

# ChemMatters<sup>®</sup>

Demystifying Everyday Chemistry

## Teacher's Guide

### December 2023

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# December Teacher's Guide Introduction

## Lesson Ideas

For each of the articles, encourage students to think about how science is done, how we know what we know, and how chemistry connects to their lives.

### Teaching Ideas for this issue:

1. "Chemistry in Pictures" on page 2 shows a photograph of biodegradable glitter. Before reading, ask students what problems glitter causes in the environment. Also ask if they have heard of biodegradable glitter and where it might be used. This photo relates to the article on pages 12 & 13 of this issue, "5 Things to Know About Glitter."
2. "Open for Discussion" on page 4 challenges students to apply their understanding of chemistry to their everyday lives. The discussion is important for teachers also because helping students connect chemistry concepts to life outside the classroom makes the learning more enduring. Fortunately, *ChemMatters* articles help students make these connections! The articles in this issue involve keeping crops from freezing in cold weather, using hot and cold packs, glitter, and the use of drugs to enhance performance in sports. Students should be able to relate to all or most of these topics. In addition, three of the articles compare intermolecular and intramolecular forces, a common source of confusion for students.
3. "Quick Read: Quantum Dots" on page 18 describes the chemistry behind the 2023 Nobel Prize in chemistry. Ask students to read to discover what quantum dots are, how they are made to produce different colors, and where they are found in our everyday lives.
4. The "Chemistry in Person" column on page 19 showcases Chemical Kim, a science education influencer on social media. Ask students to read the interview to find out what motivates her. Students can find more information about her social media presence at <https://chemicalkim.com/>
5. Assign a team of students to read each feature article, then present what they learned in a podcast, PowerPoint or similar presentation, poster or brochure, or some other engaging format.
6. Prior to reading the article, give students the Anticipation Guide for the article along with the graphic organizer and links to other information provided.
7. Be sure to ask students to include information providing evidence for the claims made in the article.
8. Alternatively, students can create concept maps about the important chemistry concepts in the article they choose.

**5E Lesson Ideas** for individual articles:

<b>Engage</b>	Provide the Anticipation Guide or ask a thoughtful question (see the individual Teacher's Guide for each article) to engage students in the reading. Students should record their initial ideas individually, in pen, so they can't be erased. Students can then discuss their initial ideas in small groups or as a whole class.
<b>Explore</b>	Students read the article to discover more about the concepts in the article. During this phase, students will revisit their beginning ideas and record how the information in the article supports or refutes their initial ideas, providing evidence from the article.
<b>Explain</b>	Students answer questions and/or complete the graphic organizer provided for each article, then discuss their learning with their classmates. Students should recognize the evidence for the claims made in the articles, and how the evidence supports the claims.
<b>Elaborate</b>	Students can pose questions for further study.  For some articles, there are related ACS Reactions videos students can watch to learn more about the concepts presented. See the individual Teacher's Guide for each article to learn more.
<b>Evaluate</b>	Students write a short summary of what they learned that describes how it connects to their lives. Students may also present their learning to their classmates or others.

## Teacher's Guide

### Fighting Frost with Ice

*December 2023*

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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.	
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This helps 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.	
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# Anticipation Guide

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

**Directions:** *Before reading the article*, in the first column, write “A” or “D,” indicating your Agreement or Disagreement 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 ( $\Delta H$ ) is positive.
		9. All chemical reactions are exothermic.
		10. Frost flowers are formed from deposition of water vapor to ice crystals.

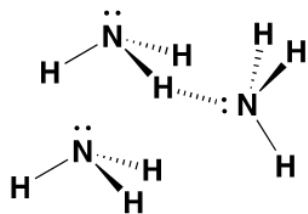
# Student Reading

## 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 than the way a snowflake forms?
2. The melting and freezing of  $\text{H}_2\text{O}$  is a reversible process that can occur repeatedly with the same  $\text{H}_2\text{O}$  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 ( $\text{NH}_3$ ).



- a. Circle or highlight one intramolecular bond.
  - b. Draw in another intramolecular bond.
  - c. Use the  $\delta^+$  and  $\delta^-$  notation to identify the atoms that might carry a partial positive ( $\delta^+$ ) charge and the atoms that might carry a partial negative ( $\delta^-$ ) charge.
7. Why does a substance need to gain energy in order to disrupt the hydrogen bonding interactions?
  8. Consider the Heating/Cooling Curve on page 7. If heat energy is continually added to the substance, then:
    - a. How is the energy being used when the temperature is changing?
    - b. How is the energy being used when the temperature is not changing?
  9. The title of this article is "Fighting Frost with Ice". Write at least 5 sentences to explain how farmers can fight frost with ice.

