Properties of Matter: Physical and Chemical – Grade 7, Level 4

Lesson Overview

In this lesson, students will participant in many activities designed to compare physical and chemical properties such as boiling/melting point, density and the ability of substances to burn or rust. Throughout the lesson, students will collect, analyze and interpret data to support claims made about the substances given.

Alignment

Standard/Indicator Addressed

Science **7.P.2B.1** Analyze and interpret data to describe substances using physical properties (including **state, boiling/melting point**, **density**, conductivity, color, hardness, and magnetic properties) and chemical (**the ability to burn or rust**).

7.P.2B.2 *Use mathematical and computational thinking to describe the relationship between the mass, volume, and density of a given substance.*

Mathematics **7.RP.2** Identify and model proportional relationships given multiple representations, including tables, graphs, equations, diagrams, verbal descriptions, and real-world situations.

ELA Writing **Standard 1:** Write arguments to support claims with clear reasons and relevant evidence.

1.1 Write arguments that:

a. introduce claims, acknowledge alternate or opposing claims, and organize the reasons and evidence logically;
c. support claims with logical reasoning and relevant evidence, using accurate, credible sources and demonstrating an understanding of the topic or text;
e. develop the claim providing credible evidence and data for each;
i. provide a concluding statement or section that follows from and supports the argument

Standard 6: Write independently, legibly, and routinely for a variety of tasks, purposes, and audiences over short and extended time frames.

6.1 Write routinely and persevere in writing tasks over short and extended time frames, for a range of domain specific tasks, and for a variety of purposes and

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audiences.

ELA Communication

Standard 1: Interact with others to explore ideas and concepts, communicate meaning, and develop logical interpretations through collaborative conversations; build upon the ideas of others to clearly express one's own views while respecting diverse perspectives.
1.2 Participate in discussions; ask probing questions and share evidence that supports and maintains the focus of the discussion.
1.5 Consider new ideas and diverse perspectives of others when forming opinions regarding a topic, text, or issue.

Standards for Mathematical Practice (as appropriate)

2. Reason both contextually and abstractly.

a. Make sense of quantities and their relationships in mathematical and real-world situations.
d. Connect the meaning of mathematical operations to the context of a given situation.

3. Use critical thinking skills to justify mathematical reasoning and critique the reasoning of others.

a. Construct and justify a solution to a problem.
b. Compare and discuss the validity of various reasoning strategies.
d. Reflect on and provide thoughtful responses to the reasoning of others.

4. Connect mathematical ideas and real-world situations through modeling.

a. Identify relevant quantities and develop a model to describe their relationships.
d. Evaluate the reasonableness of a model and refine if necessary.

6. Communicate mathematically and approach mathematical situations with precision.

a. Express numerical answers with the degree of precision appropriate for the context of a situation.
b. Represent numbers in an appropriate form according to the context of the situation.
c. Use appropriate and precise mathematical language.
d. Use appropriate units, scales, and labels.

7. Identify and utilize structure and patterns.

b. Recognize mathematical repetition in order to make generalizations.

Science and Engineering Practices

7.S.1A.1 Ask questions to (1) generate hypotheses for scientific investigations, (2) refine models, explanations, or designs, or (3) extend the results of investigations or challenge claims.

7.S.1A.4. Analyze and interpret data from informational texts, observations, measurements, or investigations using a range of methods (such as tabulation, graphing, or statistical analysis) to (1) reveal patterns and construct meaning or (2) support hypotheses, explanations, claims, or designs.

7.S.1A.5 Use mathematical and computational thinking to (1) use and manipulate appropriate metric units, (2) collect and analyze data, (3) express relationships between variables for models and investigations, or (4) use grade-level appropriate statistics to analyze data.

7.S.1A.7 Construct and analyze scientific arguments to support claims, explanations, or designs using evidence from observations, data, or informational texts.

ELA Inquiry Standards (as appropriate)

Standard 1: Formulate relevant, self-generated questions based on interests and/or needs that can be investigated.

> **1.1** Develop questions to broaden thinking on a specific idea that frames inquiry for new learning and deeper understanding

Standard 2: Transact with texts to formulate questions, propose explanations, and consider alternative views and multiple perspectives.

> **2.1** Formulate logical questions based on evidence, generate explanations, propose and present original conclusions, and consider multiple perspectives.

Standard 3: Construct knowledge, applying disciplinary concepts and tools, to build deeper understanding of the world through exploration, collaboration, and analysis.

> **3.1** Develop a plan of action by using appropriate discipline-specific strategies.
>
> **3.4** Organize and categorize important information, revise ideas, and report relevant findings.

Standard 4: Synthesize integrated information to share learning and/or take action.

> **4.1** Employ a critical stance to demonstrate that relationships and patterns of evidence lead to logical conclusions, while acknowledging alternative views.
>
> **4.2** Determine appropriate disciplinary tools and develop a plan to communicate findings and/or take informed action.
>
> **4.3** Reflect on findings and pose appropriate questions for further inquiry.

