Supporting information

Learning Outcomes and Insights from a Chocolate-based Undergraduate Materials Science Course and Other Topical Outreach Activities

Jennifer Dailey

Department of Materials Science and Engineering, Whiting School of Engineering, Johns Hopkins University, 3400 N Charles St, Baltimore, MD, USA 21218

**Syllabus for Chocolate: An Introduction to in Materials Science**

Summer 2016

**Instructor**: Jennifer Dailey (PhD candidate, jdailey4@jhu.edu)

**Course Description:**

This course will introduce students to some basic concepts in materials science including phase diagrams, crystallization, and various characterization techniques, all through the close examination of chocolate. Students will have the opportunity to try some of their own experiments to see these processes in action. This course is directed toward freshman or sophomore engineering and natural science students with no previous background in these topics. Love of chocolate is a must.

**Prerequisites**:

High school level of all algebra, chemistry, and physics. Students should not have already completed an undergraduate thermodynamics course.

**Course Goals**:

By the end of this course, students should be able to:

* Define materials science, thermodynamics, and kinetics, and understand how these concepts relate to different materials and each other.
* Identify areas on a typical one- or two-component phase diagram indicating how temperature or changes impact phases of matter
* Predict the behavior of chocolate under different conditions, and use this knowledge to their advantage in their own kitchen

**General Policies:**

***This is a chocolate class, not a ‘cake class’***, and students will be expected to treat it as they would a typical science course. Attendance is mandatory for a passing grade. All students will be expected to participate in class discussions and lab sessions in order to make this the most enjoyable, educational course possible for everyone. Students who do not complete the required assignments will not receive a passing grade.

**Absences:** Please let me know as soon as you are able if you have an emergency, illness, etc. and will need to miss class. Hopefully we will be able to come up with a solution so that you can make up the missed material in order to receive credit.

**Food in Class:** *Once chocolate enters the lab, you must respect it as a chemical and may no longer eat it*. However, you will have opportunities in the classroom to taste samples, so this should not be a huge hardship. I understand it would be cruel to forbid food in the classroom as we are discussing chocolate for hours, so you are welcome to quietly consume any non-smelly food you bring to class.

**Required Materials**:

Supplementary readings to the in-class lectures will be posted from the available literature. Students are not required to purchase any textbooks.

**Course schedule:**

*What is Materials Science? What is Chocolate? What do they have to do with each other?*

In our first week we will discuss the main themes in materials science and review a brief history and composition of chocolate. We will also review some necessary vocabulary to be better able to speak scientifically about confectionary.

*Why is that chocolate so shiny? What is ‘tempering’? How do I impress my friends with truffles?*

We will then delve into some deeper ideas about different types of crystals that appear in chocolate, and how they are formed based on kinetic or thermodynamic conditions. We will spend at least some of our time in the lab as we test out our hypotheses and try to make something beautiful.

*What is this white stuff on the outside of this old chocolate? Why did my ice cream get crunchy?*

In our final week we will uncover the mysteries behind that chocolate that seemed to get ‘moldy’ or ice cream that develops freezer burn, and we will try to understand these processes from a basic energy perspective. I am very open to exploring any other student questions that arise throughout the classes.

This syllabus is a guideline only and is subject to change.

General Background Survey (post class)

By completing this survey or questionnaire, you are consenting to be in this research study.  Your participation is voluntary and you can stop at any time.

Student Code: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

On a scale of 1-5, with 1 being “not at all” and 5 being “very much”:

1. How interested are you in learning more about materials science? \_\_\_\_\_\_\_\_\_
2. How interested are you in learning about materials science as it relates to food science? \_\_\_\_\_
3. How well do you do you think you learn from the following techniques:
   1. Lecture \_\_\_\_
   2. Reading \_\_\_\_
   3. Demonstration \_\_\_\_
   4. Experimentation \_\_\_\_
   5. Written problem solving \_\_\_\_
   6. Group work \_\_\_\_
4. How likely are you to pursue further courses in materials science or a related discipline? \_\_\_\_\_
5. How much work was required in this class compared to other college courses? \_\_\_\_
6. How much did you enjoy this class overall? \_\_\_\_\_

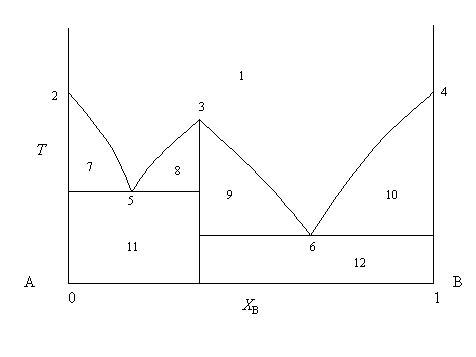
Short Answers

1. Did this class meet your expectations of what you thought it would be? How so, or why not?
2. Is/Are there any scientific concept(s) you believe you will understand 5 years from now due to this class? If so, what?

