Science and Property of Sugar Glass

By: Sean Kelly
Advised by Dr. Bill Heffner
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Overview

Project Overview:

o The goal of my project was to investigate sugar glasses and their properties and relate them to traditional glass properties in a way for high school students to understand and appreciate.

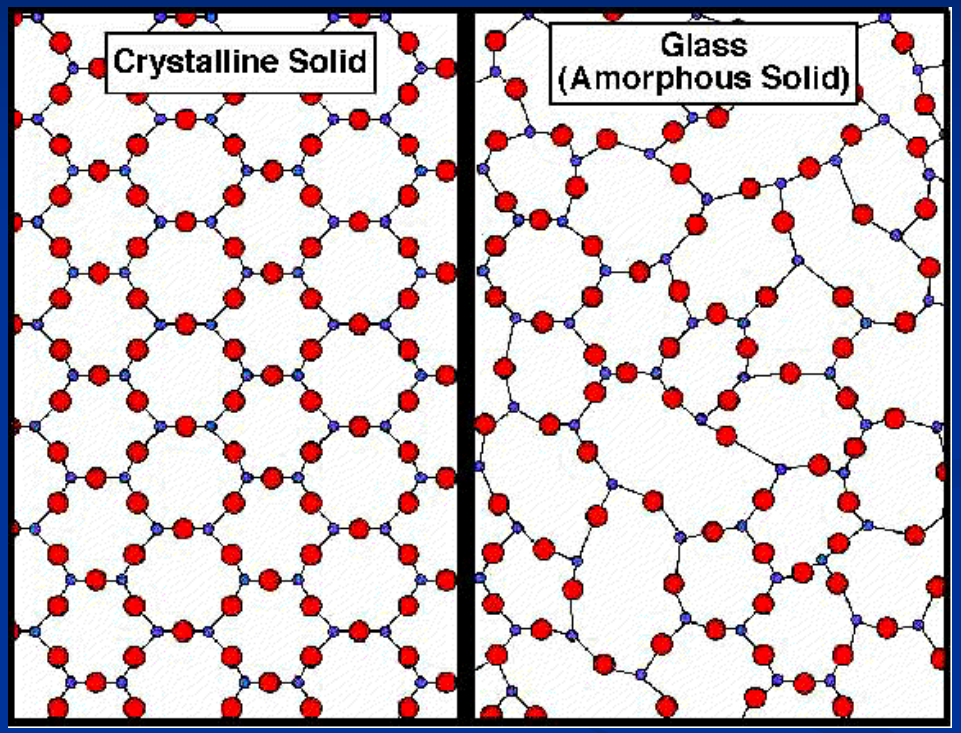
o The goal was also to perform experiments for students involving sugar glasses to demonstrate these properties.

I developed experiments involving:

- Density
- Refractive Index
- Composition
- Fiber Drawing

Background

- Glass has an amorphous structure, which means there is no crystalline structure.
- The crystalline solid shown in the left of the picture demonstrates a rigid atomic structure.
- The glass solid on the right demonstrates a non-crystalline atomic structure.