Standard 5: Reflect throughout the inquiry process to assess metacognition, broaden understanding, and guide actions, both individually and collaboratively.

> **5.1** Acknowledge and value individual and collective thinking; use feedback from peers and adults to guide the inquiry process.
>
> **5.2** Employ past and present learning in order to monitor and guide inquiry.
>
> **5.3** Assess the processes to revise strategies, address misconceptions, anticipate and overcome obstacles, and reflect on completeness of the inquiry.

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Connections

Disciplinary Literacy Strategies (for Purposeful Reading, Meaningful Writing, and Productive Dialogue)

- Pre-write
- Line of Learning
- Think Aloud
- Read Aloud
- Think-Ink-Pair-Share
- Partner Dialogue
- Exit Ticket

Computational Thinking

Computational thinking (CT) is a problem-solving process that includes (but is not limited to) the following ***characteristics****:*

- Formulating problems in a way that enables us to use a computer and other tools to help solve them.
- Logically organizing and analyzing data
- Representing data through abstractions such as models and simulations
- Automating solutions through algorithmic thinking (a series of ordered steps)
- Generalizing and transferring this problem solving process to a wide variety of problems

These skills are supported and enhanced by a number of dispositions or attitudes that are essential dimensions of CT. These ***dispositions or attitudes*** *include:*

- Confidence in dealing with complexity
- Persistence in working with difficult problems
- Tolerance for ambiguity
- The ability to deal with open ended problems
- The ability to communicate and work with others to achieve a common goal or solution

Content Area (2 or more) Connections

- Science
- Mathematics
- ELA
- *Computational Thinking*

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Lesson Plan – Part A: Melting Point

Time Required – (One 60-minute class)

Disciplinary Vocabulary – Physical properties, Chemical properties, Physical change, Chemical change, Melting point

Materials Needed:

- *For each group of **two** students:*
    - Ice (H_2O) – 100 mL
    - Sodium Chloride (NaCl) (table salt) – 5g
    - Paraffin wax ($C_{20}H_{42}$) – 5g
    - Sodium Carbonate (Na_2CO_3) – 5g
    - Sucrose ($C_{12}H_{22}O_{11}$) (table sugar) – 5g
    - Quartz crystal (SiO_2) – 1 small piece
    - Copper wire (Cu) – 5g
    - Lard (pig fat) – 5g
    - Butter (real cream butter) – 5g
    - Aluminum foil (Al) (heavy duty) – 1 sheet (enough to cover the heat source)
    - Heat source
    - Thermometer *(using probe ware will provide more accurate measurements as well as extend the opportunity Computational Thinking)*

Formative Assessment Strategies: Pre-write, Think Aloud, Line of Learning, Student Dialogue

Computational Thinking: Students are asked design an experiment then collect, organize and analyze data for multiple materials considering several scenarios. NOTE: Using probe ware will increase the accuracy of data collected as well as provide opportunity to simultaneously graph results of multiple substances.

Misconceptions: Students often incorrectly believe that temperature changes while a substance is melting. Melting/freezing and boiling/condensation are often understood only in terms of water.

Safety Note(s): Students should know and practice the procedures for glass and chemical safety. Students should use care when performing this experiment, and be wearing the proper safety equipment including aprons and goggles.

Engage

- Have students engage in a **pre-write** on the **Focus Question:** How can melting point, a physical property, be used to determine a substance?

- Dialogue as a class about "What happens to the temperature as ice is transformed from a solid to a liquid?" Capture your predictions in your notebooks. (Remember predictions are never changed once data is collected because they are never wrong; they represent ideas based on current information. However, once new information is discovered, new predictions or revised predictions can be recorded.)
- Record the initial temperature of 100 mL of ice. As the beaker of ice has constant heat added, record the time elapsed and temperature in your notebooks. Continue collecting data in regular time intervals until the after the ice has been completely melted for about 5 minutes. *Be sure to record the temperature and time elapsed as accurately and regularly as possible.*
- Graph your results. Be sure to remember DRY-MIX (**D**ependent or **R**esponding values goes on the **Y**-axis; **M**anipulated or **I**ndependent value goes on the **X**-axis) when creating your graph. For this activity, what was the independent value or the one that was manipulated? (*Answer: time*) What value recorded was in response or dependent on something else? (*Answer: temperature*)
- How do your results compare to your predictions? What surprises you? What questions are you thinking about?
- What happens to the temperature as water is being transformed from a liquid to a gas?
- Looking at your graph, what do you infer the boiling point for water to be?
- What might this graph look like if we repeated this with another solution?

Explore

- Conduct a "**Think Aloud**" around these questions:
    - Do all substances melt at the same temperature? What makes you say that? How do you know?
    - How might we design an experiment to determine the temperature at which materials will melt? (to be converted from a solid to a liquid)
    - What should be kept constant?
    - What needs to change?

