HASPI Medical Chemistry Lab 6b
Hot Pack Calorimetry
Teacher Information

Lab Overview

In this lab students measure the amount of energy released in the type of reaction that occurs in a hot pack. By linking this to the hydrated crystals lab in the fall where students heated Epsom salts (magnesium sulfate hydrate) until they lost all water, students are able to quantify the energy that they stored in their anhydrate pellet since the last lab occurred. To quantify this they must dissolve the anhydrate in water as well as the hydrate and use Hess' law to find the difference. The anhydrate dissolving in water is an exothermic reaction. The hydrate (Epsom salts) dissolving in water is a slightly endothermic reaction. Students will experience both types of reactions in this lab, and they will turn potential energy they put into their anhydrate in the previous lab back into kinetic energy which they can measure as the increase in water temperature.

Next Generation Science Standards

NGSS/Common Core State Standards
Students who demonstrate understanding can: **HS-PS1-4**: Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy. **HS-PS3-1:** Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known. **HS-PS3-3:** Design, build and refine a device that works within given constraints to convert one form of energy into another form of energy. **HS-PS3-4:** Plan and conduct an investigation to provide evidence that the transfer of thermal energy, when two components of different temperatures are combined within a closed system, results in a more uniform energy distribution among the components in the system (second law of thermodynamics). Medical Application: Hot packs and cold packs are chemical reactions that students will study.
Science and Engineering Practices
Developing and Using Models Develop a model based on evidence to illustrate the relationships between systems or between components of a system. **Using Mathematics and Computational Thinking** Create a computational model or simulation of a phenomenon, designed device, process, or system. **Constructing Explanations and Designing Solutions** Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. **Planning and Carrying Out Investigations** Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.
Disciplinary Core Ideas
PS1.A: Structure and Properties of Matter A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. **PS1.B: Chemical Reactions** Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.
Disciplinary Core Ideas (continued)

PS3.A: Definitions of Energy
Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms.
At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.
PS3.B: Conservation of Energy and Energy Transfer
Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system.
Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down).
Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior.
The availability of energy limits what can occur in any system.
PS3.D: Energy in Chemical Processes
Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.
ETS1.A: Defining and Delimiting an Engineering Problem
Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them(secondary).

Crosscutting Concepts

Energy and Matter
Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.
Systems and System Models
Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.

Connections to other DCIs in this grade-band: HS.PS1.A; HS.PS1.B; HS.PS2.B; HS.LS2.B; HS.ESS1.A; HS.ESS2.A; HS.ESS2.D; HS.ESS3.A; HS.PS3.A; HS.PS3.B; HS.PS3.D; HS.LS1.C

Articulation of DCIs across grade-bands: MS.PS1.A; MS.PS2.B; MS.PS3.A; MS.PS3.B; MS.PS3.C; MS.ESS2.A; MS.PS3.D ; MS.LS1.C

Common Core State Standards Connections: 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. *(HS-PS3-4)*
WHST.9-12.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. *(HS-PS3-3) ,(HS-PS3-4), (HS-PS3-5)*
WHST.11-12.8	Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. *(HS-PS3-4), (HS-PS3-5)*
WHST.9-12.9	Draw evidence from informational texts to support analysis, reflection, and research. *(HS-PS3-4), (HS-PS3-5)*
SL.11-12.5	Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. *(HS-PS3-1), (HS-PS3-2), (HS-PS3-5), (HS-PS1-4)*

Common Core State Standards Connections: Mathematics

MP.2	Reason abstractly and quantitatively. *(HS-PS3-1), (HS-PS3-2), (HS-PS3-3), (HS-PS3-4), (HS-PS3-5)*
MP.4	Model with mathematics. *(HS-PS3-1), (HS-PS3-2), (HS-PS3-3), (HS-PS3-4), (HS-PS3-5), (HS-PS1-4)*
HSN.Q.A.1	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data display. *(HS-PS3-1), (HS-PS3-3), (HS-PS1-4)*
HSN.Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. *(HS-PS3-1), (HS-PS3-3), (HS-PS1-4)*
HSN.Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. *(HS-PS3-1), (HS-PS3-3), (HS-PS1-4)*

Objectives

By the end of this lab students will be able to:

- Calculate the energy gained or lost in a chemical reaction using calorimetry.
- Use Hess' law to relate two experimental reactions in order to determine the change in energy for the sum of those reactions.

