LESSON PLAN

Chemical Differences in Emergency Energy Sources

Lesson 2: Developing a Model of Thermal Energy, Atoms, and Molecules

AUTHOR

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DESCRIPTION

Through a series of exploration and inquiry activities, students will explain kinetic molecular theory, atomic, and molecular structures. Students will be challenged to gradually increase the precision of their explanation of molecular-level structures and motion. This lesson facilitates in the students' development of an evidence-based argument through collaboration.

GRADE LEVEL(S)

7, 8

SUBJECT AREA(S)

Chemistry, Atomic Structure, Molecular Structure, Thermal Kinetic Energy

ACTIVITY LENGTH

10 class periods (~90-minute class periods)

LEARNING GOAL(S)

1. Students will develop a model through collaborative inquiry to explain thermal kinetic energy and predict the outcome when heat is added to a substance.
2. Students will build argumentation from evidence skills through collaborative sense-making and gallery walk presentations.
3. Students will develop a model of atomic and molecular structures.

EXPECTED CONTENT UNDERSTANDING

STUDENT BACKGROUND

Students participating in this lesson should be familiar with the following scientific concepts and practices:

- Laboratory safety:
  - Handling breakable and hot objects safely
  - Maintaining an orderly environment to allow for safe data collection
- Forms of energy and energy transformations

EDUCATOR BACKGROUND

It is useful for educators leading this lesson to be familiar with kinetic molecular theory, atomic structure, and basics of bonding(https://en.wikipedia.org/wiki/Octet_rule). This lesson does not get into the periodic table beyond how to read the square to determine the number of protons and neutrons. Students will determine the valence electrons for the sake of understanding basic molecules. The elements discussed most in depth are hydrogen, oxygen, carbon, and silicon as the context used is PV-cells and fossil fuels. In addition, teachers should be familiar with Claim/Evidence/Reasoning (https://www.edutopia.org/blog/science-inquiry-claim-evidence-reasoning-eric-brunsell) methodology for eliciting student explanations. For more info on CER Implementation, seek out resources online from chemedx.org, Edutopia, or other free tools.

This portion of the unit is based upon the American Chemical Society Middle School Chemistry curriculum (http://www.middleschoolchemistry.com/), with many omissions and a few additions.

REQUIRED MATERIALS

HANDOUTS/PRINTED MATERIALS

- **Day 1:** "Lab #1: Water Exploration" handout
- **Day 2:** Access to readings, either online or in print. If your school has a different text resource, feel free to substitute it for the resources used here.
  Free Source 1: American Chemical Society: Middle School Chemistry: Student Reading for Chapter 1 (Download from this link: http://www.middleschoolchemistry.com/lessonplans/

Free Source 2: CK-12 Middle School Level Kinetic Molecular Theory Reading: https://www.ck12.org/c/physical-science/kinetic-theory-of-matter/lesson/Kinetic-Theory-of-Matter-MS-PS/?collectionCreatorID=3&conceptCollectionHandle=physical-science-%3A%3A-kinetic-theory-of-matter&collectionHandle=physical-science

- **Day 3:** "Investigation planning sheet: Descriptive Investigation Proposal, long from Argument Driven Inquiry
- **Day 4:** No new materials needed
- **Day 5:** Thermal energy lab report writing guide and rubric
- **Day 6:** Phase change reading, demonstration observations student handouts from Middle School Chemistry, chapter 2, lessons 2 and 3.
- **Day 7:** Phase change foldable and rubric
- **Day 8:** Middle School Chemistry Chapter 4, lesson 1 and 2 student activity sheet
- **Day 9:** Middle School Chemistry Chapter 4, lesson 3 student activity sheet
- **Day 10:** Middle School Chemistry Chapter 4, lessons 4 and 5 student activity sheet
- **Day 11:** Polarity of water

CLASSROOM SUPPLIES

- White boards, markers, and erasers. Ideally 2' x 3' (Note: you can have large white boards made inexpensively at Home Depot. Purchase 4'x8' sheets of "Thrifty Coated Project Board," *typically* available in the back of the store near the saw station for approximately $15 per sheet. An employee can cut sheets down to size at no additional cost)
- Large chart paper or butcher paper, if whiteboards are not available, markers

ACTIVITY SUPPLIES (PER GROUP OF 3 – 4 STUDENTS)

DAY 1: WATER EXPLORATION LAB

- **(4)** Index cards covered in wax paper or laminated.
- **(4)** plastic pipettes
- **(3)** plastic cups or beakers, one each of hot, cold, and room temperature H2O
- **(1)** ice cube in a small container
- **(2)** small containers with six drops of food coloring, one yellow, one blue.

Days 2 - 4: Thermal Energy and Matter: Predict and describe the changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.