(*NOTE – not all substances being tested are pure substances therefore the melting points might vary some)*

- Place the heavy duty Aluminum foil on the heat source; this will serve as the testing surface for this activity.
- Using the experiment design created above, determine the melting points for the following substances:
    - Sodium Chloride (NaCl) (table salt) – 5g
    - Paraffin wax ($C_{20}H_{42}$) – 5g
    - Sodium Carbonate (Na_2CO_3) – 5g
    - Sucrose ($C_{12}H_{22}O_{11}$) (table sugar) – 5g
    - Quartz crystal (SiO_2) – 1 small piece
    - Copper wire (Cu) – 5g

  - Lard (pig fat) – 5g
  - Butter (real cream butter) – 5g
- How do your results compare with your predictions about all substances and their melting points?
- How might melting point, as a physical property, be used to determine a substance?

Explain

- With a partner, students dialogue about the following scenario: If you were a jeweler, and a customer brought in several pieces of jewelry but the composition was unknown, how might you use melting points to distinguish between the metals knowing that jewelry is commonly made from gold, silver, and platinum? The customer is not interested in keeping the jewelry intact and just wants to get the most money possible. *(Note, the melting points of gold, silver and platinum are listed on the chart at the end of the lessons.)*
- Students should revisit their response to the **Focus Question**: "How can melting point, a physical property, be used to determine a substance" and capture a **Line of Learning**.
- ***TEACHER NOTES:*** ***Melting Point*** *is a physical property of substances that represents the temperature at which a solid can change to a liquid. The temperature at which a pure substance melts is unchanging under constant conditions. Therefore, the melting point of a pure substance can be used as a physical property for identification. Ice melts to form liquid water at* 0^oC *(*32^oF*). It is important to note that most substances have a melting point and are all unique to that substance. Often, melting/freezing and boiling/condensation are often taught only in terms of water; therefore, children harbor a misconception that all substances melt at* 0^OC*.*
- Teacher should monitor partner dialogue for confusion and misconceptions. Ask probing questions as necessary to encourage students to build their conceptual understanding of melting point as a physical property used to identify substances.

Lesson Plan – Part B: Boiling Point

Time Required – (Two 60-minute classes)

Disciplinary Vocabulary – Physical properties, Chemical properties, Physical change, Chemical change, Boiling point

Materials Needed:

- *For each group of* ***four*** *students*
  - Hot plate / heat source

- Beaker (250 mL) – 6 *(NOTE: the solutions created need to be saved for use during Part C)*
- Hot pad holder
- Graduated cylinder
- Stirring rod
- Thermometer *(using probe ware will provide more accurate measurements as well as extend the opportunity Computational Thinking)*
- Timing source (stopwatch or clock)
- Balance
- Water –Distilled (1 Liter)
- Salt (200 grams)

Formative Assessment Strategies: Think-Ink-Pair-Share, Line of Learning, Student Dialogue, Exit Ticket

Computational Thinking: Students are asked to collect, organize and analyze data for multiple materials considering several scenarios then generalize and transfer this problem solving process to other real-life scenarios. NOTE: Using probe ware will increase the accuracy of data collected as well as provide opportunity to simultaneously graph results of multiple substances.

Misconceptions: Students often incorrectly believe that temperature changes while a substance is boiling. Melting/freezing and boiling/condensation are often understood only in terms of water; therefore, students often incorrectly believe that the boiling temperature is the same for all substances.

Safety Note(s): Students should know and practice the procedures for glass and chemical safety. Students should use care when performing this experiment, and be wearing the proper safety equipment including aprons and goggles.

Engage

- After viewing the simulation on Melting and boiling, https://simbucket.com/meltingandboiling/ Take a minute to **think** about the following **Focus Question**: "How can boiling point, a physical property, be used to determine a substance?" and **ink** your thoughts in your notebook then **pair** with someone in the class to **share** ideas with each other.
- Capture your predictions in your notebook. *(Remember predictions are never changed once data is collected because they are never wrong; they represent ideas based on current information. However, once new information is discovered, new predictions or revised predictions can be recorded.)*
    - Predict of what will happen to the temperature of water as it is increased to the point of boiling.

  - Predict of what will happen to the temperature of water as it is boiling.
- Record the initial temperature of 100 mL of water. As the beaker of water has constant heat added, record the time elapsed and temperature in your notebooks. Continue collecting data in regular time intervals until the water has been at a rapid boil for about 5 minutes. <u>Boiling begins when the liquid starts to form bubbles throughout, which grow larger, rise to the surface, and burst.</u> *Be sure to record the temperature and time elapsed as accurately and regularly as possible. Keep this beaker and label it "A"; it will be used for the remainder of this part and part C.*
- Graph your results. Be sure to remember DRY-MIX (**D**ependent or **R**esponding values goes on the **Y**-axis; **M**anipulated or **I**ndependent value goes on the **X**-axis) when creating your graph. For this activity, what was the independent value or the one that was manipulated? (*Answer: time*) What value recorded was in response or dependent on something else? (*Answer: temperature*)
- How do your results compare to your predictions? What surprises you? What questions are you thinking about?
- What happens to the temperature as water is being transformed from a liquid to a gas?
- Looking at your graph, what do you infer the boiling point for water to be?
- What might this graph look like if we repeated this with another solution?