Pre- Test

By completing this survey or questionnaire, you are consenting to be in this research study.  Your participation is voluntary and you can stop at any time.

Student Code: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_



The above is a two-component (versus temperature) phase diagram featuring various components including Compound A (which can form an alpha phase), Compound B (which can form a beta phase), and a line compound formed at 33% B. No gas/vapor phase is shown on the diagram. Using the numbers indicated above, please indicate to the best of your ability which material phase(s) is/are present at each location.

1. Location 1? \_\_\_\_\_\_\_\_\_\_\_
2. Compound A/alpha phase
3. Compound B/beta phase
4. Line compound
5. Liquid
6. Unsure
7. Location 7? \_\_\_\_\_\_\_\_\_\_
8. Location 8? \_\_\_\_\_\_\_\_\_\_\_\_
9. Location 9? \_\_\_\_\_\_\_\_\_\_\_\_\_\_
10. Location 10? \_\_\_\_\_\_\_\_\_\_\_\_
11. Location 11? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
12. Location 12? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Food Science 101:

Using Your Senses to Explore Edible Materials

Dear Friend and Food­Lover,

Welcome to the Department of Materials Science and Engineering. If you have never visited before, you likely have little idea of what “materials science” encompasses, but you were intrigued by the idea of free samples. Luckily for us, food ​*is*​​a material, so everything you see today is “materials science!” Our department encompasses metallurgists, biologists, chemists, and computer scientists. We study ways to make metals stronger and lighter, how to deliver cancer­treating drugs more efficiently, and frequently have fun with lasers. Today you will see a number of basic concepts of our field displayed in a series five modules to engage all of your senses. Scientist or not, you are sure to find something appetizing today!

*JD*

# Smell: The Maillard Reaction (MD Hall 5)

Also known as the “Browning Reaction,” the Maillard reaction encompasses a variety of chemical species that are strongly related to the smell and taste of much of the food we eat every day. We can easily replicate this in the lab to produce a variety of smells based on the amino acids involved in the reaction.

*Can you make the room smell like chocolate?*

# Touch: Measuring Hardness with the Nanoindenter (MD Hall 15)

Nanoindentation is an important tool for measuring hardness on a very small scale. For many materials it is vital that we know the fracture toughness or the scratch hardness, and this machine has a surprisingly simple way of telling us a lot of information. *How does hardness relate to our experience with food?*

# Sight: Looking Close with a Scanning Electron Microscope (MD Hall 15)

A scanning electron microscope can look at materials closely, ​*very*​ closely. Using a beam of electrons rather than a beam of light, we can analyze our food down to the nanometer scale. Be warned: what you see may shock, confuse, disgust, or delight you. One thing’s for sure; you’ll never look at your food quite the same way again. *Did that look anything like you expected?*

# Sound: Making Candy Crackle (Krieger Hall 65)

Remember those little candies that fizz and pop in your mouth? It turns out that creating those in a non­factory setting would require a pretty dangerous pressure cooker situation, so we made the next best thing! Come learn the chemistry that happens when these sweets hit your tongue.

*What is the physical reason that we hear a sound from this reaction?*

**5. Taste: Everything Tastes Better Dipped in Liquid Nitrogen (Krieger Hall 67)** Coconut milk is delicious on its own, but what happens when you have a few balloons, a funnel, and a bath of liquid nitrogen at your disposal? Come see (and eat!) this easy example of a delicious phase transition.