10. 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,  $C_3H_8$ .
11. Chemical reactions occur whenever there is a change in the bonding of particles. Consider the combustion of methane:  $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$
- Draw Lewis structures to represent each of the particles in the combustion equation.
    - Identify the bonds that would have to be **broken** during this reaction.
    - Identify the bonds that would be formed during this reaction.
  - Why do most chemical reactions contain both endothermic and exothermic processes?
12. Using the diagram titled, "EXOTHERMIC REACTION" on page 7, draw what the diagram would look like for an endothermic reaction.
13. 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.*

14. Find a phase diagram for water.
  - a. Identify the temperature and pressure that represent the triple point.
  - b. What is the highest temperature at which H<sub>2</sub>O could sublime (at any pressure)?
  - c. 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: \_\_\_\_\_

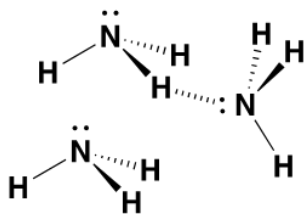
**Directions:** As you read, complete the graphic organizer below to compare the processes described in the article.

	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?				

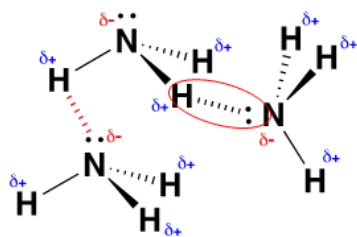
**Summary:** On the back of this sheet, write three new things you learned about chemistry from the article.

# Answers to Reading Comprehension Questions & Graphic Organizer Rubric

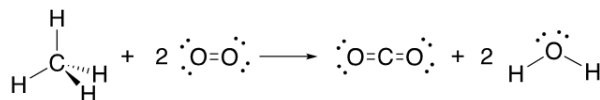
1. Both frost and snowflakes can form at a temperature below the freezing point of water. Explain how frost forms. How is this different then the way a snowflake forms?  
*Snowflakes form on small particles in the air, while frost forms on a surface, like a leaf or a window. They are both, otherwise, the same solid H<sub>2</sub>O.*
2. The melting and freezing of H<sub>2</sub>O is a reversible process that can occur repeatedly with the same H<sub>2</sub>O 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 (NH<sub>3</sub>).



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

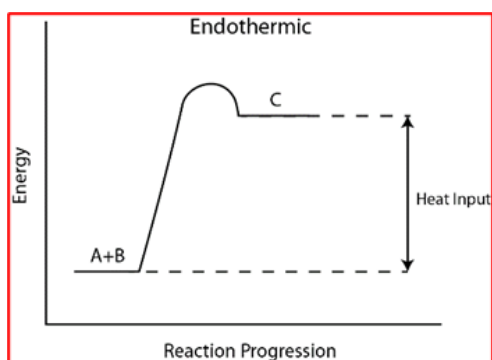


- Why does a substance need to gain energy in order to disrupt the hydrogen bonding interactions?  
**Hydrogen bonding interactions are attractive forces. As with any attractive force, energy must be used to overcome the forces and pull the particles apart.**
- Consider the Heating/Cooling Curve on page 7. If heat energy is continually added to the substance, then:
  - How is the energy being used when the temperature is changing?  
**The molecules absorb the energy which increases their motion (increasing their kinetic energy).**
  - 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.**
- 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.**
- 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,  $C_3H_8$ .  
 **$C_3H_8 + 5 O_2(g) \rightarrow 3 CO_2(g) + 4 H_2O(g)$**
- Chemical reactions occur whenever there is a change in the bonding of particles. Consider the combustion of methane:  $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$ 
  - Draw Lewis structures to represent each of the particles in the combustion equation.



- i. Identify the bonds that would have to be **broken** during this reaction.  
The C-H and O=O bonds would be broken.
  - ii. Identify the bonds that would be formed during this reaction.  
The C=O and O-H bonds would be broken.
- b. 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.

12. Using the diagram titled, "EXOTHERMIC REACTION" on page 7, draw what the diagram would look like for an endothermic reaction.



13. 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.

