



**“The Cool Chemistry of Dry Ice”**

*February/March 2018 Issue*

<http://www.acs.org/chemmatters>

**Teacher’s Guide**



**Teacher's Guide for**

***“The Cool Chemistry of Dry Ice”***

**February/March 2018**

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# Connections to Chemistry Concepts

|  |  |
| --- | --- |
| **Chemistry Concept** | **Connection to Chemistry Curriculum** |
| **Phase changes** | The transition directly from solid to gas is probably the least familiar of the phase changes. The examples of sublimation in this article provide familiar examples to tie this concept to the daily lives of students. |
| **Vapor pressure** | While studying sublimation, the article provides an example of the behavior of matter at the particle level as vapor pressure is increased. |
| **Intermolecular forces** | Information about dry ice from the Rohrig article can be used as a prime example when discussing the weak intermolecular forces present in dry ice that result in its sublimation upon increasing the energy of (i.e., heating) the solid carbon dioxide. |
| **Phase diagrams** | While studying phase change, the teacher can use the phase diagram and information in the Rohrig dry ice article to show how and why dry ice sublimates. |
| **Endothermic process** | As discussed in the Rohrig dry ice article, the commercial process for making dry ice relies on an endothermic change that results in the deposition of CO2 gas (directly) to CO2 solid. |
| **Triple point & critical temperature** | While studying solid, liquid, and gas phases of a substance, the CO2 phase-change diagram in the Rohrig article provides the opportunity to show that each phase of a substance is stable only in certain ranges of temperature and pressure, and to investigate the limits placed at the triple point and the critical temperature. |

# Teaching Strategies and Tools

## Standards

Links to **Common Core Standards for Reading**:

* + ELA-Literacy.RST.9-10.1:Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.
  + ELA-Literacy.RST.9-10.5: Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., force, friction, reaction force, energy).
  + ELA-Literacy.RST.11-12.1:Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
  + ELA-Literacy.RST.11-12.4: Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics.

Links to **Common Core Standards for Writing**:

* + ELA-Literacy.WHST.9-10.2F: Provide a concluding statement or section that follows from and supports the information or explanation presented (e.g., articulating implications or the significance of the topic).
  + ELA-Literacy.WHST.11-12.1E: Provide a concluding statement or section that follows from or supports the argument presented.

In addition to the writing standards above, consider asking students to debate issues addressed in some of the articles. Standards addressed:

* **ELA-Literacy.WHST.9-10.1B.** Develop claim(s) and counterclaims fairly, supplying data and evidence for each while pointing out the strengths and limitations of both claim(s) and **counterclaims** in a discipline-appropriate form and in a manner that anticipates the audience’s knowledge level and concerns.
* **ELA-Literacy.WHST.11-12.1.A.** Introduce precise, knowledgeable claim(s), establish the significance of the claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that logically sequences the claim(s), counterclaims, reasons, and evidence.

## Vocabulary

**Vocabulary** and **concepts** that are reinforced in this issue:

Physical properties

States of Matter

Structural Formulas

pH

Oxidation & Reduction

Enzymes

Intermolecular forces

* Some of the articles in this issue provide information about carbon dioxide and its role in the environment.
* To help students engage with the text, ask students which article **engaged** them most and why, or what **questions** they still have about the articles.
* You might also ask them how information in the articles might affect their consumer choices. Also, ask them if they have questions about some of the issues discussed in the articles.

# Reading Supports for Students

The pages that follow include reading supports in the form of an Anticipation Guide, a Graphic Organizer, and Student Reading Comprehension Questions. These resources are provided to help students as they prepare to read and in locating and analyzing information from the article.

The borders on these pages distinguish them from the rest of the pages in this Teacher’s Guide—they have been formatted for ease of photocopying for student use.

* **Anticipation Guide (p. 8):**  The Anticipation Guide helps to engage students by activating prior knowledge and stimulating student interest before reading. If class time permits, discuss students’ responses to each statement before reading each article. As they read, students should look for evidence supporting or refuting their initial responses.

