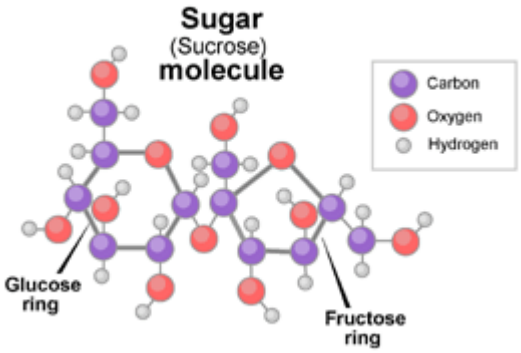
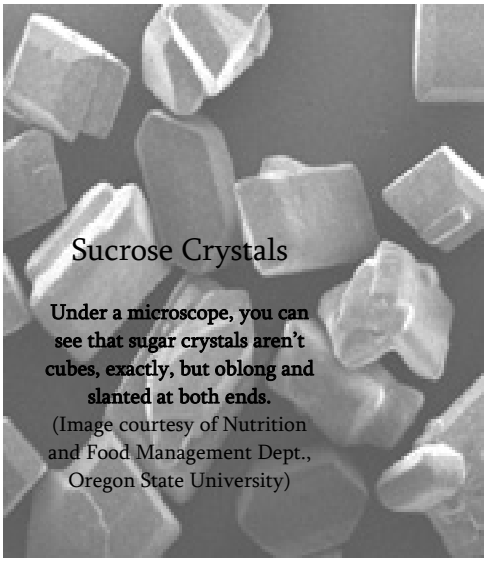
Rock Candy Lab Name:_____D/H_____

What is sugar?[1]

The white stuff we know as sugar is sucrose, a molecule composed of 12 atoms of carbon, 22 atoms of hydrogen, and 11 atoms of oxygen ($C_{12}H_{22}O_{11}$). Like all compounds made from these three elements, sugar is a carbohydrate. It's found naturally in most plants, but especially in sugarcane and sugar beets—hence their names.



Sucrose is actually two simpler sugars stuck together: fructose and glucose. In recipes, a little bit of acid (for example, some lemon juice or cream of tartar) will cause sucrose to break down into these two components.



Sucrose Crystals

Under a microscope, you can see that sugar crystals aren't cubes, exactly, but oblong and slanted at both ends.
(Image courtesy of Nutrition and Food Management Dept., Oregon State University)

If you look closely at dry sugar, you'll notice it comes in little cubelike shapes. These are sugar crystals, orderly arrangements of sucrose molecules.

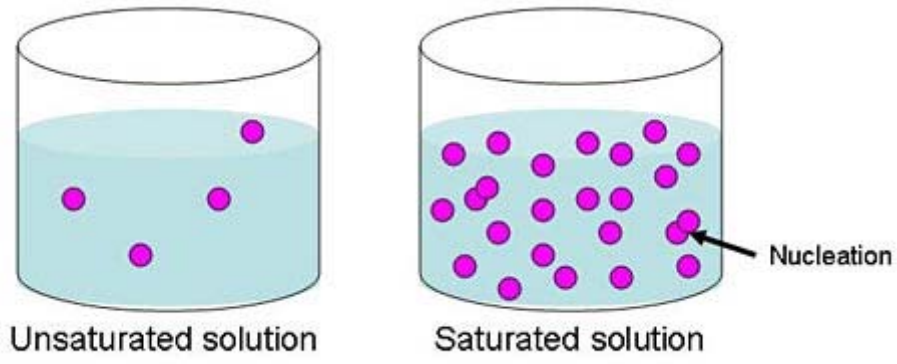
What happens when you heat a sugar solution?

When you add sugar to water, the sugar crystals dissolve and the sugar goes into solution. But you can't dissolve an infinite amount of sugar into a fixed volume of water. When as much sugar has been dissolved into a solution as possible, the solution is said to be **saturated.**

The saturation point is different at different temperatures. **The higher the temperature, the more sugar that can be held in solution.**

When you cook up a batch of candy, you cook sugar, water, and various other ingredients to extremely high temperatures. At these high temperatures, the sugar remains in solution, even though much of the water has boiled away. But when the candy is through cooking and begins to cool, there is **more sugar in solution than is normally possible**. The solution is said to be **supersaturated** with sugar.

Supersaturation is an unstable state. The sugar molecules will begin to crystallize back into a solid at the least provocation. Stirring or jostling of any kind can cause the sugar to begin crystallizing.



[1] http://www.exploratorium.edu/cooking/candy/sugar.html

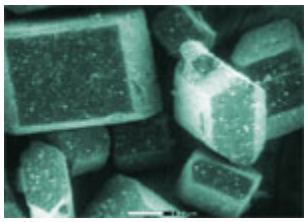
If you add more compound than can dissolve in the liquid, the undissolved bits remain as solids in the liquid. In a saturated solution, the molecules bump into one another frequently because there are so many of them. Occasionally when they bump into each other, the molecules end up sticking together; this is the beginning of the crystallization process and is called **nucleation.** Once several molecules are already stuck together, they actively attract other molecules to join them. This slow process is how the crystal "grows."

