SHORT FILMS ABOUT CHEMISTRY

Frosty Formulations

IN THE CLASSROOM

CLASSROOM LESSON PLAN
GRADES 9–12

CHEMISTRY SHORTS™

Frosty Formulations
CLASSROOM LESSON

Overview

This lesson plan contains student activities, teacher notes, and additional resource suggestions that are intended for use with the *Chemistry Shorts™* film "Frosty Formulations." The film is freely available for viewing online either at the link above or http://chemistryshorts.org. The activities stand alone, with no additional background material needed. The activities are aimed at grades 9–12. Teachers may adjust or extend discussion of the chemistry involved depending on the students' level. The plan is designed for use as a complete package, although teachers may choose individual activities.

The lesson and materials are suitable for both in-person and virtual classrooms.

Classroom Materials

- Method for viewing *Chemistry Shorts™* film "Frosty Formulations" (7 min., 26 sec.)
- Student Activity handouts (paper or digital copies)

Student Activities with Estimated Times

Pre-Class Activity Scrumptious States of Matter	(10–15 min.)
In-Class Activity Water: A Love–Hate Relationship	(15–20 min.)
In-Class Activity Ice Cream Structure (including watching the film)	(20–25 min.)
In-Class Activity Ice Crystallization	(10–15 min.)
After-Class Activity Ice Cream: From Here To There	(5–10 min.)

Related Standards

NGSS 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.

NGSS HS-PS2-6
Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.

NGSS 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.

NGSS MS-PS1-1
Develop models to describe the atomic composition of simple molecules and extended structures.

NGSS MS-PS1-2
Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

NGSS MS-ETS1-2
Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

CCSS.ELA-Literacy.RST.9-10.5
Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., *force, friction, reaction force, energy*).

CCSS.ELA-Literacy.RST.9-10.7
Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

CCSS.ELA-Literacy.RST.9-10.4 & 11-12.4
Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9-10 texts and topics/grades 11-12 texts and topics.

CCSS.ELA-Literacy.W.11-12.2
Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content.

Pre-Class Activity Teacher Notes
Scrumptious States of Matter

Suggested Extensions

- Pack/fill a small container with ice cream. Allow to melt. How does the beginning volume compare to the final volume? American Chemical Society: https://www.acs.org/education/resources/highschool/chemmatters/past-issues/archive-2013-2014/ice-cream-chemistry.html
- Prepare two samples of the same ice cream. Keep one frozen and allow the other to melt. Taste the unmelted sample, then cleanse your palate with sips of water. Taste the melted sample. Do they taste different? Does our ability to detect sweetness depend on the temperature of the food? American Chemical Society: https://www.acs.org/education/resources/highschool/chemmatters/past-issues/archive-2013-2014/ice-cream-chemistry.html
- Mix up a batch of homemade ice cream. Now, change a variable. What is the resulting ice cream like? Science Friday Educator Collaborative: https://www.sciencefriday.com/educational-resources/ice-cream-science-activity/
- A misconception may be that all of ice cream is frozen. Consider how is it possible that a portion remains liquid. American Association of Chemistry Teachers: https://teachchemistry.org/chemmatters/april-2021/what-is-ice-cream

Question 2c
Unless a student has learned about ice cream previously, their model is unlikely to be similar to the one shown in the "Frosty Formulations" film. The question is meant for students to consider how they initially picture the structure, for later comparison with the structure in the film.

In-Class Activity Teacher Notes
Water: A Love–Hate Relationship

Suggested Extensions

- "Magic Cocoa Powder or Kitchen Science?" Museum of Science, Boston: https://youtube.com/shorts/vxCAQpQNdy8 Dipping a spoonful of cocoa powder into milk is one way to show hydrophobic and hydrophilic interactions. A thin surface layer is wetted, but after that layer is poked with a toothpick, it peels back to reveal the rest of the powder dry underneath.
- "Silent Underwater Fireworks." KiwiCo: https://youtu.be/EBOxje4anbc Adding drops of water-based food coloring to a clear, colorless container of water with a thin layer of oil on top shows "fireworks" as the colored polar droplets drop through the less dense nonpolar oil and enter the polar water, to dissolve and mix.

