Latent Heat

Conservation Series

Instructor's Guide

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Developed by the Teaching and Learning Laboratory at MIT
for the Singapore University of Technology and Design

Introduction

When to Use this Video

- In Chem 101, in class or in recitation, after Lecture 21: Intermolecular interactions, solutions
- Prior knowledge: law of conservation of energy and the effects of intermolecular forces on phase transitions

Key Information

Duration: 13:51
Narrator: Stephen Ray, Ph.D. candidate
Materials Needed:
• Paper
• Pen/pencil

Learning Objectives

After watching this video students will be able to:

- Describe the energy transformations that occur during a phase change.
- Apply the law of conservation of energy to phase changes.

Motivation

- The concept of latent heat is an illustrative, but non-standard example of a phenomenon that can be explained using the law of conservation of energy.
- The idea of latent heat ties in nicely with the general chemistry topic of intermolecular forces.
- This video ties to the idea that conservation laws can be used to predict and understand system behavior. This video is designed to get students into the habit of explaining real-world phenomena or systems using conservation laws.

Student Experience

It is highly recommended that the video is paused when prompted so that students are able to attempt the activities on their own and then check their solutions against the video.

During the video, students will:

- Make a prediction while watching a demonstration of a phase change.
- Use what they know about intermolecular forces and conservation of energy to explain what they observed during the demonstration.
- Consider how the concept of latent heat can be used in building technologies.
- Choose a phase change material that could be used in a building in Singapore.

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Video Highlights

This table outlines a collection of activities and important ideas from the video.

Time	Feature	Comments
0:56	Prerequisite knowledge and Learning objectives	
1:22	A demonstration of a phase change (water freezing) is used to engage students in the video topic.	A thermocouple is used to track the temperature of a container of supercooled liquid water. Students are asked to predict what will happen to the temperature of the water when the water freezes. This demo can be shown in class, pausing when indicated to allow students to make their prediction. Students can then continue watching the video to see what happens. Alternatively, you may choose to perform the demonstration live, in class. Students could also watch the video up to the point of making their predictions and then perform the demonstration themselves to see what happens.
3:30	A brief molecular animation of water freezing is used to help students explain what they observed during the demo.	This animation will help students visualize what is happening to intermolecular forces during the phase change.
5:51	The narrator leads students through a discussion of how melting ice is used to cool buildings.	
7:59	Phase change materials are introduced.	Examples of phase change materials being investigated for use in building materials are presented.
9:16	The use of phase change materials in a roof is discussed.	Students are asked to consider how phase change insulation in a roof helps save energy.
11:05	Students are asked what phase change materials they might use in a building in Singapore.	

Video Summary

Stephen Ray, a graduate student in the Building Technology Lab at MIT, introduces students to the concept of latent heat. Students gain an understanding of latent heat from the perspective of conservation of energy. Students learn about the use of phase change materials, materials that take advantage of the phenomena of latent heat, to heat and cool buildings.

Chem 101 Materials

Pre-Video Materials

When appropriate, this guide is accompanied by additional materials to aid in the delivery of some of the following activities and discussions.

1. If you or your students would like to perform the demonstration of water freezing instead of showing the video clip, you may find these general instructions useful.

Materials needed (per demonstration):

- crushed ice
- water
- salt - table salt is perfectly fine
- spoon or some other stirring utensil
- food coloring
- a thermocouple or thermometer that can read temperatures below 0 degrees Celsius.
- ~0.5L container
- small, thin-walled container that can be nested in larger container; the video uses a candy container

Create a super cooled ice bath in the 0.5L container using the crushed ice, water, and table salt. Check the temperature of the ice bath to make sure the temperature is below $0^{o}C$. Fill the small container with water that has been faintly colored with food coloring. Immerse the small container into the larger container and allow the temperature to equilibrate. Monitor the temperature of the water in the small container. Initiate crystallization in the smaller container by adding a very small piece of crushed ice. The water should freeze quickly and you should notice a temperature increase on the thermometer.