Explore

- Predict in your notebooks if solutions all have the same boiling points? Now we are going to explore that with different concentrations of salt solution. *(Remember that the water is the Universal Solvent and the stuff being dissolved in a solvent is the solute; the amount of solute in a solvent determines the concentration - SC Science Performance Indicator 5.P.2B.4)*
- Label four beakers "B – E" and fill accordingly with solute:
  - A – 0 g NaCl (salt) + 100 mL water only (from the "Engage" above)
  - B – 10 g NaCl (salt) + enough water to total 100 mL
  - C – 20 g NaCl (salt) + enough water to total 100 mL
  - D – 30 g NaCl (salt) + enough water to total 100 mL
  - E – 40 g NaCl (salt) + enough water to total 100 mL
- Stir solutions until dissolved (add more water if necessary so volume totals 100 mL).
- Record the initial temperature of solution. As each beaker of salt solution has constant heat added, record the time elapsed and temperature in your notebooks. Continue collecting data in regular time intervals until the solution has been at a rapid boil for about 5 minutes. <u>Boiling begins when the liquid starts to form bubbles throughout, which grow larger, rise to the surface, and burst.</u> *Be sure to record the temperature and time elapsed as accurately and regularly as possible. Keep all beakers and with solutions created, they will be used for lesson C.*
- Graph your results (*use colored pencils to distinguish between the different concentrations of salt and water*). Be sure to remember DRY-MIX (**D**ependent or

Responding values goes on the **Y**-axis; **M**anipulated or **I**ndependent value goes on the **X**-axis) when creating your graph. For this activity, what was the independent value or the one that was manipulated? (*Answer: time*) What value recorded was in response or dependent on something else? (*Answer: temperature*)

- Thinking back to 5th grade *(SC Science Performance Indicators 5.P.2B.4 Construct explanations for how the amount of solute and the solvent determine the concentration of a solution; 5.P.2B.5 Conduct controlled scientific investigations to test how different variables (including temperature change, particle size, and stirring) affect the rate of dissolving)* what is the solute? What is the solvent? Compare the solutions in terms of amount of solute and rate of dissolving.
- What do you notice about each of the solutions you created? How does each solution compare in their ability to pour? (i.e. Which solutions are "thicker" than the others?) What might that "thickness" represent?
- How do your results compare to your predictions? What surprises you? What questions are you thinking about?
- What happens to the temperature as each solution was being transformed from a liquid to a gas?
- Looking at your graph, what do you infer the boiling point for each solution to be?
- What happens to the temperature as heat is added to a solution?
- What happens to the temperature as the solution is boiling?
- How is the boiling rate affected by the amount of solute in a solution?

Explain

- Have students work with a partner to discuss the following scenarios. Knowing that boiling point is a physical characteristic and a known value for substances, justify your classification based on evidence.:
  - If you were a chef at a renowned restaurant and you only wanted to use enough heat to raise the temperature to 185 ^{o}C, should you use Canola oil or Lard to cook with? Explain your response in terms of boiling point.
  - If you wanted to cook spaghetti noodles very quickly, should you boil the water on a stove at sea level or on the top of Mt. Everest? Explain your response in terms of boiling point.
  - You have found three clear colorless liquids and are trying to determine what they might be; you have conducted tests and know their boiling points are:
    - 64.6 ^{o}C
    - 78.3 ^{o}C
    - 82.5 ^{o}C
- Students complete an **Exit Ticket** to the earlier **Focus Question**: "How can boiling point, a physical property, be used to determine a substance.
- *TEACHER NOTES: **Boiling Point** is the temperature at which a liquid boils; defined as a substance changing from a liquid to a gas. Boiling begins when the liquid starts to form bubbles throughout, which grow larger, rise to the surface, and burst. As long as the*

substance is boiling the temperature of the liquid remains constant (at the boiling point). The boiling point for pure water at sea level is 100°C or 212°F. However, when a solute is dissolved in a solvent, the boiling point for the solvent is increased. Under normal conditions, temperatures will remain constant until all liquid has been converted into a gas; at that point, the temperature will begin to rise again. It should be noted that often melting/freezing and boiling/condensation are often understood only in terms of water; therefore, children often harbor a misconception that all substances boil at 100°C. For all substances, the boiling point is unchanging under constant conditions and therefore can be used as a physical property where the value can be used for identification of the substance.

