Speed Rusting and Hot Hands

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Abstract: This metals processing experiment demonstrates the heat released when iron is oxidized. Normal oxidation (rusting) provides the same heat but over a prolonged period of time. Here, the process is rapid and is quite noticeable. This is used commercially to produce hand warmers and related products. Variations in the method and constituents in the reaction demonstrate the influence of variations in processing on the properties of the product.

Module Objectives: The objective of this experiment is to demonstrate the heat released in a chemical reaction, and the influence of reaction constituents on the rate (and amount) of heat released.

Student learning objectives: Students will be able to

- Prepare chemical mixtures safely
- Identify when a chemical reaction is taking place
- Observe the results of an exothermic chemical reaction
- Observe effects of differing constituents on the rate of the reaction
- Apply their observations to the refining and corrosion of iron

MatEd Core Competencies covered:

0.B	Prepare tests and analyze data
5.A	Apply Safe and Environmentally appropriate methods to chemical handling
5.B	Demonstrate knowledge of chemistry fundamentals
6.B	Apply concepts of fluids, heat and thermal conduction
7.A	Identify the general nature of metals
7.K	Compare thermal, physical and other properties of materials
9.A	Define and Describe constituents, properties and processing of steel

Key Words: iron, reaction, heat, rusting, reaction rate variations

Type of Module/Mode of Presentation: laboratory experiment

Time required: 20 – 30 minutes.

Pre-requisites: None

Target grade levels: High school and community college technology students; also high school chemistry students

Table of Contents

List of Equipment and Supplies needed:

Iron powder or fine iron filings (see ref 5)
Sodium chloride (table salt)
Cellulose (optional)
Activated carbon (optional)
Vermiculite* (optional—see ref 5)
Plastic baggies (1 pint or larger)
Balance to weigh 1 – 25 gram amounts of material

Curriculum Overview and instructor notes

Many students have used hand warmers, as they are a quick and easy source of heat while hiking, skiing, etc. These warmers operate using a chemical reaction in which iron gives off heat in an exothermic reaction, which is basically a speeded up rusting or corrosion reaction.

The reaction itself is complex, but the basic ingredients and their function are:

- Iron powder or filings, with lots of surface area react with oxygen to produce the reaction, which is exothermic (gives off heat)
- Salt acts as a catalyst to speed up the normal rusting reaction
- Carbon helps to disperse the heat
- Vermiculite is an insulator allowing the device to retain heat longer
- Cellulose is often added as a filler in the commercial product
- Water to provide the aqueous solution to allow the oxidation to proceed.

The Iron and salt are the essential ingredients (thus in this experiment, the others are optional—although the other ingredients do help to prolong the heat cycle). Commercial products normally use all of these components so that the heat can last for several hours. The actual chemical reaction is discussed in reference 1.

This reaction is the opposite of the refining operation in which iron ore (iron oxide) is reduced to iron. The reduction reaction requires considerable heat (as in a blast furnace) because a large amount of energy is needed to separate the iron from its natural oxide (the ore). The hand warmer experiment is basically the opposite of

this reduction reaction. Usually in rusting this releases its energy over a long period of time; the sodium chloride in this experiment is a catalyst that speeds up the reaction. Note that as a catalyst, the sodium chloride does not take part in the actual reaction.

Differences in the rate of reaction are easy to observe if the amounts of the constituents are varied. Different groups of students using different amounts of the constituents will be able to report and compare the differences.

Module Procedure: Procedure A is the straight experiment, whereas Procedure B provides a means of comparing the influence of different amounts and different constituents on the reaction and the results.

Procedure A

1. Each student should weigh out 25 grams of iron powder or iron filings plus about 1 gram of sodium chloride. Place these in the plastic baggie and shake to mix. [Cover the balance with paper to avoid contamination]
2. Add about a gram of each of the other components (depending what is available). Shake the bag to mix it well.
3. Add 5 ml of water and shake the bag. The reaction will begin in a minute or so.
4. Have the students measure and record the time to the start of the reaction (when they can feel the heat), the point of maximum reaction (when it is too hot to handle) and when the reaction is over (no more heat).
5. Discuss the process and how it relates to the refining and corrosion of iron.

Procedure B

1. Proceed with step 1 above.
2. Have different students (or different groups of students) vary the constituents as follows:
    a. No sodium chloride
    b. No water
    c. Depending on what optional components are available, variations in each.
3. Have the students measure and record the time to the start of the reaction (when they can feel the heat), the point of maximum reaction (when it is too hot to handle) and when the reaction is over (no more heat).
4. Compare the results and enter them on a table on a blackboard or whiteboard. Discuss the differences with the class.
5. Discuss the role of each component and the role of the water in the process. As appropriate, discuss the chemistry of the oxidation reaction.

References

1. "How does iron rust?" is a straightforward chemical reaction discussion: http://antoine.frostburg.edu/chem/senese/101/redox/faq/how-iron-rusts.shtml
2. "Oxidation of iron," a more detailed discussion of oxidation:

http://web.njit.edu/~hsieh/ene670/oxidFE.html
3. "Warm Hands and Toes Through Chemistry, from Science IQ.com: http://www.scienceiq.com/ShowFact.cfm?ID=212
4. A simpler form of this experiment is given in the Materials Science and Technology modules from the University of Illinois: http://matse1.mse.uiuc.edu/metals/k.html
5. Iron filings and vermiculite are available at http://sciencekit.com/default.asp and at other sources on the internet.

Acknowledgements

This work was partially funded by National Science Foundation Advanced Technology Education Grant # 0501475.

Evaluation packet

Student evaluation questions (discussion or quiz)

1. Commercial hand warmers that you purchase in a sporting goods store are packaged in a plastic bag. Instructions say NOT to open the plastic bag before actual use. Why is this instruction important?
2. [When using procedure B] What is the role of each of the constituents in the reaction process:
   Iron powder or filings
   Sodium chloride
   Cellulose
   Activated carbon
   Vermiculite
   Water
3. Which of the components above are the most important in the reaction?
4. How do your results relate to the processing and rusting of iron?

Instructor evaluation questions:

1. At what grade level was this module used?
2. Was the level and rigor of the module what you expected? If not, how can it be improved?
3. Did the demonstration work as presented? Did they add to student learning? Please note any problems or suggestions.
4. Was the background material on steels and titanium sufficient for your background? Sufficient for your discussion with the students? Comments?
5. Did the demonstration/lab generate interest among the students? Explain.
6. Please provide your input on how this module can be improved, including comments or suggestions concerning the approach, focus and effectiveness of this activity in your context.

Course evaluation questions (for the student)

1. Was the experimental procedure clear and understandable?
2. Was the instructor's explanation comprehensive and thorough?
3. Was the instructor interested in your questions?
4. Was the instructor able to answer your questions?
5. Was the importance of materials testing made clear?
6. What was the most interesting thing that you learned?