Flameless Ration Heaters

Consumer Chemistry

Introduction

Take apart and analyze the contents and chemistry for a flameless ration heater (FRH), a device soldiers use to heat ready-to-eat meals.

Concepts

- Consumer chemistry
- Exothermic reactions
- Calorimetry
- Chemical forensics

Materials

Nitric acid, HNO_3, 0.5 M, 500 mL
Phenolphthalein, 1%, 100 mL
Silver nitrate, $AgNO_3$, 1 M,100 mL
Flameless Ration Heaters
Balance
Cow magnet
Heat Solution™ Instant Handwarmer (optional)
Limewater (optional)
Mini hand warmer (optional)
Splints, 20
Styrofoam® cup
Test tubes, 13 mm × 100 mm, 15

Safety Precautions

The FRH is considered nonhazardous and nontoxic when used as described. When experimenting, follow precautions particular to other chemicals and agents used. Wear chemical gloves and goggles and observe prudent laboratory practices. Avoid prolonged contact of activated FRH with exposed skin—may cause burns. Avoid contact of all chemicals with eyes and skin. Follow all laboratory safety guidelines. Please review current Material Safety Data Sheets for additional safety, handling, and disposal information. Remember to wash hands thoroughly with soap and water before leaving the laboratory.

Procedures

A number of experiments can be performed utilizing the FRHs.

1. Demonstrate the use of the FRHs by following the instructions on the heater. A large amount of heat is evolved. The amount of heat can be compared to that released by other chemical heaters/hand warmers. Have mini hand warmers (Flinn AP1931) and Heat Solution heaters (Flinn AP1933) available for students. The mini hand warmers contain iron, water, cellulose, vermiculite, activated carbon, and salt. The Heat Solution is a vinyl pouch containing a supersaturated solution of sodium acetate.
2. Quantitative determination of heat evolved.

   a. Break off a small piece of the heating pad and record its mass.

   b. Add 100 mL of water to a Styrofoam® cup (calorimeter) and record the temperature.

   c. Drop the massed sample of the heating pad into the cup of water, stir with the thermometer, and record the temperature at 30 second intervals.

   d. Plot the temperatures recorded over a 10 to 15 minute period.

   e. From the graph (a smooth curve rising to an asymptote) students can calculate the mass of the heating pad required to warm 100 mL of water from room temperature (25 °C) to its boiling point (100 °C).

   f. More advanced (AP) students can be told that the 5 mol fraction Fe-Mg alloy makes up approximately 40% by weight of the pad. From the heat evolved and chemical makeup of the pad, they can be asked to calculate the heat of reaction and to compare their value with the literature value of 351kJ/(mol Mg).

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3. Chemical forensics.

   Advanced students working in small groups can be given a pad (or pads) and asked to analyze the chemical makeup of the pads.

   After carefully cutting off one end of the green holder, the cake-like inner pad can be removed. Inspection with a hand lens reveals metallic flakes imbedded in a white cake-like matrix. A drop of phenolphthalein added to the matrix produces pink spots after a few seconds.

   A strong magnet (cow or rare-earth) will attract the pad. Allow the FRH to hang vertically and bring the magnet near the pad. The pad will move toward the magnet indicating the possible presence of elemental iron.

   Adding water to a beaker containing a piece of the FRH results in an exothermic reaction which also generates a gas and a white precipitate. The gas can be collected by displacement of water (or air) in a test tube. A burning splint brought near the mouth of the test tube results in a "pop" similar to the test for hydrogen. The gas can also be bubbled through lime water as a test for carbon dioxide. This latter test is negative.

   Phenolphthalein turns pink when added to the resulting solution. The solution can be filtered and the filtered solid mixed with distilled water. This mixture also turns phenolphthalein pink.

   Neutralize the solution with dilute nitric acid. Adding a few drops of silver nitrate to the acidified solution produces a white fluffy precipitate—silver chloride. This test indicates the possible presence of soluble chloride ion.

   Burning a small piece of the pad in a bunsen burner flame results in a few sparks. (Perform this with a small pea size sample with teacher supervision. The brilliant sparks fly off in all directions. They travel approximately half a meter from the burner.)

   A flame test of the solution produces a bright yellow flame similar to that of sodium ion solutions.

   From the above tests students can infer the presence of sodium chloride, iron, and magnesium. They can then attempt to reproduce their results.

4. Reactions of magnesium in water and in a chloride solution.

   Adding a few clean pieces of magnesium ribbon to a test tube with distilled water results in a very slow, almost imperceptible reaction.

   Adding a few clean pieces of magnesium ribbon to a test tube with a dilute solution of sodium chloride results in a much more vigorous reaction. The presence of chloride ion greatly increases the rate of the reaction of magnesium metal with water.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. Follow instructions on the FRH and allow the reaction to occur. Once completed, discard the FRH in the trash. Solutions resulting from some of the procedures detailed above should be neutralized prior to disposal.

