### Big Idea/ Topic
Solution properties and concentration

### Standard Alignment
**SC6.** Obtain, evaluate, and communicate information about the properties that describe solutions and the nature of acids and bases.
   b. Plan and carry out an investigation to evaluate the factors that affect the rate at which a solute dissolves in a specific solvent.
   c. Use mathematics and computational thinking to evaluate commercial products in terms of their concentrations (i.e., molarity and percent by mass).
   d. Communicate scientific and technical information on how to prepare and properly label solutions of specified molar concentration.
   e. Develop and use a model to explain the effects of a solute on boiling point and freezing point.

**Connection to other content areas:**
**ELAGSE11-12RI1:** Cite strong and thorough textual evidence to support analysis of what the text says explicitly as well as inferences drawn from the text, including determining where the text leaves matters uncertain.
**ELAGSE11-12RI7:** Integrate and evaluate multiple sources of information presented indifferent media or formats (e.g., visually, quantitatively) as well as in words in order to address a question or solve a problem.
**ELAGSE9-10RI8:** Delineate and evaluate the argument and specific claims in a text, assessing whether the reasoning is valid and the evidence is relevant and sufficient; identify false statements and fallacious reasoning.
**ELAGSE11-12W1:** Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.

### Instructional Design

#### Engage and Explore

**Phenomenon:** What determines the properties of solutions, such as concentration or taste?

Students begin this instructional segment with an at home solution lab.

Guiding question: What factors affect the rate at which a solute dissolves in a solvent?
Students plan an at-home investigation to determine what affects solvation rate. A primary concern is for safety of the students as they carry out the investigation. A discussion on lab safety and communication with parents/guardians are essential components if this will be included for the unit. Water and table salt are recommended to use to make the solutions. Students must design the investigation and submit the procedure for approval before conducting the lab. Encourage students to consider accuracy, controls, and consistent variables as they design the lab. A graphic organizer for planning and carrying out the investigation, such as the editable ones from thewonderofscience.com, could be useful for students. The Solution Student Lab Sheet is included.

Since students will most likely not have access to a scale in order to properly weigh the solute, they could use an approximation with volume. For example, it can be approximated that 1 teaspoon of table salt has a mass of 6 grams. Using teaspoons and standard measurements for volume will allow students to complete the lab using kitchen equipment.

Beyond students designing and completing their investigation, post lab questions or class discussions should guide to student understanding of why the solvation rate is affected by variables such as temperature.

Virtual option: for students unable to complete at-home lab, consider the same guiding question as above, but students use PhET simulations to explore (PhET Interactive Simulations University of Colorado Boulder https://phet.colorado.edu):

PhET: Sugar and Salt Solutions
PhET: Concentration

Teacher-created lab: a third option is to conduct a teacher-led lab from the science lab or from home. The investigation can still be planned by students or as a class and then observations and data shared with the group.

Unplugged: the at home lab can completed without access to technology, but students will need access to printed materials concerning lab safety and lab parameters.

Explain

In this section of the lesson, students gain an understanding of how solutions are prepared and described with concentration. The focus is on students being able to recognize and use various concentration calculations and also being able to properly prepare concentrations of specified molarity. This part of the lesson can start with a class discussion about concentration. Students may not realize that the products they use or see every day are in some way connected to a certain expression of concentration. The discussion could focus on the following questions:

- Why do we need to be able to express concentration?
- What are some examples of concentration?

Encourage students to analyze several things around them in terms of concentration. For example, they could evaluate the percent by mass for sugar in several drinks or could explore the different
ways that concentration is expressed. Unit conversion or dimensional analysis may have to be discussed or referred to as students may have to convert volume measurements.

Students will most likely not have experience working with molarity. Students may remember calculations for moles from the chemical reaction standards if already covered. A review may be necessary.

Online sources for information could include videos and corresponding Video Notes. Some topics in videos may be beyond the scope of the standard but may provide explanations and extensions if needed.

The sample beverage calculation problems could be used to guide class discussions or used to evaluate student mastery.

For students to get experience with concentration and molarity without access to a science lab, they complete the lab, What Does Molarity Taste Like? Students prepare solutions of different concentrations and describe how taste is affected. Students can use any powdered drink mix for the lab that is pre-mixed with sugar. Table sugar (sucrose) is approximated to be the drink compound to make calculations easier for students. With normal kitchen equipment, students prepare drink solutions and calculate how much solute (sugar) is needed. Since students will most likely not have access to a scale, the following conversions are useful: 1 teaspoon = 4 grams of table sugar, one 8 oz cup = 0.24L. Students may need additional support with unit conversions. Three concentrations are given for students that round to simple teaspoon measurements, but this could be modified based on need and students could make more or less different concentrations depending on materials. Students are challenged to make a solution with a concentration of their choosing.

