This 5E model for instruction helps students gain an understanding of the concepts of solution properties and solubility.	
Student Science Performance	
Grade level: 9-12 **Physical Science**	**Title:** What's Inside Our Drinks?
Topic: Solutions	

Performance Expectations for GSE:

SPS6 Obtain, evaluate, and communicate information to explain the properties of solutions.

a. Develop and use models to explain the properties (solute/solvent, conductivity, and concentration) of solutions.
b. Plan and carry out investigations to determine how temperature, surface area, and agitation affect the rate solutes dissolve in a specific solvent.
c. Analyze and interpret data from a solubility curve to determine the effect of temperature on solubility.

Performance Expectations for Instruction:

- Plan and carry out an investigation to investigate solvation of sugar.
- Analyze and interpret the data solubility curves
- Develop and use a model to explain solution properties and solubility.
- Use the model to predict dissolution rate of another solute in various conditions.

Additional notes on student supports

Materials:

- Sports drink (with electrolytes) samples
- Distilled water
- Conductivity tester
- Table salt
- Sugar: powdered, cubes, granulated
- Hot plates
- Beakers
- Thermometers
- Stir rods

Teacher Notes: if you do not have access to a conductivity tester, there are various ways to set one up using batteries and circuit equipment or multimeters; different setups can be found online.

Engaging Learners	**Phenomenon: certain drinks conduct electricity** Setup: prepare various sports drink samples and show students how they conduct electricity; have other drinks ready (cola, orange juice, etc.) as well as distilled water. As students are introduced to this concept, they complete a claim-evidence-reasoning organizer (models should include diagrams); example CER organizer.

	Possible Guiding questions: • How is the sports drink able to conduct electricity? • What is "inside" the sports drink to make this possible? • What is different about the drinks that do not conduct electricity? • Why do some drinks or liquids conduct electricity and other do not? • What would a "molecular-level" snapshot look like when electricity is conducted? • What would a "molecular-level" snapshot look of one of the drinks that do not conduct electricity? • Can certain drinks conduct electricity better than others? • Why do sports drink companies make the product this way? ***Communicating -*** Students complete models of conductive solutions and non-conducting solutions using CER organizer. *Teacher Notes: The CER organizer and guiding questions are meant to elicit student explanations of the phenomena; the engage phase is presented as to not front load students with information about solutions and properties. Additional notes about topic, focus, and phenomena can be here.*
Exploring	***Obtaining -*** To explore solution properties, students will be working pairs or small groups on the Sugar and Salt Solutions simulation; the simulation can be found on the PhET website (Attribution: PhET Interactive Simulations, University of Colorado Boulder; https://phet.colorado.edu). In this activity, students describe the micro and macro properties of solutions as well as develop an argument about how molecular and ionic compounds behave differently in solution. In addition to the simulation, students can obtain information using CK-12: Solutions and CK-12: Solubility.
	Evaluating -After completing the simulation, students evaluate their initial claim-evidence-reasoning from the engage phase. Revisiting the guiding questions might be helpful as students continue constructing explanations of the phenomenon.
	Communicating - Students will communicate their argument from the solution simulation in student groups. This could be a poster session where students (or student groups) present initial arguments from the simulation as well as initial explanations of the phenomenon. *Teacher Notes: This is phase is designed for students to gain a better understanding of solution properties as they work towards explaining the phenomenon.*