Questions 1–3
Instructors could go into more depth and relate this section to:

- Electronegativity and its trends within the periodic table
- Types of intermolecular forces (hydrogen, dipole–dipole, etc.)

In-Class Activity Teacher Notes
Ice Cream Structure

There are other applications of emulsions in familiar products such as mayonnaise, chocolate sauce, lotions, shampoo and conditioner, and laundry detergent. The American Oil Chemists' Society: https://www.aocs.org/stay-informed/inform-magazine/featured-articles/emulsions-making-oil-and-water-mix-april-2014

Suggested Extension

- Make chocolate chantilly, which brings together chocolate and water in an emulsion. Its fluffy structure incorporates air bubbles, with a structure that supports the stability of the air bubbles. A Bucket Full of Science: https://abucketfullofscience.wordpress.com/2017/04/11/science-behind-chocolate-chantilly/

In-Class Activity Teacher Notes
Ice Crystallization

Question 1, part b
Depending on what material has been covered previously in class, instructors could go into more depth about colligative properties.

Suggested Extensions

- "Instant Ice Science Experiment." Pacific Science Center: https://pacificsciencecenter.org/wp-content/uploads/2022/05/cah-instant-ice-6-8.pdf Supercool bottled water, then pour it out onto an ice cube to create an icy tower.
- "How To Make Liquid Nitrogen Ice Cream Safely." *Chemical & Engineering News*: https://youtu.be/2M1CFpvXJSs
- "Homemade Dippin' Dots with Liquid Nitrogen." The Sci Guys: https://youtu.be/O8K__2EhyNQ
- "*Untapped Potential* Lesson Plan Lab." (page 20) *Chemistry Shorts™*: https://chemistryshorts.org/wp-content/uploads/2022/09/Untapped-Potential-Lesson-Plan2022.pdf Instead of a sugar solution, a saltwater solution is concentrated by freezing. It illustrates a possible solution for a freshwater supply.
- "74,963 Kinds of Ice." American Chemical Society *Reactions*: https://youtu.be/2UmcO-qtdlM Thought there was just one type of ice? Nope! Learn what it takes to get other kinds.

After-Class Activity Teacher Notes
Ice Cream: From Here To There

Question 3
Another chemistry-specific list is at Science News Explores: https://www.snexplores.org/article/cool-jobs-people-taste-chemistry.

Other places to search online for unusual jobs that involve chemistry are in collections of "weird science jobs," such as at EduAdvisor: https://eduadvisor.my/articles/weird-jobs-in-science-you-never-knew-existed.

More of Dr. Warren's work is described at Research Champions: https://research-champions.com/ice-cream-chemistry/.

Dr. Warren also has "Ice Cream Sundays" where she shares and makes differe no-churn ice cream flavors on Instagram Live. Dr. Maya: https://drmayawarren.com/icecreamsundays

Name ______________________________ Date ____________

Pre-Class Activity
Scrumptious States of Matter

1. A luscious soda float starts with scoops of creamy ice cream in a frosty mug. Pouring in root beer or another carbonated soda finishes the sweet combination. The mixture in the mug includes three states of matter: solid, liquid, and gas. In what part(s) of the float do you find each state of matter? Fill in the table below.

State of Matter	Location in Soda Float
Solid	
Liquid	
Gas	

Name ______________________________ Date ________________

Pre-Class Activity
Scrumptious States of Matter (continued)

2. You may be surprised to learn that the scoops of ice cream themselves contain these same three phases as well. In the film “Frosty Formulations,” Dr. Maya Warren says, “Ice cream is one of the most complex foods. It has three different phases. It’s a solid, it’s a liquid, and it’s a gas all in one.”

a. The major components of the structure of ice cream are in the table below. Classify each as a solid, liquid, or gas.

Major Component of Ice Cream Structure	**State of Matter**
Fat globules (droplets)	
Syrup containing sugar and flavorings	
Ice crystals	
Air bubbles	

b. Dr. Warren also comments: “It has to stay in those phases for us to enjoy it the way that we do.” Describe a situation that would work against a serving or container of ice cream remaining in the three phases it had when it was originally made and packaged.

