UTeach Outreach The University of Texas at Austin

Chemistry Theater (States of Matter)

Length of Lesson: Four 50-minute class periods

Content Standards Addressed in Lesson:

TEKS5.5A classify matter based on physical properties, including mass, magnetism, physical state (solid, liquid, and gas), relative density (sinking and floating), solubility in water, and the ability to conduct or insulate thermal energy or electric energy (Reporting Category 1 – Readiness Standard)

TEKS5.5B identify the boiling and freezing/melting points of water on the Celsius scale (Reporting Category 1 – Supporting Standard)

TEKS6.5A know that an element is a pure substance represented by chemical symbols;

TEKS6.5C differentiate between elements and compounds on the most basic level (Reporting Category 1 – Supporting Standard)

NSES (1996) **Grades 5-8 – Content Standard B**

PROPERTIES AND CHANGES OF PROPERTIES IN MATTER

- A substance has characteristic properties, such as density, a boiling point, and solubility, all of which are independent of the amount of the sample.

Scientific Investigation and Reasoning Skills Addressed in Lesson:

TEKS6.2A in all fields of science, analyze, evaluate, and critique scientific explanations by using empirical evidence, logical reasoning, and experimental and observational testing, including examining all sides of scientific evidence of those scientific explanations, so as to encourage critical thinking by the student;

TEKS6.2E analyze data to formulate reasonable explanations, communicate valid conclusions supported by the data, and predict trends.

TEKS6.3B use models to represent aspects of the natural world;

TEKS6.3C identify advantages and limitations of models such as size, scale, properties, and materials.

NSES (1996) **Grades 5-8 – Content Standard A**

- Use appropriate tools and techniques to gather, analyze, and interpret data.
- Develop descriptions, explanations, predictions, and models using evidence.

I. Student Prerequisite Skills/Understandings

- Students have a basic understanding of the similarities/differences of atoms, elements and compounds.

II. Objectives: Students will be able to

- Draw/identify a model that represents matter in three states – solid, liquid, gas.
- Use correct terminology to describe the phase changes of matter (melting, freezing, evaporating, boiling and condensing) and be able to identify the sequence of phase changes with water.
- Explain the temperature conditions (Celsius and Fahrenheit) for water to boil or freeze.
- Predict the effect on a substance's state of matter when heat energy is increased or decreased.
- Relate the phases of matter to the relative energy level of the particles.
- Identify characteristic properties of substances that remain constant.
- Classify the effects of electrical charges at the molecular level: like charges repel and opposite charges attract.
- Read the scale on a thermometer.
- Explain **why** water particles behave they way they do when heat energy is increased/decreased

III. Supplies Needed

- Materials required for making a large thermometer (see instructions attached)
- Digital camera/printer
- Template for phase changes project
- Beaker with hot plate and ice
- Laptop or computer one per pair
- Poster board
- Two – bar magnets
- Two – brown paper bags
- A few meters of string

IV. Advanced Preparation

Day 1

- Heat a beaker on a hot plate in front of class.
- Turn on all computers and bookmark *States of Matter Basics* PhET simulation see: http://phet.colorado.edu/en/simulation/states-of-matter-basics
    - For more ways to get PhET sims on computers see: http://phet.colorado.edu/en/get-phet.

Day 2

- Make a large thermometer see attached document "How to Make a Large Thermometer."

Day 3

- Print out pictures of students from Day 2.

Day 4

- Place bar magnets in brown paper bags.
- Make oxygen and hydrogen cards.

- Print two O's and two H per student on different colored paper. Tie string between the two O cards so that students can wear it like a sandwich board. Cut the H card in half and then tie string connecting the sides of each piece so that students can wear them on their hands.

5E Organization
Day 1

Engage (10 minutes)

Content Focus: Water can exist in many forms (states of matter). Adding heat causes water to change forms. The smallest amount of water that could exist and still be water is a water particle.

Hold a piece of ice in your hand. Ask students to make observations and explain what is causing the ice to change. Students predict what they think will happen if the liquid water (from the ice) is poured into a hot beaker. Pour the melted water (from the ice cube) into a heated beaker. Note that the water started as a solid (ice), melted or turned into a liquid in your hand, and then evaporated into a gas when placed on the hot plate. Discuss what the smallest amount of water that could exist and still be water (a water particle). Fill a beaker with water from cup or your hand and place on hot plate. Ask for a student volunteer to note the initial water level and write on board. Instruct students to write a statement about the initial volume of water in the beaker and how they think it will change over time.

Questions to guide students' learning and thinking	Questions to gather information about students' understanding and learning
• [put ice cube in your hand] What is happening? • If I put this liquid water into a beaker on a hot plate, what do you think will happen? • [pour water into beaker] What is happening? • When someone asks you what your initials are, what does that mean?	• Why is the ice melting? What is causing it to melt? • Why is the water evaporating? What is causing it to evaporate? • What is the smallest amount of water that could exist and still be water?

✓ **Checkpoint:** Students can describe their observations. All students have written their statement about what they think will happen to the water in the beaker.

Explore – Chemistry Theater Act 1 – Part 1 (30-35 minutes)

Content Focus: Water can exist in various forms, the different states of matter have different properties. Matter can change states through phase changes, classify matter based on physical properties, including physical state (solid, liquid, and gas)
Investigation and Reasoning Skills: communicate valid conclusions supported by observations, use models to represent aspects of the natural world

Select a few volunteers to act as water particles in a solid ice cube. Guide students, through questioning, to become very orderly rows (to model the arrangement of atoms/particles in a solid state). Explain that a solid is a state or phase of matter. Ask students to model a liquid making connections to the melting ice cube in the Engagement. Pretend to pour the water particles (students) into a hot plate and ask the students to model

what they think will happen. Explain that this is evaporation: a liquid becoming a gas. Ask students to return to their seats. Select a volunteer to read the new water level on the beaker in the front of the class. Discuss how the volume changed and ask students to explain why using their observations from modeling water particles.

Questions to guide students' learning and thinking	Questions to gather information about students' understanding and learning
• How do you think you would position yourself in a solid/liquid/gas? • How would you stand if all of you were water particles in one ice cube? • If I told you that all the particles in a solid were very tightly packed together, how would you adjust your model? • Particles in a solid are very orderly. What should you do? • Do you think the particles in a solid move? Why or Why not? • [returning to beaker in front of class] What has changed about the water in the beaker?	• What is the difference between a solid and a liquid? A gas? • What needs to be added/removed to cause a phase change or a change in state? • How does the movement of the particles relate to the state they are in? • If there was a decrease in volume of water in the beaker, what happened to the water? • How is your prediction similar/different from what happened to the water in the beaker?