Time

Estimated Time	*Actual Time (please make note below)*
Pre-Lab: 20-30 Minutes	
Lab: 40 minutes or less	
Post Lab Calculations: 1 hour	

Materials

Supplies needed for 5 sections	Provided (P) or Needed (N)	Quantity	Company/ Item #	Approximate Cost
Epsom Salts	P	2-3g per group	Grocery/Drug Store	$3
Anhydrous magnesium sulfate You should have saved this from lab 4a *see lab notes for another option	P (if you did 4a)	2-3g per group	Flinn M0115	$17
Student made calorimeters from lab 6a		1 per group		
Thermometers		1 per group		
Balance				
Graduated Cylinders to measure 20mL of water				
Access to water				

Company Contact Information
Flinn Scientific http://www.flinnsci.com/

Prerequisite Knowledge

Students should already know the following information:

- The use of the equation $q=cm\Delta T$
- The terms endothermic and exothermic
- Conversion between kelvin and Celsius

Lab Setup

✓ Students can use their own calorimeters from lab 6a. If not, you can make your own foam cup calorimeter. To make 10 calorimeters buy 10 large cups and 20 small cups. Place a small cup inside each large cup to create an insulated device. Poke a thermometer sized hole in the other small cup and use it for a lid.

✓ Each group needs a thermometer and will need to weigh out two separate substances. Provide as many balances as you think you will need.

Lab Notes & Common Misconceptions

- ✓ The Background and Review questions are a perfect pre-lab assignment to send home with students as homework before the lab.
- ✓ If you did lab 4a you should have kept the small dried pellets. It is best if they are kept in a sealed zip top bag, but I have still had success when they are left out.
- ✓ If you did not do lab 4a you have a few options.
  - o You can purchase the anhydrate from a chemical company such as Flinn.
  - o You can anhydrate the Epsom salt at home. It needs to reach at least 450 degrees to anhydrate so you can put it in your oven for a while at a high temperature. It should be approximately half the weight at the end as it is 51.2% water.
  - o If you have Bunsen burners and crucibles the students can create the magnesium sulfate anhydrate from Epsom salts by following the procedure listed in lab 4a. The pellet must be cooled before it can be used for this lab. It will take about 10 minutes to anhydrate by Bunsen burner and another 10 minutes to cool.
- ✓ The second reaction is mildly endothermic, so students will see only a 1-2 degree change in temperature. They are often surprised to see an endothermic reaction so I find it best not to tell them ahead of time so they discover it themselves.
- ✓ The first reaction should have 3 significant figures in calculations and the second reaction should only have two significant figures in calculations depending on the temperature change they saw. It's best that you review significant figures rules before the lab to ensure they do their calculations properly.
- ✓ Let us know how it went! Go to www.HASPI.org/feedback to share your suggestions & successes.

Connections & Application

Lab 4a and lab 6a have strong connections to this lab. If you have already done these labs you might review them with your students before doing this lab to help them make connections.

- Ask students to study the reactions that have to do with cold packs.
- MRE's or "Meals Ready to Eat" are a military staple that self-heat. Have students study the reaction and find out how much energy is needed for these.
- Have students create a brochure educating a patient on when to use heat therapy and cold therapy.
- Draw an energy diagram for each of the three reactions showing the change in energy.
- Create a video animation of the processes observed in this lab.
- Explore the thermodynamics of other heat pack reaction ingredients such as iron powder.

References:

http://www.urmc.rochester.edu/encyclopedia/content.aspx?ContentTypeID=1&ContentID=4483
http://www.spine-health.com/treatment/heat-therapy-cold-therapy/benefits-heat-therapy-lower-back-pain
http://www.middleschoolchemistry.com/lessonplans/chapter5/lesson9
http://home.howstuffworks.com/question290.htm
http://prezi.com/lranljsxv4hx/copy-of-chemistry-hotcold-packs/
http://www.chemistryland.com/CHM130FieldLab/Lab11/Lab11.html

Name(s): Period: Date:

Hot Pack Calorimetry

HASPI Medical Chemistry Lab 6b

Health and Science Pipeline Initiative

Background/Introduction

http://www.chemistryland.com/CHM130FieldLab/Lab11/Lab11.html

Many common reactions in chemistry cause temperature changes. ***Endothermic*** reactions absorb heat, making the environment around them feel colder. ***Exothermic*** reactions release heat, making the environment around them feel warmer. We can use these reactions to provide thermotherapy so that treatment can be quick and can be available anywhere.

Thermotherapy is the use of heat or cold to treat an injury or illness. We use chemical reactions to create heat packs and cold packs.

Cold packs are used most often to reduce inflammation and swelling. This is best for a new injury.

