Caramel

**Name: Partner(s):**

PRELAB ASSIGNMENT

1. What are the names of the two main types of reactions that occur when we’re making caramel candy?
2. What kind of chemical reaction are they?
3. What is a colloid?
4. What is the temperature to which we will heat the mixture to make caramel?
5. What would happen if we heated the mixture hotter than that?
6. Draw the molecule glucose (as well as you can.)
7. Draw the molecule fructose (as well as you can.)

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**INTRODUCTION AND BACKGROUND:**

Caramel is a candy made primarily of sugar, but its other essential ingredient is cream or milk. Sugar (sucrose) is a fairly simple molecule – it is a disaccharide made of two simple sugars: one molecule of glucose and one molecule of fructose. “Disaccharide” just means two sugars are bonded together to make one larger molecule. A diagram of sucrose is shown below. The lines represent carbon-carbon bonds. Glucose is the 6-membered ring on the left, and fructose is the five-membered ring on the right. They are joined by an oxygen:



Cream, on the other hand, is a complex mixture – a *colloid*, in fact – of many different biological molecules, including fats, proteins, sugar, and (of course) water. (Cream isn’t pure fat – most creams are 30-40% fat. The rest is protein, a little sugar (lactose), and water.) A colloid is what we get when we mix things together that don’t normally combine – like oil and vinegar. But when we make the particles small enough, they stay mixed together in a “suspension” – like mayonnaise. Fat doesn’t usually mix well with water, sugar, or protein, but the cream we will be using has been “homogenized” – the fat particles have been made small enough that they stay suspended in the remaining water. (That’s why homogenized milk doesn’t separate into the cream layer and the reduced-fat milk layer.)

When we cook sugar, fat, and protein together, a wide variety of chemical reactions occur. Two of the most important reactions that happen when we cook are the caramelization and Maillard reactions. Caramelization is a polymerization reaction, in which small molecule units – like glucose, for example – are joined together into long chains. In addition to forming into long chains, the chains themselves can *cross-link*, or form bonds or strong intermolecular force attractions (hydrogen bonding, for example) between the chains. Polymerization reactions result in a product that is usually hard and strong compared to the original material.

Caramelization is a fairly simple polymerization reaction involving just sugar, but results in a wide variety of products with different flavors and textures, depending on the temperature to which you cook the sugar. For example, there are soft candies like fudge, firmer candies like taffy, and hard candies like lollipops. The hotter the temperature to which you cook the sugar, the harder – and the more polymerized – will be the product. Soft candies are cooked at least to 240 °F, and harder candies are cooked quite a bit hotter than that. We’ll be cooking our caramel to 248 °F, which should leave us with a fairly soft, chewy candy.

Caramelization is *also* a browning reaction – when we cook sugar to high temperatures, some of the chemicals we make look brown to us. That’s why you see “caramel color” as one of the ingredients in colas, and many other foods with brown coloring added.

Unlike caramelization, Maillaird reactions do not usually involve polymerization, but are specifically browning reactions. At the most basic level, a Maillard reaction is the reaction between a sugar molecule and an amino acid molecule (amino acids are the building blocks that make up protein molecules) – so in order to have Maillard reactions, it is necessary to have both a source of sugar and of protein. In caramel candy, the protein is present in the milk or cream. Maillard reactions are responsible for producing many of the tasty flavors we enjoy in foods, and in reality are quite a complex set of reactions, so it is difficult to identify all of the products that are formed. Any time you grill or sauté something, you’re inducing Maillard browning in the food, thereby producing many tasty products. The reaction products from Maillard reactions are why grilled meat or vegetables are so much more delicious than boiled meat or vegetables.

Caramel candy, although it is made from a lot of sugar, does not involve pure “caramelization” reactions – since we mix the sugar with milk, there is plenty of protein present, and in actuality it is a combination of caramelization of sugars, and Maillard reaction products which produces the characteristic flavor of the caramels, one of which is the molecule diacetyl, which produces a “buttery” flavor.

Both caramelization and the Maillard reaction are also called *dehydration* or *condensation* reactions, because when two sugars combine, or when an amino acid and a sugar combine, a water molecule is one of the products of the reaction. So the reaction *dehydrates* the reactants – water is a product of the reaction.

In the following laboratory experiment, we will make caramel using a tried and true recipe. Please be careful to follow the directions carefully, or the candy may not have the correct consistency. In case you wish to make caramel on your own outside of lab, I have included a complete list of the materials you will need, as well as a few optional variations in case you want to try something a little different. If you want a softer candy, experiment with decreasing the final temperature; similarly, if you want a harder candy, then cook the caramel to a higher final temperature.

Tools Needed:

One very accurate candy thermometer

One 4-quart (or larger), heavy-gauge sauce pan (pot) – make sure it doesn’t have a non-stick lining that could decompose at high temperatures. Cast iron, unlined aluminum, or enamel pots are the best.

