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Cold water + supercorrosion → hot meals

HOT MEALS

By Dan Scott and Robin Meadows

Grabbing a quick meal during combat was never appetizing. The soldier had to wait for a lull in the fighting, find a spot shielded from enemy bullets, quickly open an "entree" like spaghetti, then wolf it down—cold. But thanks to an innovative heat pack, many soldiers in Operation Desert Storm, the 1990–91 war to oust Iraq from Kuwait, had the benefit of hot food, even when they were far from an Army kitchen. "A hot meal is a real morale booster for a soldier in the field," says Donald Pickard of the U.S. Army Natick Research, Development and Engineering Center, which jointly developed the heat pack with Zesto Therm, a Cincinnati company.

U.S. soldiers are no longer subjected to the infamous, canned C-rations of World War II. The modern ration is called the "Meal, Ready-to-Eat" or MRE, and is much tastier. The main course is usually an entre, such as chicken stew or spaghetti and meat balls, packaged in a camouflage-green pouch made of aluminum foil and plastic film. The pouch can be heated by dunking it in a pot of boiling water or propping it on an engine manifold. But soldiers don't always

Where there's heat...

Where there's heat, there's an exothermic reaction. For a reaction to take place, energy must be added to break the bonds within molecules, and energy is released when the atoms re-bond to form new molecules:

reactant molecules + energy for breaking bonds → product molecules + energy from forming bonds

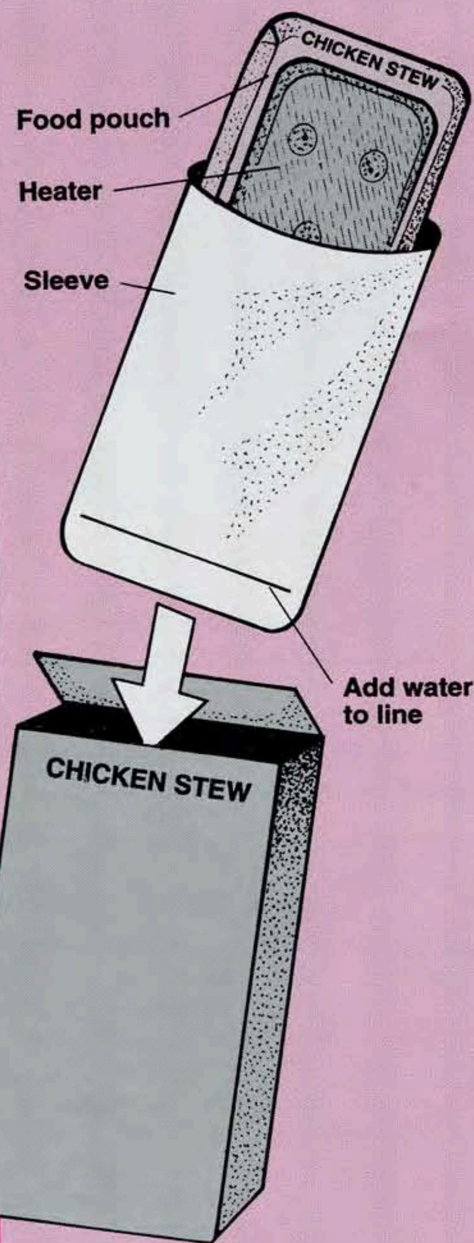
When the energy from forming bonds is greater than the energy of breaking bonds, the excess energy is released—usually in the form of heat, though it could be light or electricity. Such a reaction is called exothermic and is summarized

reactants → products + heat

Burning wood is a familiar example, where chemical bonds in the carbon–hydrogen–oxygen compounds are broken to produce carbon dioxide, water, and heat (see "Fireside Dreams," *Chem Matters*, December 1988).

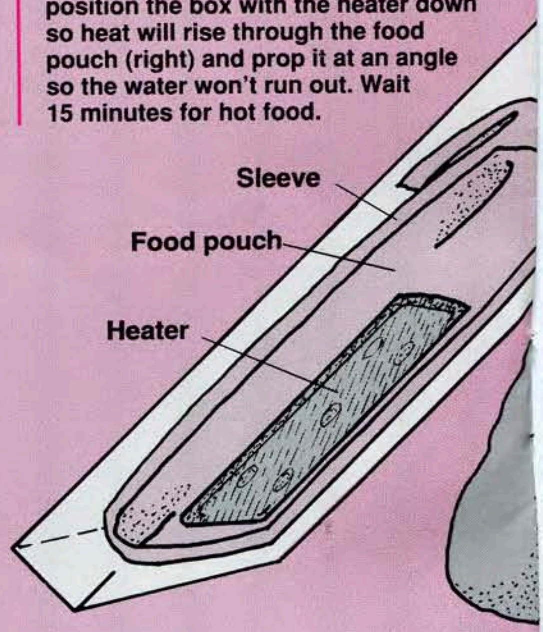
The reaction that takes place in the Army's Flameless Ration Heater (FRH) is also exothermic. The FRH contains magnesium metal which, when mixed with water, forms magnesium hydroxide, hydrogen, and heat:

