This segment is useful in connecting standard elements of solution properties. Topics covered are solvation, solution concentration, how to prepare solutions, and colligative properties. This is part 2 of 2 instructional segments for solutions.

Student Science Performance

Grade or course: 9-12 Chemistry	**Title:**
Topic: Solutions	Exploring Solutions

Performance Expectation for GSE:

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.

Performance Expectations for Instruction:

1. Explain with supporting evidence the factors that influence how a solute dissolves in a solvent.
2. Design an investigation to explore solvation.
3. Develop a particulate diagram or model that explains how adding a solute will influence the boiling point and freezing point of a solution.
4. Design a method to analyze and prepare solutions of certain concentrations.

Additional notes on student supports

Materials

Teacher demonstration of solution properties:

hot plates, beakers, salt and sugar solutions, conductivity meters
lab supplies

Solvation lab:

Hot plates, beakers, stir rods, mortar and pestle, thermometers, scales, weighing boats/paper, graduated cylinders, ice (to cool solutions)
Chemicals for this lab: solids such as $CuSO_4$ or $MgSO_4$ for chemical A and B, that can be ordered in different sizes, other chemicals also work. Sugar can be used for chemical C.

Beverage lab:

Plastic cups (large enough to mix 100 ml and smaller 1-ounce size) plastic spoons or coffee stirrers, powdered drink mix (with sugar already added), water

Freezing point and boiling point lab:

Different concentration of two salt solutions, beakers, hot plates, test tubes, thermometers, ice to cool solutions, rock salt, thermometers

Students will continuously obtain, evaluate, and communicate information. This is not a linear process. Students will communicate through writing and discussions to allow for formative assessment. This benefits the teacher, student, and whole group to guide instruction to clarify misconceptions or extend content.

Engaging Learners	**Phenomenon** The components of a solution determine its properties. Students observe that substances may appear similar but have different properties.
	Obtaining Demonstration Set up: Have three beakers for observation, a salt water solution (high concentration), sugar water solution, and pure water. Place on separate hot plates to start the demonstration. Demonstrate that only the salt water solution will conduct electricity. Other tests could be conducted here, such as pH, temperature, etc. The focus is to guide students' thinking to relate solution properties to the particulate level. Tell students that two of the beakers are solutions and that we are trying to learn about what is happening on a small scale that gives the beakers different properties, even though they look the same. At this time, turn the hot plates on the same setting and tell students that substances will heat up until boiling. Suggested questions for students: • *How could we determine which beakers contain solutions?* • *What is a solution? How do you make a solution?* • *What is happening on a small scale to make one substance conduct electricity?* • *What other measurements or data could we gather from the substances?* Students will complete a claim-evidence-reasoning form during and after the investigation. They are prompted to predict similarities/difference in boiling point, differences between solutes, as well as draw a particulate-level diagram. *Teacher Notes: Students may have had experience with solutions in a previous course and may have knowledge that will guide them with the initial claims and evidence. The focus at this part of the lesson is to encourage student claims as they build experience with solutions.*
	Evaluating Initially, students will evaluate claims as whole group as the three substances reach boiling points. Initial claims could be used to organize student groups or claims could be posted on board to support group discussion.
	Communicating Students communicate individual or group claims—evidence—reasoning during the demonstration process. Students could share to small groups or on white board presentations.
Exploring	*Obtaining* After completing the claim—evidence—reasoning form with the initial demonstration. Students will design an investigation to determine the factors that affect solvation rate. The focus moving beyond the opening demonstration is to build student understanding of solution properties, in

	this investigation, it is about solvation rate. Suggested questions to guide investigation plans: • *How is a solution made?* • *Are there certain steps required to make a solution?* • *How long does it take to make a solution?* • *What factors influence how fast a solute will dissolve?* • *Does every chemical dissolve at the same rate?* Students may be given these questions or similar and then prompted with designing the investigation or this lab could be done in a scenario/challenge format, where students are given the task of designing a procedure to prepare a solution. They could be given concentration parameters or guidelines of time limits to prepare a solution. Data would have to be collected. With this approach, students design and complete a procedure to prepare a solution in the least amount of time. As a post lab analysis, they develop a summary of the factors they observed. *Teacher Notes: Different chemicals can be used for this investigation. For solution 1, a salt that comes in different sizes (powder, and different sized crystals) works well. An optional extension is to use carbonated drinks to analyze gas solutes. The production of solubility curves is not required with the standard but could also be an extension.*
	Communicating Students will communicate lab results and analysis in group poster sessions, class discussions, or individual response.
	Evaluating As students evaluate other procedures and results from the class, they should modify or reinforce their claim—evidence—reasoning forms from the initial demonstration.
	Formative Assessment of Student Learning At this point in the lesson progression, students should be building an understanding of basic solution concepts. It is beneficial to formatively assess where students are before moving forward. Suggested formative assessment tasks: • *Draw a particulate level diagram of two equal volume NaCl solutions; one that has twice as much solute as the other.* • *How would explain the concept of "solution concentration" to a 3rd grader?* • *In one part of the lab, there were different sizes of solute—what would these look like at the particulate level?*
Explaining Finalizing Model	*Obtaining* To connect to the initial phenomenon, show a short demonstration of how concentration affects properties. Demonstration Set-up: Prepare two solutions of NaCl ahead of class; equal volumes, but one