Lesson Plan – Part C: Density

Time Required – (Two 60-minute classes)

Disciplinary Vocabulary – Physical properties, Density, Element, Atom

Materials Needed:

- *For each group of **four** students*
  - Concentrated Salt Solutions from previous lesson (Beakers A-E)
  - Beakers (100 mL) – 5 (additional to the ones with solutions above)
  - Graduated Cylinder – 100 mL
  - Balance
  - Assorted objects to test (ex. plastic centimeter cube, plastic inch cube, wooden centimeter cube, wooden inch cube, glass marble, golf ball, rubber stoppers of assorted sizes)

- *For the teacher:*
  - Large clear container
  - Assortment of different size spheres (ex. golf balls, marbles, BBs, sand, water)
  - Copy of story "Archimedes and the Golden Crown" *(See below)*

Formative Assessment Strategies: Pre-write, Line of Learning, Student Dialogue, Think Aloud

Computational Thinking: Students are asked design an experiment then collect, organize and analyze data for multiple materials considering several scenarios; then represent/sequence the data on a model to further explain their current understanding of density. Students also generalize and transfer their problem solving thinking to a variety of problems.

Misconceptions: Students often confuse the units of cubic centimeters, centimeter cubed and milliliter (cm^3 and mL); in reality these units all represent volume – solid and liquid respectively and can be used interchangeably. Students incorrectly think that mass alone is the determining factor in floating and sinking; that is heavy objects sink and light objects float.

Safety Note(s): Students should know and practice the procedures for glass and chemical safety. Students should use care when performing this experiment, and be wearing the proper safety equipment including aprons and goggles.

Engage

- Be sure that all materials are initially hidden from the students. Begin by adding the largest spheres (ex. golf balls) to the clear container and ask the students to let you know when the container is "full". Ask them to estimate the mass of the container.
- Once they are convinced it is full, bring out the next size sphere (ex. marbles) and ask if more could be added to the container. (They will say "of course" to which you reply "you just said it was full".) So, you add the next size sphere to the container until it is "full" (and hopefully they will say movement will need to occur for the second object to fit). Now, what has happened to the mass and volume of the container? (The volume is the same but the mass has increased considerably.) *Note each sphere that is added could be considered a model representation of an **atom** in an element or molecule.*
- Once they are convinced it is full with both objects, bring out the next size sphere (ex. BBs) and ask more could be added to the container.
- Continue the same process of asking probing questions and adding more materials (sand and/or water). *With each addition, the volume remains the same but the materials need to move so that each can squeeze into the "empty" space. The mass however, has increased tremendously because the container is becoming "more **dense"** with each addition.*
- Density is the concept that we are going to explore further.
- Think back to previous grades and your understanding of how things float and sink. *(SC Science Performance Indicators K.P.4A.1 Analyze and interpret data to compare the qualitative properties of objects (such as size, shape, color, texture, weight, flexibility, attraction to magnets, or ability to sink or float) and classify objects based on similar properties ; 2.P.3A.1 Analyze and interpret data from observations and measurements to describe the properties used to classify matter as a solid or a liquid; 5.P.2A.1 Analyze and interpret data from observations and measurements of the physical properties of matter (including volume, shape, movement, and spacing of particles) to explain why matter can be classified as a solid, liquid or gas.*
- What are your hunches as to why some stuff floats and others sink?
- Have students dialogue with a partner on the **Focus Question**: How can density, a physical property, be used to identify substances?

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Explore

- Measure and pour 75 mL of each solution created in Part B into clean beakers (also labeled A-E). Record the mass of each in your notebooks.
- Compare the masses of each solution. What surprises you? What are your guesses as to the differences?
- Given several objects (glass marble, plastic cube, wooden cube, golf ball, rubber stoppers), predict in your notebooks if each will sink or float in each of the five solutions. (*Remember predictions are never changed once data is collected because they are never wrong; they represent ideas based on current information. However, once new information is discovered, new predictions or revised predictions can be recorded.)*
- Test your predictions and record in your notebooks.
- How do your results compare to your predictions? What surprises you?
- Given the densities for each of the solutions A-E, infer what might be the densities for each of the four objects.
  - A – 100 mL Water + 0 g NaCl → approximately 1.0 g/cm^3
  - B – 100 mL Water + 10 g NaCl → approximately 1.1 g/cm^3
  - C – 100 mL Water + 20 g NaCl → approximately 1.2 g/cm^3
  - D – 100 mL Water + 30 g NaCl → approximately 1.3 g/cm^3
  - E – 100 mL Water + 40 g NaCl → approximately 1.4 g/cm^3
- Compare your inferences to the known values.
  - Glass marble – 2.6 g/cm^3
  - Plastic –0.86 g/cm^3 – 1.07 g/cm^3 (varies depending on type)
  - Wood – 0.79 g/cm^3
  - Golf ball – 1.18 g/cm^3
  - Rubber stopper – 1.2 g/cm^3
- Design and implement a way to "prove" the known values above given that Density = Mass / Volume (D=m/v).
  - Were the given values accurate or not – cite evidence in your argument. Capture all thoughts in your notebook.
- **Conduct research** for the remaining elements listed on the chart below to **create a model/representation** showing the location for each material in a column of salt solution based on known density.