14. Find a phase diagram for water.

- a. Identify the temperature and pressure that represent the triple point.  
The triple point is 373.99 °C and 217.75 atm.
- b. What is the highest temperature at which H<sub>2</sub>O 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.
- c. 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](#).



## Teacher's Guide

### Hot and Cold Therapies

*December 2023*

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# Anticipation Guide

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

**Directions:** *Before reading the article*, in the first column, write “A” or “D,” indicating your Agreement or Disagreement 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. Cold therapy is used to treat a chronic injury.
		2. Both hot and cold therapy are effective in reducing damage after exercise.
		3. Cold therapy was used in ancient Egypt.
		4. Plunging the body into cold water causes blood to acquire more oxygen.
		5. Only cold therapy increases norepinephrine that controls your body's flight or fight response.
		6. Heat therapy increases release of dopamine, a neurotransmitter that elevates mood, energy, and the ability to focus.
		7. Heat therapy increases blood flow to injured areas.
		8. Heat therapy affects metabolism and thinking ability.
		9. Many instant hot and cold packs work by dissolving a salt into water.
		10. Breaking bonds releases energy.

# Student Reading

## Comprehension Questions

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

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

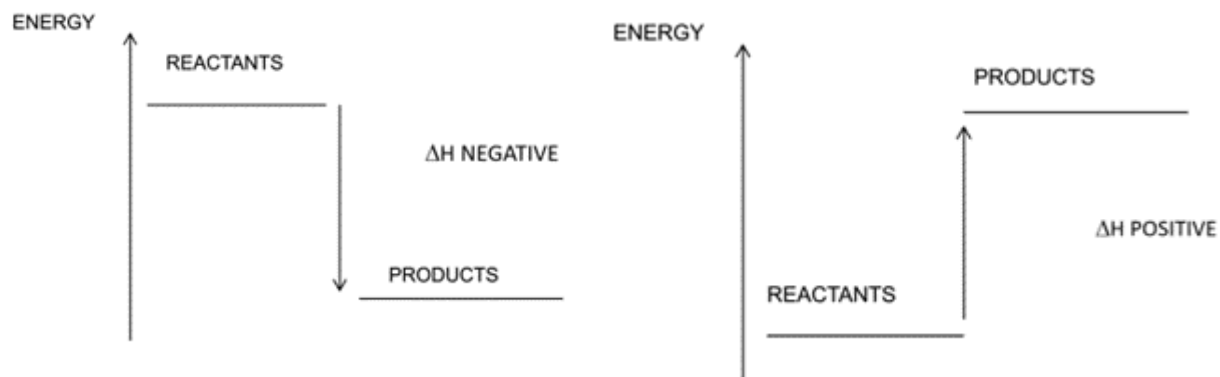
1. Define and explain the differences between thermotherapy and cryotherapy.
2. Explain what happens to blood vessels in the body during thermotherapy and cryotherapy.
3. Give some examples and uses for dry heat and moist heat.
4. Define exothermic in your own words. Give a few examples. Define endothermic in your own words. Give a few examples.
5. What is enthalpy? What is the symbol for enthalpy?
6. The breaking of chemical bonds between atoms in a molecule is typically an endothermic process. Explain why this is the case.
7. Explain some similarities and differences between ultrasound heating and the heat generated from traditional heat packs.
8. When you hold an ice cube, you say it feels “cold”. In terms of heat transfer, what is happening?
9. In a heat pack, heat is released when the chemicals react. In terms of potential energy of the reacting chemicals and the resulting products, explain where the heat energy comes from.
10. In a cold pack, heat is absorbed from the surroundings when the chemicals react (it feels cold). In terms of potential energy of the reacting chemicals and the resulting products, explain why the chemicals are absorbing the heat.

## Student Reading Comprehension Questions, cont.

### Questions for Further Learning

Write your answers on another piece of paper if needed.

11. Consider the two energy diagrams below. Determine which one is a diagram for an exothermic process, and which one is for an endothermic process. Explain your reasoning. Also, explain why the  $\Delta H$  is negative or positive in each of the diagrams.



12. Give a few reasons why heat therapy and cold therapy are good alternatives over drugs to treat illnesses and injuries.

# Graphic Organizer

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

**Directions:** As you read, complete the graphic organizer below to compare hot and cold therapy.

	Hot Therapy	Cold Therapy
Used in ancient times		
Examples		
When to use it		
What it does in your body		
Chemicals produced in your body when used		
Chemicals in instant packs		

**Summary:** On the back of this sheet, write a short email (3-4 sentences) to a friend about treating injuries with thermotherapy and cryotherapy.

# Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. Define and explain the differences between thermotherapy and cryotherapy.  
Thermotherapy uses heat to help alleviate injuries and/or illnesses. Cryotherapy is the process of using cold to do the same thing. Both processes can be used for a variety of ailments.
2. Explain what happens to blood vessels in the body during thermotherapy and cryotherapy.  
During thermotherapy, blood vessels will dilate, which allows blood flow to increase to the injured area. This extra blood will help heal any injuries to joints, muscles, and tissues. In cryotherapy, the blood vessels contract, which lessens the amount of blood flow to the injured area. The lower blood flow will reduce swelling. Additionally, the restricted vessels push the blood back to the organs, which absorbs more oxygen to bring to the affected area.
3. Give some examples and uses for dry heat and moist heat.  
Dry heat is called conductive heating. Examples of this are heat packs, hot water bottles, and heating pads. Moist heat, called convection, includes heating baths and steamed cloths or towels.
4. Define exothermic in your own words. Give a few examples. Define endothermic in your own words. Give a few examples.  
Exothermic means to release heat into the surroundings. When something burns, such as burning wood or a gas stove fire, this is exothermic. Endothermic means to absorb heat. When you hold something cold, such as an ice cube, or when a freezer cools water into an ice cube, an endothermic process is happening because something is absorbing heat to make the other object feel cold.
5. What is enthalpy? What is the symbol for enthalpy?  
Enthalpy is the amount of heat energy in a chemical. The symbol for enthalpy is H.
6. The breaking of chemical bonds between atoms in a molecule is typically an endothermic process. Explain why this is the case.  
The bonds between chemicals consist of a set amount of potential energy. For these bonds to be broken, an amount of energy greater than the bond's stored energy must be added to the chemical. The energy must come from an outside source, the surroundings; therefore, it is an endothermic process to break a chemical bond.
7. Explain some similarities and differences between ultrasound heating and the heat generated from traditional heat packs.  
Ultrasound heating is not like traditional style heating. With ultrasound heating, sound waves cause vibrations in tissues in the body. These vibrations create friction, which causes heat. With traditional heating, the substances in hot packs are already vibrating quickly, which produces the heat. The heat is then transferred to the body.
8. When you hold an ice cube, you say it feels "cold". In terms of heat transfer, what is happening?  
Heat is being transferred from your hand to the ice cube to warm the ice and as a consequence your hand feels cold. The ice cube is absorbing the heat (an endothermic process), so what you feel is the heat leaving your hand. Heat always flows from hot to cold.

9. In a heat pack, heat is released when the chemicals react. In terms of potential energy of the reacting chemicals and the resulting products, explain where the heat energy comes from.  
The initial chemicals (reactants) have higher energy than the final chemicals (products). The difference in energy between where the start of the reaction and the end of the reaction is the energy released to the surroundings. Measuring the temperature of the reaction will show an increase in temperature indicating a loss of energy.
10. In a cold pack, heat is absorbed from the surroundings when the chemicals react (it feels cold). In terms of potential energy of the reacting chemicals and the resulting products, explain why the chemicals are absorbing the heat.  
If the products of a reaction have more energy than the reactants, then heat is absorbed by the reaction. An observed decrease in temperature during the reaction is an indicator that the chemicals are absorbing energy and that the products are gaining heat, rather than giving off heat. The energy needed to complete the reaction must come from the surroundings. So the reaction absorbs the heat energy in order to make the products.
11. Consider the two energy diagrams below. Determine which one is a diagram for an exothermic process, and which one is for an endothermic process. Explain your reasoning. Also, explain why the  $\Delta H$  is negative or positive in each of the diagrams.  
The diagram on the left represents an exothermic reaction. An exothermic reaction releases heat. According to the energy diagram, the reactants have more potential energy than the products. Therefore, the extra unneeded energy is given off into the surroundings as heat. The enthalpy value is negative because the system is losing heat.  
The diagram on the right represents an endothermic reaction. An endothermic reaction absorbs heat. According to the energy diagram, the reactants have less potential energy than the products. Therefore, for the products to be formed, the system needs to get more energy from another source. This source would be the surroundings, so the system absorbs the surroundings heat energy. The enthalpy value is positive because the system is gaining heat.
12. Give a few reasons why heat therapy and cold therapy are good alternatives over drugs to treat illnesses and injuries.  
(Answers may vary). Heat and cold therapy can be used to reduce swelling and increase blood flow to injuries. They are inexpensive and can be applied immediately to non-emergent injuries. They can reduce recovery time and can mean that pain medications are not needed. They are a non-addictive method for treating aches and pains.

