

**December 2016/January 2017 Teacher's Guide for**

***Piping Hot, Ice-Cold… Thanks to Chemistry***

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# About the Guide

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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 with 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.

The *ChemMatters* DVD can be purchased by calling 1-800-227-5558. Purchase information can also be found online at <http://tinyurl.com/o37s9x2>.

# Student Questions

**Piping Hot, Ice Cold … Thanks to Chemistry!**

* + 1. What was the primary purpose of the first widely used self-heating cans?
    2. What produces heat in a flameless ration heater?
    3. In a chemical reaction, how is energy involved in breaking and in making chemical bonds?
    4. a) When you hold an ice cube in your hand, why does your hand feel cold?

b) How is heat energy used to melt the ice?

* + 1. Why is it important to avoid using a flameless ration heater near an open flame?
    2. Why does the HeatGenie™ exothermic chemical reaction occur rapidly?
    3. In the HeatGenie™ chemical reaction:

a) If each silicon atom gains 4 electrons and there are 3 silicon atoms, how many electrons are gained? Show your work.

b) If each aluminum atom loses 3 electrons and there are 4 aluminum atoms, how many electrons are lost? Show your work.

* + 1. In an endothermic reaction like the self-cooling can, in which direction does the heat energy flow to cool the surroundings?
    2. How does the release of carbon dioxide cool a beverage can?
    3. What role did a military cook play in the discovery of self-cooling food?

# Answers to Student Questions

**(taken from the article)**

**Piping Hot, Ice Cold … Thanks to Chemistry!**

1. **What was the primary purpose of the first widely used self-heating cans?**

*The primary purpose of the first widely used self-heating cans was to provide hot meals for World War II soldiers.*

1. **What produces heat in a flameless ration heater?**

*Heat is produced in a flameless ration heater by the exothermic chemical reaction that occurs when water is added to a pouch containing magnesium metal, iron and table salt.*

1. **In a chemical reaction, how is energy involved in breaking and in making chemical bonds?**

*In a chemical reaction, energy is required to break the bonds of the reactants and energy is released as new bonds are formed in the products.*

1. **a) When you hold an ice cube in your hand, why does your hand feel cold?**

*When you hold an ice cube in your hand, the heat energy from your hand flows into the ice cube leaving your hand feeling cold.*

**b) How is heat energy used to melt the ice?**

*Heat energy is used to melt the ice by breaking hydrogen bonds, the intermolecular forces that hold water molecules together as ice.*

1. **Why is it important to avoid using a flameless ration heater near an open flame?**

*It is important to avoid using a flameless ration heater near an open flame because a product of the exothermic chemical reaction, hydrogen gas (H2), is flammable.*

1. **Why does the HeatGenie™ exothermic chemical reaction occur rapidly?**

*The HeatGenie*™ *exothermic chemical reaction is rapid because the oxygen is supplied internally by silicon dioxide, the oxidizer, rather than oxygen coming from outside air.*

1. **In the HeatGenie™ chemical reaction:**
2. **If there are 3 silicon atoms and each silicon atom gains 4 electrons, how many electrons are gained? Show your work.**
3. **If there are 4 aluminum atoms and each aluminum atom loses 3 electrons, how many electrons are lost? Show your work.**

*The above equations may be more than students can be expected to provide, but student answers should at least show the same number (12) electrons lost and gained in the balanced oxidation-reduction (redox) reaction.*

1. **In an endothermic reaction like the self-cooling can, in which direction does the heat energy flow to cool the surroundings?**

*In an endothermic reaction the heat energy flows from the surroundings (the beverage) to the system. This leaves the surroundings with less energy so they are cooler.*

1. **How does the release of carbon dioxide cool a beverage can?**

*When released, carbon dioxide expands and pushes through the small opening by breaking the attractive forces (intermolecular forces) between the molecules. The energy for expansion comes from the surroundings (the beverage liquid) leaving the beverage cooler.*

1. **What role did a military cook play in the discovery of self-cooling food?**

*During the Vietnam War, a military cook used carbon dioxide fire extinguishers to quickly cool beverage cans for military officers.*

# Anticipation Guide

Anticipation guides help 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.

**Directions:**  *Before reading*, 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. Self-heating cans have been used since the 1800s. |
|  |  | 1. Flameless ration heaters developed by the military contains magnesium, iron, and sodium chloride. |
|  |  | 1. Bond breaking usually releases energy. |
|  |  | 1. Exothermic reactions release more energy than they absorb. |
|  |  | 1. In an oxidation-reduction (redox) reaction, electrons lost by one substance are gained by another. |
|  |  | 1. When an atom gains an electron, it is oxidized. |
|  |  | 1. Self-cooling cans were developed before self-heating cans. |
|  |  | 1. Self-cooling cans contain carbon dioxide gas. |
|  |  | 1. When gas is released through a small opening, the gas container becomes hot. |
|  |  | 1. Separating molecules requires an input of energy. |

# Reading Strategies

These graphic organizers are provided to help students locate and analyze information from the articles. 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 articles. The use of bullets helps them do this. If you use these reading and writing strategies 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 |

***Teaching Strategies:***

1. 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.

1. 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.

