Lesson Plan: Not Breaking Up is Hard to Do: The Properties of Glass

FOR THE TEACHER

Summary
In this lesson students will learn about the properties of glass, and relate those properties to the new engineering design of glass in a car.

Grade Level
High School

NGSS Alignment
This lesson plan will help prepare your students to meet the performance expectations in the following standards:

- **HS-PS1-1**: Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.
- **HS-PS1-2**: Construct and revise an explanation of the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.
- **HS-PS1-3**: Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.
- **HS-PS2-6**: Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.
- **HS-ETS1-2**: Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

AP Chemistry Curriculum Framework
This lab supports the following unit, topic and learning objective:

- **Unit 3: Intermolecular Forces and Properties**
  - **Topic 3.3**: Solids, Liquids and Gases
    - **SAP-6.A**: Represent a given chemical reaction or physical process with a consistent particulate model.

Objectives
By the end of this lesson, students should be able to

- Compare and contrast the properties of laminate glass and Corning® Gorilla® Glass.
- Design an experiment to examine the properties of sugar glass.
- Explain why car design benefits from stronger, lighter glass.

Chemistry Topics
This lesson supports students’ understanding of

- Physical Properties
- Elements
- Periodic Table
- Experiment Design
- Scientific Method

Time
**Teacher Preparation**: 30-45 minutes
**Lesson**: 
Engage: 10 minutes
Explore: 60-80 minutes (Part 1), 90 minutes (Part 2)
Explain: 70 minutes
Elaborate: 45 minutes
Evaluate: 60-100 minutes

Materials (For each lab group)
- 8-10 Tea Light candles with metal bases. (Note: metal base is all that is needed; the candle is not needed for experiment.
- Sugar
- Corn syrup
- Digital candy thermometer (or have available high temperature digital thermometers that can measure up to 150 °C.)
- Porcelain evaporating dishes (70 mL capacity)
- Stirring rod
- Spatula
- Crucible tongs
- Ring stand
- Utility clamp
- Hot plate
- Electronic balance
- Weighing boats

Safety
- Always wear safety goggles when handling chemicals in the lab.
- Students should wash their hands thoroughly before leaving the lab.
- When students complete the lab, instruct them how to clean up their materials and dispose of any chemicals.
- Exercise caution when using a heat source. Hot plates should be turned off and unplugged as soon as they are no longer needed.
- Use caution around hot evaporating dishes, and their contents; they are a significant burn hazard.
- Do not consume lab solutions, even if they're otherwise edible products.
- Food in the lab should be considered a chemical not for consumption.

Teacher Notes
- Engage: Show Corning ® Video, “The Glass Age—Part 2: Strong, Durable Glass.” Optional: Start video at 6 minutes, and play until end (Total Length of segment to show = 4 minutes)

The entire Corning video is excellent, but is 10 minutes long. It starts with a discussion of Gorilla® Glass in smart phones. It is suggested to just show the last part of the video starting at about 6 minutes, since this is the focus on windshields. Some students may ask about the difference between Gorilla® Glass and bullet-proof glass. Bullet-proof (more correctly called bullet-resistant) glass is a composite material, composed of layers of glass and polymer. See the following:
**Explore:** Since we cannot make glass in the lab, we are going to use a model for glass made from sugar. Before doing the lab, it would be helpful to have a discussion with the class about models; e.g., the use of an atomic model as an explanation for atomic theory.

The lab is designed as a two-part lab. Part 1 is a directed lab with a cookbook recipe. The students will learn the technique of sugar glass making and cast some samples for testing. In Part 2, the students will extend their knowledge and experiment with making different sugar glasses by changing temperatures and proportions of ingredients. Part 2 is an inquiry lab, and students can adjust the composition, process and/or testing of their sugar glass as needed. Depending on your students’ abilities, and their prior experience with inquiry labs, you may choose to do the “Explain” piece of this activity before conducting the inquiry portion of the lab.

Lab groups can be any size that is practical. The limiting factor is the number of lab benches and likely the number of hot plates available.