## 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 demos

- Handwarmer Design Challenge  
<https://teachchemistry.org/classroom-resources/handwarmer-design-challenge>
- Less Than Zero  
<https://teachchemistry.org/classroom-resources/less-than-zero>
- Energy in Hot and Cold Packs  
<https://teachchemistry.org/classroom-resources/energy-in-hot-and-cold-packs>

### ❖ Lessons and lesson plans

- Thermochemistry and Thermodynamics Unit Plan  
<https://teachchemistry.org/classroom-resources/thermochemistry-and-thermodynamics-unit-plan>

### ❖ Projects and extension activities

- Thermodynamics Escape Room  
<https://teachchemistry.org/classroom-resources/thermodynamics-escape-room>

## Teaching Strategies

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

- **Alternative to Anticipation Guide:** Before reading, ask students if they have used hot or cold therapy, and when. Ask if they have used instant hot or cold packs and if they know how they work. 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 what they learned about hot and cold therapy and treating injuries. Ask how they might use the information in the future.

# Chemistry Concepts and Standards

## Connections to Chemistry Concepts

The following chemistry concepts are highlighted in this article:

- Enthalpy
- Exothermic and endothermic
- Heat
- Molecular structure

## 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.

**HS-LS1-3.** Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.

**HS-ETS1-2.** Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

### Disciplinary Core Ideas:

- PS.1.A: Structure and Properties of Matter
- LS.1.A: Structure and Function
- ETS.1.C: Optimizing the Design Solution

### Crosscutting Concepts:

- Cause and effect
- Energy and matter

### Science and Engineering Practices:

- Constructing explanations (for science) and designing solutions (for engineering)

### Nature of Science:

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

See how *ChemMatters* correlates to the [Common Core State Standards online](#).

## Teacher's Guide

### 5 Things to Know About Glitter

*December 2023*

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Activate students' prior knowledge and engage them before they read the article.	
<a href="#"><u>Reading Comprehension Questions</u></a>	<b>29</b>
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.	
<a href="#"><u>Graphic Organizer</u></a>	<b>30</b>
This helps 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.	
<a href="#"><u>Answers</u></a>	<b>32</b>
Access the answers to reading comprehension questions and a rubric to assess the graphic organizer.	
<a href="#"><u>Additional Resources</u></a>	<b>35</b>
Here you will find additional labs, simulations, lessons, and project ideas that you can use with your students alongside this article.	
<a href="#"><u>Chemistry Concepts and Standards</u></a>	<b>36</b>

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

# Anticipation Guide

**Directions:** *Before reading the article*, in the first column, write “A” or “D,” indicating your Agreement or Disagreement 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. Intramolecular forces in glitter cause it to stick to almost everything.
		2. Uneven distribution of charges causes intermolecular forces between molecules.
		3. Glitter has three layers.
		4. Most glitter is the same thickness (1mm).
		5. Cosmetic glitter is thicker than craft glitter.
		6. Forensic scientists can link glitter to crime scenes because each manufacturer uses a unique process.
		7. Most conventional glitter is made from mylar.
		8. Biodegradable glitter is made from cellulose.
		9. Biodegradable glitter displays different colors because of dyes that are used in its manufacture.
		10. Biodegradable glitter is safe to eat.

# Student Reading

## Comprehension Questions

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

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

1. Which intermolecular forces cause glitter to stick to objects?
2. What are microplastics?
3. Which edible polymer can be used to make edible glitter?
4. List the components used to make glitter.
5. What does PET stand for?
6. What is cellulose?
7. Explain at least two characteristics of glitter that make it ideal contact trace evidence.
8. Why can glitter be considered a microplastic?
9. Explain how the size and weight of glitter particles impact their ability to stick to objects.

# Student Reading Comprehension Questions, cont.

## Questions for Further Learning

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

10. Draw a diagram or write a paragraph to explain how glitter from cosmetics might end up in our seafood.
11. Provide at least two drawbacks of nanocellulose-based glitter.
12. Explain how temporary regions of partial positive and partial negative charges occur in glitter.
13. Select one of the five facts about glitter (glitter is sticky, glitter production, components of biodegradable glitter, biodegradable glitter's impact on the environment, edible glitter) and create an infographic to summarize the information.
14. The article describes PET-based glitter as a source of microplastic pollution. Should PET-based glitter be banned? Write a paragraph to explain your response.

