conductivity indicator at the same time.

Sources:

Ionic Compounds versus Covalent Molecules Honors:
http://rabyscience.com/resources/Ionic.Covalent.Garfield.HONORS.doc

Procedure/Description of Lesson:

In this lab, we will investigate some of the differences between ionic compounds and covalent molecules through crystal structure, melting point, and conductivity.

State the Problem

State the Hypothesis

Pre-Lab

1. What are two major differences between ionic and covalent bonds?

2. Identify each as either ionic or covalent & explain why: NaCl, sugar ($C_{12}H_{22}O_{11}$), & sodium bicarbonate ($NaHCO_3$)

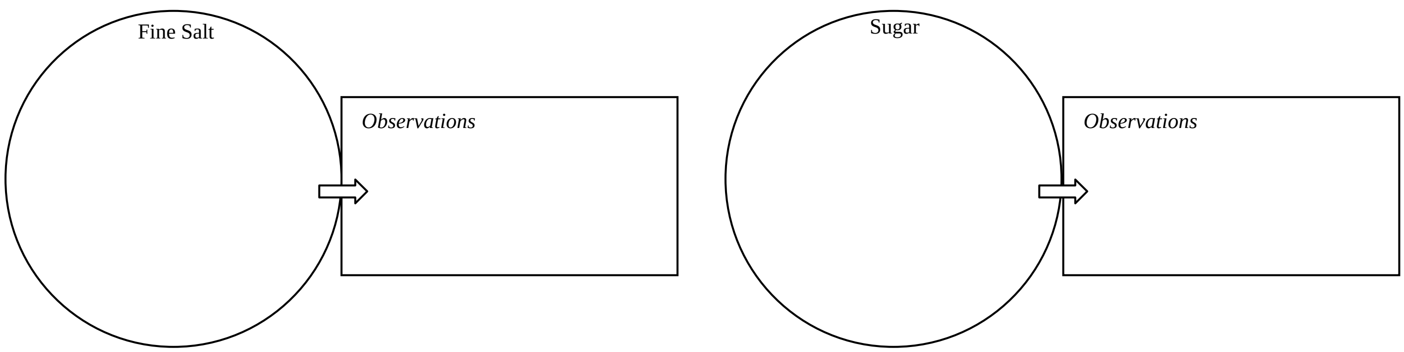
Procedure:

Part A: Crystal Structure

1. Observe salt under the microscope. Record observations.
2. Observe sugar under the microscope. Record observations.

Results:

Part A: Crystal Structure



Part B: Melting Point

1. Place a pea-sized pile of NaCl in a 100mL beaker and place on a hotplate. If NaCl melts within 3 minutes, then record the melting point as low. If NaCl does not melt within 3 minutes, record the melting point as high.
2. Repeat step 1 for sugar. Record your melting points.

Results

Part B: Melting Point

Melting Point NaCl		Melting Point Sugar	

Part C: Conductivity

1. Pour about 50mL distilled water into a clean 100mL beaker. Test the distilled water for conductivity. Record your result.

2. Add and dissolve a small pile of NaCl into the distilled water. Test for conductivity. Record your result.
3. Empty and wash out your beaker and add about 50mL distilled water.
4. Add and dissolve a small pile of sugar into the distilled water. Test for conductivity. Record your result.

Results

Part C: Conductivity

Test Substance	Conductivity (good, poor, none, etc)
Distilled Water	
NaCl + Distilled Water	
Sugar + Distilled Water	

Analysis

1. Structure analysis:
   a) What is the difference in structure between ionic and covalent bonds? Draw an atomic diagram (one that shows individual atoms) of both NaCl and sugar to help demonstrate the difference.
   b) Say you had tapped on the salt with a hammer until it broke. What would the broken pieces have looked like under the microscope? How do you know?
   c) Say you had tapped on the sugar with a hammer until it broke. What would the broken pieces have looked like under the microscope? How do you know?

2. Melting Point analysis:
   a) How does the melting point for covalent molecules and ionic compounds differ?
   b) Why are their melting points different?
   c) What does this mean in terms of their bond strength?

3. Conductivity analysis:
   a) Do ionic compounds conduct electricity?
   b) Why do you think this is the case?
   c) Do covalent molecules conduct electricity?
   d) Why do you think this is the case?
   e) When dissolving a substance in a liquid, chemists follow the rule that "like dissolves like"—this means that covalent compounds will dissolve in covalent liquids and ionic compounds will dissolve in ionic liquids. Based on this rule and your observations, is vegetable oil a covalent or ionic liquid?