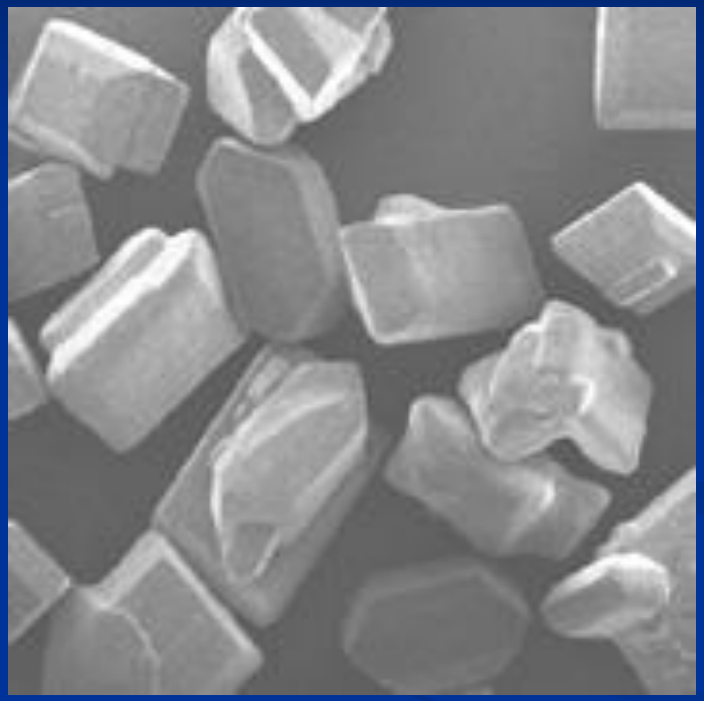
Forming Glass

Crystal Structure

- Glasses are formed by cooling the liquid sufficiently fast so that the atoms do not get a chance to form into the crystalline pattern that they would like to.
- Candy glasses are formed the same way. The melt is cooled to a temperature below the glass transition temperature (Tg).
- If the melt is cooled too slowly, then crystals will form and it will not form into a glass.

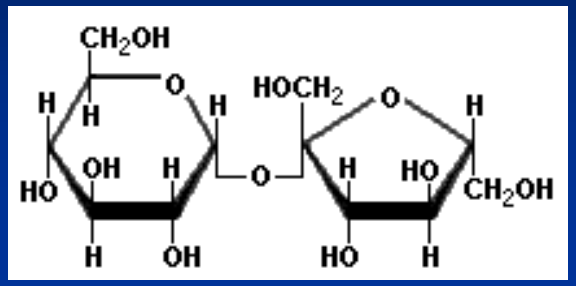
Candy and Glass

- Traditional glasses are mainly made up of silicon dioxide (sand) with other elements in lesser quantities to lower glass temperature of glass formation and improve other properties, such as $CaCN_3$ (lime) and $NaCO_3$ (washing soda).
- The sugar glass I made was a combination of household sugar (sucrose), corn syrup (glucose/fructose mixture), and water.
- The water and corn syrup are added as modifiers to help lower the melting point of the solution and suppress crystallization.

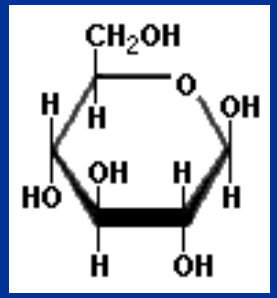


Sugar Crystals

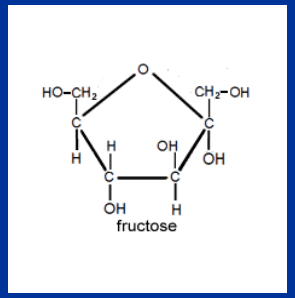
Corn Syrup vs. Sugar



Sucrose Molecule



Glucose Molecule



Fructose Molecule

- Common table sugar is called sucrose.
- The sucrose molecule is essentially a glucose molecule joined to a fructose molecule.
- The glucose molecule, which makes up the Corn Syrup, bonds well with the sucrose in the solution seeing as they are similar molecules. The extra glucose molecules actually inhibit crystallization of the sugar upon cooling because the added components make it harder for individual sugars to form crystals.

Pouring Temperature

- The temperature at which a given sugar solution can be cooled to form a glass at a room temperature varies on the percent composition of each material.
- Before we could investigate a range of glasses with different compositions, a standard for pouring had to be established.
- Fortunately, a methodology already existed. Confectioners for years have gone by a system of rating the candy on its hardness by dropping a spoonful into room temperature water. The candy can vary from soft ball to hard ball to hard crack. It is simply based on what the candy feels like to touch. When the candy snaps or cracks when dropped into water, it is at hard crack, and that is the point where it will become a glass if cooled at room temperature. That is the considered the pouring temperature.