*What could make this even yummier?*

**Activity: Tempering Chocolate**

**Relevant Courses: Thermodynamics, Kinetics, Structure of Materials**

**Recommended level: Undergraduate, advanced high school**

**Learning Objectives:**

By the end of this activity students should be able to:

Define “tempering” as it relates to a crystal structure and material properties

Describe the cooling and heating steps necessary to appropriately temper chocolate

Identify, discuss, and devise process strategies to avoid common tempering pitfalls (burning, under tempering, contamination with water, etc)

Measure appropriate samples and safely use necessary heating apparatus

**Supplies:**

Chocolate (milk or dark, minimum of about 75g per experiment to ensure proper consistency)

Thermometer (preferably instant-read digital)

Scraper tool or large knife (for cutting large chocolate pieces into smaller chunks, can be purchased inexpensively in a painting section of a home improvement store)

Large spoon or other stirring utensil (recommend for aiding first melt, before stir bar is effective)

Hot plate

Beakers large enough to hold chocolate

Silicone molds (I recommend https://www.amazon.com/Silikomart-Silicone-Easy-Chocolate-Small/dp/B00802AVWM)

Optional:

Pyrex dishes (to create heated water baths for double boiler)

Stir bar

Microwave (to compare tempering techniques)

**Outline:**

**Estimated time: 1.5-2 hours**

Recommended reading: The Science of Chocolate by Stephen Beckett

Advice to instructor: Be sure to check tempering temperatures necessary for your chocolate, as milk and dark in heating requirements. Time can be saved if hot plates are pre-set with water baths to appropriate temperatures before class. I recommend using the “strip sequence” activity (later in this document) as a pre-lab, after assigning relevant reading, to ensure students know generally why they are using this order of steps to create the desired crystal structure.

1. Allow students (or groups of 2-3) to choose one tempering method to start (milk or dark temperatures, water bath or direct heat or microwave if available, order of heating steps based on reading, etc)
2. Weigh out and chop chocolate samples very finely, place in a beaker that is at least double the volume of the chocolate
3. Heat chocolate to melting with stirring (46C for dark)
4. Cool chocolate to appropriate temperature (27C for dark, 31C for dark if seeding) (add “seed crystal” of reserved chocolate if applicable)
5. Reheat chocolate to 31C
6. Poor into molds. Allow to cool to room temperature naturally. Avoid overly humid environments

**Discussion Questions:**

1. Which heating methods were most effective? Why might the double boiler be safer in some ways but risky in others? What is the effect of a drop of water on melted chocolate?
2. What crystal polymorphs exist during each step of your process? (See Beckett)
3. Did your resulting chocolate turn out as expected? How can you tell if it is the type of chocolate you anticipated?
4. Blacksmithing and chocolate tempering are more similar than you might think. Describe how the two processes can be similar and how they are different. Think of how we each treat our materials to get the desired properties.

**Supplementary:**

If you have extra time, students can compare a variety of tempering techniques and further investigate the resulting structure using methods later described.

If you have the fortune of knowing someone with a 3D printer and a sense of adventure, tempered chocolate can be held at 37C in the printing nozzle and will result in reasonable simple creations after playing around a bit with the printer’s settings. This also allows for an introductory lesson to 3D printing that will be of intense interest to students who want to make their own chocolate frogs.

**Shortened Activity for Table-top:**

Pre-temper some chocolate and have it setting at a constant 31C. Show students the difference between smearing this chocolate along some wax paper (hardens quickly, shiny) versus some normally melted chocolate (rough appearance, stays more melted). Compare differently tempered chocolate bars (a week-old poorly tempered bar will be covered in white fat bloom, a newly melted and solidified bar will be soft, well-tempered chocolate will have a ‘snap’ when broken) and discuss how their properties differ based on crystal structure, melting point, etc.

**Activity: Testing Material Properties**

**Relevant Courses: Introduction to Materials, Microscopy, Mechanical Properties**

**Recommended level: Undergraduate (some activities can be used in middle/high school for general discussion)**

**Learning Objectives:**

By the end of this activity students should be able to:

Describe how to use chocolate samples to portray a variety of standard materials science property measurements

Use at least one tool that is new to their class (varies based on availability in your classroom, but may include any type of microscope, hardness measurement apparatus, melting point apparatus, etc)

Compare differences in measured properties and relate that to the overall quality of the chocolate

**Supplies:**

Many different chocolate samples (milk, dark, white, or student-tempered from previous lesson compared to store-tempered standard chocolate bars)

Available measurement tools may include:

Melting point apparatus and necessary capillary tubes (available from chemistry lab)

Microscope (optical, laser, SEM, etc)

XRD

Nanoindenter

Mechanical testing apparatus

**Outline:**

**Estimated Time: Variable based on tools used**

Note to instructor: Be sure to explain that, once in lab, chocolate is a chemical and is not to be eaten. Students should be reminded to thoroughly clean their spaces and dispose of their chemicals properly. Historically, we had no complaints using small samples in these testing environments.