4. Create a table with the overall properties of ionic compounds and covalent molecules including their crystal structure, melting point, conductivity, and bond strength. Feel free to add anything else!

5. a) Which has the stronger bond: CaO or H_2O? Why?
   b) Which conducts electricity in water: glucose ($C_6H_{12}O_6$) or NaBr? Why?
   c) Which has a higher melting point: NH_3 or $FeCl_2$? Why?

Assessment Ideas:

Help out Detroit Now!

You are asked to prepare a report for a new community center that will be built in Detroit if the city gets to host the Olympics. The Home Builders Association of America (HBAA) has proposed constructing all new centers out of the following materials:

- Concrete
- Ice
- Plastic
- Glass
- Steel
- Styrofoam

Remember that Detroit often has extreme heat, lightning strikes, hail, floods, acid rain, and extreme cold.

<u>Extreme Heat</u>

Consider Melting Point – Will the center melt on really hot days?

<u>Lightning Strikes</u>

Consider Electrical Conductivity – Will the center in a rainstorm conduct electricity from lightning safely to the ground?

<u>Hail</u>

Consider Strength & Malleability – Will the center break in a hailstorm?

<u>Floods</u>

Consider Density – Will the center float or sink during the flood?

<u>Acid Rain</u>

Consider Reactivity with Acid – Will the center react with acid in the rain?

<u>Extreme Cold</u>

Thermal Conductivity – Will the center keep you warm on really cold days?

Your Report

In your report be sure to discuss:

- Which material you would choose and why (base this on each condition the material will have to endure; you may want to prioritize certain conditions as more important than others).
- Exactly where in Detroit you would put the center. Consider providing a map.
- Why you would put the center in the location you choose.

<u>Phase Changes</u>

Content Statements

C4.3x – Solids

Solids can be classified as metallic, ionic, covalent, or network covalent. These different types of solids have different properties that depend on the particles and forces found in the solid.

C5.4x - Changes of State

All changes of state require energy. Changes in state that require energy involve breaking forces holding the particles together. The amount of energy will depend on the type of forces.

C5.4 - Phase/Change Diagrams

Changes of state require a transfer of energy. Water has unusually high-energy changes associated with its changes of state.

Content Expectations

C4.3i - Explain why ionic solids have higher melting points than covalent solids (for example, NaF has a melting point of 995°C, while water has a melting point of 0°C).

C5.4B - Measure, plot, and interpret the graph of the temperature vs. time of an ice water mixture, under slow heating, through melting and boiling.

C5.4d - Explain why freezing is an exothermic change of state.

C5.4e - Compare the melting point of covalent compounds based on the strength of IMF (intermolecular forces).

Instructional Background Information:

Energy

- All changes of state require energy.
    - Changes in state that require energy involve breaking forces holding the particles together.
    - The amount of energy will depend on the strength of the intermolecular forces.

Types of Phase Changes

Start from:	**Change to:**	**Name**
Solid	Liquid	**Melting**
Liquid	Solid	**Freezing**
Liquid	Gas	**Boiling**
Gas	Liquid	**Condensation**
Solid	Gas (skipping liquid phase)	**Sublimation**
Gas	Solid (skipping liquid phase)	**Deposition**

Exothermic and Endothermic

- An energy change accompanies the forming or breaking of a bond between atoms in a molecule.
    - o Energy is released when a bond forms - Exothermic
    - o Energy must be added to break the bonds in a molecule - Endothermic