Explaining	***Obtaining*** – Students will be building models for the solvation process as they carry out an investigation: Rate of Sugar Solvation. In this lab, students are guided through investigations of solubility and then develop their own experimental procedure in the second part of the lab, see Teacher Notes below.
	Evaluating – Prompt students again to re-visit their revised explanations of the phenomenon. Evaluate student understandings of solution properties and the solvation process. Consider the following questions as discussion prompts or formative assessments: • What makes a sport drink a solution? What kind of solution is it? • Is it possible to make a sports drink more conductive? Explain. • What specific compounds make the sports drink conduct electricity? • What factor from the sugar lab had the greatest influence on how fast the sugar dissolve? Explain.
	Communicating – Students analyze their lab group's data, as well as other groups, and develop a model with the following prompts (from the post lab section): • Using the data collected by the class, create a graph of temperature versus time. • Is there a pattern to the data? In other words, does there appear to be a correlation between temperature and the rate of solvation of granulated sugar? • Using the C-E-R model, work with your group to create a model at the particle level that might explain the data. • Pick another group in the class and compare your graphs as well as your model. What were the similarities? What were some of the differences? • Work with that second group to revise your models, particularly if there are differences between the two groups models. *Teacher Notes: In this phase, students are building more detailed explanations of solution properties. Other solutes, such as copper (II) sulfate, can be used that are available in different solute sizes as students apply their model from the sugar lab to a new solute; be sure to consult Safety Data Sheets before use.* ***Sugar Solvation Lab Notes:*** *This activity, especially Part II, will require a great deal of flexibility and patience. This process will likely require multiple class periods, particularly if the students have not done any experiment design prior to this activity.* *Prior to beginning Part II, it may be beneficial to brainstorm as a class about possible variables. Allow groups to test variables, even if you believe there is no correlation to rate of solvation.* *Ideally, surface area and stirring/agitation should be on the list somewhere. It may be possible that two groups choose the same two variables, but design different methods to test the variable.*

Elaborating	***Obtaining*** – After completing the Sugar Solvation lab, students should gain more experience with solubility curves. Based on their data and class discussion, students should make predictions about a solubility curve for an unknown solute in water. The setup is similar to Part I of the Sugar Solvation lab; this can be done in lab groups or as class with teacher setup. The intent is for students to consider how well their model applies to a different solute. A focus on particle level interactions and diagrams is important. Multiple solutes could be used as an alternative; a variety of salts work well, be sure to consult Safety Data Sheets before use.
	Evaluating – After the investigation, students compare results to their curve predictions. Additional solubility curves should be provided to build experience.

	Communicating – Students will consult their CER organizer from the original sports drink phenomenon. It should be revised to show understandings and explanations developed through research, the Sugar and Salt Solutions simulation and the Rate of Sugar Solvation lab. To incorporate the data and concepts from constructing solubility curves, consider designating time for students to write individually. The following prompts could be used to guide students in their writing:
	• How has your model of the sports drink changed through the activities?
	• Explain how the following factors influence solvation:
	    • Surface area
	    • Temperature
	    • Agitation
	• Using a diagram with your writing, explain what makes a solution conduct electricity?

Evaluation	***Assessment of Student Learning*** To evaluate student understandings of the phenomenon and solution properties, students are given the task of designing an electrolyte sport drink. The task requires students to choose an ionic compound, or compounds, that would make the drink conduct electricity. Other compounds could be presented, such as coloring or sugar, in the design process. Students consider solution properties, dissolution rates, and solubility curves. The task product is a written explanation and diagrams of the solution design.
SEP, CCC, DCI	**Science Essentials**
Science and Engineering Practices	• Asking questions and defining problems • Developing and using patterns • Planning and carrying out investigations • Analyzing and interpreting data • Constructing explanations • Engaging in argument from evidence • Obtaining, evaluating and communicating information
Crosscutting	• Stability and change • Systems and system models

Concepts	• Energy and matter
Disciplinary Core Ideas	From A Framework for K-12 Science Education: • PS1.A: STRUCTURE AND PROPERTIES OF MATTER • PS1.B: CHEMICAL REACTIONS

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 may need to conduct the demo more than once to allow students to see the conductivity of some and the lack of conductivity of others.
2. The teacher should provide students with the CER template.
3. The teacher should provide explicit instruction on how to fill in the CER template.
4. The teacher should have clear established guidelines for discussions in class.
5. The teacher should consider providing the guiding questions to students in advance of any discussion

to allow students time to formulate answers prior to the discussion.

6. The teacher should provide multiple formats for students to express their knowledge. These formats could include writing, drawing or designing a play.

Exploring:

1. The teacher should provide students with a data sheet and organizer for the activity. This should provide a place for students to record data, observations, questions and research.
2. Students may need additional time to revise their explanations.
3. The teacher can have each group present their explanations and then allow students to revise their explanations again.