- (1) hot plate
- (1) digital or triple beam balance
- (1) glass beaker, 150-250 mL
- (1) beaker tongs
- (1) Graduated cylinder

- (1) thermometer
- (1) timer
- Access to ice and water

Day 6: Phase Change Observations

- 2-quart size ziploc bags
- A pitcher of hot water (approximately 50°C)
- Room temperature water
- (2) squares of brown paper towel
- (2) droppers / pipettes
- (2) short, wide rimmed clear plastic cups
- (2) tall, smaller-rimmed plastic cups
- Ice
- Magnifier

Day 7: Heat Curve of Water Data Collection

- Ice
- Heat safe beakers
- Thermometers
- Timers
- Hot plate
- Beaker tongs
- If available, the Vernier temperature probes with a LabQuest or GoLink for connecting to a laptop or Chromebook are an excellent alternative that allows for automatic data visualization.

Day 8: Understanding Periodic Table Boxes

- Strips cut from plastic bags
- Periodic table cards

Day 9: Electron Arrangement

- Periodic table cards

Day 10: Covalent and Ionic Bonding

- 9-volt battery
- 2 wires with alligator clips on both ends
- 2 pencils sharpened at both ends
- Water
- Salt
- Clear plastic cup
- Tape
- Black paper
- Salt

- Cup with salt from evaporated saltwater
- Magnifier
- Permanent marker

Day 11: Polarity of Water

- Permanent markers (blue and red)
- Isopropyl alcohol (70% or higher)
- Water
- Brown paper towel
- Droppers

LESSON PROGRESSION

PLANNING AND PREP

This lesson is designed to span eleven days. Students will first examine water as a way to describe kinetic molecular theory and phase change. They will then transition to atomic and molecular structure to explain the properties of matter in the context of energy resources. This unit does not go into the detail of electron configuration beyond the octet rule nor the periodic table, as those performance expectations are in the high school NGSS standards.

Day 1: Water Exploration lab: Laminate or cover in wax paper one index card or piece of card stock for each pair of students

Day 2: Informational Text: Students prepare a concept map from a reading passage Prepare paper copies of texts on thermal energy, molecular motion, and phase change.

Day 3: Collaborative inquiry: Print the Investigation Proposal adapted from *Argument Driven Inquiry (https://argumentdriveninquiry.com/downloadable-materials).* Assemble lab stations with items listed in supply list. Each group needs access to an outlet and heat-safe surface.

Day 4: Data collection and Claim / Evidence / Reasoning collaborative sense-making

Day 5: Lab report writing

Day 6: Phase change demonstration: Heat water to approximately 50°C; assemble materials in supply list; read through Middle School Chemistry teacher background for lessons 2.2 and 2.3

Day 7: Heating Curve: Obtain ice for each group; set up lab stations with listed materials, each group needs an outlet and hot plate.

Day 8: Atomic Structure: Prepare plastic strips and periodic table cards.

Day 9: Electron Arrangement: Assemble activity supplies for each group, print student activity sheets.

Day 10: Ionic and Covalent Bonding: Assemble activity supplies for each group, print student activity sheets.

Day 11: Polarity of Water: Assemble activity supplies for each group, print student activity sheets and assessment sheets.

LESSON SEQUENCE

Day 1: Molecules Move. Hot Molecules More More. Practicing Claim / Evidence/ Reasoning

1. **(10 min)** Students explore the tendency of water to remain stuck together in droplets. Follow procedure one on the lab handout "Lab 1: Properties of Water." Collect materials or have students place them in an alternate location for the follow-up discussion.
2. **(10 min)** Show video from the American Chemical Society: Slow motion water balloon pop (http://www.middleschoolchemistry.com/multimedia/chapter1/lesson1). Discuss: why does the water keep its shape? The depth of answer at this point is simply that the molecules are attracted to each other, so the water momentarily stays in the shape of the balloon until gravity overcomes the cohesive forces. After this discussion, ask the students what will happen if you were to put a drop of water in a beaker of water. Gauge students' pre-existing knowledge and possible misconceptions as volunteers attempt to explain their expected observations in terms of the water molecules. At the conclusion of the discussion, place one or two drops of bright food coloring in room temperature water in a clear beaker or cup. Do not stir or handle the beaker. Allow students to observe the food coloring disperse in the water. A good method for this would be the document camera, as it allows all students to see without disturbing the water.
3. **(20 minutes)** Students complete the observations for procedure two on the lab handout. The expected outcome is that students will observe that the two colors of food dye mix to make green water faster in the hot water and the food dye on ice is not dispersed throughout the cube.
4. **(5 min) Claim / Evidence / Reasoning**: Once students have had an opportunity to observe the water and food coloring at various temperatures, they should clean up and the teacher should present three claims:

a. Water molecules are attracted to each other.

b. Water molecules move.

c. Water molecules at higher temperatures move faster than those at low temperatures.