Virtual option: students could explore the PhET simulation: Molarity (PhET Interactive Simulations University of Colorado Boulder https://phet.colorado.edu/) if they are not able to conduct the at-home beverage lab or would benefit from more experience with concentration.

Unplugged: the majority of the elements from this part of the lesson can be completed without access to technology. Students need access to lab sheets, problems, and printed information about concentration expressions.

Elaborate

In this section of the lesson, students will develop models for how solutes affect the freezing point of a solution. Students could conduct mini labs to get introduced to how solutes change freezing point. Students prepare various salt solutions and determine how long they take to freeze in the freezer. This could serve as an excellent launching point for a class discussion or student writing opportunity. As students build an understanding of colligative properties, they develop models, such as the Colligative Properties student sheet. Boiling point elevation may be best demonstrated through teacher-created or online videos for lab safety concerns.
Teacher-created lab: an option for this section of the lesson is to conduct a teacher-led lab from the science lab, if available. Observations and data can be shared with students that show boiling and freezing point changes. Students could complete a Claim-Evidence-Reasoning for this to document their thinking.

**Unplugged:** students will need access to printed materials about colligative properties as well as prompts to develop models and communicate with them.

**Evaluate**

Students should demonstrate their understanding as they communicate verbally and through written work about solutions and solution properties.

**Lesson Goals Checklist**

**SC6. Obtain, evaluate, and communicate information about the properties that describe solutions and the nature of acids and bases.**

- Plan and carry out an investigation to evaluate the factors that affect the rate at which a solute dissolve in a specific solvent.
- Use mathematics and computational thinking to evaluate commercial products in terms of their concentrations (i.e., molarity and percent by mass).
- Communicate scientific and technical information on how to prepare and properly label solutions of specified molar concentration.
- Develop and use a model to explain the effects of a solute on:
  - boiling point
  - freezing point

**Evidence of Student Success**

Student mastery is assessed throughout this unit using formative and summative components. Student discussion, explanations and products should reflect the understanding indicated in the sections above. Each activity in the segment functions as an assessment opportunity as well to plan targeted supports or provide extension items. Formative options using the self-evaluation checklist and at various points during the segment.

**Distance Learning Supports**

The vision for science education in the state of Georgia is as follows: All Students, over multiple years of school, actively engage in science and engineering practices and apply crosscutting concepts to deepen their understanding of the core ideas in these fields.
The learning experiences provided for students should engage them with fundamental questions about the world and with how scientists have investigated and found answers to those questions.

This lesson includes the disciplinary core ideas, science and engineering practices and crosscutting concepts to actively engage students in exploring science concepts with real world topics. As part of the vision we must support the inclusion of all students in science learning. Some general ideas to consider when designing things to support students that struggle are as follows:

- Be sure that students can access the information that they are learning. Make sure that you can answer the following questions:
  - Do students have what they need to get the information? This is about them having the book or internet access to get to the information.
  - Once students obtain the information, are students able to determine what information is important? This is about the students having materials on the appropriate grade level and that is in a format that students can understand.
  - Is the material presented in multiple ways that allows all students to interact with information in a way that works for them? Such as video, audio, and articles.
  - Consider read aloud as a potential option for students that have reading deficits as an option to assist students in accessing the material. This could be done using video, read aloud or via phone.

- Students may need ideas about where to find information. Providing students with information about what a reliable source is and even where to find reliable sources may be beneficial for students.

- Some students may find it difficult to complete the entire lesson workload. Some students may benefit from a reduced workload (note: this should be used only when absolutely necessary). Be sure that the information that is removed will not negatively impact the student’s understanding of the disciplinary core idea.

- Consider how students show their knowledge. Students need multiple ways and opportunities to show their knowledge. Things to consider:
  - Recording video or audio
  - Drawing
  - Writing
  - Typed
  - Verbal

- Provide students with a way to ask questions in a forum that does not cause anxiety. Frequently students do not want to ask questions in front of their peers because they are afraid of what their peers may think of them. So, be sure to provide students a way to ask questions that is private or anonymous.