Advise students that the boiling sugar solution is a burn hazard since it has to reach temperatures well above 100 °C. Be careful with the boiling sugar, as it will rapidly rise in temperature as it boils. If it turns brown, it has caramelized, and must be discarded.

Keep in mind that the samples must be cooled before testing, so you need to plan for doing the testing on a different day than sample preparation. If you have a double lab period, it was found that samples cooled thoroughly within 20 minutes. If you do not have a double lab period, let the samples cool overnight at room temperature.

The recipe given in Part 1 is very reproducible for a good glass. Groups may want to collaborate on finding the limits of the sugar/water/corn syrup ratio. For example, it is possible to make a glass from just sucrose and water, but it is prone to crystallization. Too much corn syrup will lead to a gummy material which is difficult to remove from the metal base. The literature reports that good glasses are obtained using a 2:1 ratio of sugar to corn syrup, with approximately 10% water. See the following resource for an in-depth analysis:


Students may also calculate the density of the candy glass. The literature (reference given above) suggests constructing a pycnometer if the samples are irregularly shaped. If the samples as constructed in the lab below are used, and are regular cylinders, their volume may be calculated using geometry. Water displacement cannot be used as the samples absorb water.

As an extension, you can also have the students explore how different heating and stirring methods impact the properties of the candy glass.

**Explain:** Students are asked to research the properties of laminate glass in a windshield using web sites such as: [http://www.madehow.com/Volume-1/Automobile-Windshield.html](http://www.madehow.com/Volume-1/Automobile-Windshield.html)

Students are then asked to research the properties of Gorilla ® Glass in a windshield using websites such as: [http://www.corninggorillaglass.com/en/videos/22](http://www.corninggorillaglass.com/en/videos/22)

After their research, they can write an essay, or use technology to make a Prezi, PowerPoint, or video that compares and contrasts conventional windshield glass with Gorilla ® Glass. Students will then share their papers or videos/PowerPoint’s with another group for comments.
• **Elaborate:** This can be done on paper, poster board, or by using technology. Groups can research and develop their ads in one day, and then present them the next day to the rest of the class.
  
  1. Show 1 minute Ford Media video showing the use of Gorilla ® Glass: https://www.youtube.com/watch?v=UENtstzpHU8
  2. Students are asked to research the advantages of lighter and stronger windshields, and then work with a group to develop a promotional ad (can be written, illustrated or done using technology) for lighter and stronger windshields in a car.

If you want to explore new technology for presentations, you can suggest students use Audacity (a free open source software for recording and editing sounds; available for free download at http://www.audacityteam.org/) or Camtasia (software that allows you to create finished videos from screen recordings; free trial but full use software is not free).

• **Evaluate:** Lab reports should be collected for evaluation. Ads should be assessed at teacher's discretion.

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**FOR THE STUDENT**

**Lesson**

**The Use of Sugar Glass as a Model for Glass Making**

**Background**

Glass is classified as an amorphous solid, which means it does not have a defined structure. Window glass is made by taking silica (silicon dioxide) and heating it with various additives. Additives such as alkali or alkaline oxides are used to lower the high melting temperature of silicon dioxide, but also change the chemical and physical properties of the glass. Similarly, in candy making, sugar can form a glass, but modifiers are used to lower the high melting temperature of sugar.

**Prelab Questions**

1. What is the melting point of pure sugar?

2. What is the definition of a glass?
3. Can you think of some properties that we expect to find in window glass?

**Objective**
To investigate how the properties of sugar glass can be changed by modifying its composition or method of manufacture.

**Materials**
- metal bases from tea candles
- water
- granulated sugar
- corn syrup
- digital candy thermometer
- porcelain evaporating dish with pouring lip, 70 mL capacity
- crucible tongs
- ring stand and utility clamps
- hot plate
- paper clips
- beakers with water
- electronic balance
- small beaker or weighing boat
- stirring rod
- spatula

**Safety**
- Always wear safety goggles when handling chemicals in the lab.
- Wash your hands thoroughly before leaving the lab.
- Follow your teacher’s instructions for clean-up of materials and disposal of any chemicals.
- Exercise caution when using a heat source. Hot plates should be turned off and unplugged as soon as they are no longer needed.
- Use caution around hot evaporating dishes, and their contents; they are a significant burn hazard.
- Do not consume lab solutions, even if they’re otherwise edible products.
- Food in the lab should be considered a chemical not for consumption.