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

* Chemical reactions
* Redox reactions
* Solubility
* Equilibrium
* Le Chatelier’s Principle
* Vitrification
* Hydrogen bonding
* Molecular structures
* Personal and community health
* Rare-earth metals
* Endothermic and exothermic reactions
* Conservation of energy

1. Some of the articles in this issue provide opportunities for students to consider how understanding chemistry can help them make informed choices as citizens and consumers.
2. Engagement suggestions:

* Prior to giving students the article “The Flint Water Crisis: What’s Really Going On?” use a Think-Pair-Share to find out what students already know about the Flint water crisis. During reading, students will reflect on what they thought and how the evidence from the article supports their original ideas (or not).
* Avoid telling students the title of the article, “No Smartphones, No TV, No Computers: Life without Rare-Earth Metals.” Instead, ask them where in their everyday lives they would find rare-earth metals and why they are used. After a short class discussion, give them the article to read.

1. 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 Background Information in the *ChemMatters* Teacher’s Guide has suggestions for further research and activities.

**Directions**: As you read the article, complete the graphic organizer below to describe what you learned about how chemistry can help us heat or cool our food.

|  |  |  |
| --- | --- | --- |
|  | **Chemicals involved** | **Endothermic or Exothermic Reaction? Explain.** |
| **Flameless ration heater** |  |  |
| **HeatGenie** |  |  |
| **Self-Cooling can** |  |  |

**Summary**: On the back of this sheet, draw a Venn diagram to compare and contrast exothermic and endothermic reactions.

# Connections to Chemistry Concepts

**(for correlation to course curriculum)**

1. **Thermodynamics**—As your students study heat energy, consider using some of the many examples provided in the Rohrig article to show how and why heat flows from hot to cold. The self-cooling beverage can provides an excellent example of how the knowledge of thermodynamic principles applied to intermolecular attractions can be used to produce cooling effects through evaporation.
2. **Hess’ Law**—During the study of heat energy in chemical bonds, Figure 1 in the Rohrig article shows the directions of heat flow in exothermic and endothermic reactions. When students use Hess’ Law to calculate enthalpy changes (ΔH), the sample calculation for the dissolution of calcium chloride in water shown in this Teacher’s Guide section “Energy from exothermic physical changes─Heat energy from the dissolving process” may present a helpful way to make this topic more relevant, especially if students are familiar with salt used on icy roads.
3. **Exothermic/Endothermic**—A common misconception of chemistry students is the idea that bond breaking releases energy (such as when high energy storage ATP releases energy to form ADP). This article dispels this myth well, by explaining that breaking a bond always requires energy and forming new bonds always releases energy.
4. **Chemical reactions**—When students study chemical reactions, use the examples given for self-heating containers and include a discussion of the improvements made by chemists and engineers in safety and time required to produce a hot meal.
5. **Physical changes**—The physical change that occurs when a solid dissolves in a liquid can be either exothermic or endothermic. The change in heat energy can be used for either self-heating (exothermic) or self-cooling (endothermic) containers.
6. **Heat of dissolution**—The heat involved when solids dissolve can be used for self-heating (exothermic) or self-cooling (endothermic) containers.
7. **Intermolecular attractions**—When studying attractions between molecules and atoms, use examples of how the breaking intermolecular attractions between water molecules (e.g., flameless ration heater) and the expanding of carbon dioxide molecules (self-cooling beverage can) both require heat energy.
8. **Oxidation and reduction (redox)**—Redox is well explained in the exothermic chemical reaction that provides energy for the HeatGenie™. This presents a good way to illustrate that this process is involved in real products, not just equations in the textbook. Many self-heating technologies rely upon oxidation and reduction chemical reactions. For example, the redox reaction between an active metal and the salt of a less active metal is always exothermic.
9. **Catalysis and activation energy**—As an extension of the article content, when you show students how to graph the process of a chemical reaction, ask them to add a line below the curve to compare the energy involved in a catalyzed process. Emphasize that the potential energy of the reactants and the products remains the same, but the path is easier so the reaction is faster when the activation energy is reduced by a catalyst. Note that a catalyst is injected into the reactants of a thermite reaction to overcome the high activation energy (provide a new reaction that has a lower curve). For reference, see the Background Information section, under “Energy from exothermic chemical reactions─Self-propagating high-temperature synthesis (SHS)” section.
10. **Single replacement chemical reactions and the reactivity series**—Some self-heating cans are powered by the energy released when the more active zinc replaces less active copper in powdered copper sulfate. Students can check the relative reactivities on a metal reactivity table or in lab.
11. **Neutralization**—We don’t usually focus on this in the acid-base section of our curriculum, but reactions between an acid and a base are always exothermic. The stronger the reactants; the more energy released—but there may be safety concerns regarding these reactions. In addition, neutralization reactions may produce less heat energy than other types of chemical reactions.

