

Lab 9. Melting and Freezing Points: Why Do Substances Have Specific Melting and Freezing Points?

Introduction

All molecules are constantly in motion, so they have *kinetic energy*. The amount of kinetic energy a molecule has depends on its velocity and its mass. *Temperature* is a measure of the average kinetic energy of all the molecules found within a substance. The temperature of a substance, as a result, will go up when the average kinetic energy of the molecules found within that substance increases, and the temperature of a substance will go down when the average kinetic energy of these molecules decreases. Temperature is therefore a useful way to measure how energy moves into, through, or out of a substance.

A substance will change state when enough energy transfers into or out of it. For example, when a solid gains enough energy from its surroundings, it will change into a liquid. This process is called *melting*. Melting is an endothermic process because the substance absorbs energy. The opposite occurs when a substance changes from a liquid to a solid (i.e., *freezing*). When a liquid substance releases enough energy into its surroundings, it will turn into a solid. Freezing is therefore an *exothermic* process because the substance releases energy. All substances have a specific melting point and a specific *freezing point*. The melting point is the temperature at which a substance transitions from a solid to a liquid. The freezing point is the temperature at which a substance transitions from a liquid to a solid.

There are three important properties of a substance that will affect its melting or freezing point. The first property is the molar mass of the molecules that make up that substance. The second property is the nature of the intermolecular forces that hold the molecules of a substance together. The third property is the shape of the molecules that make up that substance.

There are various types of intermolecular forces with different amounts of strength. One type of intermolecular force is caused by *dipole-dipole* interactions. This type of intermolecular force occurs when slightly negative atoms within a molecule are attracted to the slightly positive atoms in nearby molecules. *Hydrogen bonding* is a type of dipole-dipole interaction, in which oxygen, nitrogen, or fluorine atoms in a molecule are strongly attracted to hydrogen atoms in neighboring molecules. Another type of intermolecular force is caused when the arrangement of electrons within an atom has a momentary distribution that is not symmetrical. An asymmetrical distribution of electrons results in the molecule having a temporary dipole. This type of intermolecular interaction, called *London dispersion forces*, tends to occur in nonpolar molecules. London dispersion forces are much weaker than other intermolecular forces such as hydrogen bonding and other dipole-dipole interactions. Even though the relative strength of London dispersion forces is low, the influence of this type of intermolecular force can be magnified when large molecules interact with each other because the opportunity for these types of forces to occur increases.

In this investigation, you will explore how the three properties listed earlier in this section—molar mass, intermolecular forces, and shape of molecules—are related to the specific melting or freezing point of a substance.

Your Task

Determine the melting or freezing point of water, lauric acid, oleic acid, and stearic acid. Then develop a conceptual model that can be used to explain the observed differences in the melting or freezing points of these four substances. Your model should also be able to explain the shape of a heating or cooling curve for each of these substances. Once you have developed your conceptual model, you will need to test it to determine if it allows you to predict the melting point of palmitic acid.

The guiding question of this investigation is, **Why do substances have specific melting and freezing points?**

Materials

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

Consumables	Equipment
<ul style="list-style-type: none">• Ice• Rock salt• Lauric acid, $C_{12}H_{24}O_2$• Oleic acid, $C_{18}H_{34}O_2$• Palmitic acid, $C_{16}H_{32}O_2$• Stearic acid, $C_{18}H_{36}O_2$• Distilled water	<ul style="list-style-type: none">• Temperature sensor kit• Hot plate• Test tubes• Beaker (500 ml)• Styrofoam cup

Safety Precautions

Follow all normal lab safety rules. 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.
- Use caution when working with hot plates because they can burn skin. Hot plates also need to be kept away from water and other liquids.
- Wash your hands with soap and water before leaving the laboratory.

Investigation Proposal Required? Yes No

Getting Started

The first step in developing your model is to determine the melting point or the freezing point of each substance using the temperature sensor kit. To conduct these tests, you must determine 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:

- What type of measurements or observations will you need to record during each test?
- When will you need to make these measurements or observations?

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

- What factors will you control during your different tests?
- What types of comparisons will you need to make?
- What will you do to reduce measurement error?
- How will you keep track of the data you collect and how will you organize it?

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

- What type of calculations will you need to make?
- What type of graph could you create to help make sense of your data?
- How will you determine the melting or freezing point of the different substances?
- How many different factors do you need to include in your explanatory model?

Once you have determined the melting or freezing points of each substance, your group will need to develop your conceptual model. The model must be able to explain the differences in melting point that you observe in each substance and the shape of the heating or cooling curves you generated. Your model also must include information about what is taking place between molecules on the submicroscopic level. To develop your model, you will need to consider how the molecular characteristics of each substance, such as its molecular structure or shape and its molar mass, may or may not affect the melting or freezing point of each substance. The table below lists the molar mass and structural formula of each substance for

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 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:

- What did your group do to analyze the data, and why did you decide to do it that way?
- 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 question were you trying to answer 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!