

Metals and Hydrogen Cars: Chemistry 10-12

Lesson Summary

This is an approximately week long lesson aimed at high school chemistry. The chemistry content that is used concerns heats of reaction, activation energy diagrams, and Gibbs Free Energy. The students will use and study these concepts in the context of the use of hydrogen in vehicles.

The progress of the lesson is from a brief introduction to hydrogen technology, then into looking at a couple of endothermic or exothermic reactions. Following that, the students are introduced via a lecture to activation and Gibbs Free Energy. Using that knowledge, they are then asked to generalize their knowledge to the area of hydrogen cars and possible metals that could be used. Groups construct a ranking for various metals and finally the class decides which metal would be the most likely candidate for future research.

5 E's Lesson Plan

Description of each section of the 5E model	Teacher Lessons	State Standard Indicators for each activity
<p>I Engagement: This activity captures the students' attention, stimulates their thinking, and helps them to access prior knowledge</p>	<p style="text-align: center;">Why investigate Metal Hydrides?</p> <p>In order to grab the students' interest, they will watch a video about hydrogen fuels and where hydrogen comes from. The video was made by PBS and Scientific American and is a little under 30 min in length. After the video, the students can discuss in small groups their reaction to the video and what difficulties they see for use of hydrogen in the near future. If there is time, there is also a second short video made by Nova that can be useful.</p>	<p>Chemical Thermodynamics 7bInvestigation&Experimentation -Grades 9 to 12- 1Investigation&Experimentation -Grades 9 to 12- 1m</p>
<p>II Exploration: In this section students are given time to think, plan, investigate, collect and organize information.</p>	<p style="text-align: center;">Experiment!</p> <p>Here, students will perform 1-2 experiments (depending on time) exploring exothermic and endothermic reactions. From their investigations, they will calculate the heats of the reactions. Either both reactions can be done by a group of 4, or students can be split up and share their results at the end.</p> <p>When acetic acid reacts with sodium carbonate, an endothermic reaction happens. And when Copper sulfate reacts with zinc metal, an exothermic reaction happens. By submerging a test tube of the reaction in a styrofoam cup of water, students can measure the heat of the reaction.</p>	<p>Chemical Thermodynamics 7bChemical Thermodynamics 7dConservation of Matter and Stoichiometry 3a</p>
<p>III: Explanation: Students are now involved in an analysis of their own explorations. Their understanding is clarified and modified because of the reflective nature of the activities.</p>	<p style="text-align: center;">Analysis/Lecture Time!</p> <p>Students are introduced to the activation energy curve and the effect of a catalyst on it for both exo and endothermic reactions. After being shown how the heat of the reaction is displayed on the graph, students make their own graphs based on their experiments. They then compare their graphs with each other to see what they calculated as the heat of the reactions.</p> <p>After the comparison, introduce Gibbs Free Energy to the students. Describe the terms entropy and enthalpy, and what makes a reaction spontaneous.</p>	<p>Chemical Thermodynamics 7bChemical Thermodynamics 7fReaction Rates 8cReaction Rates 8d</p>

<p>IV Extension: This section gives students an opportunity to expand and solidify their understanding of the concepts and to apply them in a real-world context.</p>	<p style="text-align: center;">Hydrogen Cars!</p> <p>Students are given data for 9 metals that fits the equation for Gibbs free energy, however pieces are missing from the data. Students can then use their knowledge to fill out the missing information and share their answers. Once it is filled in, students are given more data on the metals (such as weights/densities, reaction with air and water, stability). Using the information from the sheet and the other data, students come up with evaluation criteria for the metals and decide in groups which metals they think would be the best to use as a storage material in a hydrogen car. They form a ranking of the top 3 metals for their group.</p>	<p>Chemical Thermodynamics 7bChemical Thermodynamics 7fInvestigation&Experimentatio -Grades 9 to 12- 1dInvestigation&Experimentatic -Grades 9 to 12- 1kInvestigation&Experimentatic -Grades 9 to 12- 1lInvestigation&Experimentatio -Grades 9 to 12- 1m</p>
<p>V Evaluation: This performance-based activity helps students to connect all of the pieces of information involved in these lessons. .</p>	<p style="text-align: center;">Wrap Up</p> <p>Groups will share their rankings from the previous activity and present the reasons that they have chosen to rank them that way. Then, through a class discussion, a more finalized list will be developed. Finally, students will write up a reflection paragraph of the ideas and concepts that they learned and explored in the lab/activity.</p>	<p>Investigation&Experimentation -Grades 9 to 12- 1dInvestigation&Experimentatic -Grades 9 to 12- 1l</p>