✓ **Checkpoint:** Students have acted out the three states of matter and can describe the properties of each.

Explore – *States of Matter Basics* PhET Simulation (15 minutes)

Content Focus: classify matter based on physical properties, including physical state (solid, liquid, and gas)
Investigation and Reasoning Skills: use models to represent aspects of the natural world, identify advantages and limitations of models such as size, scale, properties, and materials, in all fields of science, analyze, evaluate, and critique scientific explanations by using empirical evidence, logical reasoning, and experimental and observational testing, including examining all sides of scientific evidence of those scientific explanations, so as to encourage critical thinking by the student

Explain that the students will continue investigating the different states of matter using a computer simulation. Assign students to role of either Driver or Navigator and discuss responsibilities of each. Pass out laptops and give students five minutes to explore the simulation. Collect students' attention and select a few students to come to the front of the class to show what they have discovered the simulation can do using the teacher's projected computer. Pass out activity sheets (1 per pair) and allow students 15 minutes to complete their investigations. Halfway through their investigations, ask student to switch roles.

Questions to guide students' learning and thinking	Questions to gather information about students' understanding and learning
• What can you change about the simulation? • What have you tried? • What do you notice about the simulation?	• When the particles are moving really fast, does the matter being modeled have more or less heat energy? How do you know?

• What happens when you change the state using this model?	• How does each state of matter compare to the other when you keep the amount of particles and the energy the same? • How does this model connect to the Chemistry Theater we just acted out? (Discuss similarities and differences) • What is the purpose of the computer model and the Chemistry Theater we just acted out? (Try to use the words particle, heat energy, phase change and states of matter in your response) • How is the computer model not like real life? • What modifications or improvements would you make to the simulation? • What are the advantages/disadvantages of using a computer simulation?

✓ **Checkpoint:** Students have completed their *States of Matter Basics* activity sheet.

Day 2

Explain – Chemistry Theater Act 1, Part 2 (20 minutes)

Content Focus: classify matter based on physical properties, including physical state (solid, liquid, and gas), identify the boiling and freezing/melting points of water on the Celsius scale, matter changes states based on the amount of heat energy added or removed
Investigation and Reasoning Skills: in all fields of science, analyze, evaluate, and critique scientific explanations by using empirical evidence, logical reasoning, and experimental and observational testing, including examining all sides of scientific evidence of those scientific explanations, so as to encourage critical thinking by the student, use models to represent aspects of the natural world

Review what the students modeled the previous class period (the difference in movement of the particles in a solid, liquid or gas; what happens when heat energy is increased or decreased, etc.) Set boundaries in classroom and have the students model a solid again. This time use a large thermometer to adjust the heat energy within their container. Discuss the relationship between the temperature and the amount of heat energy present in the container. As students are acting out the states of matter, take a photograph of the students for them to use in their projects (to be completed on Day 3). Introduce the terms: phase change, melting, evaporation and condensation. Discuss the melting/freezing and boiling/condensation points for water. Explain that the melting and boiling points of a substance are physical properties of that substance. Ask students why knowing these values might be important. Explain that a phase change is a physical change.

Questions to guide students' learning and thinking	Questions to gather information about students' understanding and learning
• If you increased the amount of heat energy of a container of water, what do you predict would happen to the particles? • If you decreased the amount of heat energy of a container of water, what do you predict would happen to the particles of water? • Recall what we modeled yesterday with the simulation. How did you get from an orderly, tightly packed solid to free flowing liquid? • Does an ice cube have heat energy? Why or why not?	• How would you describe the difference in the movement of the particles in a solid, liquid or gas? • What does it mean when you said "add" or "turn up heat energy"? • How can we measure the amount of heat energy in matter? • When the number goes up the thermometer, what does this tell us about the heat energy? • How could I model decreasing heat energy with the thermometer? • Thinking about the ice cube, where did the heat energy come from? • Think about the water we put in the beaker on the hotplate. What changed about the water? • Why would knowing a substance's melting and boiling points be useful or important to know? • What is another physical property of a substance that can be used for identification?

✓ **Checkpoint**: Students have acted out three states of matter and key terms listed above have been introduced. **NOTE:** print pictures (one of each per group of 4) before Day 3.

Day 3

Elaborate/Evaluate – Chemistry Theater Act 1, Part 2 (continued)

Content Focus: classify matter based on physical properties, including physical state (solid, liquid, and gas), matter changes states based on the amount of heat energy added or removed
Investigation and Reasoning Skills: in all fields of science, analyze, evaluate, and critique scientific explanations by using empirical evidence, logical reasoning, and experimental and observational testing, including examining all sides of scientific evidence of those scientific explanations, so as to encourage critical thinking by the student, use models to represent aspects of the natural world

Divide students into groups of 4. Explain that the students will use the pictures taken from the previous day to help explain the relationship between heat energy and phase changes. Pass out one set of pictures per group with "Phase Changes" sheet. Students place the pictures in order, label the phase change, label the amount of energy and order/disorder using the arrows. In the beaker images, the students should draw dots to represent what the particles look like in that phase. In addition, the students should write a brief essay to explain the relationship between heat energy and phase changes.

Questions to guide students' learning and thinking	Questions to gather information about students' understanding and learning
• What physical properties of water are different? • How should you divide the pictures? • How do you know what state of matter the particles are in?	• When you make the dots to represent the water particles, why should you use the same amount of dots for each state of matter? Using the same number of dots is a way to model what concept? • Suppose one classmate uses 50 dots to represent water particles and another uses 100 dots to represent water particles. What would the difference in the number of dots represent? • What physical properties of their water are different? • When liquid water changes to a gas, what physical properties of the water change? What properties remain constant – the same?

✓ **Checkpoint:** Students have completed their diagrams and essays.

Day 4

Engage (10 minutes)

Content Focus: like charges repel and opposite charges attract
Investigation and Reasoning Skills: make predictions and formulate conclusions based on evidence

Hold up two paper bags each containing a bar magnet. Ask students to predict what they think could be in the bags and how they could determine what is inside without opening them. Put bags close each other and ask students what they think is inside. Open bags and show students the magnets.