- Cold therapy decreases blood flow
- Less blood flow leads to less swelling and inflamation
- Cold therapy is ideal for an area that is swollen or bruised
- Cold treatment is best during the first 24-48 hours after an injury
- Cold therapy should occur for 20 minutes at a time with at least 10 minutes between applications

Hot packs are used to provide pain relief. , Common uses are for back pain or arthritis pain. This treatment is best for recurring pain.

- Blood vessels are dilated so that there is an increased flow of blood to the muscles
- Blood flow brings oxygen and nutrients so that damaged tissue can heal
- The heat allows soft tissues to stretch so that there is decreased stiffness and increased flexibility This can greatly increase the range of motion
- Heat can relax joints, muscles, ligaments and tendons
- Heat therapy should occur in 20 minute increments

Hot Pack Chemistry

There are a few ways that exothermic reactions can be used as hot packs.

The reaction we will study today mixes anhydrous magnesium sulfate ($MgSO_4$) with water. When these mix heat is released. In a hot pack there is powdered $MgSO_4$ along with a small bag of water. When you squeeze the hot pack, the water packet bursts to begin the reaction. This type of hot pack can only be used one time.

Another type of hot pack uses a supersaturated solution of sodium acetate. Sodium acetate has a boiling point of 130°F, but if you melt it by heating it above that temperature, you can cool it back down and it will stay a liquid until something causes just one molecule to freeze. This causes a chain reaction until all of the sodium acetate freezes. In order for the molecules to solidify and freeze, the energy within them must be released, which is why this feels hot in your hands. These hot packs are reusable as long as you boil them to dissolve or melt the sodium acetate again.

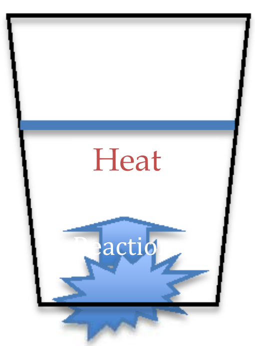
Iron filings can also be used as a hot pack. They react with oxygen in the air, so they are in a mesh packet which is sealed inside of the packaging. Once opened, the iron filings react with the oxygen in the same way they react to create rust, but it happens very quickly because the iron is in very small pieces. Water is able to speed up this reaction, increasing the heat for a moment, but the heat pack will cool more quickly if the reaction speeds up.

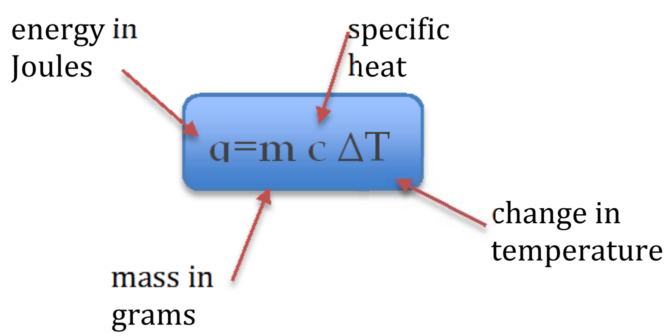
Cold Pack Chemistry
Endothermic reactions can be used as cold packs.

A commonly used cold pack contains ammonium nitrate and water. When the small bag of water inside is put under pressure it bursts to begin the endothermic reaction. This reaction needs energy, so it takes the energy from you, making you *feel* cold. Cold is just the sensation of energy moving away from you.

A New Concept - Calorimetry!
Today we will use calorimetry to study the energy given off by our reactions. Calorimetry allows us to measure the energy given to water by a reaction, or by a hot metal. This is used to find the amount of energy in our food, to identify unknown metals, and in this case, to find the Enthalpy of Hydration for our substance.

In calorimetry we are going to do a reaction in a very well insulated container, which we will make from styrofoam cups. As the reaction proceeds, the water will absorb the energy released. We can use a thermometer to measure the change in temperature of the water, then use the reaction $q=mc\Delta T$ in order to find out the quantity of energy that was released!





Review Questions

1. What is the difference between an exothermic and endothermic reaction?
2. How do you choose which therapy is right for your injury?
3. Why wouldn't a hot pack help with swelling?
4. How do you think you might be able to re-use the chemicals in a Magnesium Sulfate hot pack?
5. If the reaction creating rust (Iron Oxide) is exothermic, why don't rusty cars and nails feel warm?
6. What does the cold sensation mean in chemistry?
7. Why do we need an insulated container for calorimetry?
8. What errors do you predict we will encounter in a calorimetry lab?