Explain

- Thinking back to 6^{th} grade and the unit on Weather, explain how a "Galileo Thermometer" (as shown here) might accurately describe the temperature?
- Teacher does a **Read-Aloud** with the story about "Archimedes and the Golden Crown" (*See below*); together everyone engages in a **Think-aloud** on how might Archimedes solve the problem.
- Students discuss in small groups: How might air be used to control the floating and sinking of a submarine? *(Answer: Air can be added or removed to change the density of the submarine.)*

- Students should revisit their response to the **Focus Question**: "How can density, a physical property, be used to identify substances?" and capture a **Line of Learning**.
- *Teacher Notes: **Density** is a property that describes the relationship between the mass of a material and its volume. Substances that are denser contain more matter in a given volume. The density of a substance will stay the same no matter how large or small the sample of the substance, and therefore, density can be used as a **physical property** for identification of the substance.*
    - *For example, lead is a very heavy, dense metal (density = 11.34 g/cm^3) compared to density of the very light metal, aluminum (density = 2.7 g/cm^3).*
    - *Consider building materials, what might be some reasons for selecting lead over aluminum and vice versa.*

Archimedes and the Golden Crown (Part C: Density)

In the first century BC, there was a genius named Archimedes' whose first love was mathematics. He would often spend days so intently fixed on solving a problem that he neglected both food and his person to the point that his friends would carry him kicking and fighting to the bath. He often stooped to the ground to work mathematical problems by drawing figures in the dirt. He is even said to have carried a small wooden tray filled with sand, which he used to draw his figures and work on his mathematical problems. This tray would have been Archimedes' version of the modern lap top computer. Of course, such a device is not without its problems: A strong wind could blow away a brilliant proof; a bully could kick a theorem into your face, and should a cat wander into the tray, the outcome could be too disgusting to contemplate.

As the story goes, one day Archimedes was asked by King Hiero of Syracuse to help solve a problem. The king had commissioned a goldsmith to create an exquisite crown from a certain quantity of pure gold, and the goldsmith complied. The goldsmith delivered a beautiful crown and the king was quite pleased. However, the king soon began to hear rumors that the goldsmith had stolen the king's gold by substituting another substance for some of the gold used to make the crown, and keeping the gold that was left over. Because of these rumors, the king suspected that the gold crown was not authentic and that the goldsmith was a fraud. But how was he to prove his suspicions? The crown, after all, appeared to weigh the same as the amount of gold he had given to the goldsmith. King Hiero asked Archimedes to help him determine the truth. However, because the crown was a holy object dedicated to the gods, Archimedes could not disturb it in any way.

Later, with this dilemma on his mind, Archimedes drew a bath. Being lost in his thoughts on the problem, Archimedes did not pay close attention to the bathwater and filled the tub to the top. As he stepped into the bath, the water began to flow over the top and onto the floor. He suddenly ran home shouting loudly in Greek "Eureka! Eureka!" meaning "I have found it! I have found it!" He was so excited that he hadn't even bothered to put his clothes on! Archimedes had found a way to prove the crown's authenticity.

Based on this story, describe how Archimedes might prove whether the golden crown was real and whether the goldsmith was a fraud.

***For the Teacher ONLY**: (Part C: Density)*

Although there is speculation as to the authenticity of this story, it remains famous. Probably no other tale in all of science combines the elements of brilliance and bareness quite so effectively. Whether the story is true or not, there is no doubt to the truth of Archimedes understanding of buoyancy.

Archimedes and the Principle of Buoyancy

Here is what Archimedes had found. Since an object immersed in a fluid displaces the same volume of fluid as the volume of the object, it was possible to determine the precise volume of the crown by immersing it in water. After determining the volume of water, a piece of pure gold could easily be made to match the volume of the water, and thus the volume of the crown. In theory, if the volume of the crown and the volume of the gold block are the same, they should also have the same mass. The only reason they would not have the same mass is if one of them was not pure gold. When the two objects were placed in a balance they did not have equal mass. Faced with this evidence the craftsman confessed to his crime.

Extending this idea further, if the mass of the water displaced is greater than the mass of the object, the object will float (Note: this calculation will require that the object be forcibly submerged). If the mass of the water is less than the mass of the object, the object will sink. If by chance the two masses are equal, the object will be suspended in the water at varying depths depending on the initial depth of the object and the water's temperature and turbidity. Every vessel that has ever sailed on water, every submarine that has ever launched, and in short, all objects that come in contact with a body of water, are governed by the principle of buoyancy defined by the great mind of Archimedes.

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Lesson Plan – Part D: The Ability to Burn

Time Required – (One 60-minute class)

Disciplinary Vocabulary – Physical properties, Chemical properties, Burning, Physical change, Chemical change

Materials Needed:

- *For each group of **two** students:*
  - Flame source - 1
  - Tongs to hold substances in flames - 1
  - Wooden splint - 2
  - Paper – 1 sheet
  - Marshmallow - 2
  - Peanut - 2
  - Walnut - 2
  - Coin - 2
  - Copper wire – 2 pieces
  - Steel wool – 2 small pieces

Formative Assessment Strategies: Pre-write, Line of Learning, Think Aloud, Student Dialogue

Computational Thinking: Students are asked design an experiment then collect, organize and analyze data for multiple materials. Students are then asked to transfer their understanding to provide possible solutions for real-world problems.