Questions to guide students' learning and thinking	Questions to gather information about students' understanding and learning
• What do you think could be in these bags? • How could we determine what is inside of them without opening the bags? • [after moving bags close to each other] Now, what do you think is in these bags? • How could we test your hypothesis that they are magnets?	• What makes a magnet special? • Which poles attract and which poles repel?

✓ **Checkpoint:** Students have viewed demonstration.

Explore/Explain – Chemistry Theater Act 2 (30 minutes)

Content Focus: know that an element is a pure substance represented by chemical symbols, differentiate between elements and compounds on the most basic level, like charges repel and opposite charges attract
Investigation and Reasoning Skills: in all fields of science, analyze, evaluate, and critique scientific explanations by using empirical evidence, logical reasoning, and experimental and observational testing, including examining all sides of scientific evidence of those scientific explanations, so as to encourage critical thinking by the student, use models to represent aspects of the natural world;

Give students five minutes to discuss what they know about water with their shoulder partner (i.e. chemical name and symbols, properties, phase changes, etc). Explain that water is composed of hydrogen and oxygen and that the chemical formula for water is H_2O. Explain that the subscript "2" indicates that there are two hydrogen atoms. Review how water particles behave in the different states of matter.

Questions to guide students' learning and thinking	Questions to gather information about students' understanding and learning
• What do you know about water?	• What is the chemical name/symbols for water? • What does the chemical symbol H_2O tell us about water? • How do water particles behave when they are in a solid, liquid, gas?

Explain that today each student will act as a water particle to model the phase changes from a solid to liquid to gas. The students' torsos will represent the oxygen atom and their hands will represent the hydrogen atoms. Show H_2O a Water Molecule on document camera. Explain that the attractions and repulsions of the charges on the atoms control the arrangement of the water particles. Introduce the concept that different charges are attracted or pull toward each other and like charges are repelled or pushed away.

Questions to guide students' learning and thinking	Questions to gather information about students' understanding and learning
• [pointing to H_2O Water Molecule Model] What information does the model show us about a water particle? • What information does the model not show us?	• What do you know about how like charges interact? Different charges? • How many oxygen atoms are in a water particle? Hydrogen atoms?

Explain that when oxygen bonds with two hydrogen atoms to make water, the hydrogen atoms sit on opposite sides of the oxygen atom and form a bent "V" shape. Further, the water particles are like little bent magnets with one negative charge in the middle and positive charges on both ends.

Clear a large area in the center of the room for the "water particles" (kids) to move around. For the liquid and solid phase parts of the lesson, restrict the students to a small enough area that they can move around in (make a "beaker" out of desks or use tape marks on the floor) but are always close enough to each other to "feel" interactions.

Select three students to be water particles, two students to act as Recorders and two students to act as Directors. Explain roles to students and give recorders poster board and markers. Show Human Model of a

Water Molecule on the document camera. Instruct students to work as a team to create a solid made of three water particles. Add a few additional students and form a liquid. Using the large thermometer set the temperature to 0°C. Instruct some students to return to their seats so only 6 water particles are present. Through questions, guide the students to make a six-sided shape and show the Solid Water picture on the document camera, followed by, the Water Crystals picture. Add heat to the system. Show the Water Vapor picture and set the thermometer to 100°C. Have students model water vapor, allowing them to escape the room, if appropriate or fill all the available space in the classroom. Divide students in groups and allow students to create a skit/play to portray the life of a water particle from a solid → liquid → gas. Allow students to use the Recorders' drawings.

Questions to guide students' learning and thinking	Questions to gather information about students' understanding and learning
• How could we model a water particle? • What could a recorder do during our Chemistry Theater? Director? • What is a six-sided shape? How could our six water particles be arranged? • What could you include in your play/script?	• Why are models important in science? • What should be added/removed for a phase change to occur? • What do we know about solids? Liquids? • If heat is turned down (removed), what will happen to the movement/location of the particles? • What will happen to the water particles as heat is added?

✓ **Checkpoint:** Students have acted out the life of a water particle from solid → liquid → gas and completed their plays/scripts.

Elaborate – 10 minutes

Content Focus: water has unique physical properties

Have students reform the solid water crystal. Discuss how solid ice floats in water because it is less dense that liquid water. Ask students to justify why they think this occurs.

Questions to guide students' learning and thinking	Questions to gather information about students' understanding and learning
• Why does water take the six-sided shape when it forms a solid crystal?	• What would happen if we tried to put another water particle in the solid crystal? • What would be more dense, solid ice or liquid water? • Why do you think solid ice floats in liquid water?

✓ **Checkpoint:** Students can explain why solid ice floats in liquid water.

Evaluate

See Assessment in attached documents.

Name: _____

States of Matter Basics

I. States of Matter

a) **Explore** how you can change the state of matter. Draw the particles inside the container for each state.

State of Matter	My picture
	

b) How do you know what state of matter particles are in?

II. Changing States of Matter

a) **Explore** how you can change the state of matter of the particles in the container. Use the table above to determine what state of matter the particles are in. Fill in the table with your observations.

Challenge	Add or remove heat (circle your answer)	Observations or Picture
Solid → Liquid	Add heat Remove heat	
	Add heat Remove heat	
	Add heat Remove heat	
	Add heat Remove heat	