# Graphic Organizer

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

**Directions:** As you read, complete the graphic organizer below to compare the different types of glitter.

	<b>Conventional glitter</b>	<b>Biodegradable glitter</b>
<b>How it is made</b>		
<b>Why it is so sticky</b>		
<b>Chemicals used</b>		
<b>How colors are produced</b>		
<b>Impact on environment</b>		

**Summary:** On the back of this sheet, write a short summary (20 words or less) of the article.

# Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. Which intermolecular forces cause glitter to stick to objects?  
London dispersion forces cause glitter to stick to objects.
2. What are microplastics?  
Microplastics are tiny pieces of plastic.
3. Which edible polymer can be used to make edible glitter?  
The edible polymer that can be used to make glitter is gelatin.
4. List the components used to make glitter.  
Glitter is made of PET coated with aluminum, color, and a transparent sealant.
5. What does PET stand for?  
PET stands for polyethylene terephthalate.
6. What is cellulose?  
Cellulose is a plant polymer.
7. Explain at least two characteristics of glitter that make it ideal contact trace evidence.  
Glitter is ideal contact trace evidence because it is sticky, difficult to clean up, and can be traced back to its manufacturer.
8. Why can glitter be considered microplastic?  
PET-based glitter contains plastic and is very small, so it is considered microplastic.
9. Explain how the size and weight of glitter particles impact their ability to stick to objects.  
Glitter particles are small in size and weight, so they require low amounts of energy to make the particles stick.
10. Draw a diagram or write a paragraph to explain how glitter from cosmetics might end up in our seafood.  
Glitter from cosmetics may enter waterways through wastewater streams when it is washed off. The glitter then moves through the wastewater system and into the ocean or a freshwater source. Once it is in open water, the glitter may be consumed by fish. The fish may then be consumed by people.
11. Provide at least two drawbacks of nanocellulose-based glitter.  
Nanocellulose-based glitter takes thousands of years to break down and can lead to the growth of unwanted species in an environment.
12. Explain how temporary regions of partial positive and partial negative charges occur in glitter.  
Temporary regions of partial positive and partial negative charges occur in glitter when molecules move causing their electrons to become unevenly distributed, creating temporary regions of partial positive and partial negative charges.
13. Select one of the five facts about glitter (glitter is sticky, glitter production, components of biodegradable glitter, biodegradable glitter's impact on the environment, edible glitter) and create an



infographic to summarize the information.

*Student responses will vary and should include information from the article.*

14. The article describes PET-based glitter as a source of microplastic pollution. Should PET-based glitter be banned? Write a paragraph to explain your response.

*Student responses will vary and should include reasoning related to microplastics.*

## 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

### ❖ Simulations

- [Molecular Polarity](#) – Students can use this PhET simulation to explore electronegativity.

### ❖ Lessons and lesson plans

- [Simulation Activity: Comparing Attractive Forces](#) – This AACT lesson plan is designed to guide students through a simulation where they investigate different types of intermolecular forces, including London dispersion forces.
- [The Plasticsphere: Plastic Migration and Its Impacts](#) - This lesson plan introduces the concept of microplastics as students examine the ways that microplastics enter waterways and the difficulty of removing them.

### ❖ Projects and extension activities

- [Identifying Plastics with Density Data](#) – This activity helps students learn more about how density can be used to identify types of plastic, including PET.

## Teaching Strategies

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

- **Alternative to Anticipation Guide:** Before reading, ask students if they use glitter, and where they might use it. Also ask students if they know what glitter is made from, and why it is not good for the environment. Ask if they know of any alternatives to glitter. 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 what they learned about glitter. Also ask them how glitter impacts the environment.
- After reading, ask students how they might use information from the article to make decisions about using glitter in crafts and cosmetics in the future.

# Chemistry Concepts and Standards

## Connections to Chemistry Concepts

The following chemistry concepts are highlighted in this article:

- Intermolecular forces
- Polymers

## Correlations to Next Generation Science Standards

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

**HS-PS1-3.** Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.

**HS-ETS1-3.** Evaluate a solution to a complex real-world problem based on prioritized criteria and tradeoffs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

### Disciplinary Core Ideas:

- PS.1.A: Structure and Properties of Matter
- ETS1.C: Optimizing the Design Solution

### Crosscutting Concepts:

- Cause and effect
- Structure and Function

### Science and Engineering Practices:

- Constructing explanations (for science) and designing solutions (for engineering)

### Nature of Science:

- Science addresses questions about the natural and material world.