One 9x13 baking pan (or similar size; or several smaller ones)

One long-handled wooden spoon, or other insulated, heat-resistant stirring implement. Plastic or silicone will not work; if you use a metal spoon, make sure the handle is made of heat-resistant plastic (and not metal, or the spoon will get very hot)

Butter for greasing pan, or parchment paper for lining pan

Waxed (or parchment) paper (for wrapping candies)

Note: Please do not burn yourself. The candy will be *very* hot when first made, so even though it looks like a tasty sauce, if you stick your finger into it, you will get a nasty burn. Please do not do this.

**Students will conduct this experiment in groups of two or three. Or four, if necessary.**

**Recipe: “Sandi’s Famous Caramels”**

From Baby Catcher, by Peggy Vincent

Ingredients:

2 C white sugar

1 C light brown sugar, packed

1 C light corn syrup

1 C heavy whipping cream

1 C half and half

1 C butter (I used salted butter)

4 tsp vanilla extract

1 C chopped walnuts (optional)

High-quality chocolate for melting and dipping (optional)

Directions:

Combine all ingredients except vanilla (and optional nuts and chocolate) in the heavy-gauge sauce pan. (Do *not* use a smaller pot! A larger one is fine.) Heat on medium to medium high heat (depending on your range), while stirring, until the sugar dissolves and the butter melts. Reduce heat slightly. Attach the candy thermometer to the pot, with the tip well into the candy, and cook, stirring frequently, until the thermometer reaches 240 °F. Watch closely to prevent it boiling over. Note: the temperature is likely to stall for a while before it resumes increasing, but never fear, it will eventually start increasing again.

 After the thermometer reaches 240 °F, stir constantly to avoid scorching the candy onto bottom of pan, and cook until the thermometer reaches 248 °F exactly. This whole process will take 35-60 minutes, so if the temperature does not increase very fast up to boiling, turn up the heat a bit so it will go faster.

 Remove the pan from the heat as soon as the thermometer reaches 248 °F, and let it stand one minute. Stir in the vanilla extract and the nuts, if desired. Quickly pour into the buttered (or parchment lined) 9x13 inch pan, and cool (at room temperature is fine) for a couple of hours. If you wish to taste some caramel sooner than that, pour a small portion onto a piece of parchment paper so it cools faster.

 When you wish to remove the caramels, dip the bottom of the pan into a shallow tray of very hot water and let it sit for a couple of minutes. (Or if you’ve lined the pan with parchment, then just lift the parchment out.) This should loosen the caramels from the pan. Turn the pan upside down over a cutting board, and lever the caramel slab out onto the cutting board. Cut caramels into large or small squares (as desired). Wrap individually in wax paper, or dip individually into melted, high-quality chocolate, and store in the fridge.

 Makes 2 ½ lbs of candy, or about 70 – 100 pieces, depending on how big you cut the pieces.

Variations to the caramel recipe: of course you may add any nuts or dried fruits you wish – I’m sure it would be tasty. I’ve also substituted half of the vanilla extract with orange extract, and it turned out very nicely. You can also melt chocolate and dip the caramel in the chocolate. To melt chocolate (I would recommend using dark chocolate), put the chocolate in the outer part of a double-boiler, and warm until melted. Dip the caramels into the melted chocolate, and then set on waxed paper to solidify. (Tempering the chocolate would probably guarantee better results…but that’s a different lab.)

Use your imagination – I’m sure there are many lovely additions or modifications you could make.

Note: If you are vegan or cannot eat dairy, you should be able to replace the butter with margarine, and replace the cream with thick coconut milk. (The exact temperature and time you need to cook the mixture might change, but I think this combination should still work. I have not tried it, though; we can check the internet for recipes if necessary.)

Observations:

1. Describe your caramel mixture (color, odor, texture, etc.) right after you start heating it:
2. What was the temperature when it stopped increasing for a while? \_\_\_\_\_\_\_\_\_\_\_\_
3. Why do you think the temperature stopped increasing for a while?
4. Describe your caramel mixture (color, odor, texture, etc.) when it reached 200 °F:
5. Describe your caramel mixture (color, odor, texture, etc.) after you stopped heating it:

Concluding Questions:

1. What polymerized during this reaction?
2. What evidence do we have that both Maillard reactions and caramelization reactions both occurred while we cooked the caramel?
3. What would have happened if we had stopped heating the caramel at 240 °F, rather than continuing to 248 °F?
4. Draw the condensation reaction between two glucose molecules (one is shown below.) The –OH groups involved are the ones with arrows pointing at them.
5. Draw the condensation reaction between a glucose molecule and the simple amino acid shown below. The bond will either be through the –OH or one of the –NH’s. Draw **both** possible products.

