

**Teacher’s Guide**

**Fighting Frost with Ice**

***December 2023***

**Table of Contents**

[***Anticipation Guide***](#_1fob9te)***2***

Activate students’ prior knowledge and engage them before they read the article.

[***Reading Comprehension Questions***](#_3znysh7) ***3***

These questions are designed to help students read the article (and graphics) carefully. They can help the teacher assess how well students understand the content and help direct the need for follow-up discussions and/or activities. You’ll find the questions ordered in increasing difficulty.

[***Graphic Organizer***](#_fbh2674qb7v5) ***6***

Thishelps students locate and analyze information from the article. Students should use their own words and not copy entire sentences from the article. Encourage the use of bullet points.

[***Answers***](#_djipzn7z1r1b) ***7***

Access the answers to reading comprehension questions and a rubric to assess the graphic organizer.

[***Additional Resources***](#_8qbtv1wio6jt) ***11***

Here you will find additional labs, simulations, lessons, and project ideas that you can use with your students alongside this article.

***[Chemistry Concepts and Standards](#_gy1yjx1c39og) 13***

Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

# Anticipation Guide

**Directions: *Before reading the article*,** in the first column, write “A” or “D,” indicating your **A**greement or **D**isagreement with each statement. Complete the activity in the box.

As you read, compare your opinions with information from the article. In the space under each statement, cite information from the article that supports or refutes your original ideas.

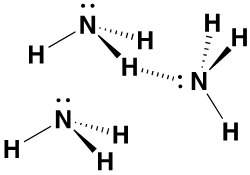
|  |  |  |
| --- | --- | --- |
| **Me** | **Text** | **Statement** |
|  |  | 1. Frost forms when water vapor in the air goes directly from a gas to a solid, with no liquid water present. |
|  |  | 2. Heat is released when water freezes. |
|  |  | 3. Farmers have been using a mixture of water and ice to protect plants from freezing for thousands of years. |
|  |  | 4. The oxygen atom in a water molecule pulls electrons from hydrogen toward it, creating a partial positive charge on the oxygen atom. |
|  |  | 5. During a phase change, the temperature remains constant. |
|  |  | 6. Energy is required to break both intermolecular and intramolecular bonds. |
|  |  | 7. The activation energy of a reaction is greater than the energy of the reactants or products in both endothermic and exothermic reactions. |
|  |  | 8. In an exothermic reaction, the enthalpy change (ΔH) is positive. |
|  |  | 9. All chemical reactions are exothermic. |
|  |  | 10. Frost flowers are formed from deposition of water vapor to ice crystals. |

# Student Reading Comprehension Questions

Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Directions**: Use the article to answer the questions below.

1. Both frost and snowflakes can form at a temperature below the freezing point of water. Explain how frost forms. How is this different then the way a snowflake forms?
2. The melting and freezing of H2O is a reversible process that can occur repeatedly with the same H2O molecules. Why, then, is it necessary for farmers to prevent plants from freezing?
3. Since farmers do not want the plants to freeze, they use a variety of methods to keep the temperature of the plants and the water on them at or above the freezing point. How is it possible for the water temperature to be at its freezing point without freezing?
4. Why must energy be released when water freezes?
5. When farmers spray water onto the plants to ensure there is continually liquid water present, the water in the plants does not freeze, even when the temperature drops well below the freezing point. Explain.
6. Hydrogen bonds (H-bonds) can also form when a molecule contains N-H bonds, such as shown for ammonia (NH3).



1. Circle or highlight one intramolecular bond.
2. Draw in another intramolecular bond.
3. Use the δ+ and δ- notation to identify the atoms that might carry a partial positive (δ+) charge and the atoms that might carry a partial negative (δ-) charge.
4. Why does a substance need to gain energy in order to disrupt the hydrogen bonding interactions?
5. Consider the Heating/Cooling Curve on page 7. If heat energy is continually added to the substance, then:
6. How is the energy being used when the temperature is changing?
7. How is the energy being used when the temperature is not changing?
8. The title of this article is “Fighting Frost with Ice”. Write at least 5 sentences to explain how farmers can fight frost with ice.
9. Combustion is a process that typically involves a large generation of heat. One type of combustion is the burning of carbon-based fuels. In this type of reaction, a carbon-based substance burns in oxygen, producing water vapor and carbon dioxide. Using the chemical equation shown on page 7 as a guide, write a balanced chemical equation to show the combustion of a different carbon-based fuel called propane, C3H8.
10. Chemical reactions occur whenever there is a change in the bonding of particles. Consider the combustion of methane: CH4(g) + 2O2(g) -> CO2(g) + 2H2O(g)
11. Draw Lewis structures to represent each of the particles in the combustion equation.
    1. Identify the bonds that would have to be **broken** during this reaction.
    2. Identify the bonds that would be formed during this reaction.
12. Why do most chemical reactions contain both endothermic and exothermic processes?
13. Using the diagram titled, “EXOTHERMIC REACTION” on page 7, draw what the diagram would look like for an endothermic reaction.
14. As mentioned in the article, the energy released when forming 1 mole of water in a chemical reaction is 286 kJ, which is equivalent to 286,000 Joules. Why is the magnitude of energy change so much higher in a chemical reaction than in a phase change?