*NEW! Instead of using the aforementioned anticipation guide, consider these ideas to engage your students in reading.*

* Ask students to list three things they already know about dry ice, including at least one safety precaution.
* As they read the article, they can compare what they knew (or thought they knew) to the information in the article.
* **Graphic Organizer (p. 9):**  The Graphic Organizer is provided to help students locate and analyze information from the article. Student understanding will be enhanced when they explore and evaluate the information themselves, with input from the teacher, if students are struggling. Encourage students to use their own words and avoid copying entire sentences from the article. The use of bullets helps them do this.

If you use the aforementioned organizers 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 |

* **Student Reading Comprehension Questions (p. 10-11):**  The Student Reading Comprehension Questions are designed: to encourage students to read the article (and graphics) for comprehension and attention to detail; to provide the teacher with a mechanism for assessing how well students understand the article and/or whether they have read the assignment; and, possibly, to help direct follow-up, in-class discussion, or additional, deeper assignments.

Some of the articles in this issue provide opportunities, references, and suggestions for students to do further research on their own about topics that interest them.

To help students engage with the text, ask students which article **engaged** them most and why, or what **questions** they still have about the articles. The “Web Sites for Additional Information” section of the Teacher’s Guide provides sources for additional information that might help you answer these questions.

“The Cool Chemistry of Dry Ice”, *ChemMatters*, February/March 2018

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

## Anticipation Guide

**Directions:**  ***Before reading the article*,** in the first column, write “A” or “D,” indicating your agreement or disagreement with each statement. 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. Dry ice is solid carbon dioxide. |
|  |  | 1. Dry ice melts at room temperature and pressure. |
|  |  | 1. Putting a piece of metal on top of dry ice will make it sublime more slowly. |
|  |  | 1. Carbon dioxide is a polar molecule. |
|  |  | 1. Dry ice was discovered by accident. |
|  |  | 1. Evaporation is an exothermic process, releasing energy to the surroundings. |
|  |  | 1. Making dry ice requires low pressure. |
|  |  | 1. Dry ice floats in water. |
|  |  | 1. One of the first uses of dry ice was to carbonate beverages. |
|  |  | 1. Inhaling the vapor from dry ice is dangerous. |

## Graphic Organizer

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

“The Cool Chemistry of Dry Ice”, *ChemMatters*, February/March 2018

**Directions**: ***As you read***, complete the graphic organizer below to describe sublimation.

|  |  |
| --- | --- |
| Definition | How to increase sublimation of dry ice (at least 2 ways)  sublimation |
| Why dry ice sublimes | Everyday examples  (not dry ice) |

Complete this graphic organizer to describe how to use dry ice safely, with the chemical reasons for each safety precaution.

|  |  |
| --- | --- |
| **Safety precaution** | **Why?** |
|  |  |
|  |  |
|  |  |

**Summary:** On the back of this paper, write one new thing you learned about dry ice that you would like to share with a friend.

## Student Reading Comprehension Questions

“The Cool Chemistry of Dry Ice”, *ChemMatters*, February/March 2018

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Name

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

1. What will you see if a piece of dry ice is left on the lab counter?
2. How do your wet clothes dry when hung outside in sub-freezing temperatures?
3. Give two factors that affect a substance’s tendency to sublimate.
4. Why does a piece of dry ice act like a puck on an air hockey table?
5. When pressed onto a piece of dry ice, why does a piece of metal (a) make a loud squealing noise and (b) increase the rate of sublimation?
6. Under what conditions of pressure and temperature will carbon dioxide exist as a liquid?