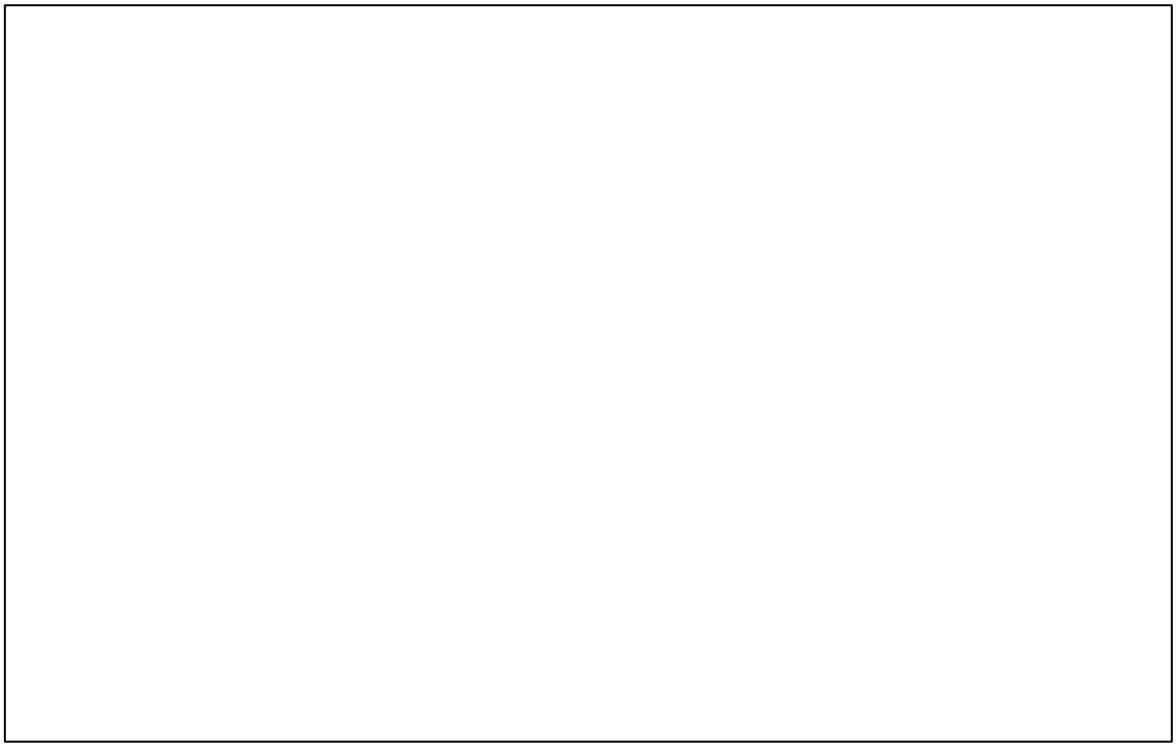
b) When heat is added or removed, what types of energy are changing?

III. Analysis of a model

1. What advantages does using a computer simulation have?

2. How is this model similar and different from what we acted out in class? List two similarities and two differences.

3. If you could change the simulation to make it a better, what would you do? Draw a picture and label your changes.



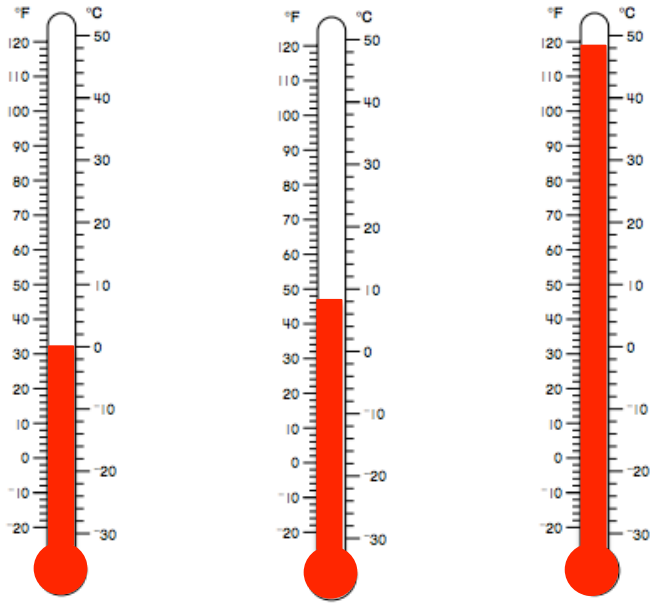
My new model

Name: _____

Show off what you know!

1. When heat energy is increased for a substance the
   a) particles move slower.
   b) particles move faster and spread out.
   c) particles move faster and move closer together.
   d) new particles are formed.

The following are temperature readings from a sample of water being heated. Use the image below to answer Questions 2 and 3.



Images of thermometers © Scott Foresman – Addison Wesley 2

2. Which thermometer represents water's melting point?
   a) A
   b) B
   c) C
   d) None of the thermometers depict the melting point of water.

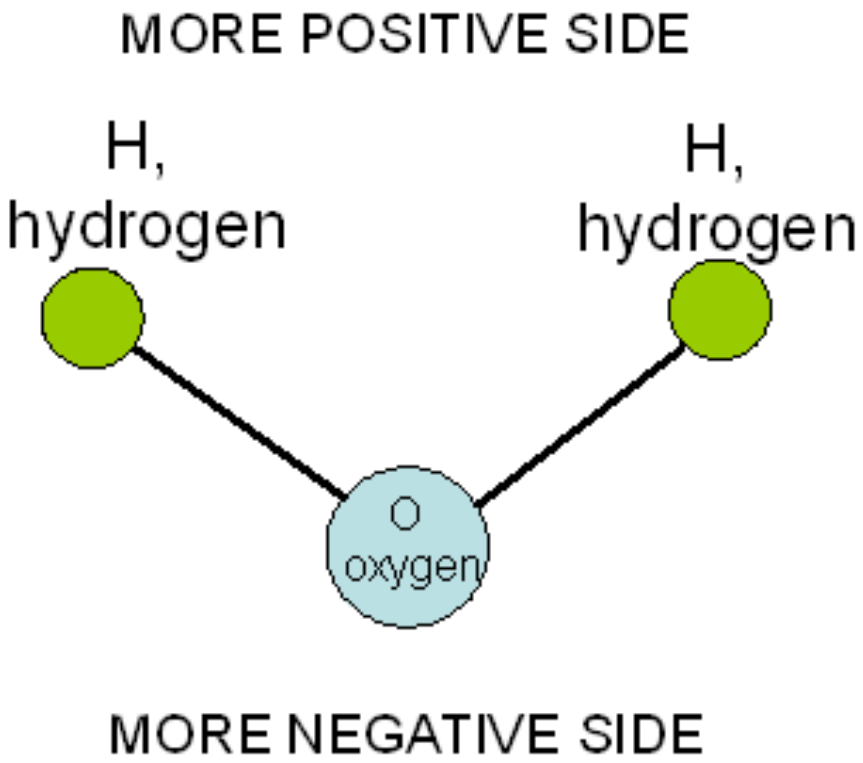
3. Which thermometer represents water's boiling point?
   a) A
   b) B
   c) C
   d) None of the thermometers depict the boiling point of water.

