

TEACHER INSTRUCTIONS

Cold and Hot Processing of Materials

Objective: To demonstrate how increasing or decreasing temperature can affect the processing of materials.

Background Information: Atoms are in constant vibration at temperatures above 0 K (-273.15°C/-459.67°F). As the temperature is increased, the vibration of these atoms is increased, which encourages them to move from one place to another inside a material. Thus, by controlling the temperature, the extent to which various reactions take place can be controlled. This allows the processing of materials from one form to the other to also be controlled. Generally, as temperature is increased, a material goes from solid to liquid to gaseous state. Decreasing temperature usually has the opposite effect.

Ice cream is processed at temperatures lower than normal room temperature, which gives it a semi-solid texture. Sugar syrup is processed at temperatures higher than room temperature so that the sugar dissolves quickly in water to form a uniform liquid.

Description: In this demonstration, students will learn about the influence of lowering temperatures by processing ice cream using liquid nitrogen. They will then learn about the influence of increasing temperatures by processing sugar syrup.

Keywords:

- temperature – a quantity which indicates how hot or cold a material is
- solid – the fundamental state of matter that is characterized by structural rigidity
- liquid – the fundamental state of matter that is characterized as having a definite volume, but no shape
- liquid nitrogen – nitrogen that is in a liquid state at a very low temperature

Materials List:

- liquid nitrogen
- styrofoam bowl (or some other well-insulating container)
- insulating gloves
- wire whisk
- half-and-half cream
- stainless steel bowl
- transparent glass cup/bowl that can be heated (e.g., a small Pyrex container or a beaker)

- spoon
- sugar
- hot plate
- vanilla or chocolate ice cream syrup
- safety glasses/goggles
- 1-teaspoon measuring spoon
- 1-cup measuring cup
- wooden spatula

Safety Precautions: Liquid nitrogen is a hazardous substance. If misused, it may cause frostbite, eye damage, torn flesh, or asphyxiation. **ALWAYS FOLLOW THESE SAFETY RULES:**

- Keep liquid nitrogen away from students.
- Wear safety goggles at all times.
- Use tweezers to handle superconductors, magnets, or other small, cold objects. Plastic tweezers are desired but should be tested for embrittlement (see last caution) before use in the classroom.
- Wear insulating gloves when handling liquid nitrogen containers or large, cold objects.
- Use liquid nitrogen only in well ventilated places.
- Do not allow liquid nitrogen to touch any part of your body.
- Items in contact with liquid nitrogen become **EXTREMELY COLD**. Do not touch any item that has been immersed in liquid nitrogen until it has warmed to room temperature.
- Do not store liquid nitrogen in any container with a tight-fitting lid. A tightly sealed container will build up pressure as the liquid boils and may **EXPLODE** after a short time.
- Many substances become brittle and may shatter when cold, sending pieces of the material flying. Avoid common glass and large, solid plastics.

Instructions:

(a) For making ice cream

1. Mix 1 quart of half-and-half cream and $\frac{1}{2}$ cup of sugar in the stainless steel bowl using the wire whisk. Continue mixing until the sugar has dissolved.
2. Add 2 teaspoons of vanilla or chocolate syrup to the cream and sugar mixture and whisk until well-blended.

3. Put on the insulating gloves and safety glasses. Using the styrofoam bowl, pour a small amount of liquid nitrogen directly into the stainless steel bowl containing the ice cream ingredients. Stir the mixture with a wooden spatula while slowly adding more liquid nitrogen until the ice cream starts to thicken.
4. Allow the remaining liquid nitrogen to boil off from the bowl. The ice cream will be left behind!
5. Serve or taste ice cream only when all the liquid nitrogen vapors have gone away.

(b) For making sugar syrup

1. Add 2 cups of normal tap water to the clear/transparent glass cup.
2. Add 1 teaspoon of sugar to the glass of water and whisk using the spoon.
3. Continue adding teaspoons of sugar to the water until the sugar will no longer dissolve. Be sure to keep track of the number of teaspoons of sugar added to the water.
4. Empty the glass and again add 2 cups of water to it.
5. Put the glass on a hot plate and heat the water to 90 °C. **Note:** the boiling point of water is 99.98°C, so the water should be almost to the boiling point.
6. Once this temperature has been attained, wear insulating gloves and safety glasses and repeat steps 2-3.

