Energy Changes in Chemical Reactions

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Subject: Chemistry

Grade Level: Middle School

Standards: Next Generation Science Standards (www.nextgenscience.org)

MS-PS1-6 Some chemical reactions release energy, others store energy.

MS-PS1-6 Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.

MS-PS3-4 Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.

Schedule: 1-1.5 hours

CCMR Lending Library Connected Activities:
Chemical Reactions

Objectives: ● Identity salts as endothermic or exothermic based on temperature changes ● Demonstrate how to increase temperature change by increasing salt concentration	**Vocabulary:** Thermal energy Temperature Endothermic Exothermic
Students Will: ● Classify a reaction as exothermic or endothermic ● Design and conduct an experiment ● Display results in a graph and draw a conclusion from the graph	**Materials:** **For Each Group (3-4 students)** ___ Insulated Cup w/Lid ___ Digital Thermometers ___ Measuring Spoons ___ Graduated Cylinder **For Class** ___ Ammonium Chloride ___ Calcium Chloride ___ Sodium Chloride ___ Sugar **Teacher Will Need to Provide** ___ Safety Goggles ___ Water
Safety	There are no major safety concerns, but students should wear goggles while doing the experiment.

Science Content for the Teacher:

Thermal energy and Temperature

Temperature and energy should have been discussed before this experiment is conducted. On a chemical level, temperature is a measurement of average kinetic energy of the molecules in a substance. Thermal energy is therefore a measure of total energy put into or taken from a system of molecules. This is why adding thermal energy results in temperature change. Both temperature and thermal energy are measurements of energy.

Here is a link for your students to explore this:
http://coolcosmos.ipac.caltech.edu/cosmic_classroom/light_lessons/thermal/differ.html

From a chemistry perspective, the thermal energy associated with dissolving a substance is known as the "heat of solution." The heat of solution for a substance is given as some unit of energy per mole (i.e. Kcal/mol) Since moles of a substance and the mass of that substance are directly proportional, temperature will vary linearly with the amount of salt added.

Exothermic and endothermic processes

This experiment demonstrates that some processes consume thermal energy, making the solution colder(endothermic). Other processes give off thermal energy, warming the solution (exothermic). This experiment shows this through dissolving several substances including several salts and simple table sugar (sucrose). It is important to note that thermal energy is not actually "created" but simply changed to/from an energy stored in the chemicals.

Here is a link for you students to explore these types of chemical reactions:
http://www.softschools.com/difference/endothermic_vs_exothermic/442/

In chemistry, the measurement of how much thermal energy is consumed or given off by dissolving a substance is called the heat of solution. These values are typically given in terms of kilojoules per mole (KJ/mol). Positive values indicate that dissolving the substance is endothermic, and negative values indicate exothermic processes.

On a fundamental level, what is happening is that the solvent (water) is breaking apart the interactions between ions (or in the case of sucrose, the attractive forces between molecules). Therefore the heat of solution is a measure of the difference between how strong ion-ion forces are and how strong ion-solvent forces are.

Since moles of a substance are directly proportional to the mass of that substance, adding more of a substance will create a larger effect on temperature.

Preparation:

Organize and lay out materials. Prepare a bucket of water at least 2 hours before conducting the experiment so it may reach room temperature.

Classroom Procedure:

Engage (Time: 10 mins)

Teacher breaks open an instant cold pack and asks students to describe how it feels. Teacher asks students to hypothesize what is happening inside the cold pack. Students might say “Some chemicals are mixing”.

Teacher reviews the difference between “thermal energy” and “temperature”. Thermal energy is the TOTAL amount of kinetic energy the molecules have and thermal energy can be added to or taken away. Temperature is the AVERAGE amount of thermal energy each particle has and describes which way thermal energy “flows”. Students fill in their own definitions on their activity sheet.

Teacher then asks students to describe why the pack feels cold using the words “thermal energy” and “temperature”. “The cold pack is colder so thermal energy “flows” from our hands to the cold pack making our hands feel cold.” The important concept for this lesson is that thermal energy can change forms.

Explore (Time: 10 mins)
In small groups, students practice adding sodium chloride in water to see how the temperature changes. This provides students with the information needed to plan their experiment and will give students time to collect their materials.