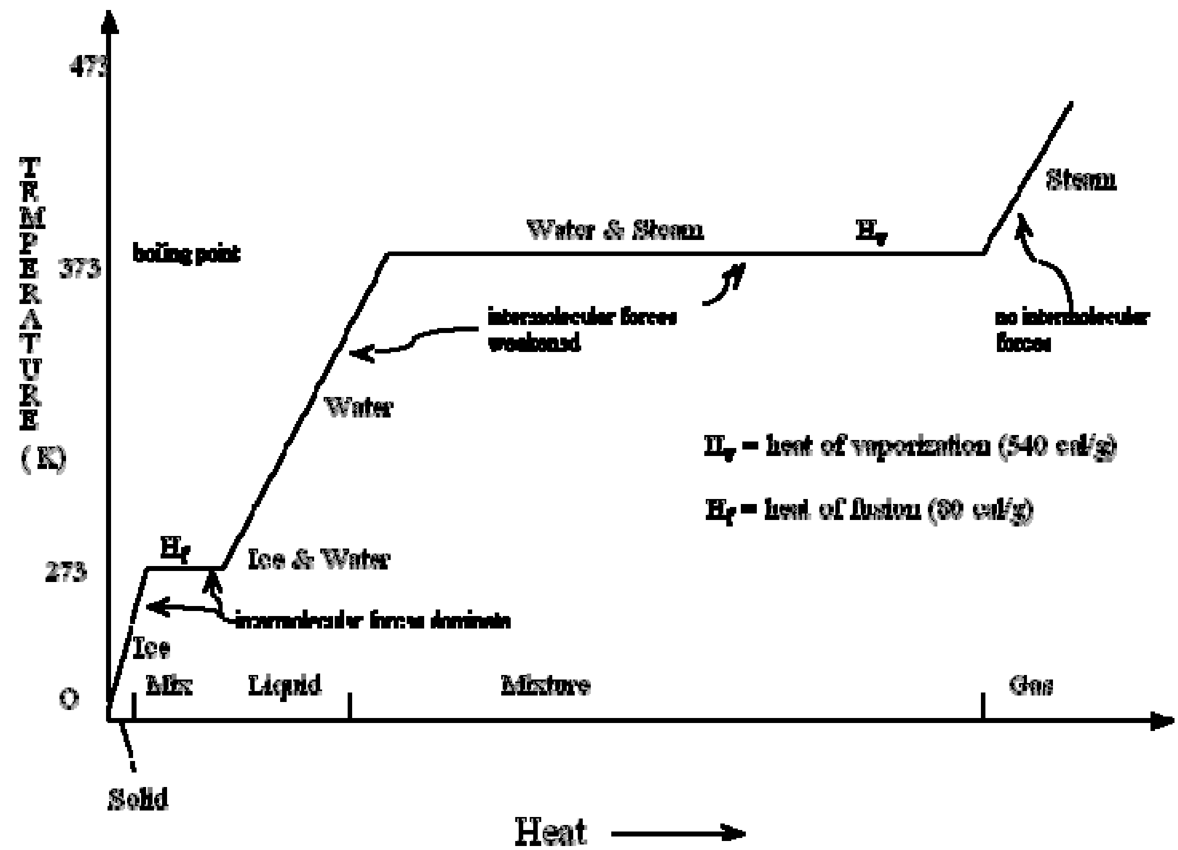
Melting Points of Ionic and Covalent Solids

- Ionic solids have high melting points and relatively strong forces that hold them together.
    - o In an ionic compound, each ion is attracted strongly to each of its neighbors and repulsions are minimized. The large attractive forces result in a very stable structure and accounts for the fact that most of the ionic compounds are crystalline solids.
    - o This is why ionic compounds have high melting temperatures.
    - o For example, NaCl has a high melting point of 801 degrees C and NaF has a melting point of 995 degrees C.
- In a covalent bond, a tug-of-war takes place between the atoms, ending more or less in a standoff.
    - o To melt this solid, enough energy must be given to the molecules to allow them to overcome the force of attraction holding them in fixed positions. This force is weak in a covalent solid and so it is easily melted.

Temperature vs. Time (Energy Added graph of Phases of Water

- A transfer of energy occurs at every change of phase.
- Heat of Fusion – the amount of energy needed to change any substance from solid to liquid (or a liquid to solid).
- Heat of Vaporization – the amount of energy required to change any substance from liquid to gas (or a gas to liquid).

Phase Change Diagram for Water



Phase Changes
Terms and Concepts

Solid	Conduction	Covalent solid
Liquids	Convection	Melting point
Gases	Malleability	Exothermic
Plasma	Ionic solid	Endothermic
Intermolecular forces		

Phase Changes
Instructional Resources

The following website contains simulations to help students understand phase change and the difference between chemical and physical changes.

http://www.bbc.co.uk/schools/scienceclips/ages/9_10/changing_state.shtml

The following website is information and is geared toward student learning and contains excellent visuals regarding states of matter, as well as phase changes.

http://www.chem4kids.com/files/matter_intro.html

Phase Changes
Activity #1--Phase changes of water

Question to be investigated:

How do you change ice to water or water to steam?

Objectives:

C5.4B Measure, plot and interpret the graph of a temperature vs. time graph of an ice water mixture, under slow heating, through melting and boiling.

Teacher Notes:

This is a lab where students create a temperature vs. time graph for heating of water.