# Possible Student Misconceptions

**(to aid teacher in addressing misconceptions)**

1. **“When carbon dioxide escapes from the self-cooling can, the rapid decrease in pressure can cause the molecules to fly apart into carbon and oxygen atoms.”** *During vaporization, only the intermolecular attractions between carbon dioxide molecules are broken. The molecular bonds (covalent bonds) within the molecule are not affected.*
2. **“I’m confused. In biology we learned that breaking ATP bonds releases energy.”** *This is a common student misconception, coming from biology classes. Breaking ATP bonds requires energy; it’s the forming of the ADP bonds (in the product) that releases energy. This release of energy as ADP forms is greater than the energy required to break the bonds in ATP. The overall energy change results in a loss of energy (exothermic).*
3. **“Carbon dioxide sublimes. This means that it can only be solid, as dry ice, or a gas. It cannot be put into a fire extinguisher.”** *At low temperatures and high pressures carbon dioxide can be liquefied for fire extinguishers. [Note: A triple point graph will show this.]*
4. **“Early ration cans must have worked by endothermic reactions, because you had to use a cigarette flame to light the wick.”** *Although the cigarette and the burning wick add energy to activate the reaction, heat evolves from the reaction because the energy used to break the chemical bonds in the fuel (endothermic) is less than the energy released when the new bonds form. To determine whether a reaction is exothermic or endothermic you must look at the overall change in energy during the reaction.*
5. **“When water evaporates, it expands to fill the space as the molecules get larger.”** *When water evaporates, the distance between the water molecules expands (increases). The size of each molecule remains the same.*
6. **“In an exothermic reaction, energy is lost. This can be measured by the loss of weight during the reaction.”** *Energy is the ability to do work; it is not a substance with mass. Heat energy can be measured in a self-heating can by its effect on the temperature as it flows from the hot chemical reaction to the surroundings (the colder beverage). Any loss of weight would probably mean that a gas was produced that left the system and became part of the surroundings.*

# Anticipating Student Questions

**(answers to questions students might ask in class)**

1. **“Carbon dioxide molecules are nonpolar, how can they be attracted to each other?”** *Since electrons are always continuously moving around in molecules, temporary dipoles (electrical differences) form, producing weak intermolecular forces of attraction between nonpolar molecules like carbon dioxide. This electrostatic attraction weakly holds carbon dioxide molecules together in the solid state (dry ice).*
2. **“How can water molecules change from a liquid to a vapor when the temperature is less than the boiling point?”** *While molecules in a pure liquid have the same* ***average*** *kinetic energy, not all of the molecules in a liquid have the same kinetic energy. When a molecule gains enough kinetic energy at a temperature below the boiling point, it escapes (evaporates) the liquid as a gas. At the boiling point, all molecules in the liquid have sufficient kinetic energy to change to the gaseous state.*
3. **“Is it a chemical change when a salt dissolves in water because energy is released to heat a can?”** *Heat is a form of energy, not a substance. When a salt dissolves in water, the salt and water (the physical substances) are still present and no new substances are formed. This is a physical, not a chemical change.*
4. **“I am confused! In biology we learned that breaking ATP bonds to form ADP releases energy. Why does the article say that breaking bonds takes in energy?”**

[Editors’ note: this question duplicates Possible Student Misconception # 2 above, but we feel very strongly that there is a need to debunk this myth that seems to originate with biology classes.]*To pull apart molecular bonds always requires energy. In the breakdown of ATP to ADP, the new bonds that form in ADP have less energy. The difference in energy between the high energy bonds of ATP and the lower energy bonds of ADP is released as energy to drive metabolic processes in the body.*

1. **“I have sensitive skin. Should I be concerned that a self-heating can could burn me?”** *This might be a problem if you were opening an early-type can, but the current models have foam insulators for protection, and some very new models have a special temperature regulator to keep the beverage at “just” drinking temperature.*
2. **“Why is gas passing through a small opening named the Joule-Thomson effect?”** *This self-cooling process was named for James Prescott Joule whose work led to development of the “Law of Conservation of Energy”. He worked with William Thomson, aka Lord Kelvin, who determined the value for absolute zero on the Kelvin scale.*
3. *“***How is the HeatGenie™ an improvement over the flameless ration heater?”**

*HeatGenie*™ *is an improvement over the flameless ration heater because it is quicker and safer. The flameless ration heater requires 10–12 minutes to heat the food and releases flammable hydrogen gas (H2), while the HeatGenie™ heats food quickly and is safer because the chemical reaction does not produce H2 and it occurs in a separate canister thus reducing the chance of burning.*

1. ***“*Why is the surface of a balloon cool immediately after you blow it up?”***The surface of a balloon cools as you blow it up by forcing your breath through a small opening in the neck of the balloon. Energy is required to break the (intermolecular) attractive forces between air molecules, allowing them to pass through the small opening. This energy comes from your warm breath, leaving it cooler as it enters the balloon. Note: For students who are unaware of this phenomenon, ask them to demonstrate—using non-latex balloons.*
2. **“Since carbon dioxide is a gas, how can it be put into a fire extinguisher?”** *At low temperatures and high pressures carbon dioxide can be liquefied and poured into fire extinguishers.*