**Student Reading Comprehension Questions, cont.**

**Questions for Further Learning**

***Write your answers on another piece of paper if needed.***

1. Find a phase diagram for water.
   1. Identify the temperature and pressure that represent the triple point.
   2. What is the highest temperature at which H2O could sublime (at any pressure)?
   3. The solid-liquid equilibrium line for water slopes in a different way than the corresponding line for many other substances. What is the significance of this difference?

# Graphic Organizer

Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

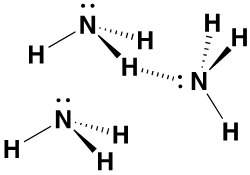
**Directions**: As you read, complete the graphic organizer below to compare the processes described in the article.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Deposition** | **Freezing** | **Melting** | **Combustion** |
| **Example from the article** |  |  |  |  |
| **Endo- or exothermic?** |  |  |  |  |
| **Phase change or chemical change?** |  |  |  |  |
| **Intramolecular or intermolecular forces involved?** |  |  |  |  |
| **How does this help protect crops in cold weather?** |  |  |  |  |

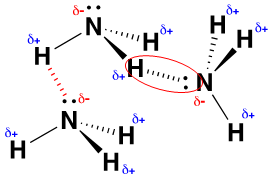
**Summary:** On the back of this sheet, write three new things you learned about chemistry from the article.

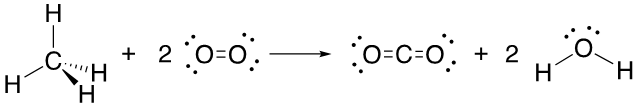
# Answers to Reading Comprehension Questions & Graphic Organizer Rubric

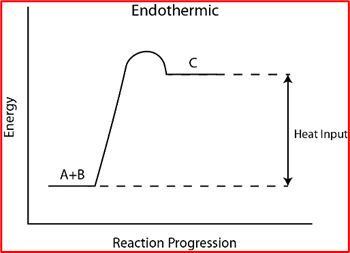
1. Both frost and snowflakes can form at a temperature below the freezing point of water. Explain how frost forms. How is this different then the way a snowflake forms?   
   Snowflakes form on small particles in the air, while frost forms on a surface, like a leaf or a window. They are both, otherwise, the same solid H2O.
2. The melting and freezing of H2O is a reversible process that can occur repeatedly with the same H2O molecules. Why, then, is it necessary for farmers to prevent plants from freezing?  
   When water freezes, it expands. In a plant cell, freezing water expands enough to burst the cell. This cell damage is not reversible, so the plant cannot survive if enough cells have burst.
3. Since farmers do not want the plants to freeze, they use a variety of methods to keep the temperature of the plants and the water on them at or above the freezing point. How is it possible for the water temperature to be at its freezing point without freezing?  
   At the freezing point, a substance can be in the liquid phase, the solid phase, or in equilibrium between them. If energy is not being removed from the water, it can stay a liquid even at the freezing point.
4. Why must energy be released when water freezes?  
   In liquid water, the molecules have enough kinetic energy that the intermolecular forces are not strong enough to hold the molecules in place. Energy must be removed so the motion of the particles can no longer disrupt the attractive forces between the molecules, allowing them to form an organized structure.
5. When farmers spray water onto the plants to ensure there is continually liquid water present, the water in the plants does not freeze, even when the temperature drops well below the freezing point. Explain.  
   When ice and water are in contact with each other they will reach thermal equilibrium such that the warmer one will lose heat to the cooler one. Once that equilibrium has been established, the ice can only get colder than freezing temperature if it gives its heat away to something that has a lower temperature than it has. Of the air, water, and plant, only the air has a chance of being cooler and, thus, taking in the energy. However, as long as water is present, it will maintain thermal equilibrium with the ice, so the ice can never get colder until all water is gone.
6. Hydrogen bonds (H-bonds) can also form when a molecule contains N-H bonds, such as shown for ammonia (NH3).