Introduce the **Claim / Evidence / Reasoning** format for presenting their thinking. Students should state the claim, present observations or evidence that support each claim, and finally, they should explain why the evidence supports the claim. For example:

Claim: Water Molecules Move.
Evidence: I saw the food coloring spread out in the beaker of water even though the teacher didn't stir the water.
Reasoning: The water molecules are in constant motion. When the dye is added to the water, the water collides with the dye molecules and separates them. Gradually, over time, the dye is pushed around to spread through the whole beaker of water.

5. Give students the assignment to turn in their claim / evidence / reasoning as a formative assessment, either on paper or through your online classroom.

Day 2: Building Scientific Knowledge: Creating a Concept Map to Support the "Reasoning" Portion of the Claim, Evidence and Reasoning

1. **(15 minutes)** A common challenge that students have when asked to use the Claim / Evidence / Reasoning format of explanation is that they restate their evidence as their reasoning. Day 2 builds on the understandings that students began to formulate on Day 1 with the exploration of water lab by providing informational text resources. By increasing their content knowledge, students are equipped to write stronger justifications of their reasoning. Read paragraph one of "Middle School Chemistry Chapter 1: Matter" aloud with your students. Set the purpose of reading: clarifying definitions and explanations of how molecules respond to thermal energy. Instruct students to underline definitions as they read and paraphrase each definition in the margin of their text.
2. **(5 minutes)** After students have read and defined the terms in paragraph one, ask students what they expect to read about in the remainder of the text. The term "matter" should go in the center of their large paper. Model how you might organize branches of the concept map, discussing how to connect related topics and categories, and supplement text with diagrams or drawings.
3. **(30 - 50 minutes, depending upon depth of concept maps created and the reading / processing pace of your students)** Students read and create concept maps for thermal energy and matter, connecting ideas about kinetic energy, energy transfer, states of matter and phase change.

4. **(10 mins)** End the class by having students pair up with a student from a different table. Students will explain their concept map to their partner, correct any misunderstood portions of their concept map, and add any missing ideas that their partner included. The concept map and marked text becomes the students' notes for the topic.

Day 3: Collaborative Inquiry: Developing a Model of Change in Matter as Thermal Energy is Added of Removed

1. **(20 minutes)** Students will work in groups of 3-4 to design and conduct an investigation using a variation of Argument Driven Inquiry model (located in the lesson documents on CEbrightfutures.org) of inquiry and justification. The ADI model includes an eight-step process which includes peer review of reports. This investigation uses the whiteboard gallery walk of initial claims, and then opportunity to collect more data before writing a report, but not the entire investigation cycle. There are two possible questions to use here, offering an excellent opportunity to differentiate. Question one: If two different volumes of water at two different temperatures are mixed, what will be the temperature of the water immediately after the water is mixed? This seemingly simple question requires proportional thinking, in addition to developing one's model of heat transfer at the molecular level. Question two: Can you develop a model that can predict the amount of time that it will take for a sample of water of a given starting temperature and volume to boil? This question requires more data collection, mathematical reasoning, and thoroughness of planning, and includes the additional concept of phase change. For twenty minutes, students discuss the question, decide the data that they need to collect, and write a procedure. Once a procedure is approved, students begin experimentation.

2. **(30 -60 minutes)** Experimentation / Data collection: Students conduct their procedures and collect the data they determined would support developing an answer to their question. Question two will require additional time for data collection. If students in the same class are investigating different questions, one could have additional time available to do some one-on-one reteaching or remediation, or it would allow students who need assistance or more time to collect data to be independent with question one and complete the investigation.

Day 4: Gallery Walk of Initial Arguments

1. **(20 minutes)** Students work in their investigation groups to prepare initial arguments on large white boards. The whiteboard is crucial to students feeling comfortable making a public claim. There is a less risk involved when the work is collective, and the surface allows for quick erasing and rewriting. Given the cost of flip chart paper, it is definitely worth the one-time investment in making 2'x2' or 2'x3' whiteboards. On the board, students state the question and their claim, which answers the question. Below their claim, students present the data that supports their claim, and then they present their justification: how does the data support the claim? Carefully explain to the students that the justification should include discussion of molecules, kinetic energy, temperature, and phase change, not a restating of the data in text.

2. **(15 minutes)** Gallery Walk: Groups elect one student to stay with the whiteboard to present the results, claim, evidence, and justification. The remaining group members leave to "spy" on other groups. Provide the spies with discussion questions to prevent presentations fizzling out in a minute or two:
    a. How did you decide to collect this data?
    b. Are you confident in your measurements?
    c. How would you change your procedure when you collect more data?
    d. What data would make you more certain of your claim?
3. **(5-15 minutes)** Class share out: Students discuss how different groups helped them to develop their understanding of thermal energy and matter, referencing specific data and explanations on whiteboards.
4. **(45 minutes)** Students write a lab report that is no more than two pages. It is written in essay form, with tables or graphs of data embedded. The simplified outline of the lab report is:
    a. What question were you trying to answer and why?
    b. What did you do to answer your question and why?

c. What is your argument? (Here is where you use data and your understanding of heat and molecular motion to support your answer to the question.)