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Name ______________________________ Date ____________

Pre-Class Activity
Scrumptious States of Matter (continued)

c. Consider what a model of the structure of ice cream with the four major components listed in question 2a would look on the microscopic level. Choose different shapes/appearances to represent each major component and add them to the table below. An example for air bubbles is shown. Then, use your chosen shapes to draw your predicted model in the large rectangle.

Major Component of Ice Cream Structure	Shape / Appearance	
Air bubbles	○	

d. Explain the reasoning behind the arrangement of your model. How does it match up with your knowledge of the ingredients used to make ice cream and your past experiences of serving and eating ice cream?

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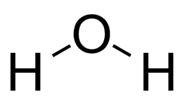
Name ______________________________ Date ______________

In-Class Activity
Water: A Love–Hate Relationship

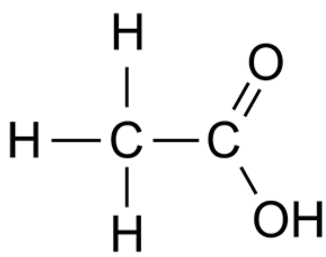
In the “Frosty Formulations” film, Dr. Warren makes salad dressing. The first two ingredients are vinegar and oil. The intermolecular interactions of each are dramatically different.

1. Household white vinegar contains water and acetic acid. The structures of these two compounds are shown below. Both molecules are polar, that is, the atoms that make up each molecule do not share electrons equally. For example, the electrons in a water molecule are more attracted to the oxygen atoms than the hydrogen atoms, and the electrons in the acetic acid molecule are more attracted to the oxygen atoms than the carbon and hydrogen atoms. This gives those parts of the molecules slight negative charges, and the rest of each molecule a slight positive charge. Nitrogen and chlorine atoms have a similar pull for electrons.

a. Label the water and acetic acid molecules below with + and – to represent these charged areas.

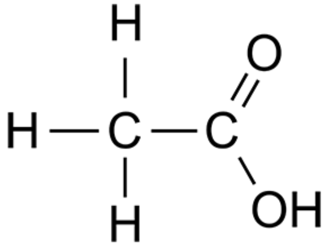


Water



Acetic acid

b. Draw two or three water molecules around the acetic acid molecule below. Since opposite charges attract (+/– rather than +/+ and –/–), how should you orient the additional water molecules around the acetic acid?



Name ______________________________ Date ______________

In-Class Activity
Water: A Love–Hate Relationship (continued)

c. A simplified statement for how two compounds generally mix is "like dissolves like." Would a combination of water and acetic acid mix or remain separate? Explain.

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d. Acetic acid is also described as *hydrophilic*, or "water-loving." Even though a molecule does not think or have emotions, how does this description fit its chemical behavior?

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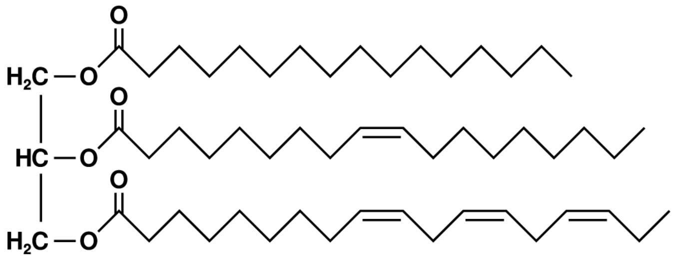
2. Triglycerides are a major component of olive oil. One example is shown below. It has three long chains called fatty acids made of carbon and hydrogen (right side of structure below) linked to glycerol (left side of structure below). Electrons are shared more equally within these molecules, making them nonpolar. Triglycerides are *hydrophobic*, or "water-fearing."



Would vinegar and olive oil mix to form salad dressing, or remain separate? Explain.

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Name ______________________________ Date ______________

In-Class Activity
Water: A Love–Hate Relationship (continued)

3. In the film, Dr. Warren adds a third ingredient—egg yolk—to the salad dressing. Its molecules have both hydrophilic and hydrophobic regions, so it serves as an emulsifier.

a. What is the purpose of the emulsifier?