Materials:

Thermometer
Ring stand with thermometer clip
Hot Plate
Crushed Ice
100 mL Beaker
Stirring Rod

Safety concerns:

Students must wear goggles and avoid contact with hot plate and beaker.

Real world connections:

The chemical water can be a solid (ice), a liquid (water), or a gas (steam). Solid, liquid, and gas are the three phases of matter. Water, oxygen, iron, and every other chemical can exist in any of these three phases. In this investigation you will find out exactly how to change water from one phase to another. You will also discover why we don't often find solid oxygen and gaseous iron on Earth.

Sources:

Hsu, Chaniotakis, Damelin. A Natural Approach to Chemistry. 2008 Lab Aids Incorporated.

Procedure:

1. Fill the beaker half full with crushed ice and a little water.
2. Record the temperature of the ice water in the table below. This is the temperature at '0 minutes.'
3. Turn the hot plate on.
4. Measure the temperature every 30 seconds until the water begins to boil. Also, watch carefully and note the time when all the ice has melted and also when the water begins to boil by making a mark in your data table.
5. Stir the beaker constantly but, gently.
6. Continue to take the temperature until almost all the water has boiled off.
7. Be sure to note the last time and temperature taken.
8. DO NOT TOUCH YOUR BEAKER!! & TURN YOUR HOT PLATE OFF!!!!

Table 1: Temperature of Water

Time (Seconds)	Temperature (degrees Celsius)

Analyzing the Data:

When the experiment is done, graph the data from Table 1.

Observations:

1. Describe the temperature vs. time graph. Are some parts sloped differently than others?

2. A chemistry book writes H_20 (s), H_20 (l), and H_20 (g). What do the letters in the parentheses mean?

3. At ordinary atmospheric pressure, what is the highest temperature that liquid water can reach before it boils? Your data from Table 1 should show you this. Compare your results with the rest of the class and figure out the average value.

Phase Changes

Activity#2-- Exothermic Sodium Acetate Lab/Demonstration

Questions to be investigated:

How does a chemical reaction give off heat?

Objectives:

C5.4d Explain why freezing is an exothermic change of state.

Teacher notes:

This demonstration illustrates how chemical reaction can either give off heat (exothermic) or absorb heat (endothermic). The crystallization of a supersaturated sodium acetate solution is an exothermic process that is available commercially in the form of hand warmers. This demonstration can also be carried out in a large flask by seeding the supersaturated solution with a small sodium acetate crystal.

Materials:

Flask of supersaturated sodium acetate
Sodium acetate seed crystals
Hand warmers (one for each or every other student)
125 mL Erlenmeyer flask
Glass stirring rod
Squeeze bottle of water

Safety Concerns:

Hand warmers do tend to get very warm. It is possible that someone who is sensitive to heat or cold could be burned. Always were safety goggles when working with these chemicals. Be sure to provide safety goggles for any of the audience members who may be helping you or who are handling these demonstrations.

Source:

Endothermic and Exothermic Reactions:
http://www.chem.umn.edu/outreach/endoexo.html

Procedure:

Hand warmers can be passed out among the audience (for smaller groups there should be enough for each or at least every other student). Have the student click the metal disk inside the hand warmers to activate the crystallization. They should notice that the crystallization will begin at the metal disk and spread outward though the whole package. As an alternative, the large flask containing the sodium acetate solution can be used. To activate the crystallization, add a single seed crystal of sodium acetate. If the solution has been regenerated properly you should observe a long crystalline spike run out from the seed crystal and eventually spread through the whole solution. As the solution crystallizes, the system will give off heat.

Phase Changes

Activity #3: Endothermic & Exothermic Reactions Demo

Questions to be investigated:

What is the difference between endothermic and exothermic reactions?

Objective:

C5.4d Explain why freezing is an exothermic change of state.

Materials:

Thermometer
Two 250 mL beaker
9 g anhydrous borax
13 g Epsom salt
Water

Safety Concerns:

Flush solutions down the drain with plenty of water.

Real World Connections:

Students will gain a better understanding of chemical reactions.

Sources:

Buthelezi, T. et al. Glencoe Science Chemistry Matter and Change, Columbus, OH: The McGraw-Hill Companies, Inc.,2008.

Procedure:

Measure 100 mL of water into each of two 250 mL beakers. Put a Celsius thermometer in each beaker and allow students to read the water's temperature. Record the temperatures and remove the thermometers. While you add approximately 9 g of anhydrous borax to one beaker have a student add approximately 13 g of Epsom salt to the second beaker. When dissolved, read and record the temperature of the solutions.