# Activities

**Labs and Demos**

1. **Demonstrate “Cooking an Egg Chemistry Style”:** This YouTube video (3:26) shows how to use an aluminum pan of calcium oxide and water to create enough heat to fry an egg in a second pan nestled above the reaction. (<https://www.youtube.com/watch?v=Y_FaU__XhPE>) A FlinnFax explains the same demonstration and includes the chemistry involved using ΔH calculations. (<https://www.flinnsci.com/media/522046/cf0203.00.pdf>)
2. **Demonstrate using a fire extinguisher to chill soda:** In this YouTube video (1:45), a fireman uses an out of date fire extinguisher to chill a bucket of soda cans. The extinguisher covers the cans and splatters the floor with dry ice before the fireman drinks the cold beverage. Perhaps your local fire station would do this demo for your students. Be certain to use a carbon dioxide fire extinguisher. Note that many school fire extinguishers emit monoammonium phosphate, colored yellow to distinguish it from other white powders. This chemical is not toxic but it may cause minor skin irritations and it will not chill a can. (<https://www.youtube.com/watch?v=sQOLeAfWbPA>)
3. **Metal reactivities lab:** This experiment will demonstrate the reactivities of various metals, including the replacement of copper by zinc, one of the energy-yielding reactions used in self-heating cans.(<https://www.chemedx.org/system/files/relative_reactivities_of_metals_ngss_lab.pdf>)
4. **Lab strategies: “5E Metal reactivities lab” (17 slides):** Prezi presentation software is used to show the 5E model applied to the metal reactivities lab. The presentation includes analysis of sample student papers. (<https://prezi.com/441osa9si-x7/5e-metal-activity-series/>)
5. **The thermite reaction demonstration:** On his Web site, David Katz (Pima College, Pima, AZ) shows how to demonstrate this reaction safely. He suggests doing it outdoors with a safety shield between the reaction and your students. Check with your local school or district since this demonstration is frequently banned for safety reasons. Excellent photos of each stage of the reaction are shown along with lab instructions. The video section of this Teacher’s Guide lists a YouTube video of the thermite reaction. (<http://www.chymist.com/Thermite%20reaction.pdf>)
6. **Lab:** “**Reaction in a Bag”:** This is a Flinn lab done in a Ziploc bag. Students are given labeled containers of four chemicals: calcium chloride, water, sodium bicarbonate and phenol red. They mix various combinations of these and record the results. This includes dissolving calcium chloride in water. Student handouts including data tables and questions, and a Teacher’s Guide with answers is provided. This could provide the opportunity for an experimental design if data tables and specific instructions are not given to students. (<https://www.flinnsci.com/media/621024/91419.pdf>)
7. **3 lab ideas: Heating and cooling with chemical and physical changes:** Three laboratory exercises were written by German teachers for 14 year-old chemistry students: “The heat is on: heating food and drinks with chemical energy” is published in *Science in School*, a European journal for science teachers. The first lab uses self-heating food packaging available from Amazon UK. This packaging seems to be sold only with meals in the U.S. The explanation of the chemistry involved in this lab can be used as an introduction to the second lab that uses anhydrous calcium chloride as the energy source. In the third lab, students also use anhydrous calcium chloride, but they add sodium chloride and mix with ice to measure the cooling effect. This would be a nice addition to the study of colligative properties. All labs are accompanied by a detailed discussion of the relevant chemical concepts; pictures and student data tables are included. English translations are given. Although heating packages are not readily available in the United States, the second and third labs require the use of common high school stockroom chemicals. (<http://www.scienceinschool.org/2011/issue18/lncu>)
8. **Laboratory investigation: self-heating food products:** Students calculate the heat produced by self-heating food reactions and dissolving processes. Only the abstract is available at this Web site. *Journal of Chemical Education* subscribers have free access to the article. (<http://pubs.acs.org/doi/pdfplus/10.1021/ed086p1277>)
9. **Laboratory investigation: flameless heaters:** In this FlinnFax lab activity, students analyze the contents of a flameless ration heater. As with other FlinnFaxes, concepts are covered; materials needed are listed; and safety precautions and procedures are given. Analysis for the teacher is provided. (<https://www.flinnsci.com/media/620738/91305.pdf>)
10. **Laboratory investigation: zinc/copper sulfate reaction:** In “Heat of reaction: the zinc/copper(II) sulfate(VI) reaction” students will measure and graph the change in temperature as a function of the volume of copper sulfate solution reacted with excess metallic zinc. This lab is designed for high school students. (<http://www.cleapss.org.uk/attachments/article/0/Draft%20-%2010_Heat_of_reaction_Bob_ks.pdf?Conferences/ASE%202013/>)

This lab activity is the same chemical reaction as 10, above, but written as a complete lab designed for IB Chemistry. (<https://chemicalparadigms.wikispaces.com/file/view/Determining+enthalpy+change+zinc+and+copper+sulphate_wiki.pdf>)