Why investigate Metal Hydrides?

In order to grab the students' interest, they will watch a video about hydrogen fuels and where hydrogen comes from. The video was made by PBS and Scientific American and is a little under 30 min in length. After the video, the students can discuss in small groups their reaction to the video and what difficulties they see for use of hydrogen in the near future. If there is time, there is also a second short video made by Nova that can be useful.

Objectives

- To introduce students to the concept of hydrogen as a fuel and its use in cars with metal hydrides.
 - To show students some of the ways that hydrogen is produced and some of the difficulties in it.
- To have students come up in their own groups with some ideas of problems that might be found in the future use of hydrogen in the world.

Materials

Projector and Internet access

OR

Video that discusses hydrogen fuels and cars

<http://www.pbs.org/saf/1506/video/watchonline.htm>

Procedure

1. Students watch the video(s)
2. Students brainstorm and discuss energy and the current problems the world is facing and will face in the future and the feasibility of using hydrogen as a way to help the problems.
3. Students share out some of what they came up with in a brief class discussion section.

(If there is additional time, the 2nd video by Nova can be added to the Scientific American one. It focuses more on how hydrogen is used in the car and not on metal hydrides, but is an interesting show that includes the CarTalk guys.)

References

State Standards

Chemical Thermodynamics 7b-

7. Energy is exchanged or transformed in all chemical reactions and physical changes of matter. As a basis for understanding this concept:
 - b. *Students know* chemical processes can either release (exothermic) or absorb (endothermic) thermal energy

Investigation&Experimentation-Grades 9 to 12- 1l-

1. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other four strands, students should develop their own questions and perform investigations. Students will:
 - I. **Analyze situations and solve problems that require combining and applying concepts from more than one area of science.**

Investigation&Experimentation-Grades 9 to 12- 1m-

1. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other four strands, students should develop their own questions and perform investigations. Students will:
 - m. **Investigate a science-based societal issue by researching the literature, analyzing data, and communicating their findings. Examples of issues include irradiation of food, cloning of animals by somatic cell nuclear transfer, choice of energy sources, and land and water use decisions in California.**

Lesson Resources

Why investigate Metal Hydrides?: Nova



Download

<http://iisme.5ecommunity.org>

Why investigate Metal Hydrides?: Scientific American



Download

<http://iisme.5ecommunity.org>

Experiment!

Here, students will perform 1-2 experiments (depending on time) exploring exothermic and endothermic reactions. From their investigations, they will calculate the heats of the reactions. Either both reactions can be done by a group of 4, or student can be split up and share their results at the end.

When acetic acid reacts with sodium carbonate, an endothermic reaction happens. And when Copper sulfate reacts with zinc metal, an exothermic reaction happens. By submerging a test tube of the reaction in a styrofoam cup of water, students can measure the heat of the reaction.

Objectives

- Students will experience 2 reactions, one endothermic and one exothermic
- Students will measure the temperature change caused by the reaction and calculate heats of reaction
 - Students will use the terminology of system and surroundings to discuss their findings.