**Student Reading Comprehension Questions, cont.**

“The Cool Chemistry of Dry Ice”, *ChemMatters*, February/March 2018

1. What are the conditions of pressure and temperature at the triple point of dry ice? (Use the phase diagram for CO2 to answer this question.)
2. What is the meaning of the term “critical temperature”, and what is the value of the critical temperature of CO2?
3. Why will the sublimation rate increase substantially when dry ice is placed in water?
4. What makes freezing an exothermic process?
5. Why does CO2 make an excellent fire extinguisher?
6. Use the table below to list the three safety precautions from the article and the possible consequences of each.

|  |  |
| --- | --- |
| **Safety Precaution** | **Possible Consequence(s)** |
|  |  |
|  |  |
|  |  |

## Answers to Student Reading Comprehension Questions

1. **What will you see if a piece of dry ice is left on the lab counter?**

*If a piece of dry ice is left on the lab counter, you will see it get smaller until it disappears, with no liquid left around it.*

1. **How do your wet clothes dry when hung outside in sub-freezing temperatures?**

*The liquid water on your clothes freezes to ice, then the ice sublimates, changing directly from solid ice to water vapor, leaving your clothes dry.*

1. **Give two factors that affect a substance’s tendency to sublimate.**

*A substance’s tendency to sublimate is affected by its vapor pressure and the forces of attraction among its particles. If the forces of attraction between particles are weak, as in dry ice, the substance will be more likely to change phases directly from solid to vapor.*

1. **Why does a piece of dry ice act like a puck on an air hockey table?**

*As a piece of dry ice sublimates, it becomes surrounded by CO2 gas that reduces the friction between the dry ice puck and the hockey table, so the puck glides on a cushion of CO2 gas just like an air hockey puck glides on air.*

1. **When pressed onto a piece of dry ice, why does a piece of metal (a) make a loud squealing noise and (b) increase the rate of sublimation?**

*A piece of metal*

1. *makes a loud squealing noise when pressed onto the dry ice, because, as the CO2 gas escapes, it makes the pressure fluctuate and the metal vibrates, causing the squealing sound as the gas escapes, and*
2. *increases the rate of sublimation because metals are good conductors of heat, so when pressed onto dry ice, the metal quickly releases heat energy to the ice, increasing the rate of sublimation.*
3. **Under what conditions of pressure and temperature will carbon dioxide exist as a liquid?**

*Carbon dioxide will exist as a liquid at a pressure of 5.1atm or greater and between –56.4 and 31 oC.*

1. **What are the conditions of pressure and temperature at the triple point of dry ice? (Use the phase diagram for CO2 to answer this question.)**

*From reading the phase change diagram, the pressure at the triple point is 5.1atm and the temperature is –56.7 oC.*

1. **What is the meaning of the term “critical temperature”, and what is the value of the critical temperature of CO2?**

*The critical temperature is the temperature where the vapor of a substance can no longer be liquefied by any amount of pressure. The critical temperature of CO2 is 31 oC, as shown in the phase diagram in the article.*

1. **Why will the sublimation rate increase substantially when dry ice is placed in water?** *The sublimation rate of dry ice will increase substantially when it is placed in water because water is a better heat conductor and denser than air so it will continuously release heat to the dry ice thus accelerating sublimation.*
2. **What makes freezing an exothermic process?**

*Freezing is an exothermic process because energy is released from the system to the surroundings.*

1. **Why does CO2 make an excellent fire extinguisher?**

*CO2 makes an excellent fire extinguisher because the CO2 is denser than air, so it sinks and displaces the air surrounding the fire, depriving the fire of oxygen.*

1. **Use the table below to list the three safety precautions from the article and the possible consequences of each.**

|  |  |
| --- | --- |
| **Safety Precaution** | **Possible Consequence(s)** |
| *Don’t touch dry ice.* | *Frostbite occurs from contact with the skin for more than a few seconds.* |
| *Don’t inhale dry ice; work in a ventilated area.* | *Too much CO2 in the blood may make the pH of the blood too acidic, which can be fatal; or it may cause asphyxia, due to depriving the body of O2.* |
| *Don’t put dry ice in a closed metal container.* | *As dry ice sublimates, pressure from the carbon dioxide gas may increase explosively.* |