1. An easy low-tech test is to compare the “snap” of tempered chocolate (hard) to melted and solidified chocolate (soft, like a candy that previously melted in your bag).
2. If SEM is used, be sure to deposit some platinum on your fracture surface (not a surface that has been in contact with a knife, but one that fractured naturally), in order to see the structure. Structure is surprisingly informative to compare between varieties.
3. Melting point testing should show that dark chocolate melts at a higher temperature than milk or white chocolate, and that tempered chocolate also has a higher melting temperature (why it melts on your tongue!)
4. XRD of cocoa butter polymorphs is available online and can be compared to resulting peaks.
5. Ask students if they can think of any other way they want to quantify their samples- answers may surprise you!

**Discussion Questions:**

1. What can you tell about a chocolate sample based on a particular test? What does this say about quality?
2. Are any of these tests useful for companies trying to improve their products? Why or why not?
3. What would these material tests traditionally be used for (if not chocolate)?

**Activity: Maillard Reaction**

**Relevant Courses: Biochemistry, Food Science introduction**

**Recommended level: Beginning undergraduate, advanced high school chemistry**

**Learning Objectives:**

By the end of this activity students should be able to:

Describe the Maillard reaction as it relates to amino acids in foods

Predict which amino acids may be found in common foods

**Supplies:**

Beakers

Hot plates

Stir bars

Sunflower seed oil

Glucose

Variety of pure amino acids (Valine, variety of others optional including L-Leucine, L-Threonine, L-Glutamine, available from BulkSupplements on Amazon for reasonable cost)

**Outline:**

**Estimated time: 1-2 hours, including set-up and clean-up**

**Note to instructor: This activity necessitates picking up on mild smells, so it is most effective in a clean environment (no other reaction smells around, or they will overpower your own). There is rarely a “right answer”, and in practice we found some interesting results where vegetarians all agreed one sample smelled “like bad meat” but the omnivores did not smell any sign of that. Have fun with it!**

1. Students should complete the pre-lab “strip sequence” activity before this, or at least complete a reading assignment regarding the Maillard reaction (I recommend Stephen Beckett’s “The Science of Chocolate” or even Wikipedia, though more heavily chemistry-based descriptions are also available.
2. Students working in groups of 2-3 should begin by collecting their beakers, stir bars, hot plates. It may be necessary to explain to students how to measure/tare chemicals on the balance if this is their first lab class.
3. A good starting amount for reactions is: 20ml water, 3.6 g glucose, 0.6 g of any amino acid, and 2 ml of oil in the beaker. Allow this to stir and dissolve, while heating to just below simmering. An aroma should develop after 20-30 minutes. I recommend starting a few reactions at once so that smells can be compared.
4. Students should take turns smelling (by wafting, not immersing the nose!) each mixture in turn and predicting which foods contain which amino acid based on smell. Valine is considered to smell chocolate-y, though not all students tend to agree.

**Discussion Questions:**

1. What is the chemical reaction going on that produces this aroma?
2. How is this reaction similar to or different from caramelization, another famous cooking chemical reaction?
3. Look up online to find foods that are high in your tested amino acids. Is this surprising, or could you smell it already?

**Lesson: Phase Diagrams**

**Relevant Courses: Thermodynamics, Kinetics, Introduction to Materials**

**Recommended level: Undergraduate**

**Learning Objectives:**

By the end of this lesson students should be able to:

Identify the eutectic point and describe its importance

Discuss how common food combinations (salt+water, chocolate+milk) can be described in terms of a two-component phase diagram

**Demonstration:**

This is meant to be an addendum/replacement for part of a tradition phase diagram lesson.

Leading demonstrations that can start student discussion include gradually dissolving a large amount of salt in a cup of water and asking students to describe the present phases. Students can then be guided to ask questions about melting point and boiling point of water with the inclusion of salt (discussing icy walkways, etc).

**Class Group Activity:**

Using labelled axes of a two-component phase diagram of chocolate and milk (one set of axes on the white board for each group), groups of students can begin trying to fill this in with minimal hints from the instruction. Students should identify hot chocolate, chocolate milk, some form of ice cream, etc. Leading hints asking “What phases are present if you try to dissolve too much chocolate powder in your milk?” can help students understand the idea of two-phase coexistence, which is frequently a difficult concept in this first lesson.