- Consider materials that students need to complete the assignments.
  - Do students have needed materials?
  - What are some alternative materials that students may have available to them?

- Have a clear and consistent set of guidelines for providing consistent feedback to all students.

- Utilize graphic organizers such as those from the Wonderofscience.com

- Use high leverage and evidence-based practices to reach all students.
Some ideas for supporting **this lesson specifically** would be to make sure to consider the following:

- Teachers should consider providing students with graphic organizers to assist in the planning investigation, organizing student ideas and information that students are obtaining.
- The teacher should consider providing an example of figuring out concentration of an everyday item. The teacher may need to have some examples ready to work with students.
- The teacher should consider providing students with a list of different everyday items that they can analyze when looking for concentrations.
- Teachers may need to remind students to label concentrations of any solutions that they make.
- The teacher should lead a discussion about student findings and information that was obtained as part of their investigations.
- The teacher should consider providing students with pictures of freezing and boiling. Students could put them in chronological order and then explain why if they are unplugged.
- A time lapse video might be beneficial for students that cannot conduct the freezing experiment at home. It would be a good way to share the information of things boiling as well.
- The teacher should be sure that students have multiple ways to share their knowledge.
- The teacher should consider sentence frames for any writing assignments that students are being asked to do.

### Engaging Families

Additional resources to support chemistry understandings in this segment include [Georgia Virtual School](https://www.gatschool.org) and [GPB: Chemistry Matters](https://www.gpb.org). Selections from online textbooks could also be used to provide a print resource or remain digital, such as [OpenStax Chemistry](https://openstax.org).
Solution Student Lab Sheet

Guiding Question: What factors affect the rate at which a solute dissolves in a solvent?

Lab Safety: Based on class discussions and communication with your teacher, what lab safety protocols will you be following?

Procedure: What steps will you take to obtain information and evidence to answer the guiding question?

Observations and Data:

Post Lab Questions:

1. What variable that you tested affected the rate of solvation the most? Why do you think?
2. What variable that you tested appeared to not influence the solvation rate? Why do you think?
3. When the solute was dissolving, what was happening on a small scale? In other words, if you were watching it happen on a molecular level, what would it look like? Complete the following molecular level models to show the process. Include labels.

![Diagram of solute and solvent mixing]
Commercial Product Concentration

1. The concentration of phosphoric acid in Coke is 0.00912 M, how many grams are in a 20-ounce serving?
2. There are 56 mg of caffeine (C₈H₁₀N₄O₂) in a 20-ounce serving of regular cola, what is the molarity of caffeine in cola?
3. In a sports drink, there are 300 mg of sodium chloride in a 12-ounce serving. What is the concentration of salt?
4. A sports drink has 14 grams of sugar per 8 ounces, what is the concentration?
5. Sweet tea has concentration of sugar of 0.4932 M of sugar. How many grams of sugar are in an 8-ounce serving?
What Does Molarity Taste Like?

Purpose: To determine the perfect concentration (molarity) of a drink.

Method: Make three solutions of a drink with different concentrations and taste them to decide which one is the correct concentration. You will prepare 0.24 Liters of each of the following solutions: 0.097 M, 0.15 M, 0.19 M

Materials:
Drink mix powder  water  measuring cups  teaspoon measurements

Procedure:
1. Calculate (and show your work) how much mix solid you will need to make 0.24 L of each solution.

The powder is already mixed with sugar; the majority of the mixture is sugar, so you can assume that the molar mass of the mix is the same as sugar. If the drink concentrate is not already mixed with sugar, combine the powdered mix and sugar according to the drink directions, do not add water yet.

Show your calculations on your own paper for:
- The molar mass of table sugar (sucrose)
- Mass of solute needed for the 0.097 M solution
- Mass of solute needed for the 0.15 M solution
- Mass of solute needed for the 0.19 M solution

2. Determine the mass (and then teaspoons) of sugar mixture needed for each solution.

3. Measure out the correct mass of the sugar mixture with teaspoons.

4. Add the correct amount of water stir with a spoon.

5. Pour the solution into the smaller cups to taste the mixture. Record your observations of each solution on your lab sheet.

6. Compare the solutions and decide which one is closest to the correct concentration according the drink mix instructions. Finally, you and your family members can design your own perfect combination by determining what the ideal molarity should be. Record all calculations.

Post-Lab:
1. What concentration was closest to real drink? What was wrong with the other solutions?