# Possible Student Misconceptions

1. **“Yes, I’ve seen what happens when dry ice dropped in water forms a cloud. This must be a chemical change, because a new substance—“fog”—forms.”** *Actually, dry ice undergoes a physical change when it sublimates from the solid to the gaseous state without first melting into a liquid. The same carbon dioxide is still present, it just undergoes a phase change to become a colorless gas. The fog is composed of a mixture of the sublimated carbon dioxide gas and the water vapor from the air that has been condensed into tiny fog-like droplets by the cold CO2 gas.*
2. **“I watched a demonstration of the “sublimation of iodine”. I thought this would be like dry ice, and extreme pressure would be required to melt it.”** *While solid iodine easily sublimates at room temperature or upon slight heating, it can be melted if the temperature is very carefully controlled to reach just above its normal boiling point (114 oC). Then the melt will quickly evaporate into its characteristic purple vapor.*
3. **“As the temperature rises, I think that all solids melt to become liquids first, and then boil to become gases.”** *No, some solids, like dry ice and mothballs (naphthalene), have intermolecular forces that are so weak that their vapor pressure is greater than atmospheric pressure, allowing the molecules to change from solid to gaseous states directly, without becoming a liquid—as long as the temperature is below the melting point of the substance****.***
4. **“Sublimation is just like evaporation, the substance becomes a gas.”** *While in both sublimation and evaporation the substance becomes a gas, each process reaches the gaseous state differently. During sublimation, a solid goes directly to the gaseous state (bypassing the liquid state); in evaporation, a liquid goes to the gaseous state.*
5. **“I don’t think that sublimation can be reversed.”** *Sublimation can be reversed. For example, water vapor in sub-freezing air will change directly into ice without becoming a liquid first, this is called deposition.*

# Anticipating Student Questions

1. **“Why does a punch bowl bubble when dry ice is added?”** *As the dry ice sublimates, the solid becomes carbon dioxide gas that bubbles out through the liquid punch as it leaves the liquid punch and enters the surrounding air.*
2. **“How do mothballs kill moths?”** *When solid mothballs sublimate, the resulting gas vapor contains insecticides that kill moth larvae. The larvae hatch from eggs left on garments by adult moths. Note: The Environmental Protection Agency (EPA) places restrictions on the sale of mothballs because their vapors can be harmful or toxic to humans and pets, as well.*
3. **“As dry ice sublimates in a bowl of warm water, why does the fog that forms stay near the bowl?”** *When dry ice is added to warm water it sublimates and the cold carbon dioxide gas cools the water vapor in the warm air, condensing it into suspended water droplets. The fog is a heavier-than-air mixture of water droplets and gaseous carbon dioxide that settles below the surrounding air, due to the greater density of CO2 relative to that of air.*
4. **“Can a gas change directly into a solid?”** *Yes. This change, considered the opposite of sublimation, is called deposition. For example, in sub-freezing temperatures, the water vapor in the air may change directly into ice without becoming a liquid as it forms an ice deposit on windows.*
5. **“Do all solids sublimate?”** *Yes, most solids will sublimate to some extent, especially at low pressures (under a vacuum); however, when the intermolecular forces are very strong, as in sodium chloride where its ions are bound tightly in lattices, sublimation will be unnoticeable. A few solids with weak intermolecular attractions such as dry ice, mothballs, and iodine (when gently heated) sublimate at room temperature and pressure.*

# Activities

**Labs and demos**

**Lab: finding the triple point of dry ice:** This microscale lab brings together the excitement of actually “seeing” carbon dioxide liquefy, and calculating the value for its triple point. (<http://bcpshelpdeskhighschoolscience.weebly.com/uploads/6/3/4/6/6346142/lab_-_how_sublime_ltf_triple_point.pdf>)