1. **Demonstration: energy of crystallization:** Supersaturated sodium acetate solution is used in a FlinnFax demonstration. With a slight heating and cooling, the solution can be reused for the next class. (<https://www.flinnsci.com/media/620509/91215.pdf>)
2. **Laboratory Activity: heat of dissolution of sodium thiosulfate pentahydrate:** In this lab, students measure and calculate the energy absorbed during an endothermic dissolving process (+ΔH). An addendum to the lab is measuring the heat of dissolution of calcium chloride, an exothermic, (–ΔH) process. (<http://teachers.sduhsd.net/jnewman/Gen%20Chem%20labs/Heat%20of%20Solution%20Lab.pdf>**Quick introduction: exothermic/endothermic:** Begin the study of thermodynamics by giving students small test tubes and access to calcium chloride dihydrate (exothermic) and ammonium chloride (endothermic). Ask students to dissolve a small scoop of the salt in a small amount of water and observe. The temperature changes provide the opportunity to discuss energy of hydration and their use in hot and cold packs. (Other salts can be used and, in a cold climate, substitute “road salt”.).
3. **Demonstration: spontaneous endothermic reaction:** I use this demonstration for all my classes from AP to general high school chemistry. These directions are complete and even include a short video (1:17) of the process: “Spontaneous Endothermic Reaction”. (<http://depts.washington.edu/chem/facilserv/lecturedemo/EndothermicReaction-UWDept.ofChemistry.html>)
4. **Demonstration─temperature of balloon surface during inflation:** Ask students to blow up non-latex balloons and note that the temperature changes during the process. This is the technology behind some self-cooling cans. The surface of a balloon cools as you blow it up by forcing your breath through a small opening in the neck of the balloon. Energy is required to break the (intermolecular) attractive forces between air molecules allowing them to pass through the small opening. This energy comes from your warm breath, leaving it cooler as it enters the balloon.

**Media**

1. **YouTube video (2:04): Self-heating can construction:** This video could be used as an introduction to the study of self-heating containers. The step-by-step process of constructing an OnTech company self-heating can of “Hillside latte” is shown and explained. Heat energy is supplied by a calcium oxide reaction with water. The water is foil-sealed in a separate container that can be easily punctured. The coffee surrounds the heat source. (<https://www.youtube.com/watch?v=pAquMQT0Nkg>)
2. **YouTube video (23:34): “Galvanic Cells (Voltaic Cells)”:** This video provides a complete explanation of the Cu/Zn oxidation/reduction process. Students are shown how to set up a cell using two beakers of solutions, a wire and a salt bridge. Small cards labeled with the ions and atoms involved are moved in to show the chemical reaction and the movement of electrons to produce electrical energy. Finally the program shows how to write redox   
   half-reactions. This video can be used to enhance understanding of redox at the particle level. Viewing might follow a similar classroom chemical lab activity. **(**<https://www.youtube.com/watch?v=7b34XYgADlM>)
3. **YouTube video (1:54): “Cu-Zn electrochemical animation”:** This is short, animated and excellent! You might consider showing it twice, providing an opportunity for students to ask questions between showings. Water molecules, copper and zinc atoms and molecules are used to show what happens in the two beakers and at the anode and cathode. The need for a salt bridge is clearly animated. (<https://www.youtube.com/watch?v=J1ljxodF9_g>)
4. **YouTube video (1:24): HeatGenie**™ **technology:** This short video shows and explains the construction of a self-heating HeatGenie™ can. (<https://www.youtube.com/watch?v=yb8WZM3T_uc>)
5. **Brief animation of CaldoCaldo:** If you hover over the “How to Use” on this site, you will see instructions for use in a quick animation.(<http://r-and-r.ws/calcaldo.html>)
6. **YouTube video (0:56) from eCoupled electronics:** This video of the Fulton Innovations Company presentation at the January 2011 Consumer Electronics Show (CES) in Las Vegas shows and explains the activation of a self-heating can of chicken noodle soup with wireless power. (<https://www.youtube.com/watch?v=TGNiqkxkn4Q>)

**YouTube video (4:34): Interactive and intelligent food packaging:** A Fulton Innovations booth at the 2011 Consumer Electronics Show in Las Vegas demonstrates eCoupled technology used to remotely “self-heat” a can of soup wirelessly. (<https://www.youtube.com/watch?v=MpKukF48Tac>)

1. **YouTube video (1:03) thermite reaction:** A thermite-like reaction between iron(III) oxide and calcium silicide served as the heating element for World War II self-heating cans produced by the Heinz company. This video shows the reaction between iron(III) oxide and aluminum. (<https://www.youtube.com/watch?v=818YAUHrE9w>)
2. **YouTube video (2:39): HeatGenie**™ **Coffee Demonstration:** This video shows how the HeatGenie™ process heats a cup of coffee in two minutes, using solid fuel.(<https://www.youtube.com/watch?v=Q2r5qa2P45I>)
3. **YouTube video (3.55): self-cooling technology using water evaporation:** “Tempra IC Can Self-Chilling Can” video shows and explains the Tempra technology that uses water evaporation in a vacuum to chill a can of beer. (<https://www.youtube.com/watch?v=Qof_KAirUh0>)

**Lessons and Lesson Plans**

1. **KhanAcademy videos: “redox reactions” and “electrochemistry lessons”:** There are many lessons, complete with skill checks that cover student redox study at the general, honors and advanced placement levels of chemistry. First, click on the arrow next to the title to bring up each video. Next, note that under the video screen there are places to “ask a question” and open the video “transcript”. When you click on the screen arrow to begin the video, the time is shown. These can be studied individually in class, by student groups, or assigned as homework during the study of oxidation and reduction. This URL takes you directly to the KhanAcademy redox videos where the time for each is given, along with a brief description of its contents. (<https://www.khanacademy.org/science/chemistry/oxidation-reduction/redox-oxidation-reduction/v/introduction-to-oxidation-and-reduction>)
2. **Redox lesson using film clips:** Film clips provide the opportunity for using real-world examples of oxidation and reduction in “Oxidation-Reduction Reactions (redox), Using a Film Clips from Daylight and YouTube”. (<http://www.teachwithmovies.org/snippets/sn-sci-chem-redox-daylight.html>)
3. **Lesson on potential energy diagrams:** This is a complete lesson with explanations and many diagrams designed as a lecture presentation. (<http://www.ck12.org/user:sarah_bergman/book/DCISM-Chemistry-2012-2013/section/49.0/>)