Misconceptions: Students often incorrectly believe that the substances once burned disappear instead of being converted into something else.

Color is another physical property used to identify substances; however, by itself color is not a significant identifier. The absence of color is also a physical property. This information has been included within this lesson instead of providing a separate lesson for solely color and needs to be explicitly addressed with the children.

Safety Note(s): Students should know and practice the procedures for glass, chemical and fire safety. Students should use care when performing this experiment, and be wearing the proper safety equipment including aprons and goggles.

When burning nuts be sure to know if anyone has nut allergies; also, nuts tend to produce a lot of smoke when burned – be prepared to ventilate the room.

Engage

- Conduct a "**Think Aloud**" on the following questions:
    - How do you know when something is burning?
    - Give examples of things that you know burn? How do you know?
    - What might they be made of that allows them to burn?
    - **Focus Question:** How can the ability to burn, a chemical property, be used to determine a substance?

Explore

- Capture in your notebook all predictions whether the following substances will burn or not:
    - Wooden splint
    - Paper
    - Copper wire
    - Steel wool
    - Coin
    - Marshmallow
- Design an experiment to test your predictions for the above substances. Be sure to include safety procedures and methods for data collection in your design.
- Conduct the experiment designed above.
- How did your results compare to your predictions? What surprised you?
- How can burning be used as a chemical property to identify substances?

Explain

- Have students discuss how might astronomers use the chemical property of burning to identify the composition of stars? *(Teacher Note: each metal has a specific color it glows when burning; these colors can be used to identify the composition of the star through a telescope)*
- Have students engage in the Virtual Lab to determine which element is represented by the resulting tests (density, flame color, melting point, boiling point) http://www.glencoe.com/sites/common_assets/science/virtual_labs/E21/E21.html
- Students should revisit their response to the **Focus Question**: "How can the ability to burn, a chemical property, be used to determine a substance?" and capture a **Line of Learning**.
- *Teacher Note: The ability **to burn** is defined as reacting quickly with oxygen to produce light and heat. This is also known as **combustibility**. Burning is a chemical property can be used to identify unknown substances.*

Lesson Plan – Part E: The Ability to Rust

Time Required – (One 60-minute class) *(NOTE: the experiment may need to sit overnight for dramatic observations to be made)*

Disciplinary Vocabulary – Physical properties, Chemical properties, Rusting, Physical change, Chemical change

Materials Needed:

- *For each group of **two** students:*
  - Beaker (3) – 100 mL
  - Steel Wool (Fe) – 3 pieces
  - Vinegar (CH_3COOH) – 50 mL
  - Water (H_20) – 50 mL
  - Thermometer *(using probe ware will provide more accurate measurements as well as extend the opportunity Computational Thinking)*

Formative Assessment Strategies: Pre-write, Line of Learning, Student Dialogue

Computational Thinking: Students are asked design an experiment then collect, organize and analyze data for multiple materials. Students are then asked to transfer their understanding to provide possible solutions for real-world problems. NOTE: Using probe ware will increase the accuracy of data collected as well as provide opportunity to simultaneously graph results of multiple substances.

Misconceptions: Students need to understand that all substances containing iron (Fe) have the potential to rust when in contact with Oxygen (O_2). Many factors contribute to the rate of the chemical reaction commonly known as rusting.

Color is another physical property used to identify substances; however, by itself color is not a significant identifier. The absence of color is also a physical property. This information has been included within this lesson instead of providing a separate lesson for solely color and needs to be explicitly addressed with the children.

Safety Note(s): Students should know and practice the procedures for glass and chemical safety. Students should use care when performing this experiment, and be wearing the proper safety equipment including aprons and goggles.

Engage

- We see rust, that reddish-brown flaky stuff, on the sides of old cars, or on our bicycle that we absent-mindedly left outside for an entire winter. But what is rust caused by? Have a class discussion to generate ideas.
- Have students capture thoughts to the **Focus Question** in their notebooks: How can the ability to rust, a chemical property, be used to determine a substance?
- Design an experiment to see what effects water, air and vinegar might have on steel wool using the materials listed above.

Explore

- Use the experiment design you created above to test the effect water, air and vinegar have on steel wool. *(Submerge one piece of steel wool in 50 mL of water, another in 50 mL of vinegar and the third in a beaker with air.)*
- Record observations and temperature changes in regular intervals.
- What do you notice? What surprises you?
- What might be causing the rust?
- How can the ability to rust be a chemical property used to identify substances?