**Sublimation of iodine demonstration:** This activity should be done as a demonstration (best under a chemistry hood) due to the irritating iodine fumes that may escape. However, students will be amazed, as the purple iodine vapor forms beautiful crystals on a cold surface (deposition). (<https://lsa.umich.edu/content/dam/chem-assets/chem-docs/Sublimation%20of%20Iodine.pdf>)

**Simulations**

**“States of Matter (Inquiry based) Phase Change and Phase Diagrams”:**  This PhET simulation program includes an “Atomic Interactions” simulator. As students manipulate the atoms, the changing effects can be seen on a graph of the potential energy as a function of the distance between the atoms. (<https://phet.colorado.edu/en/contributions/view/3168>)

**Media**

**“Phase Diagrams” (12:35) video lesson:** This video compares phase diagrams of water and carbon dioxide, including a discussion of triple and critical points, as well as supercritical fluids. This program comes from a series of 8 KhanAcademy Videos on “States of Matter and Intermolecular Forces”; links to each are located in the left margin. (<https://www.khanacademy.org/science/chemistry/states-of-matter-and-intermolecular-forces/states-of-matter/v/phase-diagrams>)

**Terrific dry ice demos:** This Flinn Scientific video (10:30) not only demonstrates how to easily perform several demonstrations that explain concepts well beyond “gee-whiz” presentations, but it also explains the observations, using the structural formula and density of dry ice. (<https://www.youtube.com/watch?v=QhTekm5NdiE>)

**Lessons and lesson plans**

**“The sublimation of air freshener”:** This lesson plan from the British Royal Society of Chemistry (RSC) contains background information about the concept of sublimation for teacher use, to prepare students before, during, and after demonstrating this sublimation. Safety hazards are also given, as well as extension possibilities. (<http://www.rsc.org/learn-chemistry/resource/res00000404/the-sublimation-of-air-freshener?cmpid=CMP00005967>)

**“The Behavior of Atoms—Phases of Matter and the Properties of Gases”:** This is a well prepared, comprehensive *Annenberg Learner* unit lesson plan that includes the history and derivation of gas laws, shows and compares the difference between phase diagrams for water and carbon dioxide, and discusses physical changes at the particle level. The program includes items that could stand alone, such as a video (28:28) on drawing phase diagrams, an Interactive chemistry timeline, a unit guide, and a glossary. (<https://www.learner.org/courses/chemistry/text/text.html?dis=U&num=Ym5WdElUQS9NeW89&sec=YzJWaklUQS9NU289>)

# References

**The references below can be found on the *ChemMatters* 30-year DVD, which includes all articles   
published from the magazine’s inception in October 1983 through April 2013; all available Teacher’s Guides, beginning February 1990; and 12 *ChemMatters* videos. The DVD is available from the American Chemical Society for $42 (or $135 for a site/school license) at this site:** [**http://ww.acs.org/chemmatters**](http://www.acs.org/chemmatters)**. Click on the “Teacher’s Guide” tab to the left, directly under the “*ChemMatters Online"* logo and, on the new page, click on “Get the past 30 Years of *ChemMatters* on DVD!” (the icon on the right of the screen)**

**Selected articles and the complete set of   
Teacher’s Guides for all issues from the past three   
years are available free online at the same Web site, above. Click on the “Issues” tab just below the logo, *“ChemMatters Online”*.**



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This article describes the 1997 Presidential Green Chemistry Challenge Award for designing polymer surfactants that reduce the surface tension of supercritical carbon dioxide. This increases the solubility and usefulness of CO2 as a dry-cleaning reagent. (Kirchoff, M. A Supercritical Clean Machine. *ChemMatters,* 2000, *18* (2) pp 13–15)

This article provides activities that are shown and described as a way to study the physical and chemical behavior of carbon dioxide. Students can use dry ice and/or vinegar and baking soda to prepare carbon dioxide gas to perform the experiments described by the diagrams. (Becker, B. A Pourable Green House Gas. *ChemMatters,* 2009, *19* (special edition 1), pp 10–11)