Experiment (40-60 mins)
Students design their own experiments in groups to ***test how 2 different salts affect the temperature of water when dissolved***. They will need to come up with a plan that describes how they will control their control variables and measure their dependent variable. Each experiment should be run in pairs or singly but can be done in a variety of ways in the interest of time or collaboration. If time is an issue, each group can do one of the two salts and share their data upon completing the experiment.

WHOLE CLASS: Each pair or single person tests a different salt and makes a graph which they display on a table or on the wall. Then each student can look at the graphs to make their own conclusions. This requires a whole class discussion on how to run the experiment.
GROUPS: Groups of four measure all the salts and make their own conclusions from their data.

Teacher will approve plans before students begin their experiments. Some questions to ask students are…
"How will you control the amount of water between experiments?"
"How will you measure the temperature?" (Possible answers: "Wait until the temperature stays constant for 10 seconds", or "wait until the temperature starts to go down" (not recommended due to time constraints) or "wait until all the salt is visibly dissolved")
"What will be on your x-axis and your y-axis? How will you label your temperature axis?" (start at zero or elsewhere)
"How much salt will you add and in what increments?"

Explain (Time: 15 mins)

Once most students have completed their experiment and graphs, teacher leads a discussion on how to read graphs of temperature versus mass of salt added. Students will need to pay attention to the way the axes are labelled to see which salts changed the temperature the most.

Teacher can ask "If you were to categorize these salts into two different groups, how would you do so?" Students answer "Salts that make the temperature go up and salts that make the temperature go down"

Teacher explains that a salt breaks a bond when it goes into water and becomes two smaller pieces. Some salts change their chemical potential energy to thermal energy energy when they break their bond, these are called "exothermic" reactions. An analogy is a firecracker where a tiny spark can release a lot of thermal energy energy. Attention should be drawn to the prefix "exo-" and suffix "-thermic". Students will probably be able to think of words beginning with "exo-"

Some salts take in thermal energy energy to break their bond and create chemical potential energy, like breaking a pencil takes some energy. These are called "endothermic". Students will be less familiar with the "endo-" prefix. Could describe that if insects have "exoskeletons" then people have "endoskeletons".

Students are to categorize their salts into the two different categories and possibly rank them based on how endothermic and exothermic they are.

Application (Time: 15 minutes)
Students will use their data and design an experiment where they will mix together ½ tsp of ammonium chloride and an amount of calcium chloride to get 0 temperature change. Once the correct amount of calcium chloride is determined, students will perform the experiment, and write observations and possible sources of error.

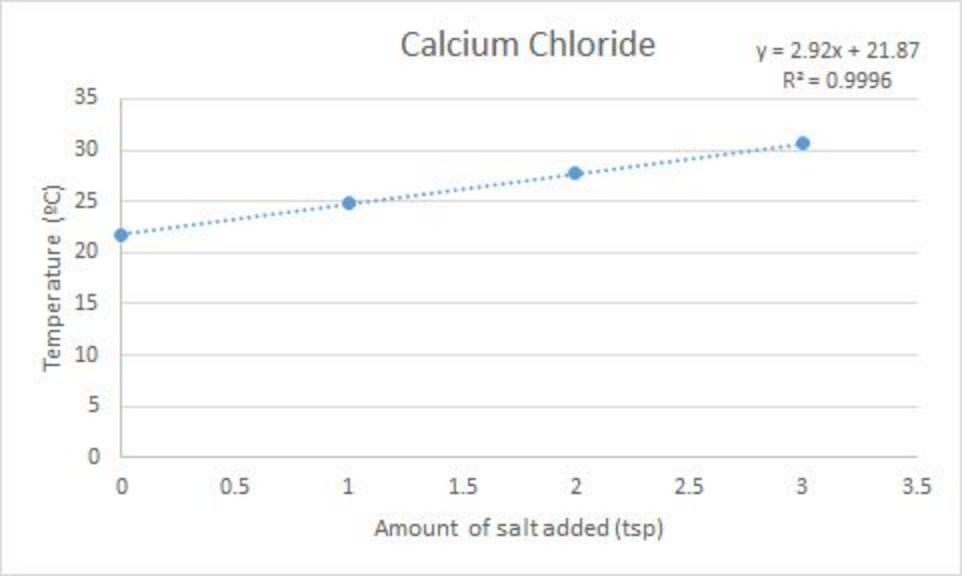
Additional Demonstrations (Extra: 10 minutes)
As a demonstration of extreme endothermicity, teacher can show a video of the reaction of ammonium chloride and barium hydroxide, e.g. https://www.youtube.com/watch?v=GQkJI-Nq3Os.