Name(s): **Period:** **Date:**

Hot Pack Calorimetry

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Objectives

Find the amount of energy released when $MgSO_4$ is rehydrated to form $MgSO_4 \bullet 7H_2O$
Specifically:

- Calculate the Enthalpy of Hydration (ΔH) for $MgSO_4$
- Learn Calorimetry techniques
- Apply Hess' Law
- Use the equation $q=mc\Delta T$

Materials

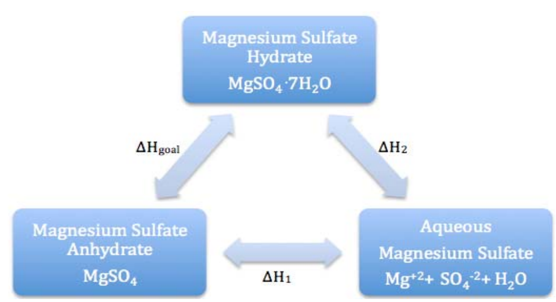
- Foam Cup Calorimeter
- Thermometer
- Anhydrous $MgSO_4$
- $MgSO_4 \bullet 7H_2O$ crystals
- DI or distilled water
- Digital Balance and weigh boats
- 50ml or 100mL Graduated cylinder

Connections to past lab

You prepared the anhydrate by heating the $MgSO_4 \bullet 7H_2O$ (s) last semester in the hydrated crystals lab. It took heat to remove the water from the crystals, which meant it was an endothermic reaction. That energy has been stored in the anhydrate and when the reaction is reversed the energy you put into the MgSO4 with your Bunsen burner will now be released in an exothermic reaction.

Scenario

In this lab we will dissolve Magnesium Sulfate hydrate ($MgSO_4 \bullet 7H_2O$) and magnesium sulfate anhydrate ($MgSO_4$) to find the ΔH values for each process.



A hydrate is a chemical with water trapped in its crystalline structure. When you look at the hydrate you will notice it looks dry, not wet. That is because the water is trapped. We use a dot in the formula of a hydrate to show that the water molecules are trapped.

In order to find the ΔH (enthalpy of hydration) we will perform two separate experiments, and then relate them to find our goal reaction.

Reaction 1: $MgSO_4(s) \xrightarrow{H_2O} Mg^{+2}(aq) + SO_4^{-2}(aq)$
Here we will add water to the anhydrate to dissolve the substance.

Reaction 2: $MgSO_4 \bullet 7H_2O\ (s) \xrightarrow{H_2O} Mg^{+2}(aq) + SO_4^{-2}(aq) + 7H_2O(l)$
Here we will dissolve the hydrated crystal in water.

Goal Reaction: $MgSO_4(s) + 7H_2O(l) \xrightarrow{H_2O} MgSO_4 \bullet 7H_2O\ (s)$
By adding the above reactions together we can determine the ΔH for this reaction.

Using Hess' law you can reverse the second reaction and add it to the first in order to calculate the ΔH of the goal reaction. First we will calculate the ΔH for reaction 1 and reaction 2 using calorimetry.

Procedure and calculations for Reaction 1: $MgSO_4(s) \xrightarrow{H_2O} Mg^{+2}(aq) + SO_4^{-2}(aq)$

1. Obtain a sample of the anhydrous $MgSO_4$. Weigh the sample and record the mass in *Data Table 1*. It should be about 1.50-3.00g.
2. Add exactly 20.0mL of DI water to your calorimeter.
3. Record the initial temperature of the water.
4. Add the $MgSO_4$ anhydrate to your calorimeter and immediately close the lid.
5. Stir until the temperature stops increasing.
6. Record the highest temperature reached as the final temperature.

DATA TABLE 1	
Mass of anhydrous $MgSO_4$ pellet or powder	
Mass of water used (same as mL)	
Initial temperature of the water	
Final Temperature of the water	
ΔT (Final - Initial)	

Calculations for Reaction 1	
1. Use q=mc Δ T to find out how many joules of energy were absorbed by the water. Remember that the specific heat of water is 4.184J/g°C. Be sure to use the mass of water for this calculation. (For water 1mL = 1g)	a) Energy in Joules b) Energy in kJ
2. Find the moles of anhydrate used a. What is the molar mass of $MgSO_4$? b. Convert the grams of $MgSO_4$ in *Data Table 1* into moles	a) molar mass of $MgSO_4$ b) moles of $MgSO_4$ used
3. Find the joules of heat released from the reaction in kJ. Remember, energy absorbed by water is negative the energy released from the reaction.	Energy=
4. Find the Δ H for this reaction in kJ/mol. (divide kJ by moles)	ΔH_1 =
5. Is this reaction endothermic or exothermic?	

