

Lab 8. Solutes and the Freezing Point of Water: How Does the Addition of Different Types of Solutes Affect the Freezing Point of Water?

Introduction

When substances undergo a change in phase, whether it is solid to liquid, liquid to gas, or the reverse, a transfer of energy must occur. Phase changes can be described as *endothermic* (absorbing energy) or *exothermic* (releasing energy) processes. Consider what happens when water freezes. When water changes from a liquid to a solid, the molecules lose energy and become more ordered; thus, freezing is an exothermic process because energy is released. Alternatively, when ice melts or water boils, the ice or liquid water gains or absorbs energy from its surroundings; thus, melting and boiling are endothermic processes.

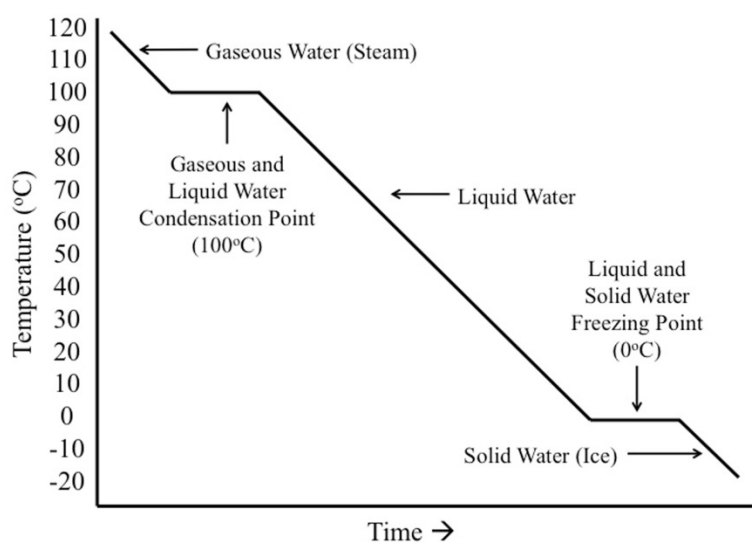
A graph of a cooling curve provides a visual representation of what happens during phase changes. Figure L8.1 shows a cooling curve for a sample of water being cooled at a constant rate. The sample of water starts at 120°C in the gas phase. As it is cooled, the temperature of the sample decreases because the average kinetic energy of the water molecules in the sample is decreasing over time. At 100°C, the cooling curve levels off and the temperature remains constant until all of the steam has condensed into a liquid. This period of time represents the *condensation point*. At this point, the water molecules no longer

have enough kinetic energy to remain in the gas phase. The liquid water then begins to decrease in temperature again as it loses more kinetic energy. At the freezing point, 0°C, the temperature of the sample levels off again and the liquid water transitions to a solid state. Once all the liquid water has become ice, the sample will once again decrease in temperature as it continues to lose energy.

When a solute is added to water, some of its physical properties may change. An example of a physical property of water that can change with the addition of a solute is its ability to conduct electricity. Pure water does not conduct electricity. However, when an *electrolyte* is added to water, the resulting solution is able to conduct electricity. Water, however, will not conduct electricity when a *non-electrolyte* is added to it. Electrolytes are ionic compounds such as sodium chloride and potassium chloride. Ionic compounds consist of ions joined together by ionic bonds, but these compounds dissociate into individual ions when mixed with water. Non-electrolytes, in contrast, are molecular compounds such as sucrose and propanol. Molecular compounds are made up of molecules that consist of atoms joined together by covalent bonds. The molecules found within a molecular compound do not break down when the compound is added to water; the molecules simply dissociate from each other as a result of the dissolution process. Other physical properties of water, such as its freezing point or boiling point, may also change in different ways when different types of solutes are added to it. In this investigation, you will determine how the addition of different types of solutes affects the freezing point of water.

FIGURE L8.1

Cooling curve for water



Your Task

Determine how the addition of electrolytes and non-electrolytes affects the freezing point of water. Your group may test any of the following solutes:

| Non-electrolytes | Electrolytes |
|---|--|
| <ul style="list-style-type: none">• Glycerin ($C_3H_8O_3$)• 2-Propanol (C_3H_8O)• Sucrose ($C_{12}H_{22}O_{11}$) | <ul style="list-style-type: none">• Potassium chloride (KCl)• Sodium chloride (NaCl)• Sodium nitrate ($NaNO_3$) |

The guiding question of this investigation is, **How does the addition of different types of solutes affect the freezing point of water?**

Materials

You may use any of the following materials during your investigation:

| Consumables | Equipment |
|--|--|
| <ul style="list-style-type: none">• $C_3H_8O_3$• C_3H_8O• $C_{12}H_{22}O_{11}$• KCl• NaCl• $NaNO_3$• Rock salt• Ice• Distilled water | <ul style="list-style-type: none">• Temperature probe• Styrofoam cup• Test tube (medium: 20 × 150 mm)• Erlenmeyer flasks• Graduated cylinder (100 ml)• Parafilm |

Safety Precautions

Follow all normal lab safety rules. 2-Propanol is flammable so be sure to keep it away from flames. Your teacher will explain relevant and important information about working with the chemicals associated with this investigation. In addition, take the following safety precautions:

- Wear indirectly vented chemical-splash goggles and chemical-resistant gloves and apron while in the laboratory.
- Handle all glassware with care.
- Wash your hands with soap and water before leaving the laboratory.