4. Sam was outside swimming in the pool when his mom brought him a glass of ice water. He noticed that the outside of the glass was wet after a few minutes. Over time, the there were no ice cubes in his glass and he just had liquid water. What phase change(s) were present in this situation?

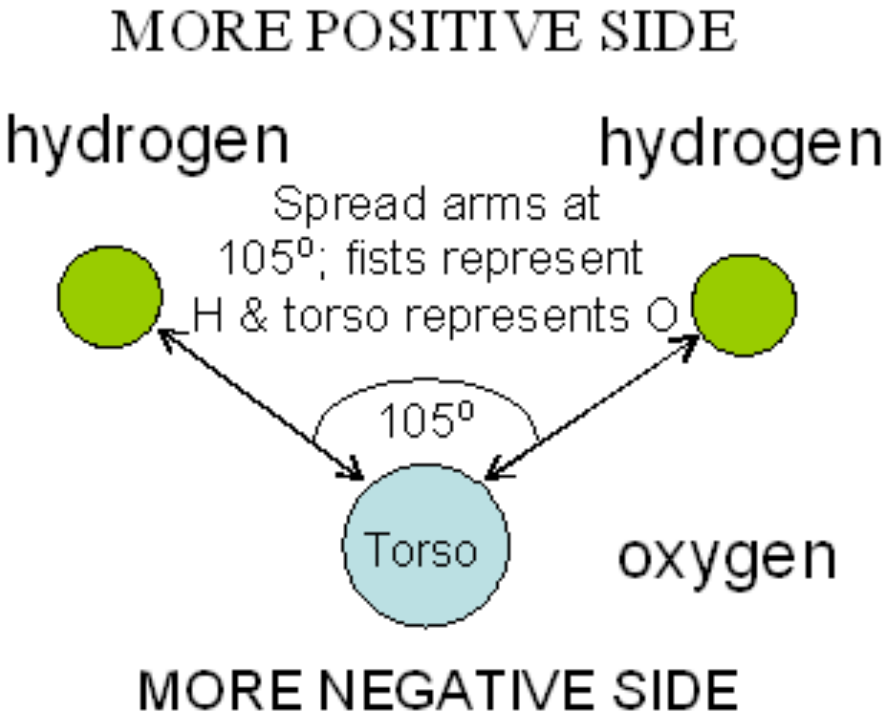
a) melting
b) condensation
c) freezing and evaporation
d) melting and condensation

5. Explain how water molecules interact in a solid, liquid and gas state using pictures and words.

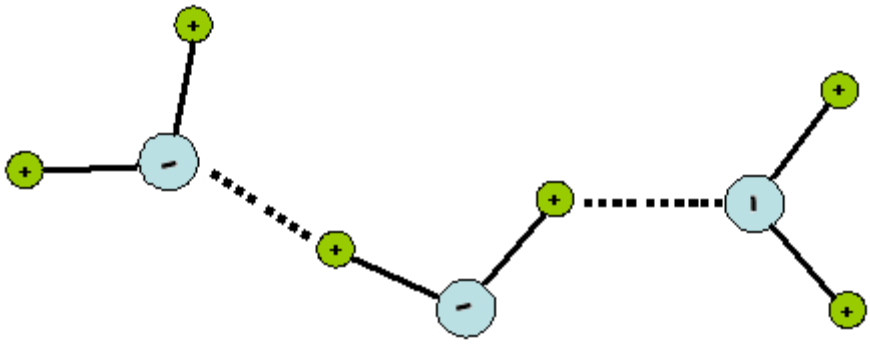
H_2O, a Water Molecule



Human Model of the Water Molecule
(as seen from above)