1. Circle or highlight one intramolecular bond.
2. Draw in another intramolecular bond.
3. Use the δ+ and δ- notation to identify the atoms that might carry a partial positive (δ+) charge and the atoms that might carry a partial negative (δ-) charge.



1. Why does a substance need to gain energy in order to disrupt the hydrogen bonding interactions?  
   Hydrogen bonding interactions are attractive forces. As with any attractive force, energy must be used to overcome the forces and pull the particles apart.
2. Consider the Heating/Cooling Curve on page 7. If heat energy is continually added to the substance, then:
3. How is the energy being used when the temperature is changing?  
   The molecules absorb the energy which increases their motion (increasing their kinetic energy).
4. How is the energy being used when the temperature is not changing?  
   When the temperature levels out, the molecules have reached the maximum kinetic energy possible in the current arrangement. At this point, the energy is being used to overcome the attractive forces (potential energy) and pull the molecules out of their arrangement.
5. The title of this article is “Fighting Frost with Ice”. Write at least 5 sentences to explain how farmers can fight frost with ice.   
   Response should include the interaction between frost, water, and the plant, and should correctly describe the appropriate energy exchanges.
6. Combustion is a process that typically involves a large generation of heat. One type of combustion is the burning of carbon-based fuels. In this type of reaction, a carbon-based substance burns in oxygen, producing water vapor and carbon dioxide. Using the chemical equation shown on page 7 as a guide, write a balanced chemical equation to show the combustion of a different carbon-based fuel called propane, C3H8.  
   **C3H8 + 5 O2(g) -> 3 CO2(g) + 4 H2O(g)**
7. Chemical reactions occur whenever there is a change in the bonding of particles. Consider the combustion of methane: CH4(g) + 2O2(g) -> CO2(g) + 2H2O(g)
8. Draw Lewis structures to represent each of the particles in the combustion equation.
   1. Identify the bonds that would have to be **broken** during this reaction.  
      The C-H and O=O bonds would be broken.
   2. Identify the bonds that would be formed during this reaction.  
      The C=O and O-H bonds would be broken.
9. Why do most chemical reactions contain both endothermic and exothermic processes?  
   Chemical reactions involve a change in bonding. This means that one or more bonds in the reactants must break, and new bonds will form to create new substances. Breaking bonds is endothermic and bond creation is exothermic.
10. Using the diagram titled, “EXOTHERMIC REACTION” on page 7, draw what the diagram would look like for an endothermic reaction.



1. As mentioned in the article, the energy released when forming 1 mole of water in a chemical reaction is 286 kJ, which is equivalent to 286,000 Joules. Why is the magnitude of energy change so much higher in a chemical reaction than in a phase change?

During phase changes, only the weaker intermolecular forces are disrupted, and the particles change position. During chemical reactions, it is the bonding that changes.

1. Find a phase diagram for water.
   1. Identify the temperature and pressure that represent the triple point.

The triple point is 373.99 °C and 217.75 atm.

* 1. What is the highest temperature at which H2O could sublime (at any pressure)?

The highest temperature that a sample could sublime is 0.02 °C at 0.006 atm and at higher pressure the temperature would be much colder.

* 1. The solid-liquid equilibrium line for water slopes in a different way than the corresponding line for many other substances. What is the significance of this difference?

The negative slope for the solid/liquid line in a phase diagram is an indication that the solid is less dense than the liquid. When the solid forms fewer molecules are present in the same amount of volume. This explains why solid water floats on liquid water.

**Graphic Organizer Rubric**

If you use the Graphic Organizer to evaluate student performance, you may want to develop a grading rubric such as the one below.

|  |  |  |
| --- | --- | --- |
| **Score** | **Description** | **Evidence** |
| 4 | Excellent | Complete; details provided; demonstrates deep understanding. |
| 3 | Good | Complete; few details provided; demonstrates some understanding. |
| 2 | Fair | Incomplete; few details provided; some misconceptions evident. |
| 1 | Poor | Very incomplete; no details provided; many misconceptions evident. |
| 0 | Not acceptable | So incomplete that no judgment can be made about student understanding |

# 

# Additional Resources and Teaching Strategies

**Additional Resources**

* **Labs and demonstrations**
  + AACT Demo/Activity “An Exploration of Intermolecular Forces”

<https://teachchemistry.org/classroom-resources/an-exploration-of-intermolecular-forces>

* + AACT Short Lab Activity “Exploring Intermolecular Forces”