**Projects and Extension Activities**

1. **Project: An advertisement and engineering design:** Ask students or student groups to use their knowledge of the self-heating or self-cooling process to develop an advertisement for a self-heating or self-cooling product that they have designed. To appeal to consumers, their product should be cost effective, attractive, heat or cool quickly, address the environmental impact (recyclable materials, greenhouse-friendly gases), etc. The project could be introduced by videos like these for HeatGenie™ (self-heating) and/or West Coast Chill (self-cooling) cans. HeatGenie™ video (1:14): (<http://www.heatgenie.com/how-it-works>); West Coast Chill video (3:54): (<https://www.youtube.com/watch?v=c0QsXNU0KY4>)
2. **Research Project/Presentation/Debate: HFCs:** Student groups can use the five questions in the article below as a springboard for a group presentation to the class centered on the effect of HFCs on the atmosphere and the increase in the greenhouse effect. In recognition of the signing (October 2016), of the HFC amendment to the International Montreal Protocol, *The Wall Street Journal* highlights five things that you should know about HFCs. The article contains five paragraphs: (1) What are HFCs? (2) Why are they dangerous? (3) Why are they relevant now? (4) If they are so bad, why were they used at all? (5) What are the alternatives to HFCs? (<http://blogs.wsj.com/briefly/2016/10/16/5-things-to-know-about-hfcs/>)

# References

**(non-Web-based information sources)**

**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 directly under the *ChemMattersonline* 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, *“ChemMattersonline”*.**



***30* Years of *ChemMatters !***

Available Now!

This article describes construction and chemistry of the hot and cold packs used for sports injuries. It includes a description of the hydration of salts, including nice diagrams showing water molecules attracting both the positive and the negative ions of the salt. (Marsella, G. Hot & Cold Packs. *ChemMatters,* 1987, *5* (1), pp 7–11)

The construction and chemistry of Military Meals Ready to Eat (MREs) are illustrated and discussed. The meals shown were prepared for the U.S. Army fighting in Operation Desert Storm. (Scott, D.; Meadows, R. Hot Meals. *ChemMatters,* 1992, *10* (1), pp 12–13)

Some history, uses, and the chemistry of the thermite reaction is discussed in this article. Nice photos of explosions are included as well. (Tinnesand, M. Mighty Thermite. *ChemMatters,* 2002, *20* (1). pp 14–15)

The technology involved in the function of a heat pump described in this article is similar to the self-cooling process used in Tempra technology to cool a can by the expansion of a gas (water). (Becker, B. Question from the Classroom. *ChemMatters,* 2006, *24* (3), p 2)

Students may find this article on race cars interesting and it may present a good way to emphasize the energy behind gas expansion. The exothermicity of the expansion of gases pushes the piston in NASCAR cars. (Rohrig, B. The Science of NASCAR. *ChemMatters,* 2007, *25* (1), pp 4–7)

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Matthews, G. Demonstrations of spontaneous endothermic reactions. *Journal of Chemical Education,* 1966, 43 (9), p 476. This article describes high school demonstrations of spontaneous endothermic reactions involving hydrated metal chlorides and thionyl chloride. (Note: *Journal of Chemical Education* articles are available free to subscribers only.) (<http://pubs.acs.org/doi/abs/10.1021/ed043p476>)

# Web Sites for Additional Information

**(Web-based information sources)**

**Sites on history of self-heating cans**

This site contains additional information about the first self-heating cans and contains a link to more information on a Wikipedia site. (<http://pages.rediff.com/self-heating-can/516130>)

**Sites on Puck litigation**

This article, “Too Hot to Handle: Problems Boil Over for Celebrity Chef’s Self-Heating Lattes” provides details of the complicated legal process of assigning the blame for the defective cans to various entities involved. These include Puck’s branding corporation, OnTech designers, subcontracted can suppliers, supermarkets and Puck. (<http://www.bevnet.com/news/2006/04-28-2006-wolfgang_puck_self_heating_cans.asp>)

The *New York Times,* May 2, 2006 edition, ran this column, “Self- Heating Latte Cans Bring out Lawyers”. Additional details are provided with a discussion of the lawsuits that resulted from the problems with Puck’s lattes. (<http://www.nytimes.com/2006/05/02/business/02puck.html?_r=0>)

**Sites on technology**

Smithers Rapra analytical and chemical laboratories provides testing, analysis and calibration services. This publication (January 2, 2011), Section 2.1.11, page 40 “Self-heating and Self-cooling Cans (Metallic and Plastic Chambers)” contains nice diagrams of self-heating cans. There is interesting discussion on problems with can construction such as leaking seals and bleeding label inks, as well as the concern for food safety. (<http://www.smithersrapra.com/SmithersRapra/media/Sample-Chapters/Food-Packaging-and-Food-Alterations.pdf>)

This Web site describes the Thermotic technology behind the Nestle self-heating coffee can. Details of construction and materials, as well as information about relationships between the involved companies are discussed. (<http://www.packworld.com/package-component/label/nestl%C3%A9-tests-award-winning-can>)

This innovations report, “Self-Heating Cup, Or Heat In Any Weather”, the Bargan Production Group, a Moscow company, discusses how they approached the task of designing a self-heating container. In the process of producing and patenting this device, they identified the factors to consider when using a zinc/copper sulfate reaction as their energy source.