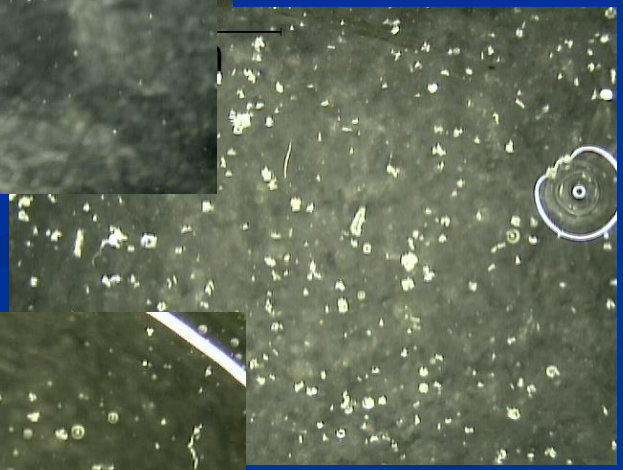
Crack Temp. vs. Composition

- Each sample was made with 10% water, therefore, as the amount of sucrose increased, the amount of corn syrup used decreased.

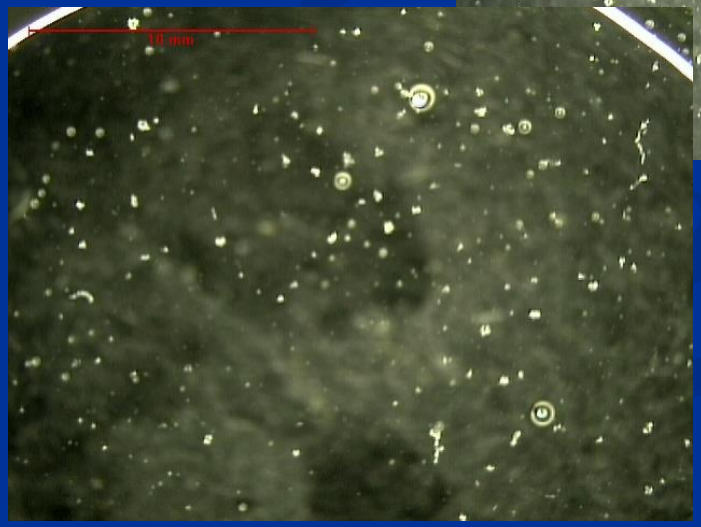
Experimenting

- To find the optimal glass forming composition, a series of samples were made with varying amounts of sucrose and corn syrup.
- Each day observations were taken about the crystallization of the samples.
- It was eventually concluded that as the percent corn syrup in the sample increased, the affect of crystallization decreased.
- The composition of this sample is 30% sucrose, 60% syrup and 10% water

Day One

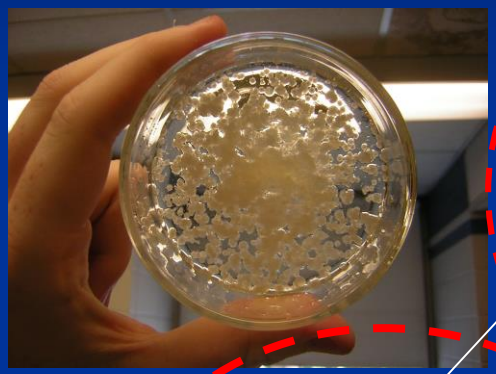


Day Two



Day Five

Sugar Solution Ternary Diagram



- **Despite the amount of water in the solution, it will not form a glass until most of it has boiled off, therefore the only area of concern is the percent sucrose versus percent corn syrup.**

Pictures taken after one day.

Specific Gravity Experiment

• A specific gravity experiment was set up in hopes of finding a correlation involving the composition.

Step 1: Measure weight of jar and water.