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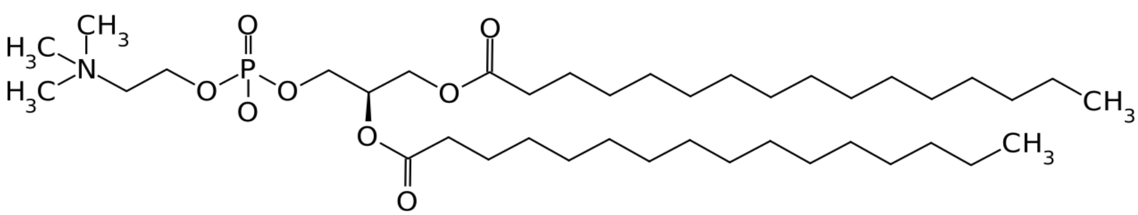
b. Lecithin from egg yolks and from soybeans is a common emulsifier. One example from this group of compounds is shown below. Which part is hydrophilic? Hydrophobic? Circle each type of area within the molecule and label each circle *hydrophilic* or *hydrophobic*.

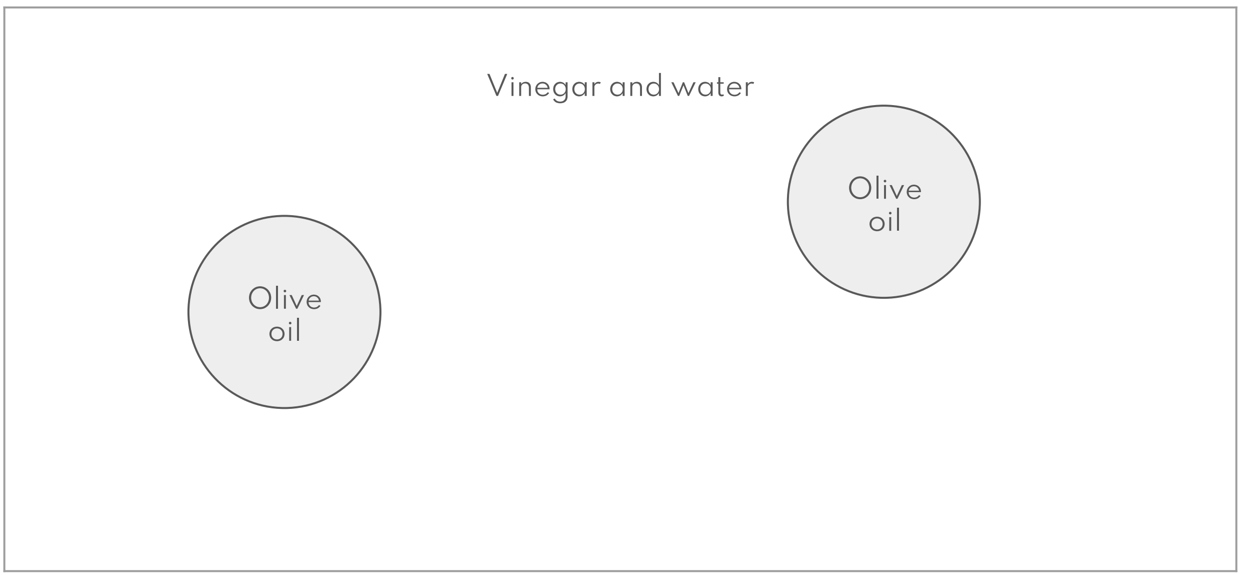


c. What simplified drawing is used to represent an emulsifier in the film and elsewhere? Draw it below, then use *hydrophilic* and *hydrophobic* to label two areas of the drawing.

Name ______________________________ Date ________________

In-Class Activity
Water: A Love–Hate Relationship (continued)

d. The circles below represent olive oil droplets, while the rest of the rectangle represents vinegar and water. Draw multiple emulsifier molecules using the simplified representation you drew for part c. Where would they be located and oriented?



4. Liquid dish detergents also serve as emulsifiers. How does their use support the washing away of cooking grease and oils?

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Name ______________________________ Date ________________

In-Class Activity
Ice Cream Structure

1. In the film “Frosty Formulations,” Dr. Warren says that a problem for ice cream scientists is how to bring together ingredients that don’t want to combine, to produce a perfectly creamy treat. She uses the example of oil and vinegar salad dressing to illustrate a similar situation.

a. When Dr. Warren made oil and vinegar salad dressing, how were the ingredients able to come together, when they normally would not? What was needed?