Investigation Proposal Required? Yes No

Getting Started

To measure the freezing point of distilled water or a solution made from one of the solutes, you can use rock salt and ice to create a supercool environment (less than $0^\circ C$). The basic setup is illustrated in Figure L8.2. The aqueous solutions that you test should have a concentration of at least 0.5 M and no more than 1.0 M. When you make your solutions, use 100 ml of H_2O and prepare them in an Erlenmeyer flask. Be sure to swirl the mixture until all the solute dissolves.

Now that you know how to measure the freezing point of distilled water or an aqueous solution using this equipment, you will need to design an investigation to answer the guiding question. You will therefore need to think about what type of data you need to collect, how you will collect the data, and how you will analyze the data.

To determine *what type of data you need to collect*, think about the following questions:

- How will you know when an aqueous solution has reached its freezing point?
- What type of measurements will you need to record during your investigation?

To determine *how you will collect the data*, think about the following questions:

- What will serve as a control (or comparison) condition?
- What types of treatment conditions will you need to set up and how will you do it?
- What will you need to keep constant across comparisons?
- How will you make sure that your data are of high quality (i.e., how will you reduce error)?

To determine *how you will analyze the data*, think about the following questions:

- How will you determine if there is a difference between the treatment conditions and the control condition?
- What type of table could you create to help make sense of your data?

Connections to Crosscutting Concepts, the Nature of Science, and the Nature of Scientific Inquiry

As you work through your investigation, be sure to think about

- the importance of identifying patterns,
- how energy and matter are related to each other,
- how imagination and creativity are used during your investigation, and
- the nature and role of experiments.

Initial Argument

Once your group has finished collecting and analyzing your data, you will need to develop an initial argument. Your argument must include a *claim*, which is your answer to the guiding question. Your argument must also include *evidence* in support of your claim. The evidence is your analysis of the data and your interpretation of what the analysis means. Finally, you must include a *justification* of the evidence in your argument. You will therefore need to use a scientific concept or principle to explain why the evidence that you decided to use is relevant and important. You will create your initial argument on a whiteboard. Your whiteboard must include all the information shown in Figure L8.3.

Argumentation Session

The argumentation session allows all of the groups to share their arguments. One member of each group stays at the lab station to share that group's argument, while the other members of the group go to the

FIGURE L8.2

Equipment used to measure the freezing point of water or an aqueous solution

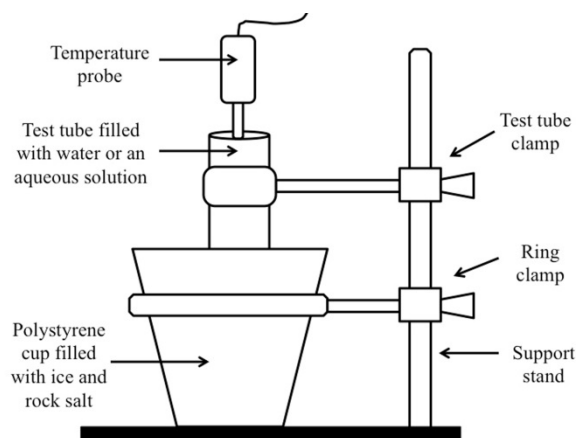


FIGURE L8.3

Argument presentation on a whiteboard

| | |
|-----------------------|------------------------------------|
| The Guiding Question: | |
| Our Claim: | |
| Our Evidence: | Our Justification of the Evidence: |

other lab stations one at a time to listen to and critique the arguments developed by their classmates. The goal of the argumentation session is not to convince others that your argument is the best one; rather, the goal is to identify errors or instances of faulty reasoning in the initial arguments so these mistakes can be fixed. You will therefore need to evaluate the content of the claim, the quality of the evidence used to support the claim, and the strength of the justification of the evidence included in each argument that you see. To critique an argument, you might need more information than what is included on the whiteboard. You might therefore need to ask the presenter one or more follow-up questions, such as:

- How did your group collect the data? Why did you use that method?
- What did your group do to make sure the data you collected are reliable? What did you do to decrease measurement error?
- What did your group do to analyze the data, and why did you decide to do it that way? Did you check your calculations?
- Is that the only way to interpret the results of your group's analysis? How do you know that your interpretation of the analysis is appropriate?
- Why did your group decide to present your evidence in that manner?
- What other claims did your group discuss before deciding on that one? Why did you abandon those alternative ideas?
- How confident are you that your group's claim is valid? What could you do to increase your confidence?

Once the argumentation session is complete, you will have a chance to meet with your group and revise your original argument. Your group might need to gather more data or design a way to test one or more alternative claims as part of this process. Remember, your goal at this stage of the investigation is to develop the most valid or acceptable answer to the research question!

Report

Once you have completed your research, you will need to prepare an *investigation report* that consists of three sections that provide answers to the following questions:

1. What were you trying to do and why?
2. What did you do during your investigation and why did you conduct your investigation in this way?
3. What is your argument?

Your report should answer these questions in two pages or less. The report must be typed and any diagrams, figures, or tables should be embedded into the document. Be sure to write in a persuasive style; you are trying to convince others that your claim is acceptable or valid!