Kenneth A. Jackson at the University of Arizona has a phase diagram of chocolate and milk available online which is entertaining and educational for students.

**Lesson: “Imperfections” in Chocolate (Diffusion, Structure)**

**Relevant Courses: Structure of Materials, Introduction to Materials Science, Thermodynamics, Kinetics**

**Recommended level: Undergraduate**

**Learning Objectives:**

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

Identify two or three “imperfections” that can occur in chocolate and describe them scientifically

Discuss how diffusion can cause macroscopic changes in solids

Explain why adding new compounds (or, if this is a chemistry-based class, impurities) to our system will frequently lower the melting point.

**Outline:**

**Phase Diagram Discussion:**

Discussing eutectics, show how impurities such as adding salt to water will decrease the melting point; ask students to explain why this is useful.

Using a sugar+water diagram, try to get students to analyze whether an ice pop or an ice cube or the same shape would melt first due to their respective compositions.

(ASIDE FOR AN ADULT AUDIENCE: Using an ethanol+water diagram, try to identify what percentage of ethanol in a system would still freeze in a traditional -5C freezer… which could be useful for parties)

**Diffusion Discussion:**

Freezer burn on ice cream: Ice crystals coarsening and subliming in a low-humidity freezer to create a spikey, crunchy dessert. Can be avoided by placing plastic wrap on the surface of the ice cream.

Fat bloom on chocolate: Causes ugly white powdery “fungus” to appear on the outside of chocolate and a chalky texture if eaten. Diffusion of fat molecules (coarsening, Ostwald ripening, etc) can be discussed. This chocolate is safe to eat, and can be made delicious again through tempering.

Sugar bloom on chocolate: Water in contact with the outside of chocolate will create a white coating due to dissolved sugar recrystallizing on the surface. This is why it is important not to get chocolate wet.

**Discussion Questions:**

1. Why does poorly tempered chocolate develop bloom faster?
2. Can you think of any other foods where this type of diffusion-based spoilage occurs?
3. How does temperature play a role in these various types of diffusion?

**Lesson: Sustainability in Chocolate**

**Relevant Courses: Introductory Engineering, General**

**Recommended level: Undergraduate, high school**

**Learning Objectives:**

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

Identify social and agricultural issues associated with the production of chocolate

Define “sustainability” and how it relates to food production and consumption

**Outline:**

Bringing “green” ideas into engineering courses allows for a wide variety of discussions to occur that relate to environmental engineering, bioengineering, and social impacts and ethical concerns of engineers. For additional resources and information related to this topic, I encourage you to visit the Center for a Livable Future website through the Johns Hopkins School of Public Health.

**Discussion Questions:**

1. What is “fair trade” chocolate? How is it different from other types?
2. Where could scientists or engineers problem-solve throughout the manufacturing process from bean to bar in order to increase sustainability and ethical treatment of people?

**Project: Open-Ended “Science of Food” Options**

**Relevant Courses: Introductory Science, general**

**Recommended level: Any**

As a final project for students in my Chocolate: An Introduction to Materials Science course, students had three options.

1. **Write a long paper about a food science topic (all sciences welcome, all aspects of food welcome)**
2. **Write a somewhat shorter paper and demonstrate your food/technique/experiment**
3. **With a partner, create a 15 minute PowerPoint presentation about your topic to teach the class, and bring in some sort of demo.**

Having a variety of options allowed students who were uncomfortable presenting the option of showing their work entirely through writing, and allowed students who wanted to explore their “creative sides” the chance to do so. The results were spectacular.

* Examples of possible topics to study which I proposed included:
* Environmental impacts of cocoa plants?
* Packaging requirements to stay fresh?
* How does food stay preserved longer?
* Use of some specific food additive?
* Molecular gastronomy?

What I received from the students included:

* How to make powdered Nutella
* How to keep apples from browning , which method works best?
* Baking soda versus baking powder for more delicious cupcakes?
* Why does aged cheese taste different?
* Does the shape of a pan impact the cooking of brownies?

Students were guided through choosing appropriate questions, taken to a library session to find valid journal articles, taught to annotate and discuss the articles appropriate to answer their questions, and lent out a large amount of kitchen equipment (surprisingly, I got it all back!). This project was very well received by the students and most of them seemed legitimately interested, especially when they discussed the projects in one-on-one sessions for feedback and guidance. It also made the last day of class a pretty fun party!