See how *ChemMatters* correlates to the [Common Core State Standards online](#).

## Teacher's Guide

### Keeping the Playing Field Level

*December 2023*

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Activate students' prior knowledge and engage them before they read the article.	
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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.	
<a href="#"><u>Graphic Organizer</u></a>	<b>41</b>
This helps 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.	
<a href="#"><u>Answers</u></a>	<b>42</b>
Access the answers to reading comprehension questions and a rubric to assess the graphic organizer.	
<a href="#"><u>Additional Resources</u></a>	<b>45</b>
Here you will find additional labs, simulations, lessons, and project ideas that you can use with your students alongside this article.	
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# Anticipation Guide

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

**Directions:** *Before reading the article*, in the first column, write “A” or “D,” indicating your Agreement or Disagreement 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. Athletes have used performance enhancing drugs (PEDs) only since the 1950s.
		2. The International Olympic Committee (IOC) has required drug testing at all Olympic events since 1960.
		3. The National Basketball Association (NBA) required drug testing prior to the National Football League (NFL) and Major League Baseball (MLB).
		4. Five categories of drugs are responsible for most doping violations by athletes.
		5. Blood and urine tests are used to look for banned drugs and their metabolites.
		6. Mass spectrometry and chromatography are used to identify substances in blood or urine.
		7. The first known synthetic testosterone was made in 1995.
		8. The ratios of carbon isotopes in hormones naturally produced by the body are compared to determine if one of the hormones is synthetic.
		9. Steroids account for only about 10% of all positive doping tests in sports.
		10. Steroid users have a higher mortality rate than non steroid users.

# Student Reading

## Comprehension Questions

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

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

1. The World Anti-Doping Agency (WADA) developed a wide-ranging set of regulations when it was founded in 1999. What are the five major categories of prohibited substances and methods regulated by WADA?
2. Which of these five major categories accounts for over 50% of positive doping tests in sports?
3. If an athlete participated in archery, which type of performance-enhancing drug might they use? Explain.
4. Explain how the liver helps increase the solubility of the steroid stanozolol.
5. What is the purpose of the magnets in the mass spectrometer?
6. What are isotopes?
7. Use the mass spectrum graph to determine the percent abundance of carbon-12 and carbon-13.
8. Explain how the ratio of different carbon isotopes can be used to differentiate between a non-performance enhancing steroid that is produced in the body from a synthetic steroid used to enhance athletic performance.
9. How is the carbon-13 to carbon-12 ratio measured by the mass spectrometer?
10. What could cause a false positive test for synthetic steroids?

# Student Reading Comprehension Questions, cont.

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## Questions for Further Learning

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

11. Research the dangers of long-term use of steroids. Identify at least two hazardous side effects.
12. Draw a diagram that shows how anabolic steroids accelerate muscle growth on the cellular level.



# Graphic Organizer

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

**Directions:** As you read, complete the graphic organizers below. In the first organizer, choose any four banned substances described in the article. In the second organizer, describe how IRMS works.

Drug	Drug type	Formula	Why is it used?

	Determines	How the analysis helps identify doping
Isotope Ratio		
Mass		
Spectrometry		
Chromatography		