<https://teachchemistry.org/classroom-resources/exploring-intermolecular-forces>

* + AACT Demo “Intermolecular Forces and Physical Properties” <https://teachchemistry.org/classroom-resources/intermolecular-forces-and-physical-properties>
  + AACT Lab “Heating & Cooling Curve”   
    <https://teachchemistry.org/classroom-resources/heating-cooling-curve>
* **Simulations**
  + AACT Simulation “Intermolecular Forces”   
    <https://teachchemistry.org/classroom-resources/intermolecular-forces-2020>
  + AACT Activity using Odyssey software “Simulation Activity: Exploring Intermolecular Forces with Odyssey”   
    <https://teachchemistry.org/classroom-resources/intermolecular-forces-simulation>
  + AACT lesson with simulation and animations “Simulation Activity: States of Matter and Phase Changes”   
    <https://teachchemistry.org/classroom-resources/simulation-activity-states-of-matter-and-phase-changes>
* **Lessons and lesson plans**
  + Simulation “Comparing Attractive Forces”
    - AACT Lesson with Models and Simulation  
      <https://teachchemistry.org/classroom-resources/an-exploration-of-intermolecular-forces>
    - Activity Guide “Simulation Activity: Comparing Attractive Forces”<https://teachchemistry.org/classroom-resources/simulation-activity-intermolecular-forces>
  + AACT AP Review “Intermolecular Forces Review”   
    <https://teachchemistry.org/classroom-resources/intermolecular-forces-review>
  + AACT Unit Plan “Phase Changes and Heat Transfer Unit Plan”<https://teachchemistry.org/classroom-resources/phase-changes-and-heat-transfer>
  + AACT Activity using Ice Melting Blocks “Modeling the Melting of Ice”<https://teachchemistry.org/classroom-resources/modeling-the-melting-of-ice>
  + AACT Activity and Lesson Plan “What Makes Something Feel Warm”<https://teachchemistry.org/classroom-resources/what-makes-something-feel-warm>
  + Teaching Channel Activity “The Life Cycle of a Snowflake”<https://www.teachingchannel.com/k12-hub/downloadable/the-life-cycle-of-a-snowflake/>

* **Projects and extension activities**
  + Students could investigate the science of crystallization.
  + Students could study how cooking differs at sea level and in high altitude locations due to pressure differences.
  + Students could investigate how vapor pressure differs with temperature and for different substances.
  + Students could make a stop action film that models the formation of frost and of snowflakes.

**Teaching Strategies**

Consider the following tips and strategies for incorporating this article into your classroom:

* **Alternative to Anticipation Guide:** Before reading, ask students what farmers can do to protect their crops from freezing. Also ask why freezing temperatures damage crops. Their initial ideas can be collected electronically via Jamboard, Padlet, or similar technology.
  + As they read, students can find information to confirm or refute their original ideas.
  + After they read, ask students how a knowledge of chemistry is helpful to farmers in choosing how to protect their crops from cold.
  + Although not mentioned in the article, the method described in the article is used in orange groves and with other crops.
* **Misconceptions:** Students may have several misconceptions regarding the concepts in this article. Some are below. Through probing questions, guide students to a better understanding as they read and discuss the article.
  + Students may confuse heat and temperature.
  + Students may think that molecules of water get closer together when water freezes, but in fact they get farther apart.
  + Students may not realize that the temperature remains constant as liquid water freezes to become solid ice.
  + To help students realize that when water freezes to ice, heat is released, ask if they have ever put wet fingers (or their tongues) on a frozen metal surface. If they have, they may have felt the heat released as the water on their fingers (or tongues) freezes.

# Chemistry Concepts and Standards

**Connections to Chemistry Concepts**

The following chemistry concepts are highlighted in this article:

* Physical change
* Chemical change
* Activation energy
* Energy diagrams
* Enthalpy
* Exothermic and endothermic
* Intramolecular forces
* Intermolecular forces

**Correlations to Next Generation Science Standards**

This article relates to the following performance expectations and dimensions of the NGSS:

**HS-PS1-4.** Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends on the changes in total bond energy.

**Disciplinary Core Ideas:**

* PS.1.A: Structure and Properties of Matter
* PS.2.B: Chemical Reactions

**Crosscutting Concepts:**

* Cause and effect
* Systems and system models
* Energy and matter

**Science and Engineering Practices:**

* Obtaining, evaluating, and communicating information

**Nature of Science:**

* Scientific knowledge assumes an order and consistency in natural systems.

See how *ChemMatters* correlates to the[**Common Core State Standards** online](https://www.acs.org/content/acs/en/education/resources/highschool/chemmatters/teachers-guide.html).