Explain

- In small groups, have students discuss:
  - How might you test other substances to determine the rate at which iron will rust?
  - What might be done to prevent metals from rusting?
  - Identify professions that might work with or be concerned by the chemical property of rusting. How could this impact their product or outcome?
- Students should revisit their response to the **Focus Question**: "How can the ability to rust, a chemical property, be used to determine a substance?" and capture a **Line of Learning**.
- *Teacher Notes: **Rusting** is a slow combination of iron with oxygen. When this happens, heat energy is released. The heat released by the rusting of the iron causes the liquid in the thermometer to expand and rise. Rust is a chemical reaction with identifiable products ($4Fe + 3O_2 \rightarrow 2F_2O_3$). Iron or steel wool will turn reddish-brown when it rusts. The vinegar is an acid that removes any protective coating from the steel wool, allowing the iron in the steel to rust quicker. Water also allows a reaction between the iron and oxygen; only it occurs at a slower rate. Air will also rust the steel wool, but at an even slower rate due to the protective coating on the strands of steel wool.*

Other information on this indicator(s) can be found in the support documents/resources on the SC State Department website.

www.ed.sc.gov (Instruction → Standards and Learning → Mathematics or Science → Support Documents and Resources)

Content Area (Disciplinary) Literacy strategies and descriptions can be found on the S2TEM Centers SC website:

s2temsc.org (Resources → Disciplinary Literacy Virtual Library → Strategy Warehouse)

Additional Information

Level 1 lessons contain a realignment to the 2014 Science and/or the 2015 Mathematics Standards.

Level 2 lessons contain Level 1 information and Content Area Literacy and Disciplinary Literacy Strategies.

Level 3 lessons contain Level 1 and 2 information and Computational Thinking Connections.

Level 4 lessons contain Level 1, 2, and 3 and integration of at least 2 content areas.

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Name of Substance	State at Room Temperature (25°C / 77°F)	Melting Point °C °F	Boiling Point °C °F	Density g/cm^3
Aluminum (Al)	Solid	660 °C 1220 °F	2519 °C 4566 °F	2.7 g/cm^3
Alcohol, Ethanol (C_2H_5OH)	Liquid	-114.2 °C	78.3 °C 173 °F	0.8 g/cm^3
Alcohol, Isopropyl (C_3H_8OH)	Liquid	-89 °C	82.5 °C 181 °F	0.8 g/cm^3
Alcohol, Methanol (CH3OH)	Liquid	-97.7 °C	64.6 °C 150 °F	0.8 g/cm^3
Butter (real cream)	Solid	90-95 °C 194-203 °F	177 °C 350 °F	0.391 g/cm^3
Canola Oil	Liquid	-10 °C 14 °F	225 °C 400 °F	0.92 g/cm^3
Copper (Cu)	Solid	1085 °C 1981 °F	2856 °C 5173 °F	8.9 g/cm^3
Gold (Au)	Solid	1063 °C 1945 °F	2856 °C 5173 °F	19.3 g/cm^3
Lard (pig fat)	Solid	43 °C 110 °F	183-207 °C 361-401 °F	0.92 g/cm^3
Lead (Pb)	Solid	327 °C 621 °F	1749 °C 3180 °F	11.3 g/cm^3
Paraffin wax ($C_{20}H_{42}$)	Solid	65.6 °C 150 °F	n/a	0.9 g/cm^3
Platinum (Pt)	Solid	1773 °C 3224 °F	3825 °C 6917 °F	21.4 g/cm^3
Silicon Dioxide (SiO_2) – Quartz / Sand	Solid	1723 °C 3133 °F	2230 °C 4046 °F	2.6 g/cm^3
Silver (Ag)	Solid	961 °C 1761 °F	2162 °C 3924 °F	10.5 g/cm^3
Sodium Carbonate (Na_2CO_3) *Anhydrous*	Solid	851 °C 1564 °F	1600 °C 2912 °F	2.54 g/cm^3
Sodium Chloride (NaCl) (table salt)	Solid	801 °C 1474 °F	1413 °C 2575 °F	2.17 g/cm^3
Sucrose ($C_{12}H_{22}O_{11}$) (table sugar)	Solid	186 °C 367 °F	n/a	1.6 g/cm^3

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Name of Substance	**State at Room Temperature (25ºC / 77ºF)**	**Melting Point ºC ºF**	**Boiling Point ºC ºF**	**Density g/cm^3**
Titanium (Ti)	Solid	1668 ºC 3034 ºF	3287 ºC 5949 ºF	4.5 g/cm^3
Water (at sea level)	Liquid	n/a	100 ºC 212 ºF	1.0 g/cm^3
Water (at top of Mt. Everest)	Liquid	n/a	68 ºC 154 ºF	1.0 g/cm^3
Water, Ocean	Liquid	n/a	*Varies depending on salinity*	1.23 g/cm^3 *varies depending on salinity*
Ice	Solid	0 ºC	n/a	0.92 g/cm^3
Hydrogen (H)				
Carbon (C)				
Nitrogen (N)				
Oxygen (O)				
Chlorine (Cl)				
Magnesium (Mg)				
Zinc (Zn)				
Phosphorous (P)				
Iodine (I)				
Silicon (Si)				
Iron (Fe)				
Helium (He)				
Potassium (K)				
Fluorine (F)				

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