**Strip Sequence Activities:**

Inspired by CITRL and the Center for Educational Resources at Johns Hopkins University, the following “Strip Sequence Activities” are meant to be completed by single or groups of students as a method to check comprehension of relevant pre-labs.

Highlighted portions should be separately cut out into strips and mixed together in an envelope, while the blank spaces are left with only the guiding words on the document given to students. Instructions will likely need to be altered based on the available equipment in the lab space.

For a more challenging experience, strips from multiple experimental procedures may be mixed in the same envelope.

Approximate time: 5-10 minutes

**Lab Safety**

This will help us:

Help to keep you and your classmates safe

You will be sure to:

Wear the provided safety goggles when instructed, wear long pants and shoes covering the whole foot, and tie back loose hair or jewelry

You will not:

Eat chocolate in lab

You will know you’re doing it right when:

You leave class in as good of health as you started

**Lab Safety**

This will help us:

You will be sure to:

You will not:

You will know you’re doing it right when:

**Maillard Reaction**

This will help us:

Show an example of a common chemistry phenomenon in food science

The first step at this station will be:

Weigh out appropriate amounts of amino acids and glucose

Then you will:

Mix together 20 ml water, about 3.6g glucose, 0.6g of an amino acid, and a stir bar in a beaker

Next, you should:

Turn the stirrer on and add 2mL of oil. Then turn on the heat (you should never need to go above 3!) and place a thermometer in the beaker.

You will know you’re doing it right when:

A clear liquid starts to smell (kind of) like chocolate

An interesting experiment to try is using different ratios of different amino acids to see the result. We will keep track of each group’s attempts and see who can come closest to the real thing!

**Maillard Reaction**

This will help us:

The first step at this station will be:

Then you will:

Next, you should:

You will know you’re doing it right when:

An interesting experiment to try is using different ratios of different amino acids to see the result. We will keep track of each group’s attempts and see who can come closest to the real thing!

**Melting Point Apparatus**

This will help us:

Show an example of thermodynamic properties, since it is a slow process.

The first step at this station will be:

Make sure the apparatus has a functioning light source and is cool (about room temperature) according to the thermometer

Then you will:

Shave extremely small amounts of different chocolate into the capillary tubes

Next, you should:

Place the capillary tubes into the 3 provided slots and make sure you can see the chocolate through the lens

Next, you should:

Very, very slowly (did I say slowly?), begin turning up the power (you should not have to go above 4 ever!), making sure one team member is watching the chocolate at all times, one member is reading the thermometer, and one is recording the results

You will know you’re doing it right when:

You are able to record the start temperature at which the chocolate begins to melt (a droplet forms) and the end temperature at which it is completely melted.

**Melting Point Apparatus**

This will help us:

The first step at this station will be:

Then you will:

Next, you should:

Next, you should:

You will know you’re doing it right when:

**Tempering Chocolate**

This will help us:

Show an example of kinetic properties, since we observe how structure changes based on speed of reactions

The first step at this station will be:

Measure out some finely chopped chocolate into a beaker with a stir bar

Then you will:

Turn the hot plate and stirrer on (you should never need to go above 3!) and place a thermometer in the beaker.

Next, you should:

Allow the chocolate to increase to 46C with stirring. Do not allow it to burn!

1. Next, you should: Allow the chocolate to cool to 27C (either in the beaker or on the table with scraping, if you feel adventurous).
2. Next, you should: Allow the chocolate to increase to 31C. Do not allow it to burn! Hold it steady.

OR

ALTERNATIVELY

1. Next, you should: Add in a chunk of already-tempered chocolate (this is called “seeding”)
2. Next, you should: Allow the chocolate to cool to 31C.

You’ll know you’re doing it right when:

You are able to pour the chocolate into molds and form something beautiful.

As long as the chocolate doesn’t burn, you can keep trying this until you get it right. I recommend investing in a Trader Joe’s “Pound Plus” bar of pure chocolate if you want to try this at home.

**Tempering Chocolate**

This will help us:

The first step at this station will be:

Then you will:

Next, you should:

(a)Next, you should:

(b)Next, you should:

OR

ALTERNATIVELY

1. Next, you should:
2. Next, you should:

You’ll know you’re doing it right when:

As long as the chocolate doesn’t burn, you can keep trying this until you get it right. I recommend investing in a Trader Joe’s “Pound Plus” bar of pure chocolate if you want to try this at home.