2. Phase change (Appendix A1)

This clicker question will require students to think about the relative energy required to melt or vaporize a substance compared to simply raising its temperature. Students can reference heat capacities and enthalpies of melting/vaporization in their textbook to answer this question.

3. Do water and alcohol mix?

Use this demonstration to get students thinking about intermolecular forces.

Materials needed:

- warm water, approximately 300mL
- isopropanol, at least a 70% solution, approximately 300mL
- table salt
- stirring utensil
- two 0.5L containers

Pour ~150mL of water into each of the 0.5L containers. In one, dissolve as much salt as needed to create a super-saturated solution. Label or mark this container so that it is clear that it contains salt.

Tell students that you are going to add ~150mL of isopropanol to the container that contains just water. Ask them to predict whether or not the water and alcohol are miscible. Encourage them to draw the chemical structures and explain their reasoning. Add the alcohol to the water, stir, and show the students what happened. (They are miscible.)

Next, tell students that you are going to add ~150mL of isopropanol to the container that contains salt water. Ask them to predict whether or not the salt water and alcohol will be miscible. Again, encourage them to draw the chemical structures and explain their reasoning. Add the alcohol to the salt water, stir, and show the students what happened. (The alcohol and salt water will separate into two phases, with the alcohol on top. Water and alcohol form hydrogen bonds. However, ion-dipole forces between ions from the salt and the water molecules will disrupt the hydrogen bonds between water and alcohol, causing phase separation.)

Because it can be hard to see the layers from far away, invite students to come up to the demonstration table and see the container or slowly pass it around the room. If enough materials are available, you can also have the students do this themselves in small groups of 2 or 3 students.

Post-Video Materials

Use the following activities to reinforce and extend the concepts in the video.

1. Phase change materials (Appendix A2)

Project the slide of example phase change materials discussed in the video. In small groups, have students discuss what types of intermolecular forces might be present in these materials.

2. Ask students to research other technologies that utilize the concept of latent heat. Students can also brainstorm ideas for new products that utilize latent heat. To see a student design project that utilized phase change materials, go to the following video from MIT's Product Engineering Process course for mechanical engineering students:
http://designed.mit.edu/gallery/view-2011-thermAssist.html

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Additional Resources

Going Further

This video can serve as a nice link between the general chemistry topics of intermolecular forces and thermochemistry. Introductory thermodynamics concepts of state functions and enthalpies of reaction follow logically from this video.

References

The following paper contains additional information about phase change materials.

- Kosny, J., Yarbrough, D., Miller, W., Petrie, T., Childs, P., Syed, A., & Leuthold, D. (2007). Thermal Performance of PCM-Enhanced Building Envelope Systems. *Thermal Performance of the Exterior Envelopes of Buildings X*, proceedings of ASHRAE THERM X, Clearwater, FL.

The following papers contain information about student misconceptions related to intermolecular forces.

- Ozmen, H. (2004). Some Student Misconceptions in Chemistry: A Literature Review of Chemical Bonding. *Journal of Science Education and Technology, 13*(2), 147-159.
- Peterson, R. F. & Treagust, D. F. (1989). Grade-12 Students' Misconceptions of Covalent Bonding and Structure. *Journal of Chemical Education, 66*(6), 459-460.

Which of the following requires the most energy?

a) Raising the temperature of 1g of liquid water from 40^{o}C to 90^{o}C
b) Melting 1g of ice at 0^{o}C
c) Raising the temperature of 1g of ice from -60^{o}C to -10^{o}C
d) Vaporizing 1g of liquid water at 100^{o}C

Phase Change Materials

Material	T_f (°C)	ΔH_f (kJ/kg)
$CaCl_2$*$6H_2O$	29	190.8
Paraffin wax	64	173.6
Octadecane	27	238.9
Palmitic acid	64	185.4
Caprylic acid	16	148.5