Materials

Chemicals:

- Acetic Acid
- Sodium Carbonate
- Zinc metal pieces
- Copper sulfate solution

Lab Supplies (per group):

- Styrofoam Cups (2-3)
- Test tubes (medium size) (2-3)
- stoppers for test tubes (with pass through holes) (2-3)
 - thermometers (2-3)
 - water
- balances (1, can be shared between groups)
- graduated cylinders (100mL and 10mL)
 - glass stir rods (2-3)

Procedure

Teacher Prep:

Distribute lab supplies to each lab station for groups.

Make up a copper sulfate and acetic acid solution in advance to be dispensed.

Put out the sodium carbonate and zinc next to the balances so students can weigh them out.

This section is open to you (the teacher) as to how experimental you let your students be. If you feel comfortable letting them take the supplies to figure out how to measure the heat of a reaction and what chemicals to mix together in what quantities then let them at it. Depending on their level of experience in the lab, students may be able to design their own procedure although it is unlikely they will determine amounts on their own, so suggesting mL and grams would be a good idea to avoid overly wasting the chemical supplies. Some suggestions to give the students about how to set up their procedure if you let them be open would be:

- Make sure you minimize the amount of heat "lost" that you can't measure. Which of the materials will help minimize loss?
 - Make sure you make all the measurements you need to in order to calculate your heat (have them figure out the equations in advance)
- Refer them to a picture of a calorimeter (either in their book or in a drawing). That can give them a good idea of their setup should be similar to.

If you want to give more guidance, you could provide an example (such as measuring the heat of ice melting) previous to the explore section. Or you may specify how much and which of the chemicals to be combined by the students to ensure they obtain measurable temperature changes. A suggested student procedure is given below, it will help the students obtain reasonably accurate results.

Student Experiment:

1. Fill the cups with 100-150 mL of water (measured exactly)
2. Measure the temperature of the water before the reaction
3. Weigh out a given amount of either the sodium carbonate or zinc
 4. Measure out the volume of acetic acid or copper sulfate.
5. Insert the test tube into the water with the bottom below the water line.
6. Put in the solid, then dump in the liquid and cap off the test tube. Shake/swirl lightly to ensure reaction.
 7. Measure the temperature of the water every 10 seconds.
 8. Make sure to record the highest temperature attained.

After Experiment:

Students can calculate the heat of the reaction by first calculating the heat change in the water (surroundings) and then find out the reaction (system) change. They will need to use $q=mc(\Delta T)$ for the water, then realize the heat of the reaction is negative of that.

References

Endothermic reaction: <http://chemistry.about.com/od/lecturenotes13/a/endorxns.htm>

Exothermic Reaction: NSTA 2006 CD

State Standards

Chemical Thermodynamics 7b-

7. Energy is exchanged or transformed in all chemical reactions and physical changes of matter. As a basis for understanding this concept:
- b. *Students know* chemical processes can either release (exothermic) or absorb (endothermic) thermal energy

Chemical Thermodynamics 7d-

7. Energy is exchanged or transformed in all chemical reactions and physical changes of matter. As a basis for understanding this concept:
- d. *Students know* how to solve problems involving heat flow and temperature changes, using known values of specific heat and latent heat of phase change.

Conservation of Matter and Stoichiometry 3a-

3. The conservation of atoms in chemical reactions leads to the principle of conservation of matter and the ability to calculate the mass of products and reactants. As a basis for understanding this concept:
- a. *Students know* how to describe chemical reactions by writing balanced equations

Lesson Resources

Experiment!: Calorimeter Drawing



Download

<http://iisme.5ecommunity.org>

Analysis/Lecture Time!

Students are introduced to the activation energy curve and the effect of a catalyst on it for both exo and endothermic reactions. After being shown how the heat of the reaction is displayed on the graph, students make their own graphs based on their experiments. They then compare their graphs with each other to see what they calculated as the heat of the reaction.

After the comparison, introduce Gibbs Free Energy to the students. Describe the terms entropy and enthalpy, and what makes a reaction spontaneous.