See the included rubric for more guidelines for writing the report.

Optional Day 5 of Homework Assignment: Complete writing lab report and have students do a peer review of a classmate's lab report.

Day 6: Phase Changes in Water:

In Chapter Two (Lessons 2 and 3 of Middle School Chemistry) students expand their understanding of thermal energy in water to include phase change. There are two activities to explore evaporation and condensation: Lesson 2.2 and 2.3. Students write molecular level explanations of their observations of evaporation and condensation at different temperatures. I suggest modifying these activities to make them demonstrations, guiding students through the activity sheets as they further develop their models of molecular movement as thermal energy is added. The student chapter provides an additional resource for students to strengthen their understanding and ability to explain the changes in matter as thermal energy is added. Students will use their understanding as they create a phase change graph for water in day 7.

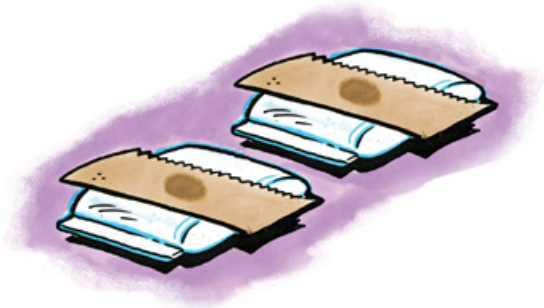

Figure 1 Images: American Chemical Society, 2018. (http://www.middleschoolchemistry.com/lessonplans/chapter2)

Day 7: Phase Changes Curve for Water:

Students will collect phase change temperature data as they heat water from ice water to boiling. As they collect data, they will work on a Phase Change Foldable to communicate how thermal energy affects molecular motion during phase changes.

1. **(10 minutes)** Introduce the guiding question for data collection: How does temperature change as ice is heated to steam? Ask students to table talk to decide the data that they would need to be able to answer these questions. Have students jot down a quick procedure and sketch a data table. Circulate during this time to listen to student conversations and to view initial procedures and data tables.
2. **(10 minutes)** Have students share out their plans and refine the procedure as a group. Be sure that students have considered the time interval of taking the temperature.
3. **(5 minutes)** Introduce the Phase Change Foldable assessment. Instruct students to work on the foldable during data collection.
4. **(55 minutes)** Students collect data and work on Phase Change Foldable. Teacher circulates to teach in small groups and clarify expectations for the foldable.

Day 8: Atomic Structure Introduction:

Use Middle School Chemistry lessons 4.1 and 4.2 as written. Students will use strips of plastic grocery bags to observe generating a charge by transferring electrons between two objects and the resulting attraction due to opposing charges. After dealing with the concept of opposite charges attracting, students learn how to read a box from the periodic table and do a card sort activity to identify elements. Conclude class with a quick formative assessment: project images of periodic table squares and have students identify the number of protons, neutrons, and electrons present, writing the number on small, individual whiteboards.

Day 9: Electron Configuration:

Use Middle School Chemistry lesson 4.3 as written.

Day 7: Ionic Bonding and Covalent Bonding:

Use Middle School Chemistry lessons 4.4 and 4.5 as written

Day 11: Polar Covalent Bonding in Water:

Use Middle School Chemistry lesson chapter 5.1 as written. Students learn that water is a polar covalent molecule and compare its properties to isopropyl alcohol. Once the lesson concludes, have students complete the Water Molecule assessment.

ASSESSMENT AND EXTENSIONS

FORMATIVE ASSESSMENT

Day 1: Exit ticket: Claim / Evidence / Reasoning on molecular motion

Day 2: Individual Concept Map

Day 4: Group poster / Whiteboard

Day 6: Student activity handouts

Day 8: Exit Quiz: Project images of periodic table squares and have students write the number of protons, neutrons, and electrons on a small whiteboard. Can be adapted to be a written, verbal or online assessment.

Day 9: Exit Quiz: Project images of periodic table squares and have students write the number of valence electrons on a small whiteboard. Can be adapted to be a written, verbal or online assessment.

Day 10: Review student answers to student activity sheet.

SUMMATIVE ASSESSMENT

Day 4-5: Lab report

Day 7: Phase Change Foldable

Day 11: Water molecule diagram and application of polarity to the idea that water takes a lot of energy to boil.

LESSON EXTENSIONS

There are excellent resources on The Science Spot (http://sciencespot.net/) to reinforce the atomic structure and bonding content. Lesson three of this unit will make more concrete connections between the content of this section and the energy and emergency preparedness focus of the unit.