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b. How is the problem of making ice cream similar to that of making the salad dressing? Which ice cream ingredients are analogous to the oil and vinegar in the dressing?

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2. Milk proteins are also part of an ice cream mix. The proteins have at the same time both polar and nonpolar amino acids as part of their structures.

a. How would these proteins be likely to interact with other ingredients in the mix?

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b. How would this interaction support bringing together ingredients that would not normally combine?

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Name ______________________________ Date ______________

In-Class Activity
Ice Cream Structure (continued)

3. In ice cream, fat globules have different possibilities for how they arrange themselves.

a. The film "Frosty Formulations" uses visuals of soap bubbles to show three arrangement possibilities. Based on the film, fill in the table below with a brief description of each arrangement and a sketch of its appearance.

Possible Fat Globule Arrangements	
Description	**Drawing**

b. Which of the three arrangements is ideal for fat globules to make ice cream with a creamy texture? What does the film call this arrangement?

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Name ______________________________________ Date ________________

In-Class Activity
Ice Cream Structure (continued)

4. Milk proteins keep fat globules separated in the mix's water. For globules to combine in the ideal arrangement from question 3b, one or more additional emulsifiers are needed. Some examples are mono- and di-glycerides and Polysorbate 80, which have hydrophilic and hydrophobic regions.

   a. Emulsifier molecules displace some of the milk proteins on the fat globules. What effect does this have on how the fat globules can now interact with each other?

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   b. How does the arrangement of the fat globules support the overall structure and creaminess of the ice cream?

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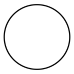
5. Revisit the ice cream molecular representation you made in the Pre-Class Activity question 2c. Based on the film, draw an updated representation below.

Major Component of Ice Cream Structure	**Shape / Appearance**	
Air bubbles		

Frosty Formulations

STUDENT ACTIVITY

Name ______________________________ Date ______________

In-Class Activity
Ice Crystallization

1. Unfrozen ice cream mix contains water from its ingredients, since a large percentage of cream and milk is water. What role does water, in both solid and liquid forms, play in the mix?

a. What is the freezing point of pure water? ______________

b. Imagine the grids below as solutions of sugar (S) and water (W) in ice cream mix. In grid A, what would the concentration of the unfrozen mix be (4 sugar, 12 water)? How does adding a sugar solute affect the freezing point of pure water?

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S	W	W	W
W	S	W	W
W	W	S	W
W	W	W	S

A. Before freezing

S	W	W	W
W	S	W	W
W	W	S	W
W	W	W	S

B. Freezing, part 1

S	W	W	W
W	S	W	W
W	W	S	W
W	W	W	S

C. Freezing, part 2

c. Follow the directions below for grids A, B, and C.

- Grid A: Leave unshaded. This represents the unfrozen ice cream mix.
- Grid B: Shade or draw an X in any 4 of the W boxes (touching or not touching). This represents some of the solution crystallizing into ice.
- Grid C: Shade or draw an X in any 8 of the W boxes (touching or not touching). This represents a larger portion of the solution crystallizing into ice.

d. In grid B, as portions of the water crystallize into ice, how does the concentration of the remaining solution change?

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Name ______________________________ Date ________________

In-Class Activity
Ice Crystallization (continued)

e. In grid C, some of the water remains unfrozen. This is true for ice cream as well, even at low freezer temperatures. Why is this necessary for us to use and enjoy ice cream?

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2. What is the pattern of your shaded/X ice squares for question 1, grid C? Circle I, II, or III below.

I. Many individual ice crystal squares that don't touch the full side of another ice crystal square

II. Only larger groupings of ice crystal squares that touch the full side(s) of another ice crystal square

III. A mixture of larger and individual ice crystal squares

a. The best ice creams tend to have very small ice crystals. When the crystals get larger than 50 micrometers, they can be detected in the mouth, giving it a coarse texture instead of smooth and creamy. What would the texture of your grid C ice cream be?

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b. Small ice crystals result from a faster freezing process that includes agitation. The faster the freezing, the smaller the crystals. From the following processes, which would likely result in the creamiest ice cream? Explain your choice.