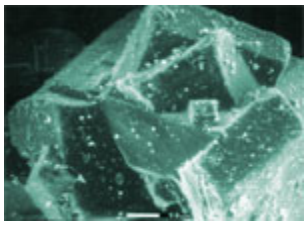
Why are crystals undesirable in some candy recipes—and how do you stop them from forming?

The fact that sugar solidifies into crystals is extremely important in candy making. There are basically two categories of candies - *crystalline* (candies which contain crystals in their finished form, such as fudge and fondant), and *noncrystalline*, or *amorphous* (candies which do not contain crystals, such as lollipops, taffy, and caramels). Recipe ingredients and procedures for noncrystalline candies are specifically designed to prevent the formation of sugar crystals, because they give the resulting candy a grainy texture.

One way to prevent the crystallization of sucrose in candy is to make sure that there are other types of sugar—usually, fructose and glucose—to get in the way. Large crystals of sucrose have a harder time forming when molecules of fructose and glucose are around. Crystals form something like Legos locking together, except that instead of Lego pieces, there are molecules. If some of the molecules are a different size and shape, they won't fit together, and a crystal doesn't form.

A simple way to get other types of sugar into the mix is to "invert" the sucrose (the basic white sugar you know well) by adding an acid to the recipe. Acids such as lemon juice or cream of tartar cause sucrose to break up (or invert) into its two simpler components, fructose and glucose. Another way is to add a nonsucrose sugar, such as corn syrup, which is mainly glucose. Some lollipop recipes use as much as 50% corn syrup; this is to prevent sugar crystals from ruining the texture.





We will make crystalline rock candy

When you make rock candy, you can see the shape of sugar crystals on a giant scale. The key is giving them lots of time (about 7 days) to grow. As the water evaporates, sugar crystals form on the string or stick, and the shapes that they form reflect the shape of individual sugar crystals.[2]

Key Vocabulary

- Amorphous solid
- Crystalline solid (also known as crystal)
- Molecule
- Solution
- Compound
- Saturated
- Nucleation
- Seed crystal

[2] http://www.exploratorium.edu/cooking/candy/recipe-rockcandy.html

Rock Candy Lab Name:_____D/H_____

Questions

- How do you make a saturated solution?
- Which holds more sugar: cold water or hot water?
- How do crystals grow?
- What is nucleation?

Materials and Equipment

This project is customized for containers that hold approximately 14 oz. If your containers are larger you will need to double the amount of water and sugar.

- cotton string (about 1.5 feet)
- Water
- Cup
- Tablespoon measuring spoon
- Small plate
- Granulated white sugar (3 cups)
- Wax paper
- Screws, wooden beads, or other small nontoxic objects to use as weights (2)
- Wooden skewers, Popsicle® sticks, or pencils (2)
- Marker to write with
- Ruler (with centimeter markings)
- Tape
- Glass containers, make sure they are identical in size and shape (2)
- Pot
- Burner
- Measuring cup (for liquid ingredients)
- Measuring cup (for dry ingredients)
- Wooden mixing spoon
- Pot holders
- Paper towel

Experimental Procedure

Caution: This science project requires the use of a burner to make a boiling sugar-water solution. Use caution and only do this under the supervision of an adult; the sugar-water solution is extremely hot and can cause a bad burn if spilled.

Day 1

1. Cut two pieces of string. Each piece should be approximately 1 inch longer than the height of the glass containers.
2. Soak the pieces of string in a cup of water for 5 minutes.

3. After soaking, use your hand to squeeze the excess water from the string. Roll the string in 1 tablespoon of sugar on a plate. The string will be coated with sugar. These small bits of sugar are the seeds on which other sugar crystals might grow.

4. Lay both your (sugar-coated) string on a piece of wax paper overnight. Make sure they are not touching.

Day 2

1. Prepare the strings.

   a. Take your seeded string and tie one end to a screw, wooden bead, or other small object that can serve as a weight. It is ok if some of the sugar falls off while you're tying it to the weight.

   b. Tie the end of each piece of string to a skewer, popsicle stick, or pencil. See Figure 2.

   c. Lower the weighted end of the seeded string into one of the containers and rest the skewer across the mouth of the container. Roll the skewer to wind the string until the weight is suspended approximately 1 centimeter (cm) from the bottom of the container, which you can measure with your ruler. Tape the string around the skewer so that the length of the string cannot change.

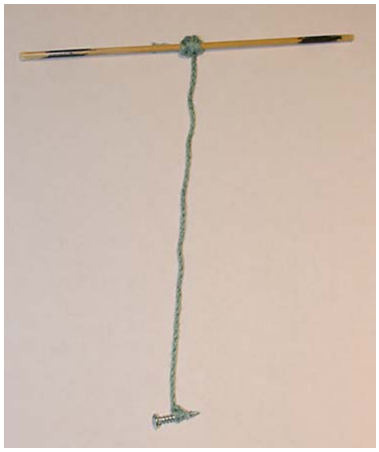


Figure 2. The string in this photo has been tied to a skewer and weighted down with a screw on the other end. It is ready to be used to make rock candy.