In the context of describing food for astronauts, this article does a nice job of explaining the process and advantages of freeze-drying food. The phase diagram for water is used to explain the process of sublimation for freeze-drying food. (De Antonis, K. Space Food. *ChemMatters,* 2009, *27* (4), pp 11–13)

The Teacher’s Guide for the article “From Fish Tank to Fuel Tank” in the April 2012 issue of *ChemMatters* explains the extraction of biodiesel from algae by a process using supercritical CO2 (sCO2) as the solvent to dissolve the biodiesel. This process is not only better for the environment but it extracts 100% of the biodiesel, in contrast to the use of flammable, toxic cyclohexane as the extraction solvent that retrieves only 95% of the biodiesel.

# Web Sites for Additional Information

**Sublimation**

This site uses structural diagrams to discuss the polarizability of various molecules and describes how this leads to different types and strengths of intermolecular forces between them. (<http://chemistry.bd.psu.edu/jircitano/IMforces.html>)

This site describes the industrial steps used to freeze-dry food and medicines, the various uses and reasons for freeze drying, and ways to do-it-yourself for backpacking food.

(<https://science.howstuffworks.com/innovation/edible-innovations/freeze-drying.htm>)

**Deposition**

This site shows how the exothermicity of deposition provides the energy to produce safer (nonflammable) solid-state lithium-ion batteries for electric cars. (<https://arxiv.org/ftp/arxiv/papers/1709/1709.02918.pdf>)

The company Semi-Core’s Web site advertises “complete solutions for standard custom vacuum deposition”, describes many uses for physical vapor deposition (PVD), and contains links to more information about the process. PVD products include coatings to reduce friction for high performance moving parts, coating as rust repellants for metals, and alloys, including solar panels. (<http://www.semicore.com/what-is-pvd-coating>)

**Supercritical carbon dioxide—a cleaner energy source and a solvent**

This U.S. Department of Energy (DOE) Web page describes the development of efficient ways to replace fossil fuels with more efficient, “greener”, supercritical carbon dioxide (sCO2) as the working fluid (at room temperature) to convert its thermal energy to electrical energy. sCO2 is “greener” because it isn’t a volatile organic compound (VOC), as described in this article (which also has nice graphs and schematics to accompany explanations of the process).(<https://energy.gov/under-secretary-science-and-energy/supercritical-co2-tech-team>)

This article from *Chemical Engineering* is an excellent summary of a 233-page report that includes a list of supercritical fluids, with the critical temperature and pressure given for each. A phase diagram of sCO2 is clearly explained, along with a discussion of its solubility, its use in extracting processes, and the limitations to its use. (<http://www.chemengonline.com/supercritical-co2-a-green-solvent/?printmode=1>)

**Vibration of metals**

This article does a nice job of using Bernoulli’s Principle and the ability of metals to conduct heat to explain the vibration and subsequent squealing of a metal spoon as it touches dry ice. (<https://sciencing.com/metal-scream-touches-dry-ice-7187818.html>)

“Cacophanies from Metal on Dry Ice” is from the *All Things Considered* National Public Radio (NPR) program. Note that sounds differ when a professional sound recordist tosses various types of metal on dry ice; both the script and the recorded sounds can be accessed on the sites below. Script: (<https://www.npr.org/templates/story/story.php?storyId=12309256>), sounds: (<https://www.npr.org/programs/all-things-considered/2007/07/27/13120894/>)

**Conflicting history of the discovery of dry ice**

The first version of the discovery of dry ice is the one in the Rohrig dry ice article.