	with much greater concentration. Suggested prompts: • *Both of these solutions are NaCl, what do you expect to see for the conductivity? (complete conductivity test)* • *If solutions are both NaCl, what might cause the difference?* *Teacher Notes: The point of this demonstration is for students to see that the identity of the solute is not the only thing that determines properties. Students should have experience with concentration, but guide them to the conclusion that we need to be able to quantify concentration—this leads into the next investigation.* In the Beverage Concentration Lab, student get first-hand experience with molarity through taste tasting different concentrations. After discussing a need to quantify concentration with the demonstration, introduce molarity. *Teacher Notes: Lab equipment cannot be used for this investigation, plastic cups and spoons can be used. One suggestion is to have plastic cups pre-marked at the 100 ml mark so graduated cylinders are not needed. Each lab group could use a plastic cup to weigh and mix and then pour into smaller 1-ounce plastic cups for tasting. A drink mix that already has sugar combined with the flavor is the easiest to use; for calculations, students can approximate the mass of the solute to be sugar.* Following the lab, students continue exploring concentration by analyzing commercial products. This could be structured where students are given certain substances and using nutrition labels, determine concentration of components, such as caffeine or sugar. This could also be more open-ended where students research or analyze products they choose. Molarity, percent by mass, and other concentration methods could be explored. As students build experience with determine solution concentrations, they are required to communicate how to prepare and label solutions. The dilution equation could be used in combination with molarity to task students with preparing solutions. Start with a concentrated solution, and students must make a series of dilutions to prepare given concentrations.
	Evaluating Student feedback is evaluated continually through these lab-based activities; this format allows students to self-evaluate their skills at preparing or analyzing solutions.
	Communicating Students communicate findings about commercial products and solution preparation on data collection and calculation sheets.

Elaborating Applying Model to Solve a Problems	**Phenomenon** Discuss the initial demonstration of the differences in boiling point or show the demonstration again.
	Obtaining In groups, students conduct investigations to determine the effects of solutes on boiling point and freezing point. Different solutes and amounts should be used to demonstrate effects. Prepare two solutions of simple salts, such as NaCl or $MgSO_4$; two different concentrations of each. Students groups could be assigned one or two solutions. In ice water baths, with rock salt, student groups could experiment on the same salt solutions in test tubes for freezing point. As data is gathered, students should complete model diagrams of the process. In both cases, students should compare results to deionized water.
	Evaluating Evaluate student understandings through discussion of lab results and model diagrams.
	Communicating Students can communicate through white board presentations, group sharing or through written responses. Students groups should have analyzed the same salt with different concentrations. This should be communicated in model diagrams.
Evaluation	***Assessment of Student Learning***
	Post lab questions and analysis will be used to assess student learning, in addition to formative assessments throughout the unit.
SEP, CCC, DCI	**Science Essentials**
Science and Engineering Practices	• Planning and carrying out investigations • Using mathematics and computational thinking • Obtaining, evaluating, and communicating information • Developing and using models
Crosscutting Concepts	• Systems and system models • Structure and function • Energy and matter
Disciplinary Core Ideas	From a ***K-12 Framework for K-12 Science:*** • PS1.A: Structure and Properties of Matter • PS1.B: Chemical Reactions • PS2.B: Types of Interactions

Additional Supports for struggling learners:

The following supports are suggestions for this lesson and are not the only options to support students in the classroom. These supports target students that struggle with science material, this lesson or a previous lesson. These are generalized supports and do not take the place of IEP accommodations as required by each student's Individualized Education Program.

General supports for the following categories:

Reading:	Writing:	Math:
1. Provide reading support by reading aloud or doing partner reads 2. Have the teacher model what they are thinking when reading the text 3. Annotate the text with students so that they may refer to it as they work through the lab	1. The teacher can provide a sentence starter for the students. 2. The teacher can give students an audience to write to (i.e. Write a letter to your sibling explaining this topic). 3. The teacher can provide constructive feedback during the writing process to help students understand the expectations.	1. Provide calculators as needed. 2. Provide graph paper as needed.