As the Russian group works on this redox reaction, they have experimented with different concentrations of the chemicals, as well as particle size. Their product requires nine minutes to reach 95 0C (203 0F) and the container plus water weighs 300 grams, making it inconvenient for hiking or backpacking. (<http://www.innovations-report.com/html/reports/life-sciences/report-66411.html>)

Recent self-heating cans are constructed with drawn and ironed (D&I) technology. D&I construction of cans is both explained and pictured in 15 steps on this UK Metal Packaging Manufacturers Association website. (<http://www.mpma.org.uk/pages/data/2piecedrinkscan.pdf>)

**Sites on eCoupled Technology**

This site provides additional information about eCoupled wireless technology with an emphasis on power efficiency. Wireless provides a much more efficient use of electrical power than the traditional kitchen with wired plug-in appliances. (<http://metro.co.uk/2011/03/02/ecoupled-technology-brings-kitchen-appliances-powered-without-wires-642121/>)

**Sites on self-heating baby food**

This information is from the Aestech website and offers a thorough explanation of their new self-heating technology, especially designed for baby formula bottles and baby food containers. Several pictures are used to describe the construction of their product. (<https://bestinpackaging.com/2013/02/21/self-heating-packaging-for-baby-formula/>)

**Sites on the E.U. Food Standards Agency**

The E.U. Food Standards Agency Web site lists the E-Codes and separates types of food additives. Calcium oxide and calcium hydroxide (used in self-heating baby food containers are listed in the “others” category and are described as:

Acid, acidity regulators, anti-caking agents, anti-foaming agents, bulking agents, carriers and carrier solvents, emulsifying salts, firming agents, flavour enhancers, flour treatment agents, foaming agents, glazing agents, humectants, modified starches, packaging gases, propellants, raising agents and sequestrants.

(<https://www.food.gov.uk/science/additives/enumberlist>)

**Sites on flameless ration heaters (FRH)**

This patent application describes the magnesium oxidation process that provides energy for military type flameless ration heaters. The heater described in this patent uses a powdered magnesium-iron alloy composed of 95% magnesium and 5% iron by weight. In this unit, when 7.5 grams of this alloy reacts with 30 mL of water, the temperature of a 230 gram meal rises by 37.8 0C (68 0F) in 10 minutes. A list of related U.S. patents is also provided. (<https://www.google.com/patents/US5611329>)

This patent lists the steps involved in generating heat from the reaction between magnesium dust and water. (<https://www.google.com/patents/US4017414>)

Detailed instructions and diagrams are provided for the use and activation of a flameless ration heater. (<http://www.mreinfo.com/mres/flameless-ration-heater/>)

The patent document on this URL provides detailed information on the technology and chemistry of FRH. (<https://www.google.com/patents/US5611329>)

**Sites on self-heating can technologies**

This patent was submitted for a self-heating can that used the energy released when anhydrous calcium chloride is dissolved in water. The patent includes diagrams, descriptions and data obtained from beverage testing. (<http://www.google.com/patents/US5628304>)

A *New Atlas* “outdoors” column describes “HotCan” technology and the use of the calcium oxide and water reaction to supply heat energy. (<http://newatlas.com/hot-can-self-heating-beverages/25646/>)

The Can Maker site discusses the business end of self-heating cans, including the worldwide launch and production of “HotCan” and other brands. (<http://www.canmaker.com/online/malaysian-self-heating-drinks-cans-for-the-us/>)

**Sites on chemistry**

An excellent and very thorough description of the exothermic process of calcium chloride dissolving in water and the use of the enthalpies of solution and hydration to calculate the energy produced during this process is given here: <http://www.chemguide.co.uk/physical/energetics/solution.html>.

*Wikipedia* gives a complete description of the preparation of quicklime, the modern uses and its use as a weapon in 80 BC. (<https://en.wikipedia.org/wiki/Calcium_oxide>)

Using graphed laboratory data, the calculation of the enthalpy of a reaction between zinc and copper sulfate solution is shown. (<http://www.academia.edu/3516201/Determining_the_Enthalpy_Change_for_a_Reaction_of_Copper_Sulphate_and_Zinc_IB_Chemistry_HL_Internal_Assessment>)

These are two lab examinations for determining the enthalpy for a reaction between copper sulfate and zinc. They are based on labs that students have done before. This site goes over sample calculations and includes a graph for the teacher. (<https://www.scribd.com/doc/30755429/Heat-Determining-Enthalpy-Change-Lab-Assessment-Part-I-Part-2>)

On the HeatGenie™ site, the section on “How it Works” discusses the chemistry, as well as the technology of construction of this self-heating can. (<http://static1.squarespace.com/static/57572f2d59827e49522c994e/t/57b632e120099ebf80b298af/1471558371042/HTG_Specs_and_Details.pdf>)