Demo Delivery Hints: At room temperature, the liquid nitrogen is already boiling and thus depletes very quickly. While making ice cream, be sure to whisk swiftly to minimize the use of the liquid nitrogen. While making the sugar syrup, the glass cup and hot plate can get very hot. Make sure to wear insulating gloves or use tongs to avoid accidentally burning your hands.

Troubleshooting: If the ice cream does not thicken after adding liquid nitrogen, then continue to add more liquid nitrogen. During the sugar syrup demonstration, if the sugar takes too much time to dissolve, do not hesitate to raise the temperature of the hot plate.

Cleanup/Replacement parts: Dispose of the liquid nitrogen by either letting it boil away completely, or for a bit more excitement, pour it carefully onto the floor where the liquid will form small spheres that will scatter and dissipate quickly. The half-and-half cream will also need to be replaced every time the ice cream is made.

TEACHER DISCUSSION QUESTIONS

Cold and Hot Processing of Materials

Discussion Questions to Ask Before the Demo

What is material processing?

Discussion: Material processing is converting from one form of matter/material into another more useful or desired form.

Discussion Questions to Ask During the Demo

1. Why does the liquid half-and-half cream become semi-solid when the liquid nitrogen is added?

Discussion: As liquid nitrogen is poured on the half-and-half cream, it cools it and thus reduces the vibrations of the atoms. This causes the half-and-half cream to change its state from liquid to semi-solid.

2. Ask students what they think will happen when sugar is poured in hot water as compared to cold water?

Discussion: Sugar in hot water dissolves much faster as water molecules have lots of energy/vibrations due to the heat and want to move quickly. This creates more space between the water molecules, which allows more sugar particles to fill in this space.

Discussion Questions to Ask After the Demo

What other material processing requires increasing or decreasing temperature?

Discussion: There are a variety of applications that students may mention. For example, frozen meals require heating to continue cooking the food and convert it to a semi-solid state appropriate for eating.

STUDENT QUESTION HANDOUT

Cold and Hot Processing of Materials

1. What happens to the half-and -half cream when the liquid nitrogen is added?
2. Why do you think this happens?
3. How many teaspoons of sugar were added to the room temperature water?
4. How many teaspoons of sugar were added to the hot water?
5. Was there a difference? Why or why not?

The American Ceramic Society Materials Science Kits Warranty Disclaimer, Limitation of Liability and Safety Disclaimer

NO WARRANTY – DISCLAIMER OF WARRANTY

THE AMERICAN CERAMIC SOCIETY (ACerS), OFFERS THE MATERIALS SCIENCE KITS “AS-IS”, WITH NO WARRANTIES WHATSOEVER, EXPRESS OR IMPLIED, INCLUDING, WITHOUT LIMITATION, WARRANTIES OF MERCHANTABILITY, SAFETY, FITNESS FOR ANY PARTICULAR PURPOSE OR NON-INFRINGEMENT OF PATENTS, COPYRIGHTS OR OTHER PROPRIETARY RIGHTS OF OTHERS. SOME STATES AND JURISDICTIONS DO NOT ALLOW LIMITATIONS ON IMPLIED WARRANTIES, SO THE ABOVE LIMITATIONS MAY NOT APPLY TO CUSTOMER. WHEN THE IMPLIED WARRANTIES ARE NOT ALLOWED TO BE EXCLUDED IN THEIR ENTIRETY, THEY WILL BE LIMITED TO THE SHORTEST DURATION PERMITTED UNDER APPLICABLE LAW. CUSTOMER MAY ALSO HAVE OTHER RIGHTS WHICH VARY FROM STATE TO STATE.

WITHOUT LIMITING THE GENERALITY OF THE FOREGOING, ACerS DOES NOT WARRANT THAT EACH MATERIALS SCIENCE KIT IS COMPLETELY ERROR FREE, WILL OPERATE WITHOUT INTERRUPTION, OR IS COMPATIBLE WITH ALL EQUIPMENT AND SOFTWARE CONFIGURATIONS. CUSTOMER EXPRESSLY ASSUMES ALL RISK FOR USE OF THE MATERIALS SCIENCE KITS.