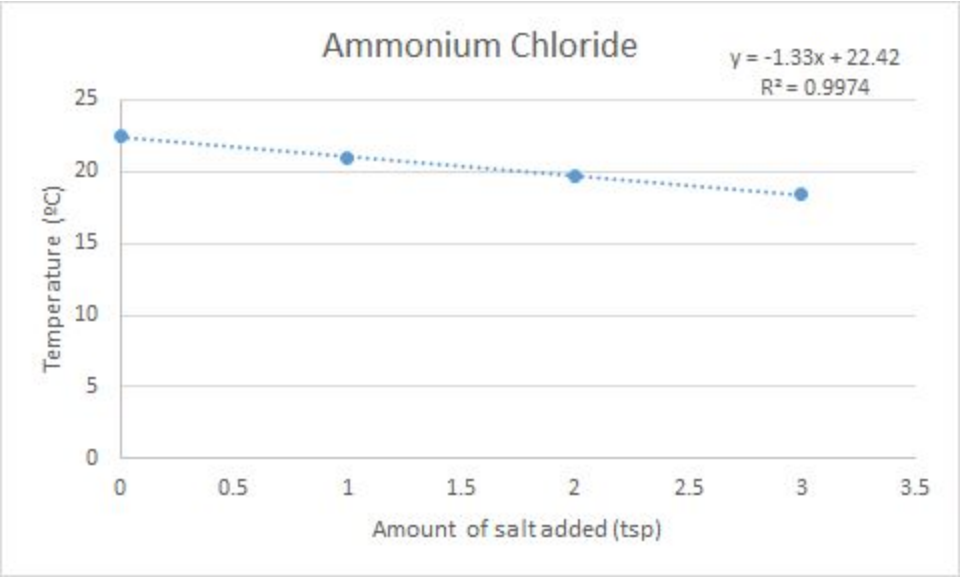
To connect to salts students are more familiar with, teacher can also perform a demonstration with 1 tbsp of sugar (not a salt) and students will identify whether it is endothermic or exothermic.

Relevant Information:

Below are plots of the salts (temperature vs amount salt added). It is important to note that the amount of salt used by students will be in ¼ tsp measurements, while this data pertains to 1 tsp measurements.

For no change to occur in “Making a salt that causes no temperature change”, students will need to add a little more than 1 tsp, tell students to not level off the salt for this to occur.





Assessment:

The following rubric can be used to assess students during each part of the activity. The term “expectations” here refers to the content, process and attitudinal goals for this activity. Evidence for understanding may be in the form of oral as well as written communication, both with the teacher as well as observed communication with other students. Specifics are listed in the table below.

1= exceeds expectations
2= meets expectations consistently
3= meets expectations occasionally
4= not meeting expectations

	Engage	Experiment	Application
1	Shows leadership in the discussion and offers creative ideas reflecting a good understanding of energy flow in chemical reaction.	Designs and conducts experiment creatively and scientifically while providing an explanation for what is observed. Works very well with group.	Provides an in-depth explanation of findings, makes excellent use of vocabulary and examples.
2	Participates in the discussion and shows an understanding of energy flow in chemical reactions.	Designs and conducts experiment creatively and scientifically. Works cooperatively with group.	Provides clear explanation of findings. Makes good use of vocabulary, provides some examples.
3	Contributes to the discussion, but shows little understanding of energy flow in chemical reactions.	Works cooperatively with group, but makes some mistakes with the procedure.	Provides a limited explanation of findings. Uses a few vocabulary words or examples.
4	Does not participate in discussion. Shows no understanding of energy flow in chemical reactions.	Has trouble working with group. Does little to complete the procedure.	Is not clear in explanation of findings. Does not make use of vocabulary or examples.