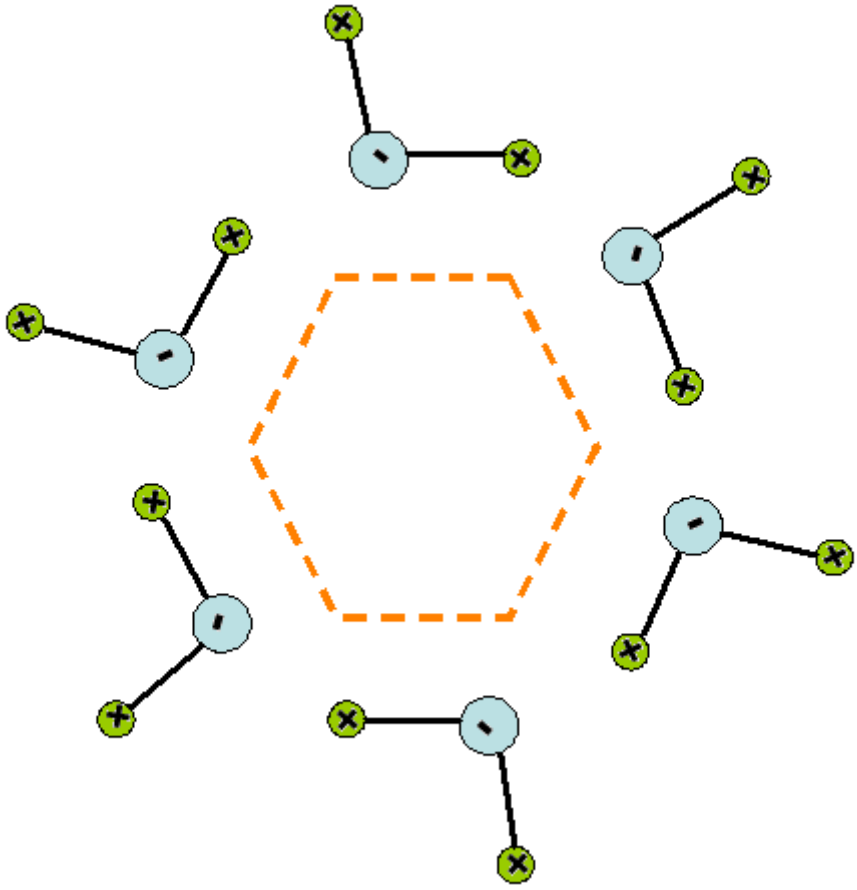


Water Molecule Interactions



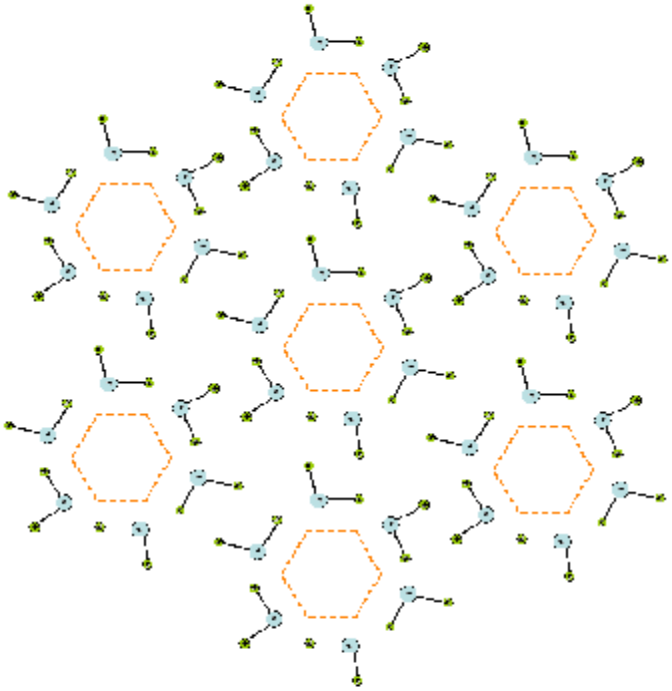
- **The two hydrogen atoms stay at the same 105° angle.**
- **Water is very stable, so every oxygen keeps its two hydrogen atoms.**
- **Opposite charges attract or pull toward each other, but they never touch.**
- **Like charges repel or push away from each other.**

Solid Water (Ice)

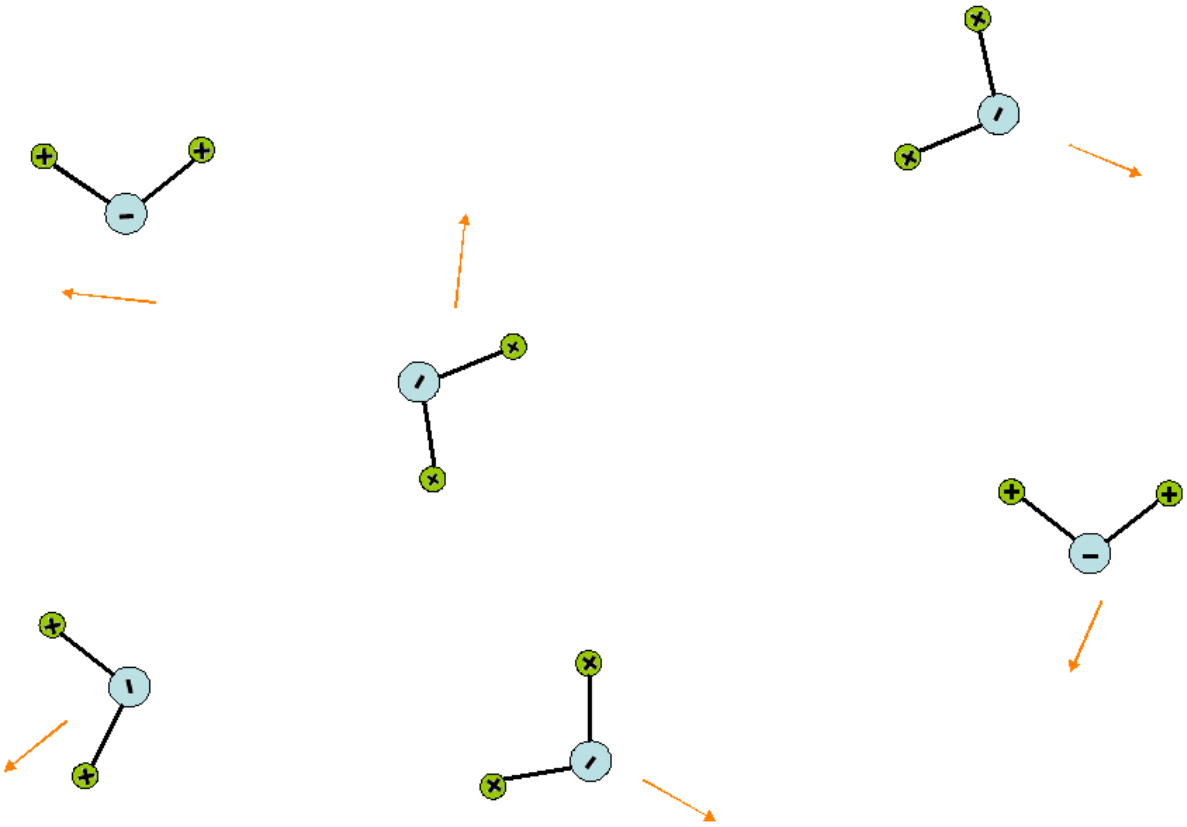


- **In the solid form, the water molecules still vibrate but don't move.**
- **In this shape, the attractions and repulsions are balanced and the crystal is stable.**
- **What would happen if you tried to squeeze another water molecule into the center?**