Step 2: Measure weight of glass

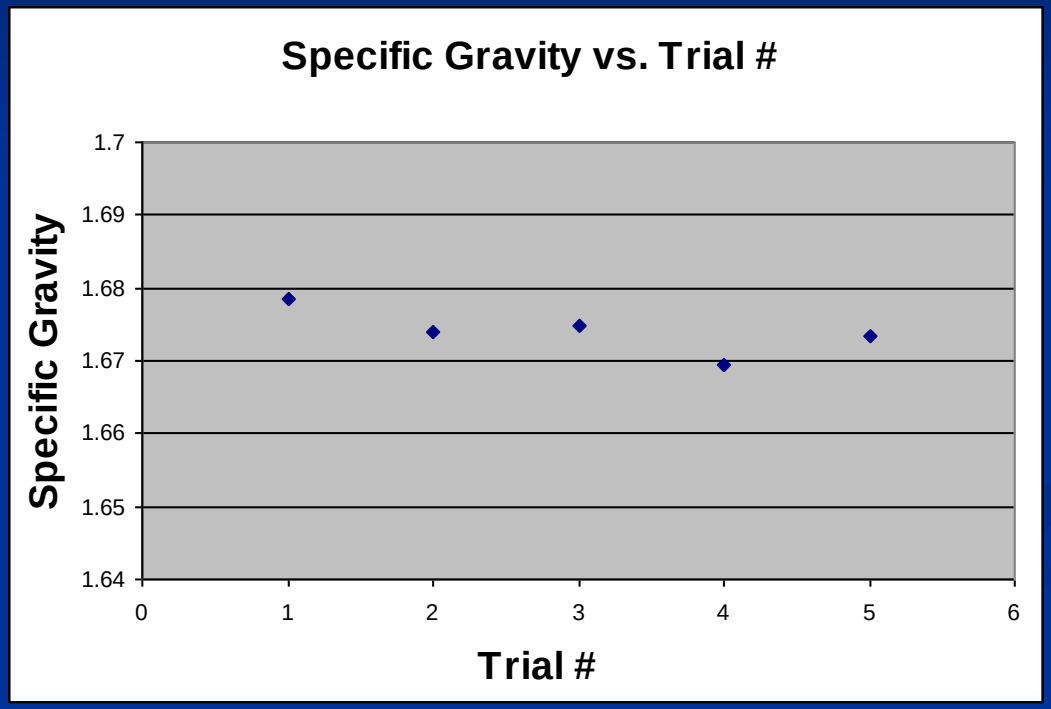
Step 3: Measure weight of jar and glass together.

Specific Gravity, p = (wt of glass) / (wt of glass) – (Δ wt of jar) ,

where Δ wt of jar is the difference between the weight of water in the jar and the weight of the water and glass in the jar.

• It was first performed using pieces of glass (with a known specific gravity) and once successful, was adapted for testing sugar glass.

Specific Gravity Results (Glass)