Supports for this specific lesson if needed:

Performance expectations for instruction:

1. The teacher should provide information to students in various formats to reach as many students as possible.
2. The students should be given adequate time to complete each part of the lesson.
3. The students should be allowed to express their knowledge in various formats.
4. The teacher should be sure to provide multiple ways for the students to communicate their knowledge of the material.

Engage:

1. The teacher should consider giving an organizer for observations during the demo.
2. The teacher should go over lab safety procedures.
3. The teacher should have clear and consistent guidelines for class discussions. This should decrease anxiety for students and increase student participation.
4. The teacher should provide multiple ways for the student to express their knowledge. These formats could include writing, drawing or designing a presentation.
5. Students may need additional time to complete their CER, similarities/differences and particulate diagram.
6. The teacher should use intentional and flexible grouping to assign student groups. Best practice is to use data to assign student groups.

Exploring:

1. The teacher should consider giving students an organizer to help plan their investigation.

2. The teacher should consider giving the questions that are meant to guide students in setting up their investigation.
3. The teacher should provide multiple ways for the student to express their knowledge. These formats could include writing, drawing or designing a presentation.
4. Students may need additional time to complete the plan and carry out investigation assignment.

Explaining:

1. The teacher should consider providing an organizer to students for students to record observations about the demo.
2. The teacher should consider providing an organizer for students to record their observations, data and research.
3. The teacher should try to provide more structure for students that are struggling.
4. The teacher should consider providing students with a rubric to self-evaluate their work. This increase student ownership of the work.
5. The teacher should provide a calculator for students to use in calculations.

Elaborating:

1. The teacher may need to show the demo again to allow students to observe what is occurring again.
2. The teacher should use flexible and intentional grouping to group students. Best practice is to use data to group students.
3. The teacher should consider giving students an organizer to plan their investigation, record data and observations.
4. The teacher should provide multiple ways for the student to express their knowledge. These formats could include writing, drawing or designing a presentation.
5. Students may need additional time to complete their assignments.

Evaluating:

1. The teacher should consider providing multiple ways for students to communicate their knowledge of the material. These formats could include writing, drawing or designing a presentation.
2. Students may need additional time to complete their assignments.

Claim—Evidence—Reasoning

Guiding Question: What is happening on the particulate level that gives the three substances different properties? **Claim:**
Evidence:
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.
Diagram: What is happening at the particulate level with the three substances? Label structures and substructures.

Return to Instructional Segment

Lab Challenge: Solution Design

Challenge: Your lab group must design a procedure to prepare various solutions given certain parameters. In order to justify procedure, data must be gathered for each solution type. For each process, model diagrams should be developed.

Materials: the typical equipment in the chemistry lab is allowed but must be approved by your teacher. Ice is also available.

Solution 1: Chemical A and water

The task: design a procedure that makes a solution with 5 grams of chemical A for every 100 ml of water. There are four sizes of solute available.

Solution 2: Chemical B and water

The task: design a procedure that makes a solution with the maximum amount of solute in 100 ml of water.

Solution 3: Chemical C and water

The task: collect data to show the effect that temperature has on how well the same amount of solute will dissolve in solution

Return to Instructional Segment

Beverage Concentration Lab

What concentration tastes the best?

Procedure: Your lab group will prepare four different concentrations of drink. Choose any concentrations to make within the range of 0.05M and 0.80M

Materials:

You cannot use any lab equipment for this lab—it is not sanitary and approved hold food or drink. Use supplies as directed by your teacher.

Procedure:

For each solution:

- Show calculations to determine how much solute is needed.
- Describe your observations.

Post –Lab:

1. Have you had this drink before? If so, which of your groups concentrations is closest?
2. For the most and least concentrated solutions, complete particulate level diagrams. Label all parts.
3. If your favorite soft drink/juice was just sugar and water (to simplify things), what do you think the molarity would be based on how sweet your solutions were? How many grams of sugar would be in a 20-ounce bottle based on your concentration estimate?

Return to Instructional Segment

Solution Boiling Point and Freezing Point Lab

How does a solute influence the physical properties of a solvent?

Boiling point:

Draw diagrams of what is happening on a particulate level with pure water and the salt solution at the boiling point. Label all components.

Freezing point

Draw diagrams of what is happening on a particulate level with pure water and the salt solution at the freezing point. Label all components.

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