2. How is taste related to concentration? Why are they related in this way?

3. What kind of mixture is the drink mix? Explain.

5. Look up the nutrition info for your favorite drink (or any drink) that has sugar, how many grams of sugar are in a 20-ounce serving? What would the molarity be if we ignored all ingredients except sugar?
Video #1: What Happens When Stuff Dissolves?

Video Notes. Video Link

With the naked eye, mixing salt and sugar in water both look the same. At the atomic level, things are different.

It depends on whether something is an ________ or ________ compound as to how it dissolves.

Salt: Ionic: metal + ________; made of ___ ions and ___ ions
Sugar: Covalent: nonmetal + ____ ; C, H, and O atoms

--A grain of sugar is more “messy” and not nearly as organized as salt

How they dissolve:

Draw a diagram of how salt dissolves: Draw a diagram of how sugar dissolves:

Sugar breaks up into individual ________; the molecules ________
Video #2: Crash Course Chemistry Solutions

**Video Link**

A solution is a mixture in which the particles of _______ are dissolved in the particles of the ________

Air is a solution: Nitrogen is the ________; oxygen and other gases are dissolved in it

All solutions have certain properties because of:

1. Molecular Structure
2. Pressure
3. Temperature

These factors affect the solubility: the amount of solute that will ______________ of solvent

Dilute and concentrated can be vague terms, we need to be more precise in chemistry:

_________ (M): number of moles of solute per _____ of solution

_________ (m): number of moles of solute per _________ of solvent

Mass Percent: mass of _______/mass of _______ x 100%

Not every solvent can dissolve every solute; liquid solvents have molecular interactions, and the molecular structure determines if something will dissolve.

**Attributes that affect solubility:**

1. **Polarity:** for a substance to dissolve—it needs to interact _______ y with the solvent; this happens if they have similar ________

   Fugu (puffer fish) example: contains tetrodotoxin, which causes paralysis, suffocation, and death. Why? In part because of its polarity.

   -the toxin is covered on its outer surface with polar _______ and _________ groups—→ so it dissolves easily in ____________, like water, and affects the sodium channels of _______

2. **Pressure:** (example: dissolving carbon dioxide gas in cola)

   Partial pressure: the portion of pressure caused by the gas being dissolved

   In order to keep the CO₂ dissolved in cola, the partial pressure must be higher than the pressure of the CO₂ trying to make it out of the solution. This is why cola bottles are pressurized

   The amount of CO₂ dissolved in a cola bottle if it was normal atmospheric pressure:

3. **Temperature:** solubility generally goes up as temperature _________ for solids dissolving in liquids. This is the opposite for gases; example: dissolved oxygen in water for fish
Colligative Properties Problem Set

1. Draw diagrams of what pure water looks like at an atomic level. For each diagram, draw 5 molecules and discuss the relative strengths of IMFs:
   Solid:  
   Liquid:  
   Gas:  

   IMF:  
   IMF:  
   IMF:  

2. Water is a polar molecule—what does this mean?

3. Draw a diagram of a single water molecule; Clearly indicate what areas of the molecule have a net positive and net negative charge.

4. When an ionic solid dissolves in water what happens to the solid on an atomic level?

5. Are chemical bonds broken \(\text{\textit{intra}}\text{\textit{molecular forces}}\) within the \textit{solvent} particles? Explain
6. Develop a model of NaCl dissolved in liquid water. Clearly label the attractions between the solvent and solute particles. Include 4 solvent molecules and 2 units of NaCl. Different colors help!

7. Using your model from question 5, explain why this solution does not freeze at 0°C [Hint: think about what has to happen for pure water to become ice].

8. Using your model from question 5, explain why this solution does not boil at 100°C [Hint: think about what has to happen for pure water to become steam].

9. Application: car engines use an ethylene glycol solution (antifreeze) in the coolant system. If your car is serviced and the solution was replaced with pure water, explain the potential risks?
### Claim—Evidence—Reasoning

**Guiding Question:** What is happening on the particulate level that gives the three substances different properties?

**Claim:**

<table>
<thead>
<tr>
<th>Evidence:</th>
</tr>
</thead>
</table>

**Reasoning:**

**Prediction:** Will there be a difference in how/when the three substances reach boiling point? What will be the same or different (temperature, time, etc.)? Explain your prediction.

<table>
<thead>
<tr>
<th>Diagram:</th>
<th>What is happening at the particulate level with the three substances? Label structures and substructures.</th>
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</table>