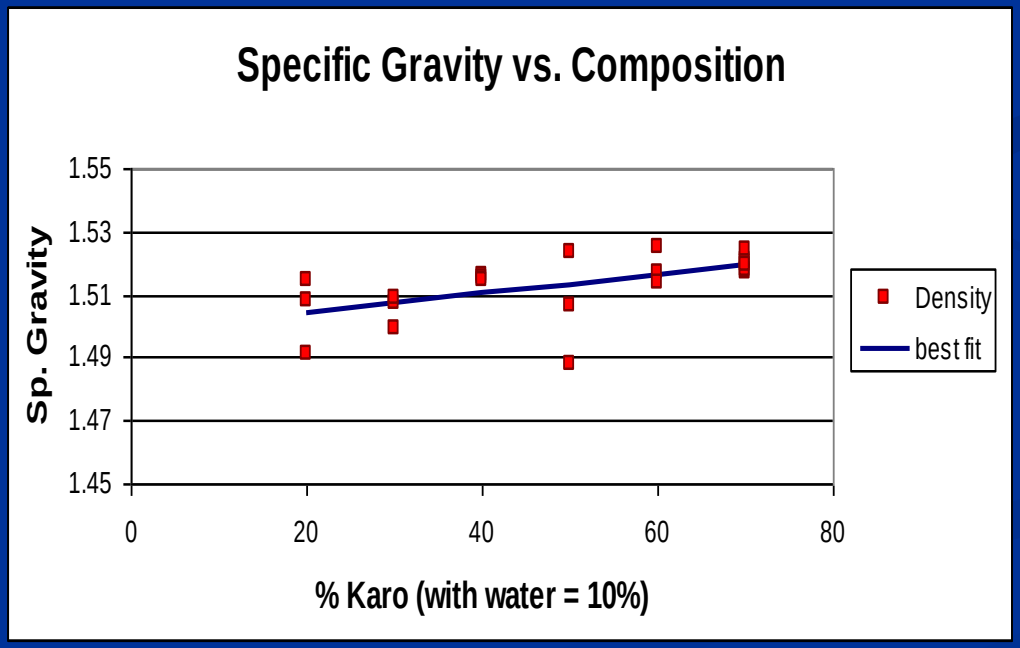


- Many surprising hurdles had to be overcome, such as the difficulty of eliminating all air bubbles, but eventually solid data was ascertained.

This led to an average specific gravity of 1.674

Specific Gravity Results (Candy)

- To measure the specific gravity of the candy glass, the candy was poured into a mold (film container) that was ideal for the size of the jar.
- The process was then repeated for the candy samples similar to that of the pieces of glass.



- The data and the resulting graph show a small trend of increasing specific gravity with increasing corn syrup.

Fiber Drawing Demo

- Since one of the aims of my project is to help convey the interesting properties of glass to high school students, a hands on experiment was created for these students to experience glass fiber drawing using candy glass.
- In the demo they were able to experience the properties and the uses of drawing fiber. They also experienced some of the scientific issues involved in pulling glass fibers.
- The stable glass range on the ternary diagram helped to select an ideal composition for both stability and good glass pulling for the demo.

Index of Refraction (Future)

• Although the experiment has not been completed yet, I am hoping to finish it by the end of the program.

• Index of refraction can be measured easily by using a simple student spectrometer that most high schools would have. It is important that the only instruments being used are those that would be available to high school students.

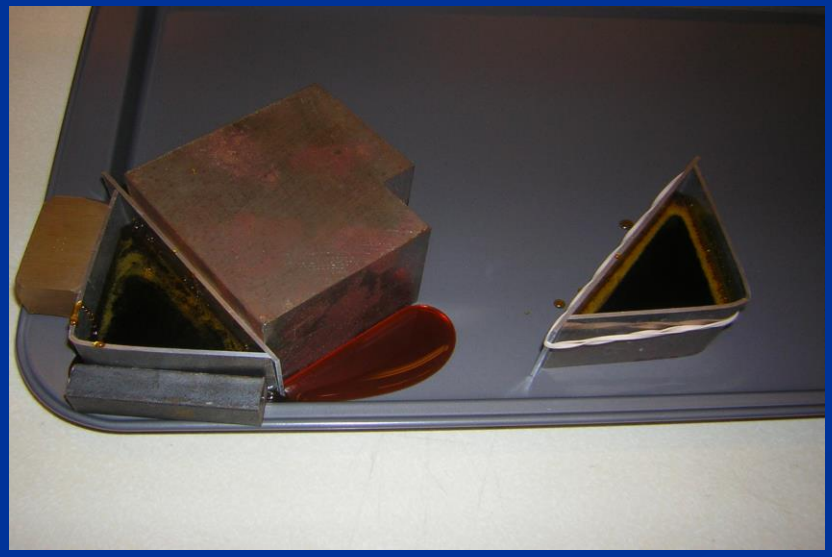
• The spectrometer works by directing light through a glass prism with known angles and finding the minimum angle of deviation. The index can then be found using the equation below.

• **Index of Refraction = Sin((A + δ)/2) / Sin (A/2),**

where A is the angle of the prism and δ is the minimum angle of deviation.

Index of Refraction (Future)

- To make a candy glass prism, a technique had to be developed for a mold where the candy could easily be removed with ruining the sample.
- Currently, candy is being poured into metal prism molds that have been made to be 90-45-45 degree triangles in order to act like a glass prism.



Further Readings

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- Arthur Hardy and Fred Perrin, *The Principals of Optics*, 1st Ed. (McGraw-Hill, New York, 1932)
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