Procedure and calculations for Reaction 2:

$$MgSO_4 \bullet 7H_2O(s) \xrightarrow{H_2O} Mg^{+2}(aq) + SO_4^{-2}(aq) + H_2O(\ell)$$

1. Weigh out about 2.00g of crystalline $MgSO_4 \bullet 7H_2O$
2. Add exactly 20.0mL of DI water to your calorimeter
3. Record the initial temperature of the water
4. Add the $MgSO_4$ hydrated crystals to your calorimeter and immediately close the lid
5. Stir until the temperature stops increasing
6. Record the final temperature reached by the solution after it stops changing

DATA TABLE 2	
Mass of $MgSO_4 \bullet 7H_2O$	
Mass of water used (same as mL)	
Initial temperature of the water	
Final Temperature of the water	
ΔT (Final - Initial)	

Calculations for Reaction 2	
1. Use $q=mc\Delta T$ to find out how many joules of energy were absorbed by the water. Remember that the specific heat of water is 4.184J/g°C. Be sure to use the mass of water for this calculation. (For water 1mL=1g)	a) answer in Joules b) answer in kJ
2. Find the moles of anhydrate used a. What is the molar mass of $MgSO_4 \bullet 7H_2O$? b. Convert the grams of $MgSO_4 \bullet 7H_2O$ in Data Table 2 into moles	a) molar mass of $MgSO \bullet 7H_2O_4$ b) moles of $MgSO_4 \bullet 7H_2O$ used
3. Find the joules of heat absorbed in the reaction in kJ. Remember, energy lost by water is negative the energy gained by the reaction.	Energy=
4. Find the ΔH for this reaction in kJ/mol. (divide kJ by moles)	ΔH_2 =
5. Is this reaction endothermic or exothermic?	

Conclusions: Calculate the ΔH for the goal reaction using the given reactions

1. Label each reaction with the enthalpy of reaction you found in the lab

Reaction 1: $MgSO_4(s) \xrightarrow{H_2O} Mg^{+2}(aq) + SO_4^{-2}(aq)$ $\Delta H_1 =$

Reaction 2: $MgSO_4 \cdot 7H_2O\ (s) \xrightarrow{H_2O} Mg^{+2}(aq) + SO_4^{-2}(aq) + 7H_2O(l)$ $\Delta H_2 =$

2. In order to find the goal reaction, the above reactions may be reversed or multiplied as needed so that they add up to make this reaction: $MgSO_4(s) + 7H_2O(l) \rightarrow MgSO_4 \cdot 7H_2O\ (s)$

Remember that a reversed reaction causes the sign on the ΔH value to reverse, and a doubled reaction doubles the ΔH value. Cancel out anything that appears on both sides of the arrows.

Show your work as you add these reactions together:

Reaction 1: $\Delta H =$

+

Reaction 2: $\Delta H =$

Equals

Goal Reaction $MgSO_4(s) + 7H_2O(l) \rightarrow MgSO_4 \cdot 7H_2O\ (s)$ $\Delta H =$

3. When you add together the ΔH values, what is the ΔH of hydration for $MgSO_4$?

4. If the theoretical value is -104kJ/mol, what is the percent error?

5. List 2 sources of unavoidable error

Applications:
1. Explain the difference between potential energy and kinetic energy in 2-3 sentences.
2. Using the terms *potential* and *kinetic* energy, describe what happened in the first reaction, where you dissolved the anhydrate in water.
3. The law of conservation of energy states that the total energy of an isolated system cannot change. How does this apply to our lab?
4. What could you do to increase the amount of energy released in reaction 1?
5. At the end of the trial, the temperature began to decrease. What happened to the energy that was in the calorimeter?
6. What changes could you have made to the lab apparatus to improve your results, reducing your percent error?

7. Draw a diagram of each experiment, including the calorimeter, the chemical and the water. Use arrows to show the flow of energy between the magnesium sulfate and the water.	
Experiment 1: Dissolving the Anhydrate	Experiment 2: Dissolving the Hydrate

Resources and References

http://www.urmc.rochester.edu/encyclopedia/content.aspx?ContentTypeID=1&ContentID=4483
http://www.spine-health.com/treatment/heat-therapy-cold-therapy/benefits-heat-therapy-lower-back-pain
http://www.middleschoolchemistry.com/lessonplans/chapter5/lesson9
http://home.howstuffworks.com/question290.htm
http://prezi.com/lranljsxv4hx/copy-of-chemistry-hotcold-packs/
Pictures:
http://www.chemistryland.com/CHM130FieldLab/Lab11/Lab11.html