- Freeze by placing container of ice cream mix in a freezer and leaving until frozen.
- Freeze in a home ice cream maker that uses ice and salt for freezing.
- Freeze by pouring liquid nitrogen into the ice cream mix.
- Freeze a plastic zip seal bag of ice cream mix by placing it in a larger bag of ice and salt, while kneading/shaking it.

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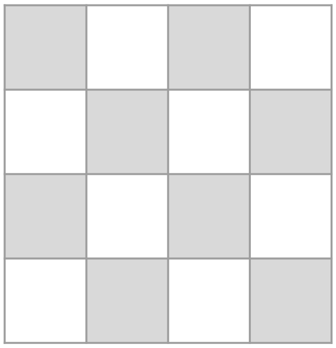
Name ______________________________ Date ____________

In-Class Activity
Ice Crystallization (continued)

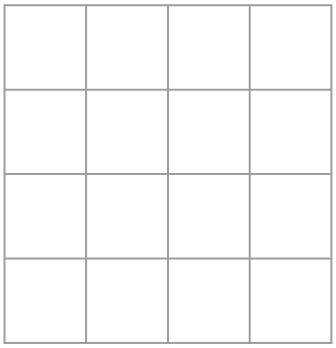
3. As ice cream is transported, stored, and used, it can undergo changes in temperature. These can affect the ice cream texture.

a. Follow the directions below for grids A, B, and C.

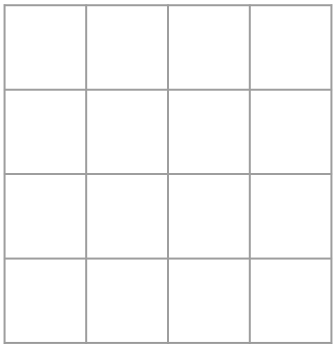
- Grid A: Leave for comparison. This represents many small crystals (gray squares that do not touch the full side of another gray square.
- Grid B: Copy the pattern from grid A, but choose 3 of the gray squares to leave unshaded. This represents some small crystals melting.
- Grid C: Copy the pattern from grid B, then shade in 3 more gray squares that connect with the side of at least one other gray square. This represents water depositing onto the surface of existing crystals rather than renucleating.



A. Initial temperature



B. Partial melting



C. Refreezing

b. What would the texture of the refrozen grid C ice cream be like in the mouth?

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c. What are tips you would recommend to avoid having melted, then refrozen ice cream when you purchase it at the store, transport it home, and put it in your freezer?

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Frosty Formulations

STUDENT ACTIVITY

Name ______________________________ Date ______________

After-Class Activity
Ice Cream: From Here To There

1. Describe an ice cream innovation that you have tasted or heard about.

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2. Some recent innovations or ideas for new products are:

- Fortifying ice cream with protein and thickening it for easier swallowing
- Using plant-based milks
- Using alternative sweeteners
- Storing ice cream as shelf-stable, single-serve containers that consumers freeze only when they want to eat it

Choose one of the innovations above, or the one you described in question 1. What benefit does the innovation have? How does it solve a problem or fill a need?

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Name ______________________ Date ______________

After-Class Activity
Ice Cream: From Here To There (continued)

3. Dr. Warren's food science career has involved more than just thinking up new ice cream flavors and mixing them up. She describes some of her experiences at https://www.mentalfloss.com/article/626268/meet-ice-cream-scientist-dr-maya-warren, particularly work she does in connection with ice cream in other countries. For example, she sources milk products that are affordable to use in other countries, sometimes consulting with them about how they could build their own dairies.

What is another job that uses chemistry in an unexpected way? In what way does it use it? To brainstorm, check out https://www.acs.org/careers/chemical-sciences/profiles.html and https://www.purdue.edu/science/careers/what_can_i_do_with_a_major/chem/index.html.

Chemistry Shorts™ is a film series that communicates the breadth and depth of chemistry's impact on humankind in an approachable manner, sponsored by the Camille and Henry Dreyfus Foundation. These films will celebrate the science and the people who share a passion for the vital role chemistry plays in the biggest issues, including human health, renewable energy, the nature of life, sustainability, new materials, and climate change. Each film incorporates a lesson plan that offers ideas for ways they may be incorporated into the classroom. We welcome your feedback at: chemistryshorts.org.

SHORT FILMS ABOUT CHEMISTRY