Objectives

- Students will learn about activation energy curves and catalysts
- Students will connect their experimental findings to energy diagrams
- Students will learn about Gibbs free energy, entropy, and enthalpy

Materials

Lecture materials (whiteboard/chalkboard/Powerpoint)
Students' results from lab experiment calculating heat of reaction

Procedure

Make sure students have calculated their heats of reaction from the previous day's experiment.

Introduce students to the concept of activation energy and the diagrams for exothermic and endothermic reactions. Also discuss the role of a catalyst and how it affects the energy diagram.

Once students have taken notes on activation energy, have them draw out diagrams for the two reactions they did in lab and label the sections of the graph. Have students work within groups and then between groups compare their graphs to see any differences in how they are drawn and different numbers obtained.

When students have finished comparing their data from lab, introduce them to the concept of Gibbs free energy, enthalpy, and entropy. Also include that reactions are spontaneous when ΔG is negative.

References

Energy Diagram References:

<http://www.sparknotes.com/testprep/books/sat2/chemistry/chapter8section1.rhtml>
<http://www.gcsescience.com/rc23.htm>

Gibbs Free Energy References:

<http://wine1.sb.fsu.edu/chm1046/notes/Thermody/Gibbs/Gibbs.htm>
<http://xenon.che.ilstu.edu/genchemhelphomepage/topicreview/bp/ch21/gibbs.html>
<http://mc2.cchem.berkeley.edu/Java/Gibbs/Gibbs.html>

State Standards

Chemical Thermodynamics 7b-

7. Energy is exchanged or transformed in all chemical reactions and physical changes of matter. As a basis for understanding this concept:

- b. *Students know* chemical processes can either release (exothermic) or absorb (endothermic) thermal energy.

Chemical Thermodynamics 7f-

7. Energy is exchanged or transformed in all chemical reactions and physical changes of matter. As a basis for understanding this concept:

- f. * *Students know* how to use the Gibbs free energy equation to determine whether a reaction would be spontaneous.

Reaction Rates 8c-

8. Chemical reaction rates depend on factors that influence the frequency of collision of reactant molecules. As a basis for understanding this concept:

- c. *Students know* the role a catalyst plays in increasing the reaction rate.

Reaction Rates 8d-

8. Chemical reaction rates depend on factors that influence the frequency of collision of reactant molecules. As a basis for understanding this concept:

d. * *Students know the definition and role of activation energy in a chemical reaction.*

Lesson Resources

Hydrogen Cars!

Students are given data for 9 metals that fits the equation for Gibbs free energy, however pieces are missing from the data. Students can then use their knowledge to fill out the missing information and share their answers. Once it is filled in, students are given more data on the metals (such as weights/densities, reaction with air and water, stability). Using the information from the sheet and the other data, students come up with evaluation criteria for the metals and decide in groups which metal they think would be the best to use as a storage material in a hydrogen car. They form a ranking of the top 3 metals for their group.

Objectives

1. To have students analyze various data sets and learn information on different metals
2. To have students come up with various criteria that they will evaluate the metals on for their use in hydrogen cars
3. To have students rank the metals in terms of which they think would be the most viable for use in a hydrogen car

Materials

- Data on various types of metals
- Heats of reactions (enthalpy, entropy, Gibbs free energy and temperature)
 - Weights/Densities
 - Other information (reaction with air and water, stability)

Procedure

1. Give students data sheets on various metals. Assign one-two metals per group and have them quickly fill in the missing information, then share out the data to the rest of the class so others can fill in their sheets
 2. Give students additional information sheets with properties of metals
3. Ask students to evaluate the different metals in relation to the possibility of using them as a storage material. They should pick the 3 top metals and rank them with their own criteria

For teacher:

For the students to use the thermodynamic data and evaluate it for which metal would work the best, they're going to need to go back to the activation energy diagram. First, the hydride should be at a lower energy than the metal and hydrogen gas that in a car at rest the hydrogen would remain bound up. Therefore, the metals with a negative delta G will work the best. Second, neither the products or the reactants should be "too" stable relative to the other, or the reaction will never reverse. The closer the reactants and the products are, the easier it will be to go backwards and forwards.