Version 2: In 1823 while using pressure to liquefy various gases, Michael Faraday found that when a gas exceeded a certain temperature (critical temperature), no amount of pressure would liquefy it. During this study, Faraday is credited with the discovery of liquid carbon dioxide that to his surprise liquefied at a fairly low pressure (5.1 atm). (<https://books.google.com/books?id=04xk5M168nEC&pg=PA57&lpg=PA57&dq=Michael+Faraday+dry+ice&source=bl&ots=R1hDgX3oxY&sig=WxH5DSG8et07W5nE15Pu-igl8rA&hl=en&sa=X&ved=0ahUKEwjZ0q_h-ZPYAhXLPCYKHVhpBxkQ6AEIPTAI#v=onepage&q=Michael%20Faraday%20dry%20ice&f=false>)

Version 3: In 1835 the French scientist, Adrien-Jean-Pierre Thilorier used his award-winning compressor to liquefy and study the properties of carbon dioxide. Excerpts (translated on this site) from his fascinating biography include his description of the exciting, serendipitous discovery of dry ice. (<https://upclosed.com/people/adrien-jean-pierre-thilorier/>)

**How to make dry ice**

This article from “How Products are Made” is a good information source for the physical process and properties of dry ice, including manufacturing history and current production processes (note the incorrect caption on a schematic labeled as chemical reactions rather than physical processes or changes!). The information includes present use to slow bud growth in flower shops, and possible future uses: killing gophers in their holes and removing car dents. (<http://www.madehow.com/Volume-7/Dry-Ice.html>)

“How to make dry ice at home (or in the classroom)” is a step-by-step guide on how to use a compressed carbon dioxide fire-extinguisher to provide dry ice for experiments. Of course, it is usually much cheaper to purchase a block from an ice cream shop (frozen cakes), meat market, or another retail source. (<https://www.wikihow.com/Make-Dry-Ice>)

**Uses for dry ice**

A major supplier, Dry Ice Corp, suggests special effects for Halloween and provides an interesting list of unusual dry ice uses, including floor tile removal, sand-blasting, making root beer, and food preservation during electrical outages. There are also links to specifics, such as medical uses and how dry ice serves as a safe replacement for toxic cleaners. (<http://www.dryicecorp.com/dry-ice-applications/>)

In 2015, a British scientist proposed using the significant deposits of dry ice from the Mars polar ice caps as the power source for electrical generators for future Mars colonies. (<https://theconversation.com/how-energy-from-dry-ice-could-power-human-colonies-on-mars-38250>)

Although this may sound far-fetched, since it would require a considerable amount of dry ice, NASA has recently (2015) discovered at Mars’ south pole an underground deposit of dry ice of approximately 3,000 cubic miles, that augments the sizeable amounts already known to be on the surfaces of both poles. (<https://www.nasa.gov/mission_pages/MRO/news/mro20110421.html>)

**Safety precautions**

“Cool Science Experiments with Dry Ice” from Owl Education includes a good, basic list of precautions about how to use dry ice safely in the classroom. Several dry ice demonstrations, including “dry ice with dish soap” and “screaming metal,” are also located on this site. (<https://owlcation.com/stem/dryiceexperiment>)

Continental Carbonic, a manufacturer and distributor of dry ice, provides basic instructions for handling, storage, and ventilation for dry ice on their Web page. A click at the bottom of the page produces a two-page safety brochure in both English and Spanish. (<https://www.continentalcarbonic.com/dry-ice-safety.html>)

# About the Guide

Teacher’s Guide team leader William Bleam and editors Pamela Diaz, Steve Long and Barbara Sitzman created the Teacher’s Guide article material.

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Articles from past issues of *ChemMatters* and related Teacher’s Guides can be accessed from a DVD that is available from the American Chemical Society for $42. The DVD contains the entire 30-year publication of *ChemMatters* issues, from February 1983 to April 2013, along with all the related Teacher’s Guides since they were first created in the February 1990 issue of *ChemMatters*.

The DVD also includes Article, Title, and Keyword Indexes that cover all issues from February 1983 to April 2013. A search function (similar to a Google search of keywords) is also available on the DVD.

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