**Procedure**

**Part I: Making and Testing Sugar Glass from a Known Recipe**

**A. Preparation of the Sugar Glass Samples**
1. Tare an evaporating dish on a balance.
2. Add 7.50 g of corn syrup to the dish.
3. Tare the dish and syrup, and add 5.00 g of water.

4. Weigh out 30.00 g of sugar in a small beaker or weighing boat.

5. Pour the sugar into the evaporating dish.

6. Place the evaporating dish on a hot plate, and turn the hot plate on to about 50% heat.

7. Fasten a utility clamp to a ring stand. Position the ring stand next to the hot plate.

8. Place the thermometer in the utility clamp, and insert in the sugar/corn syrup/water mixture. See Figure 1 for set-up.

9. Use the stirring rod to stir the sample, until all the sugar is melted.

10. Stop stirring, and bring the mixture to a boil.

11. Continue boiling while the temperature rises. Stop stirring after the mixture rises! Do not look away; the temperature will rise rapidly as the boiling continues.

12. When the temperature reaches 154 °C, raise the thermometer from the mixture. Use the crucible tongs to lift the evaporating dish from the hot plate.

13. Carefully pour the sugar glass mixture into the metal bases, dividing equally into four bases. See Figure 2.

14. Allow each sample to cool thoroughly before testing.

15. Clean up using hot water to dissolve the sugar residue from the evaporating dish, thermometer and stirring rod.

**B. Testing of the Sugar Glass Samples**

1. **Testing relative durability:** Take a meter stick and fasten it to a ring stand so that it stands perpendicular to the bench top. Place a tray or large container on the bench top. Now, drop the glass sample from a height of 10 cm. onto the tray or container. Does it break? If not, continue raising the sample 10 cm. at a time until it breaks. Record the height in the data table.

2. **Optical clarity:** Use a Sharpie® pen to write your name on an unlined piece of paper. Now, use the sample to read your name. Classify the clarity of the sample as a 1 (can read your name clearly), a 2 (your name is a little fuzzy) or a 3 (your name is totally obscured). Record your observations in the data table below.
3. **Observations:** Examine the sample closely, and record your qualitative observations. For example, does it feel hard or soft? What is the color? Are there a lot of bubbles in it? Does it appear the same throughout (Is it homogenous)? Record your observations in the data table below.

### Data

<table>
<thead>
<tr>
<th>Sample #</th>
<th>Relative Durability (Maximum height of drop)</th>
<th>Optical Clarity</th>
<th>Observations</th>
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### Part II: Inquiry Lab

1. Brainstorm with your lab partner(s) about modifications that you would like to make in this lab to change the properties of the sugar glass. For example, you can alter the recipe or the process of sugar glass manufactured to improve the properties. In addition, if there is another test you would like to conduct on the finished product, you can add that to the lab.

2. After you have finished your brainstorming, write a new procedure that incorporates your modifications. Show your teacher your modifications and your new procedure before continuing.

3. Make a new data table to reflect your changes.
4. Conduct your new experiment, recording your new data in it.

**Analysis**

1. How much did the boiling point of the first mixture differ from that of the melting point of pure sugar?

2. Why would this difference be important to a manufacturer?

3. Did you observe any differences in durability or clarity between the samples poured from the same evaporating dish in either Part 1 or 2? If so, why do you think this occurred?

4. How did your modifications change the properties of the sugar glass? If you tested a new property, justify its importance to the manufacturer.

**Conclusion**

Write a short summary of your observations and data about sugar glass samples. In your conclusion, you should compare and contrast the data from Part 1 and 2.