Discussion

Flameless Ration Heaters (FRHs) represent the latest in culinary technology developed by the United States Army for heating its Meals Ready to Eat (MREs). Combat soldiers supplied with FRHs and MREs no longer have to worry about cold rations. FRHs are nontoxic, self-contained, compact, and do not produce a flame. The heaters not only provide soldiers with hot meals but they also provide teachers with an inexpensive, real-world, inherently interesting application of chemical technology.

Patent Number 4,522,190 describes the heaters as follows:

> "This invention is for an inexpensive flexible heater material (heat pad) for food heating, medical compresses and the like. The heater pad is a composite material consisting of a supercorroding metallic alloy powder dispersed throughout a porous polyethylene matrix. The supercorroding alloy material consists of a powdered alloy of magnesium and iron which is produced by high energy powder metallurgical milling techniques. Pressureless sintering of a mixture of the supercorroding alloy powder with UHMW (ultra high molecular weight) polyethylene powder results in the formation of a flexible porous material with active ingredients therein that are readily activated with a suitable electrolyte fluid.[1]"

According to the patent, the FRH using 4 g of Mg·5 at % Fe is capable of increasing the temperature of 151 g of food approximately 55 °C; with an initial temperature of 21 °C, and final temperature of 76 °C. Higher temperatures can be achieved by using heater pads with more supercorroding alloy. Some heat escapes the package in the form of steam and hydrogen gas. The hydrogen gas dissipates rapidly and does not present a hazard for individual package use. Attempts to ignite the hydrogen with an open flame and spark have failed to produce ignition. Heat from the heater pads is transferred to the food by conduction.[2]

The heat is produced by the reaction of magnesium metal and water to form hydrogen and magnesium hydroxide.

$$Mg(s) + 2H_2O(l) \rightarrow Mg(OH)_2(s) + H_2(g) + \text{heat } [\Delta H = -351 \text{ kJ/(mol Mg)}]$$

Although highly exothermic, the reaction is kinetically very slow. "The inventors (William E. Kuhn, et al) tried to make the reaction practical by overcoming its extreme slowness. They found that small amounts of elemental iron, 1·5 mole fraction Fe, increases the rate significantly. To ensure close contact between the two metals, the metal powders are blended together in a ball mill. The iron is not a catalyst, however; it is a promoter or activator, which initiates reaction at the magnesium surface by producing reactive intermediates. The reaction cannot be sustained, because magnesium's reactive surface is shielded by its $MgO/Mg(OH)_2$ coating. A further increase in rate and maintenance of smooth, steady reaction is achieved with chlorine ion, which replaces hydroxide in the coating. The replacement of hydroxide by chloride destabilized the coating, producing fractures that function as channels leading the water directly onto the magnesium surface, where the large thermodynamic driving force is fully realized and the reaction becomes self-sustaining. Chloride redissolves in solution and is therefore a true catalyst."[3]

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
- Evidence, models, and explanation
- Constancy, change, and measurement
- Form and function

Content Standards: Grades 5–8
- Content Standard A: Science as Inquiry
- Content Standard B: Physical Science, properties and changes of properties in matter, motions and forces, transfer of energy
- Content Standard F: Science in Personal and Social Perspectives, science and technology in society

Content Standards: Grades 9–12
- Content Standard A: Science as Inquiry
- Content Standard B: Physical Science, structure of atoms, structure and properties of matter, chemical reactions, motions and forces, conservation of energy and increase in disorder, interactions of energy and matter
- Content Standard F: Science in Personal and Social Perspectives, science and technology in local, national, and global challenges
- Content Standard G: History and Nature of Science, historical perspectives

References

[1] Kuhn, W.E., U.S. Patent 4,522,190.

[2] Kuhn, W.E., U.S. Patent 4,522,190.

[3] Kustin, K., Brandeis University/U.S. Army Natick Research Center. Personal Communication.

Flinn Scientific—Teaching Chemistry™ eLearning Video Series

A video of the *Flameless Ration Heaters* activity, presented by Kathleen Dombrink, is available in *Consumer Chemistry*, part of the Flinn Scientific—Teaching Chemistry eLearning Video Series.

Materials for *Flameless Ration Heaters* are available from Flinn Scientific, Inc.

Catalog No.	Description
AP8695	Flameless Ration Heater
AP1931	Mini Hand Warmer
AP1933	The Heat Solution Instant Handwarmer
P0019	Phenolphthalein, 1%, 100 mL
AP1944	Cow Magnet
N0051	Nitric Acid Solution, 0.5 M, 500 mL
S0171	Silver Nitrate, 1 M, 100 mL
AP4444	Wood Splints, Pkg/100
GP6063	Test Tubes, 13 × 100 mm

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.