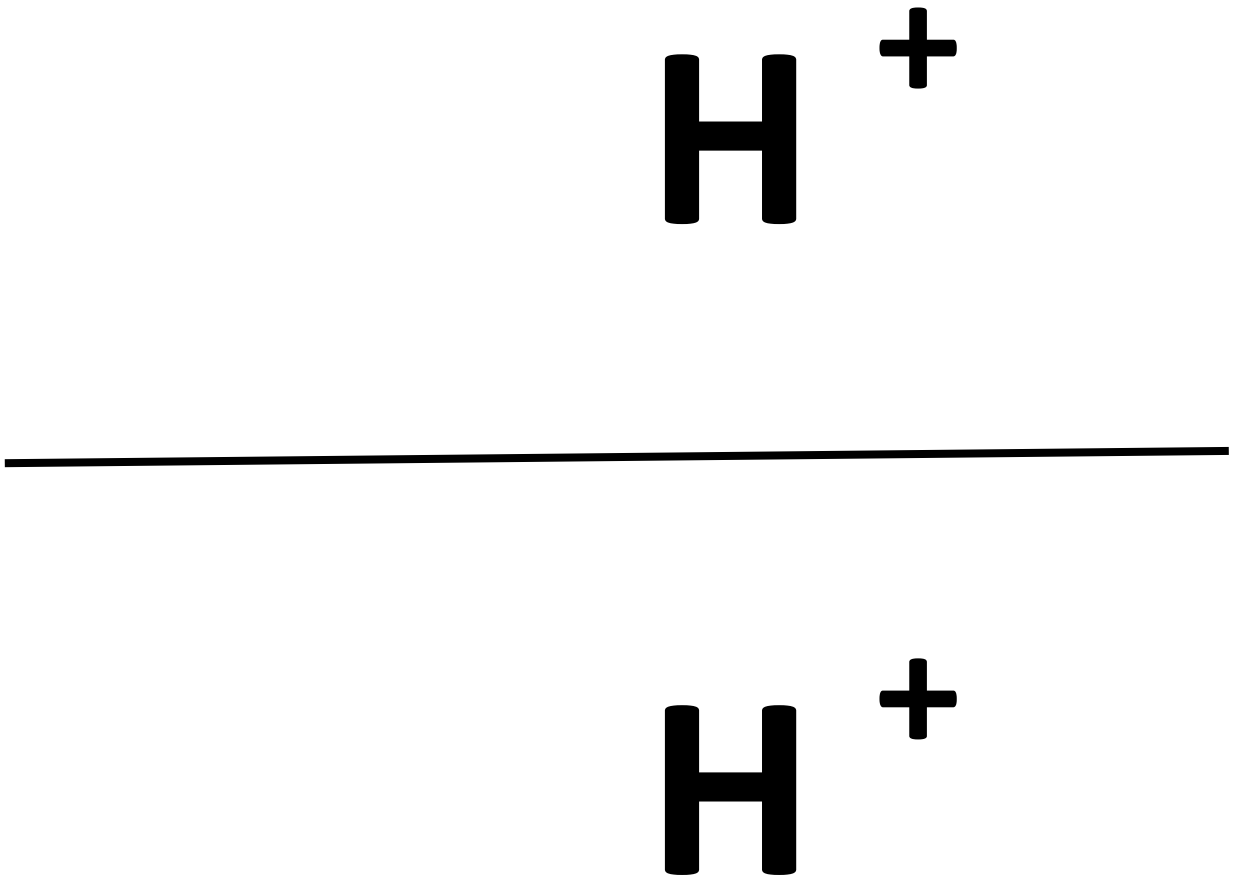
Water Crystals



Water Vapor



- As heat is added, water molecules move faster and break away from each other.
- They now move in random directions until they run into something and bounce away.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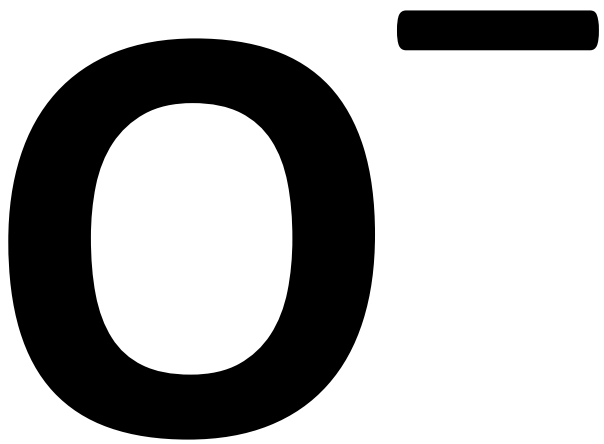
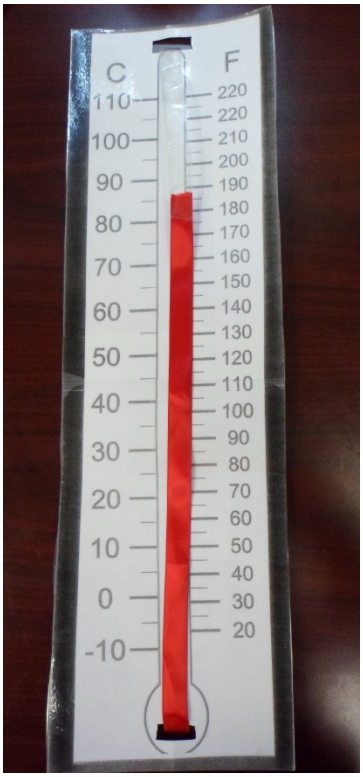
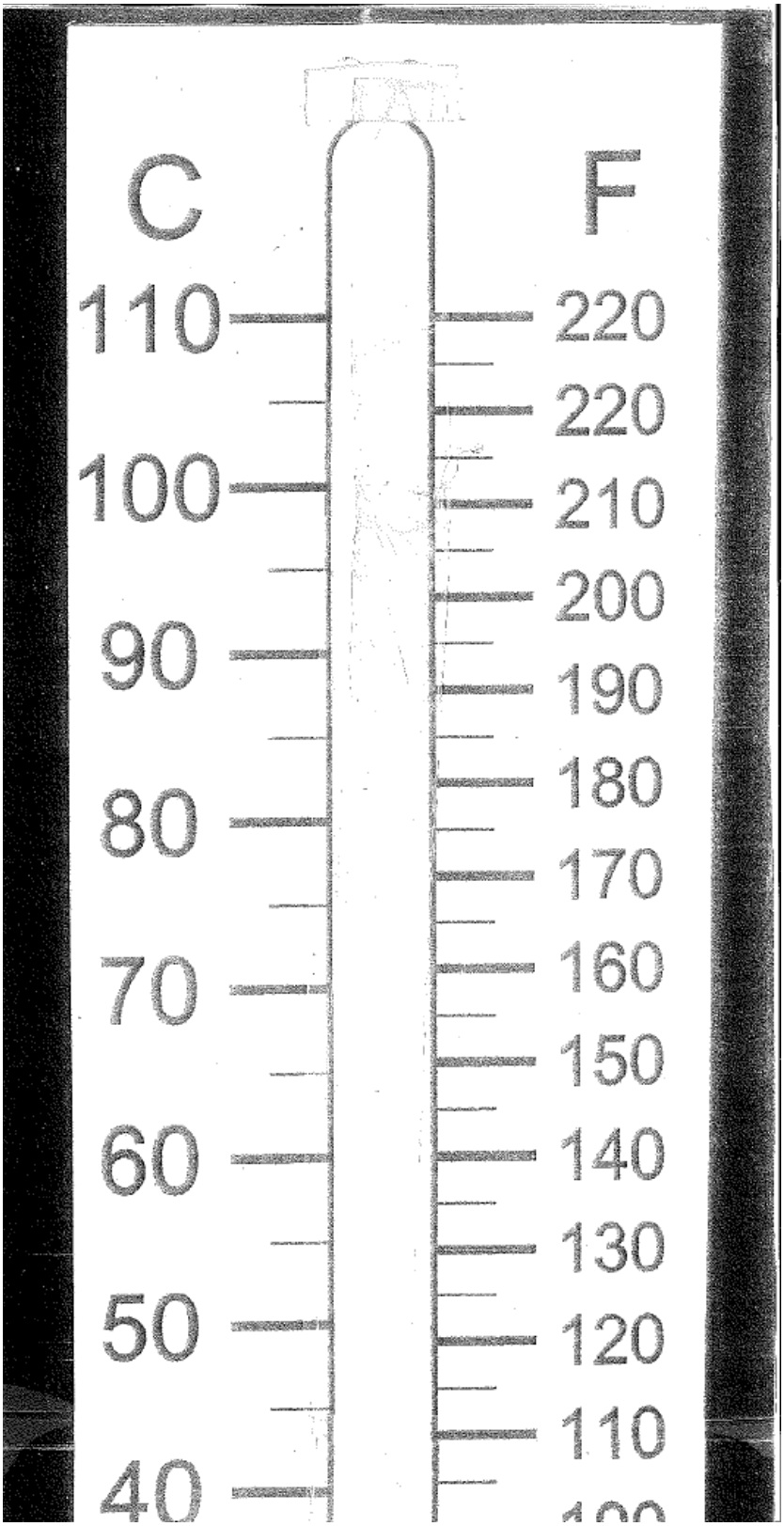