Explaining:

1. The teacher should allow multiple formats for the students to express their models. These formats could include drawing, writing or designing a play.
2. Students may need additional time to construct their models.
3. The teacher should provide the students a data sheet to record their data and a template to design their own experiment.
4. The teacher may want to consider doing a demo on how to write a procedure. The teacher can do a demo on making a sandwich (PB&J if no one is allergic to peanuts in the class) where the students are providing the instructions. The teacher should be prepared for this demo to be strange because students will forget directions like "open the jar" and the teacher will find themselves doing things like trying to get jelly out of a closed jar. The teacher should do nothing that the students do not instruct them to do.
5. The teacher should consider providing the guiding questions to students in advance of any discussion to allow students time to formulate answers prior to the discussion.
6. The teacher should consider giving an example graph. This way students can see what they are making and compare their graph to the sample. This can allow student ownership of their work.
7. Students may need additional time to construct and analyze their graph.

Elaborating:

1. The teacher should consider giving a formative assessment of solubility curves. The teacher can re-teach, review or enrich as needed for each student.
2. The teacher should provide an organizer for students to record their hypothesis, data, observations and research.
3. The teacher should consider giving students a rubric to guide students evaluation of their work.
4. The teacher should explicitly ask students to compare their model to different solutions and solutes.
5. The teacher should consider providing solubility curves to practice reading the curves.
6. The teacher should allow multiple formats for the students to express their models. These formats could include drawing, writing or designing a play.
7. Students may need additional time to write responses.
8. The teacher should consider providing sentence starters for students that struggle with writing.

Evaluating:

1. The teacher should allow multiple formats for the students to express their models. These formats could include drawing, writing or designing a play.
2. Students may need additional time to design their electrolyte drink.

Return to Instructional Segment

Claim-Evidence-Reasoning

<table>
<tr><td colspan="2">How is the sports drink able to conduct electricity?</td></tr>
<tr><td>Claim:</td><td>The sports drink can conduct electricity because
____
____
______________________________</td></tr>
<tr><td>Evidence</td><td>1.______________________________
2.______________________________
3.______________________________</td></tr>
<tr><td rowspan="2">Reasoning</td><td>What is happening on a small scale when the drink conducts electricity?

Draw a diagram of what a "molecular-level" snapshot would look like:</td></tr>
<tr><td>What would a "molecular-level" snapshot look of one of the drinks that do not conduct electricity?

Draw a diagram of what a "molecular-level" snapshot would look like:</td></tr>
</table>

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Sugar and Salt Solutions

Instructions

This activity utilizes the Sugar and Salt Solutions simulation developed by PhET (Attribution: PhET Interactive Simulations, University of Colorado Boulder; https://phet.colorado.edu)

Macro

1. The first tab, "Macro" will allow you to shake either salt or sugar into the water container. Click "Show values" to get concentration values to appear in the graph. Then, drag the conductivity meter on the right-hand side of the screen so that the two electrodes are dipped into the solution.
    a. What happens to the light bulb when the concentrations of each substance are zero?

    b. Shake some of the salt into the water to create a salt-water solution. What is the relationship between salt concentration and light-bulb brightness?

    c. Click "Remove salt," and then switch the shaker from "Salt" to "Sugar." Shake some of the sugar into the water to create a sugar-water solution. What is the relationship between sugar concentration and light-bulb brightness?

Micro

2. Click over to the second tab, “Micro.” The shaker present should be “Sodium Chloride.” If not, select this substance in the “Solute” box.
    a. Shake the sodium chloride into the water. Watch how the substance appears before entering the water and after it enters the water. Describe that change.

    b. Click “Remove solute” and switch the shaker over to “sucrose.” Shake the sucrose into the water and watch how the substance appears before entering the water and after it enters the water. Describe that change.

3. Compare and contrast the dissolution of sodium chloride to the dissolution of sucrose at the Micro level. What are the similarities and what are the differences? Be sure to make reference to the bar graph at the right.

4. Click “Reset All.” There is an arrow pointing to the right next to the word “Solute” in the box. Click once to the right so the two substances are sodium chloride and calcium chloride.
    a. After shaking both substances into the water individually and describing the process, as you did in ‘2a’ and ‘2b’ previously, compare and contrast the dissolution of both substances at the Micro level. What are the similarities and what are the differences? Be sure to make reference to the bar graph at the right.