Ask students which of theses processes is exothermic and which is endothermic. Have students pair and share to discuss what is happening in each process.

Note:

Temperature should increase with the dissolved borax and should decrease with the dissolved Epsom salt.

The dissolving of the borax is exothermic and the dissolving of the Epsom salt is endothermic

Phase Changes

Activity #4--Phase Change/Inquiry Lab

Questions to be investigated:

Does temperature increase as a phase change occurs?

Objectives:

C5.4B Measure, plot and interpret the graph of a temperature vs. time graph of an ice water mixture, under slow heating, through melting and boiling.

Teacher notes:

This is an inquiry based lab where students are going to investigate temperature changes for the heating of water.

Materials:

Thermometer
Ring stand with thermometer clip
Hot Plate
Crushed Ice
100 mL Beaker
Stirring Rod
Graph paper

Safety Concerns:

Students must wear goggles and avoid contact with hot plate and beaker. It should be noted that the hand warmers can be recharged by boiling them in water for six to ten minutes. Be sure to collect all of the hand warmers when you are done, the have a tendency to disappear. Ask the students see if they can come up with any practical applications for exothermic reactions. They may suggest something like a car battery heater or a chemical ice pack for injured muscles.

Real World Connections:

The chemical water can be a solid (ice), a liquid (water), or a gas (steam). Solid, liquid, and gas are the three phases of matter. Water, oxygen, iron, and every other chemical can exist in any of these three phases. In this investigation you will find out exactly how to change water from one phase to another. You will also discover why we don't often find solid oxygen and gaseous iron on Earth.

Sources:

Hsu, Chaniotakis, Damelin. A Natural Approach to Chemistry. 2008 Lab Aids Incorporated.

Procedure:

Directions: Design an investigation to answer the following question: “How is temperature effected as phase change occurs?”

Develop each component of the investigation including a hypothesis, procedures, data analysis, and conclusion.

Implement your procedure only when it has been approved by your teacher.

Phase Changes

Activity #5-Everyday Reactions

Question to be Investigated:

What exothermic and endothermic reactions do you encounter on a daily basis?

Objective:

C5.4d Explain why freezing is an exothermic change of state.

Teacher Notes:

This is a structured inquiry project that should be done when students have a strong understanding of exothermic and endothermic reactions and heat flow.

Real World Connections:

Students are tying in real world examples of heat flow in systems.

Source:

Buthelezi, T. et al. Glencoe Science Chemistry Matter and Change, Columbus, OH: The McGraw-Hill Companies, Inc.,2008.

Procedure:

Student Directions: Think about two exothermic and two endothermic reactions or processes that you encounter in your everyday life.

Record the following information:

- a description of each reaction or process
- the direction of heat flow
- the change in the enthalpy of the system
- change in enthalpy of the surroundings

Phase Changes

Activity #6—Phase Change Problem Solving Lab

Question to be investigated:

How can you derive the heating curve for water?

Objective:

C5.4B Measure, plot and interpret the graph of a temperature vs. time graph of an ice water mixture, under slow heating, through melting and boiling.

Materials:

Graph paper

Source:

Buthelezi, T. et al. Glencoe Science Chemistry Matter and Change, Columbus, OH: The McGraw-Hill Companies, Inc.,2008.

Procedure:

Water molecules have a strong attraction to one another because they are polar. They form hydrogen bonds that affect water's properties. The polarity of water accounts for its high specific heat and relatively high enthalpies of fusion and vaporization.

Analysis:

Use the data in the table to plot a heating curve of temperature vs. time for a 180 g sample of water as it is heated at a constant rate from -20 degrees Celsius to 120 degrees Celsius. Draw a best-fit line through the points. Note the time required for water to pass through each segment of the graph.

Time (min)	Temperature (degrees C)	Time (min)	Temperature (degrees C)
0.0	-20	13.0	100
1.0	0	14.0	100
2.0	0	15.0	100
3.0	9	16.0	100
4.0	26	17.0	100
5.0	42	18.0	100
6.0	58	19.0	100
7.0	71	20.0	100
8.0	83	21.0	100
9.0	92	22.0	100
10.0	98	23.0	100
11.0	100	24.0	100
12.0	100	25.0	120

Think Critically:

Analyze each of the five regions of the graph, which are distinguished by an abrupt change in slope. Indicate how the absorption of the heat changes the energy (kinetic and potential) of the water molecules.