2. Preheat the glass containers. This will ensure that you are not adding your hot sugar-water solution to a cold container, which would result in a dramatic temperature change that might make small crystals form along the glass. The small crystals would disrupt your rock candy formations.

   a. Boil enough water to fill both containers. When the water is boiling, carefully pour it into the containers. (use beaker tongs)

   b. Let the full containers sit, with the hot water in them, until your sugar-water solution is ready.

3. Make the sugar-water solution.

   a. Using a liquid measuring cup, add 1 cup of water to a pot. Bring the water to a rolling boil on the stove. Turn the heat down to low. Note: if you are using containers that are larger than 14 oz, heat 2 cups of water.

   b. Using a dry measuring cup, add 2 cups of sugar to the hot water. Note: if you are using containers that are larger than 14 oz, add 4 cups of sugar.

   c. Mix with a wooden mixing spoon until all the sugar has dissolved.

   d. Turn the heat back up and wait until the sugar-water solution returns to a rolling boil. Make sure to keep stirring so the temperature is consistent throughout the solution.

   e. Remove the boiling sugar-water solution from the burner.

f. Continue to add sugar 1 tablespoon at a time. Stir thoroughly after each added spoonful, making sure that the sugar is completely dissolved before adding another spoonful. Note: do not confuse the tiny little bubbles in the solution for undissolved sugar. You can tell them apart by stopping your stirring for a moment; the sugar will settle to the bottom of the pan, the bubbles will remain suspended throughout the solution.

g. Keep adding sugar until no more will dissolve in the solution. If you think you've added too much sugar to your solution, don't worry. Keep stirring and if even after a full 2 minutes of stirring you have undissolved sugar at the bottom of your pot, return the pot to the burner. Heat the solution until it just begins to boil then remove it from the burner. This should help you to get that last bit of sugar into the solution.

4. After the last bit of sugar has been dissolved, allow the solution to cool for 5 minutes.

5. Pour the hot water out of the preheated glass containers.

6. After the sugar-water solution has cooled for 5 minutes, pour the solution into the two preheated glass containers, dividing the liquid equally between the two containers. **Caution:** Be extremely careful when pouring the sugar-water solution; it is hot and will burn if spilled on your skin.

7. Using paper towel, move the containers of sugar-water solution to a place where they can be left undisturbed for one week. Place both containers in the same location. Large fluctuations in temperature can interfere with the crystallization process, so avoid putting the containers in places that get direct sunlight, or are near a heating or cooling vent.

8. Gently lower the weighted strings into the containers of sugar-water solution, one string per container.

9. Securely tape the skewers holding the strings to the edges of the containers to prevent the strings from being accidentally jostled. See Figure 3 below.

10. Loosely cover the containers with a paper towel to prevent dust and debris from flying in, while still allowing evaporation to occur.

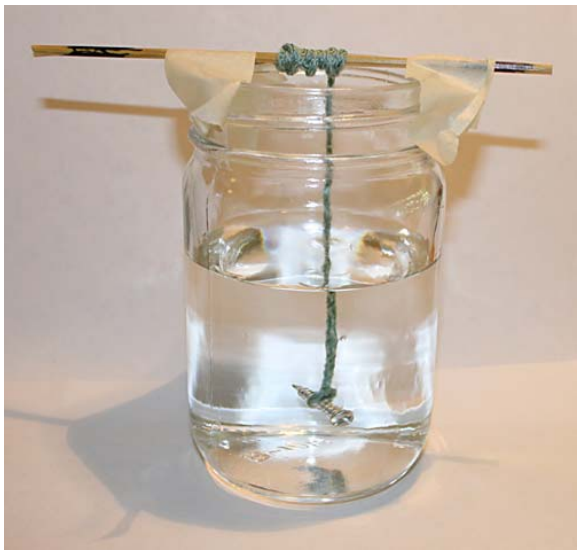


Figure 3. When the experiment is all set up, your rock candy growing containers should look like the one pictured here.

Observations and Measurements

1. Look at your containers once a day. What do you see? Are there any crystals growing? Where are the crystals?

Days Spent in Container	Observations
Day 1 (the day the sugar-water solution was made)	
Day 2	
Day 3	
Day 4	
Day 5	
Day 6	
Day 7	

2. Make observations of your sugar-water solution containers for one week. On the seventh day, remove the strings from the containers and take measurements of your rock candy crystals.
    a. If there is a layer of hardened sugar syrup coating the top of your container, you can use a spoon to gently break that layer before pulling out your sugar crystals.
    b. Briefly rinse the rock candy crystals in cold water, then leave them on a paper towel for 30 minutes to dry.
    c. Once you've recorded all your measurements and observations, you can enjoy all your hard labor by eating the rock candy you grew!