How to Make a Large Thermometer



Directions:

1. Cut out the two templates provided
2. Tape or glue the two sheets together; you will have to overlap to them.
3. Laminate the connected sheets (optional)
4. Cut a 1 ¼ in slit at the bottom of the thermometer about ¾ in from the bottom
5. Cut a 1 ¼ in slit at the top of the thermometer about ½ in from the top.
6. Take the packing tape and fold and cut it so that it is the same width as the ribbon. Make sure there are no sticky sides on the tape.
7. Connect the packing tape and ribbon together on one end, leaving the other end free.
8. String the ribbon/packing tape through the holes. Cut or overlap the tape if there is excess and connect the two ends together.
9. Hot glue the cardboard piece to one side on the back of the "thermometer" for stability.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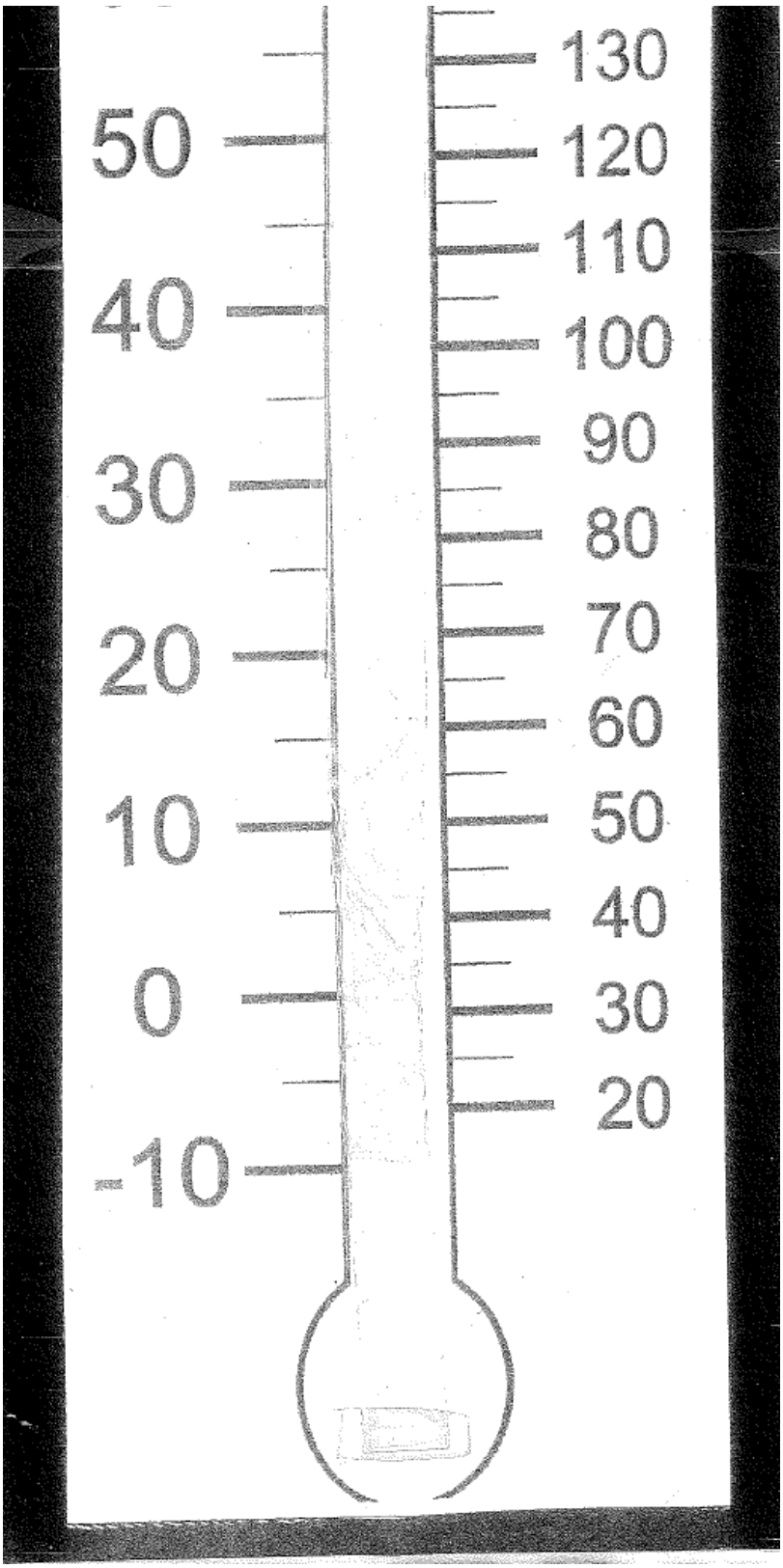
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