**Summary:** On the back of this sheet, write three interesting facts you learned about how PEDs are detected.

# Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. The World Anti-Doping Agency (WADA) developed a wide-ranging set of regulations when it was founded in 1999. What are the five major categories of prohibited substances and methods regulated by WADA?  
**Anabolic steroids, peptide hormones, stimulants, beta blockers, diuretics**
2. Which of these five major categories accounts for over 50% of positive doping tests in sports?  
**Steroids**
3. If an athlete participated in archery, which type of performance-enhancing drug might they use? Explain.  
**Archery requires very steady hands in order to aim properly. Because beta blockers lower heart rate and blood pressure, this class of drugs would help an archer perform better.**
4. Explain how the liver helps increase the solubility of the steroid stanozolol.  
**Cytochrome P450 in the liver metabolizes the stanozolol—a synthetic form of a steroid that mimics testosterone—to 3'-hydroxystanozolol by adding an -OH group to the molecule. The presence of this group allows for increased hydrogen bonding between water and 3'-hydroxystanozolol, leading to increased solubility.**
5. What is the purpose of the magnets in the mass spectrometer?  
**Magnets bend the path of the molecular ions based on their mass, such that one type of ion hits the detector at a time.**
6. What are isotopes?  
**Isotopes are different forms of the same element with different numbers of neutrons, so they have different masses. Carbon has four isotopes.**
7. Use the mass spectrum graph to determine the percent abundance of carbon-12 and carbon-13.  
**Carbon-12 is overwhelmingly more abundant ~ 99% and carbon-13 is ~ 1%.**
8. Explain how the ratio of different carbon isotopes can be used to differentiate between a non-performance enhancing steroid that is produced in the body from a synthetic steroid used to enhance athletic performance.  
**The ratio of carbon-13 to carbon-12 isotopes is 1:99 in carbon-containing compounds like steroids produced in the body. However, synthetic steroids have a different carbon-13 to carbon-12 ratio, because these compounds are made from plants. This difference can be detected by isotope ratio mass spectroscopy.**
9. How is the carbon-13 to carbon-12 ratio measured by the mass spectrometer?  
**The compound in question is burned in the presence of oxygen to produce water vapor and carbon dioxide gas. The molecular mass of a molecule of carbon dioxide containing carbon-12 is 44 amu, but**

the molecular mass of a molecule of carbon dioxide containing carbon-13 is slightly heavier, 45 amu. The mass spectrum will show the abundance of the two forms of carbon dioxide, by the height of their peaks, and the ratio of their respective carbon isotopes can be calculated from these peak heights.

10. What could cause a false positive test for synthetic steroids?

A diet high in plant foods would mimic the carbon-13 to carbon-12 ratio often found in synthetic steroids, leading to a false positive test.

11. Research the dangers of long-term use of steroids. Identify at least two hazardous side effects.

Answers will vary depending on student research. Some examples include increased chance of cancer, liver disease and heart problems.

12. Draw a diagram that shows how anabolic steroids accelerate muscle growth on the cellular level.

The diagram should show that anabolic steroids attach to androgen receptors within the cells. This causes changes in receptor proteins that can then move from the cytoplasm of the cells to the nucleus and attach to the cell's DNA. This changes the expression of the genes that make certain proteins, resulting in muscle growth.

# 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

- Students investigate solubility and polarity of various solutions.  
<https://teachchemistry.org/classroom-resources/solubility-and-compound-type>

### ❖ Simulations

- Students inspect isotopes of many chemical elements.  
<https://phet.colorado.edu/en/simulations/isotopes-and-atomic-mass>
- Students explore a simulation of how a mass spectrometer works.  
<https://applets.kcvs.ca/MassSpectrometer/massSpec.html#>

### ❖ Lessons and lesson plans

- Students read and research about the development of medicinal steroids and their structure in this multi-part lesson and activity.  
<https://teachchemistry.org/classroom-resources/steroid-medicines-a-profile-of-chemical-innovation>
- Students learn more about doping in sports.  
<https://www.compoundchem.com/2016/08/09/doping/>

## Teaching Strategies

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

- **Alternative to Anticipation Guide:** Before reading, ask students what performance enhancing drugs (PEDs) they have heard of, and how the tests for them are done. Ask if they know of any sports figures who have been penalized because of PEDs, and why. 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 what they learned about the chemistry of performance enhancing drugs and the tests that are done to find them.
- After students have read and discussed the article, ask students what information they would like to share with friends and family about PEDs and how their ideas about PED testing have changed after reading the article.
- Consider showing the ACS Reactions Video: “How to catch Dopers” (3:45)  
<https://youtu.be/oWOWLwMc0rc?si=3w02K3hLuActj6LG>. The video focuses on anabolic-androgenic steroids and augments some of the information in the article.

# Chemistry Concepts and Standards

## Connections to Chemistry Concepts

The following chemistry concepts are highlighted in this article:

- Molecular structure
- Pharmaceuticals
- Instrumentation

## Correlations to Next Generation Science Standards

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

**HS-ETS1-1.** Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

### Disciplinary Core Ideas:

- PS.1.A: Structure and Properties of Matter
- ETS1.C: Optimizing the Design Solution

### Crosscutting Concepts:

- Scale, proportion, and quantity
- Structure and Function

### Science and Engineering Practices:

- Analyzing and interpreting data

### Nature of Science:

- Scientific knowledge is based on empirical evidence.

See how *ChemMatters* correlates to the [Common Core State Standards online](#).