$$Mg + 2H_2O \rightarrow Mg(OH)_2 + H_2 + \text{heat}$$



Twenty-four grams of magnesium (one mole) yield 355,000 joules (85 kilocalories) of heat, which is enough energy to boil a liter (about one quart) of water, without any flame or smoke. Corrosion is the process of a metal reacting with air or water, and scientists usually want to stop corrosion—as when iron corrodes to rust. In this case, they wanted to speed up the process—get supercorrosion—to produce heat quickly.

To heat a meal, add to the bag-like sleeve a pouch of food, a heater, some water, then fold over the top of the sleeve and slide it into the cardboard box the meal came in (left). Next position the box with the heater down so heat will rise through the food pouch (right) and prop it at an angle so the water won't run out. Wait 15 minutes for hot food.



have the time to boil up a pot of water or wait for their dinner to heat on an engine. To provide guaranteed hot meals in the field, the researchers designed a heat-producing plastic sleeve for the MRE entree. The sleeve, called the Flameless Ration Heater, contains chemicals in a perforated fiberboard box that produce heat when mixed with water (see box "Where There's Heat..."). Soldiers simply drop the entree pouch into the sleeve, add about 30 mL (an ounce) of water, and wait 12 to 15 minutes for the food to reach about 60 °C. The sleeve adds little weight to the MRE and, if the soldiers have to move quickly, they can slip the whole thing into a pocket where the sleeve will keep the food warm for an hour.

"Getting the MRE hot was a breakthrough," says Pickard. "Soldiers have always made jokes about military food. It's high quality food but you can take the best food in the world and serve it cold, and people won't like it. When you heat up an MRE, it's good."

References

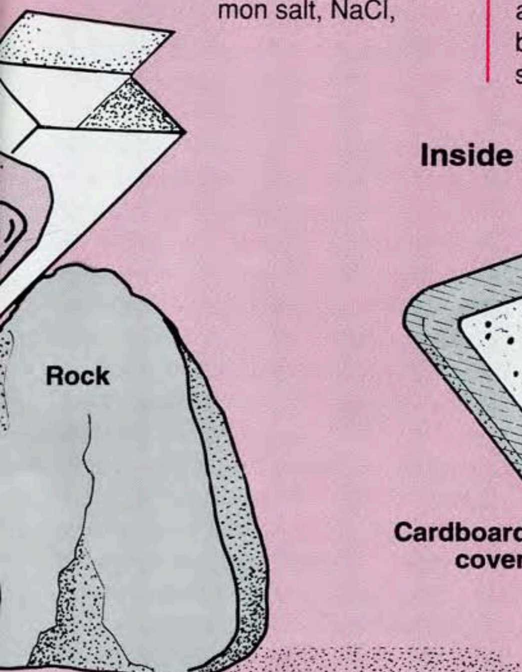
Cotton, A.; Wilkinson, G. *Advanced Inorganic Chemistry*; Fifth ed., Wiley: NewYork, 1988.

Kuhn, W. E.; Hu, K. H.: Black, S. A. *Flexible Electrochemical Heater*, U.S. Patent 4,522,190; June 11, 1985.

However, the designers of the FRH faced one major complication: magnesium metal usually has a natural protective coating. When exposed to air, magnesium reacts with oxygen, forming a film of magnesium oxide, MgO, on the surface. This film prevents further oxidation, but also prevents the spontaneous reaction of magnesium with water. In order for supercorrosion to take place, this oxide barrier must be penetrated.

The inventors of the FRH found that they had to mix the magnesium with iron and salt to penetrate the oxide barrier. Common salt, NaCl, speeds up the corrosion because the chloride ion, Cl^-, reacts with the magnesium hydroxide product to form MgOHCl, and the oxide coating is more soluble in MgOHCl than it is in water or magnesium hydroxide solution.

In effect, the MgOHCl eats away at the protective oxide coating and eventually allows the water to react directly with the magnesium metal. Though the role of the iron is not totally understood, scientists think that it promotes the reaction between the water and the magnesium by creating a site where hydrogen atoms and electrons can be transferred between the water and the magnesium.



Inside view of heater