LIMITATION OF LIABILITY

TO THE MAXIMUM EXTENT PERMITTED BY LAW, ACerS WILL NOT HAVE ANY LIABILITY OR RESPONSIBILITY TO CUSTOMER FOR DAMAGES OF ANY KIND, INCLUDING SPECIAL, INDIRECT OR CONSEQUENTIAL DAMAGES (INCLUDING, WITHOUT LIMITATION, DAMAGES FOR LOSS OF DATA), ARISING OUT OF OR RESULTING FROM THE MATERIALS SCIENCE KITS, ANY COMPONENT, DOCUMENTATION, SERVICES OR MATERIALS MADE AVAILABLE TO CUSTOMER IN CONNECTION WITH THE MATERIALS SCIENCE KITS OR THE USE OR MODIFICATION OF ANY OF THEM, EVEN IF ACerS HAS BEEN ADVISED OF THE POSSIBILITY OF THE DAMAGES. IN ANY CASE, ACerS AND ITS LICENSORS' ENTIRE LIABILITY UNDER ANY PROVISION OF THIS AGREEMENT WILL BE LIMITED TO THE AMOUNT ACTUALLY PAID BY CUSTOMER TO ACerS FOR THE PRODUCT OR TEN DOLLARS (\$10.00), WHICHEVER IS GREATER. Some states do not allow the limitation or exclusion of liability for incidental or consequential damages, or have legislation which restricts the limitation or exclusion of liability, so the above limitation may not apply to Customer.

CALIFORNIA RESIDENTS

California Residents: I understand that I am waiving rights with respect to claims that are at this time unknown or unsuspected, and in accordance with such waiver, I acknowledge that I have read and understand, and I hereby expressly waive, the benefits of section 1542 of the civil code of California, and any similar law of any state, country or territory, which provides as follows: “A general release does not extend to claims which the creditor does not know or suspect to exist in his or her favor at the time of executing the release, which if known by him or her must have materially affected his or her settlement with the debtor.”

MATERIALS SCIENCE SAFETY DISCLAIMER

The materials science kits contain lessons that are believed to be reliable regarding the safe use and handling of these materials in laboratories and student classrooms. ACerS, however, does not represent or warrant in this, or in any other publication, to specify minimum safety or legal standards or to address all of the compliance requirements, risks, or safety problems associated with the handling of hazardous materials, their use, or the methods prescribed for using them in laboratories or classrooms. This information is intended to serve only as a beginning point for information and should not be construed as containing all the necessary compliance, safety, or warning information, nor should it be construed as representing the policy of ACerS. The kits should be used by minors (under 18) only with adult supervision.

Without limiting the generality of the foregoing disclaimers, no warranty, guarantee, or other form of representation is made by ACerS as to the accuracy or sufficiency of the information and guidelines included with the materials science kits, and ACerS assumes no liability or responsibility concerning the use of such instructions and guidelines for any purpose. It is the responsibility of the users of these materials to consult and comply with pertinent local, state, and federal laws, regulations, and standards with respect to the handling of materials. Users of the materials science kits should consult with the school's legal counsel or other professional advisers about the applicable laws, safety issues, and compliance issues for the storage of materials and the methods for using the materials in school classrooms and laboratories.

THIS DISCLAIMER APPLIES TO ANY LIABILITY THAT IS, OR MAY BE INCURRED BY, OR ON BEHALF OF THE INSTITUTIONS THAT USE THE MATERIALS SCIENCE KITS; INCLUDING, WITHOUT LIMITATION, THE FACULTIES, STUDENTS, OR PROSPECTIVE STUDENTS OF THOSE INSTITUTIONS; AND ANY MEMBER OF THE PUBLIC AT LARGE; AND INCLUDES, BUT IS NOT LIMITED TO, A FULL DISCLAIMER OF ANY LIABILITY THAT MAY BE INCURRED WITH RESPECT TO POSSIBLE INADEQUATE SAFETY PROCEDURES TAKEN BY ANY USER.