**Sites on** **the thermite reaction**

This Rutgers site shows the preparation and demonstration of the thermite reaction. This demonstration is banned from most high school classrooms and laboratories, but can be described and shown as a video (see the section on videos in the activities section, above). This site contains a short video, but the quality is poor. (<http://cldfacility.rutgers.edu/content/thermite-reaction>)

**Sites on** **best packaging**

The 10 best packaging materials are described on this site. These include packaging used for candy and other types of edible bars. (<https://boschpackagingblogna.com/2013/06/28/top-10-packaging-materials-films-used-on-horizontal-flow-wrappers/>)

Kraft’s sustainability program highlighting greener packaging is discussed on their corporate website. (<http://www.greenerpackage.com/corporate_strategy/global_collaboration_enables_kraft_foods%E2%80%99_culture_change>)

**Sites on use and dangers of hydrofluorocarbons (HFCs)**

The dangers and regulations of HFCs including HFC-134a (1,1,1,2-tetrafluoroethane) and HFC-152a (1,1-difluoroethane) are discussed in relationship to their use as coolants for self-cooling cans as well as for other refrigerant purposes. (<http://www.motherjones.com/politics/1997/07/chill-can-packs-heat>)

The European Union was far ahead of the United States in banning the use of HFCs in “environmentally safe” electric cars. The Chevy Volt, Nissan Leaf and Tesla Roadster all use HFC-134a as the refrigerant in their air conditioning systems. This article about the “dirty little secret” is a scathing report on the use of these greenhouse gases. (<https://insideclimatenews.org/news/20140319/electric-cars-have-dirty-little-secret>)

This paper “Climate Change regulation and the Next Generation of Refrigerants”, prepared by Ingersol Rand Inc., provides details including graphs on the worldwide use and regulation of fluorine refrigerants, including HFC 134a. (<http://www.trane.com/commercial/uploads/pdf/cso/138/refrigerants.pdf>)

This is *The Washington Post* announcement of the October 2016 ban on HFCs. It also provides the history and teachable details, including scientific evidence on the dangers of these ozone destroying gases. (<https://www.washingtonpost.com/news/energy-environment/wp/2016/07/18/this-could-do-more-to-save-the-planet-this-year-than-any-other-action/?utm_term=.b097b450ee50>)

**Sites on** **self-cooling can technology**

**“**Mundane Utility/Real Life”, by *tv/tropes,* provides many interesting anecdotes about the ways that fire fighters, soldiers and pilots use equipment for “Not Intended Use” to heat, cook and cool their food. ([http://tvtropes.org/pmwiki/pmwiki.php/MundaneUtility/REALLIFE#](http://tvtropes.org/pmwiki/pmwiki.php/MundaneUtility/REALLIFE)!)

This *Wall Street Journal* article describes the twists and turns of working to find a solution to the production of a self-cooling can by Tempra Technology of Bradenton, Florida. The company has been involved in some questionable business practices. In addition, they are challenged by the technical problems inherent in the development of suitable and affordable packaging for a self-cooling can. (<http://www.wsj.com/articles/SB967764392506284518>)

This July 1997 *Mother Earth* article, ”Chill Can Packs Heat” discusses the problems, including the EPA concerns, about early self-cooling cans that use hydrofluorocarbon gas coolants. (<http://www.motherjones.com/politics/1997/07/chill-can-packs-heat>)

The *Orange County Register* announced that an Irvine company introduced a can which chills itself—developed and sold by an Irvine (Orange County), California firm. The history of Mitchell Joseph’s design, the technology involved, and the liquid contents of the West Coast Chill Can are described. (<http://www.ocregister.com/articles/chill-339616-joseph-beverage.html>)

In June 2012, *Popular Science Magazine* carried a column on Mitchell Joseph’s carbon dioxide gas expansion technology to cool a beverage can. This article has a nice picture of the West Coast Chill Can and suggests when and where it will be available for purchase. (<http://www.popsci.com/gadgets/article/2012-06/first-ever-self-chilling-can>)

This site explains the Tempra technology that uses the evaporation of water by a vacuum to chill the beverage in a self-cooling can. (<https://1o218khorweisean.wikispaces.com/Self+Cooling+Can>)

This patent for self-cooling containers was awarded to Empire Technology Development, LLC on November 20, 2014. It lists the enthalpies for the dissolution of many salts, exothermic and endothermic, bit without regard for their toxicity. (<http://www.google.tl/patents/WO2014185925A1?cl=en>)

**Sites on the EPA “Stratospheric Ozone Protection Award”**

Awards and other honors for Mitchell Joseph’s Chill-Can are described on their Web site. This includes the EPA Stratospheric award for ozone protection. (<http://chillcan.com/awards-and-accolades/>)

This document is a progress report from the EPA, highlighting the achievements honored by the Stratospheric Ozone Protection Award. (<https://www.epa.gov/sites/production/files/2015-07/documents/achievements_in_stratospheric_ozone_protection.pdf>)

**Sites on** **self-cooling for candy bars**

This reference suggests and describes several future technologies as possibilities for self-cooling films designed to prevent the melting of Kraft Milka chocolate bars. (<https://bestinpackaging.com/2010/10/19/self-cooling-chocolate-packaging-kraft-invites-people-to-join-them-in-research/>)