5. Click “Remove Solute.” Click the arrow to the right of “Solute” once to switch the compounds to sodium chloride and sodium nitrate.
    a. After shaking both substances into the water individually and describing the process, as you did in ‘2a’ and ‘2b’ previously, compare and contrast the dissolution of both substances at the Micro level. What are the similarities and what are the differences? Be sure to make reference to the bar graph at the right.

    b. Nitrate, NO_3^-, is known as a polyatomic ion. Based on your observations in this activity and your prior knowledge, how would you describe the various bonding that occurs in a salt that contains a polyatomic ion?

Argument

6. Address the following question: How do ionic compounds and molecular compounds behave differently in solution?
    a. Write a claim statement answering this question.

    b. Provide 3 pieces of evidence derived from your answers to the questions in the Macro and Micro sections above.

    c. Explain your reasoning for why/how your evidence supports your claim. Use the following terms and concepts:
        i. conductivity, ions, dissociate, dissolve, concentration, molecules

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What Factors Affect the Rate of Dissolution?

Introduction

A solution is a homogeneous mixture of two or more substances. Recall, that the substance that is being dissolved is called the solute, and the substance that does the dissolving is called the solvent. Solubility describes the amount of solute that will dissolve in a given amount of solvent at a particular temperature. Among other things, solubility depends on the nature of the solute and solvent and how they interact. It is important to understand not only how much of a particular solute will dissolve in a solvent (at a given temperature), but also what factors affect the rate that the solute will dissolve.

The experiment consists of two parts:

1) test the effect of temperature on the rate of solvation of sugar

2) as a group, design an experiment to explore another factor that may affect rate of solvation.

Your Task

Your group will first test the rate of solvation of sugar, in water, at several temperatures. Then develop a conceptual model that can be used to explain *why* these factors influence the rate of dissolution. Once you have developed your conceptual model, you will need to test it to determine if it allows you to predict the dissolution rate of another solute under various conditions.

Materials

You may use any of the following materials during your investigation:

- sugar cubes
- granulated sugar
- powdered sugar
- stir rods or stir plate
- thermometer
- 5 cups
- Graduated cylinder
- hot plate
- paper towels
- safety goggles
- beakers - 250mL and 400ml for cold water baths
- ice
- beaker tongs or hot pads
- water
- stopwatch or timer function on phone

Safety Precautions

- Wear goggles at all times during the lab.
- Never taste any of the chemicals (including the rock candy).
- Handle all glassware with care.
- Use caution when working with hot plates.
- Be careful when using liquids around electrical devices (i.e.; hot plates)

Part I: Temperature

Your groups will be assigned a particular temperature at which you will attempt to dissolve the sugar. During this part of the experiment, you will ONLY place the sugar in the beaker of water and record time – DO NOT STIR.

1) Prepare your beaker of water by obtaining exactly 100 mL of water.

For hot water:

2) set your beaker of water on the hot plate and set the hot plate to setting 4 or 5.

3) Place the thermometer in the water and monitor the temperature. You will most likely need to adjust the setting on your hotplate to achieve the desired temperature.

4) Once you have reached your assigned temperature AND maintained that temperature for at least 3 minutes. Prepare the sugar.

For cold water:

2) place some water and ice in the 400 mL beaker – fill no more than 1/3 full, using more ice for colder temperatures.

3) Place the 250 mL beaker (with 100mL of water in it) in the ice bath.

4) Place the thermometer in the water and monitor the temperature. You will most likely need to add remove either ice or water in the 400 mL beaker to achieve the desired temperature.

5) Once you have reached your assigned temperature AND maintained that temperature for at least 3 minutes. Prepare the sugar.

6) Measure 50.0 g of granulated sugar in a weigh boat.

7) add the sugar to the water and start the timer to begin timing the process.

8) Stop the timer once ALL of the sugar has gone into solution – you see no sugar granules left in the bottom of the beaker.

9) Once done collecting data, clean up your materials and report your groups data to the teacher.

10) When all the groups are done, be sure to record all of the data that was collected. You should have a time value for each group.

Post Lab Questions/Conclusions

1) Using the data collected by the class, create a graph of temperature versus time.

2) Is there a pattern to the data. In other words, does there appear to be a correlation between temperature and the rate of solvation of granulated sugar?

3) Using the C-E-R model, work with your group to create a model at the particle level that might explain the data.