You may want to tell that information to your students, hint at it, or let them try to come up with it themselves. Depend on your assessment of your class.

References

Heats of Reaction Data:
Chemical Reaction and Equilibrium Software HSC Chemistry 5.11

Properties Data:
<http://www.webelements.com>

State Standards

- Chemical Thermodynamics 7b-
7. Energy is exchanged or transformed in all chemical reactions and physical changes of matter. As a basis for understanding this concept:
 - b. *Students know* chemical processes can either release (exothermic) or absorb (endothermic) thermal energy

Chemical Thermodynamics 7f-

7. Energy is exchanged or transformed in all chemical reactions and physical changes of matter. As a basis for understanding this concept:

f. * *Students know* how to use the Gibbs free energy equation to determine whether a reaction would be spontaneous.

Investigation&Experimentation-Grades 9 to 12- 1d-

1. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other four strands, students should develop their own questions and perform investigations. Students will:

d. **Formulate explanations by using logic and evidence.**

Investigation&Experimentation-Grades 9 to 12- 1k-

1. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other four strands, students should develop their own questions and perform investigations. Students will:

k. **Recognize the cumulative nature of scientific evidence.**

Investigation&Experimentation-Grades 9 to 12- 1l-

1. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other four strands, students should develop their own questions and perform investigations. Students will:

l. **Analyze situations and solve problems that require combining and applying concepts from more than one area of science.**

Investigation&Experimentation-Grades 9 to 12- 1m-

1. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other four strands, students should develop their own questions and perform investigations. Students will:

m. **Investigate a science-based societal issue by researching the literature, analyzing data, and communicating the findings. Examples of issues include irradiation of food, cloning of animals by somatic cell nuclear transfer, choice of energy sources, and land and water use decisions in California.**

Lesson Resources

Hydrogen Cars!: Heats of Reaction Data



Download

<http://iisme.5ecommunity.org/members/krotter/images/1154460ion.xls>

Hydrogen Cars!: Properties of Metals



Download

<http://iisme.5ecommunity.org/members/krotter/images/1154465als.doc>

Wrap Up

Groups will share their rankings from the previous activity and present the reasons that they have chosen to rank them that way. Then, through a class discussion, a more finalized list will be developed. Finally, students will write up a reflection paragraph of the ideas and concepts that they learned and explored in the lab/activity.

Objectives

1. Have students/groups as a class share their rankings for the metals
2. Come to a class decision on the best metal(s) for hydrogen car research
3. Have students evaluate their learning in the activity and a wrapup

Materials

1. Previous work on rankings
2. Lab results from lab

Procedure

1. Have groups prepare a brief (minute or two) presentation on why they ranked the metals in their order. Which pieces of information did they find most helpful to look at?
 2. Write the rankings on the front board for each group.
 3. Have a teacher led discussion of the criteria students' used and what differences in the rankings mean.
 4. Have students individually evaluate their learning.
1. What were some of the tradeoffs you had to make when your group settled on the best metal for hydrogen cars? How did you decide what was most important?
2. During this lab, what new knowledge or understanding have you gained concerning hydrogen cars, heats of reaction and/or the Gibbs free energy equation?
3. Aside from hydrogen fuel/vehicles, where else in the world could you use the knowledge you have gained in this lab?

References

State Standards

Investigation&Experimentation-Grades 9 to 12- 1d-

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Investigation&Experimentation-Grades 9 to 12- 1l-

1. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other four strands, students should develop their own questions and perform investigations. Students will:

l. Analyze situations and solve problems that require combining and applying concepts from more than one area of science.

Lesson Resources