4) Pick another group in the class and compare your graphs as well as your model. What were the similarities? What were some of the differences?

5) Work with that second group to revise your models, particularly if there are differences between the two groups models.

Part II: Designed Experiment

For part 2, your group will design an experiment to test another variable which could impact the rate of solvation of sugar. Looking at the materials that are available, your group must first pick a variable to test. For example, in part 1 you examined how temperature affected the rate of solvation of granulated sugar. To conduct this experiment(s), you must determine what type of data you will need to collect, how you will collect the data, and how you will analyze the data to answer a guiding question.

Your guiding question will be in the form of "How does ________________, impact the rate of solvation of _______________________?"

To determine *what type of data you need to collect*, you need to think about the following questions:

- What types of measurements or observations will you need to collect during the experiment?
- At what point in the experiment will you need to make these measurements or observations?

To determine *how you will collect the data*, think about the following questions:

- What will serve as your independent and dependent variables?
- How will you vary the independent variable?
- What steps can you take to minimize date error?
- How will you organize the data that you collect?

To determine *how you will analyze the data*, think about the following questions:

- What representation of your data will make it easiest to make sense of your data (data table, line graph, bar graph, pie chart, etc.)?
- What conclusions do you hope to be able to draw from your data (this should relate directly to you guiding question)?
- How can you best shar your data and conclusion with the class (handouts, presentation, poster, power point, group discussion, etc.)

Your proposal must include the following, in writing:

- Guiding question
- Materials required
- Safety concerns/precautions
- Detailed procedures – these must be thorough enough that another group could perform your designed experiment using only the written instructions.
- Data collection/organization – is this a data table? Or possibly Cornell style notes with observations?

<u>You must have your teacher approve of your proposal before you will be allowed to begin your experiment.</u>

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Electrolyte Drink Design

Task: Your task is to design a sports drink with electrolytes. You are responsible for determining the ingredients, the procedure to make it, and other aspects.

Drink Name:

Ingredients:

- Label each ingredient as ionic or covalent, including formulas; label solute/solvent
- Include amounts needed for a one serving container

Procedure:

- What steps are required to prepare the drink? Explain/justify each step in the procedure
- Design the process so the solutes dissolve quickly in the solvent; include a solubility curve for the ionic compound that justifies the temperature chosen to make the drink
- Determine the concentration of one solute in the drink

Molecular level:

- What is happening on a molecular-level in the drink after it is prepared?
- Include molecular-level diagrams showing solute and solvent particles
- Describe how the drink is able to conduct electricity with the particles present

Electrolytes:

What is the purpose of including electrolytes in sports drinks?

Label:

What does the label look like for the drink? What is there a slogan?

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Stability and Change in Reactions GSE: SPS6a,b,c; SPS7a			
Anchoring Phenomenon: Cars and rockets are powered by chemical reactions.			
Topic	**Focus**	**Lesson Phenomenon**	**GSE/Notes/Language**
Solutions	● Students will define and describe solutions and build molecular models showing how solutes and solvents interact to form solutions. ● Students will demonstrate that the degree to which a solute dissolves is based on the properties of the solvent and solute. ● Students will understand how solutions can be used to conduct electrical charges. ● The properties of any solution are due to the properties and interactions of the solvent and solute.	*Certain drinks conduct electricity*	SPS6a. Develop and use models to explain the properties (solute/solvent, conductivity, and concentration) of solutions.
Solvents	● Students will show how temperature, smaller surface area and agitation affects rate of dissolution. ● Simple labs of time required to dissolve the same mass of salt or sugar in water at different temperatures, different sizes of sugar cubes, and stirring are examples	*Heated water dissolves sugar more quickly.* To make sweet tea, the solvent (water) is heated to dissolve the large amount of sugar (solute) added to make the sweet tea solution. This is an example of supersaturation.	SPS6b. Plan and carry out investigations to determine how temperature, surface area, and agitation affect the rate solutes dissolve in a specific solvent. SPS6c. Analyze and interpret data from a solubility curve to determine the effect of temperature on solubility.

	of solvent activities. ● Students will relate temperature to the amount of solute that can be dissolved using/or creating a solubility curve.	If you attempt to add the same amount of sugar to cold water, the sugar will take much longer to dissolve.	

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