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INSTRUCTOR'S GUIDE

EXPERIMENT 1 — FUSION COOKIES

Purpose

To simulate a fusion reaction by using a microwave oven to cook dough and have students measure the amount of mass "lost."

Objective

After completing this activity, students will be able to explain the following:

1. How heat will fuse two lighter atoms into a heavier atom — a new element.
2. Why during this fusion process, a small amount of matter is lost — converted into energy.
3. Microwaves can be used to heat fusion fuel.

Skills Required

Microwave oven operation. Analytical scale operation.

Time

45 minutes.

Required Equipment and Supplies

1. Commercial cookie dough in tube. (Homemade dough can be substituted.)
2. Microwave oven.
3. Electronic or triple beam balance.
4. Bread board.
5. Wax paper.
6. Plastic knife.
7. Scissors.

Theoretical Background

In a fusion reaction, two light atoms combine or fuse at very high temperatures to form a heavier atom (new element) and release energy (E = mc2). The fusion process accounts for the creation of all elements beyond hydrogen in the universe. In addition, during a fusion reaction, a small amount of matter is "lost" or converted into pure energy. This energy powers the thermonuclear engines of the sun and stars and provides the energy for almost all life on earth. For 40 years, researchers around the world have studied methods to control thermonuclear reactions. There was early optimism that taming fusion would be as easy as controlling fission (the splitting of atoms). This early optimism soon gave way to the sobering reality that controlling fusion would be accomplished only after many years of painstaking research, technological advancements, and engineering breakthroughs. Why the difficulties in achieving fusion? The answer lies within the atom itself. Practically all physical matter on earth is composed of one of the three "common" states of matter — solid, liquid, or gas. In these states, electrons revolve around nuclei composed of neutrons and protons. In the rest of the universe, however, the most common state of matter is plasma — it makes up the sun and stars. In a hydrogen plasma at approximately 100 million Kelvin, the electrons have been stripped away from the central nucleus creating a hydrogen ion. At these extremely high temperatures, the hydrogen nuclei finally overcome their natural electrostatic repulsion and through a series of steps fuse together to form helium (alpha particle) thereby releasing an energetic neutron which carries away heat. During this process, a small amount of matter (approximately 38 parts out of 10,000) is converted completely into energy. As Einstein's equation E = mc2 indicates, even a small amount of matter can produce an enormous amount of energy. The massive gravitational field of stars confines and sustains their fusion reactions, but confining hot plasmas on earth has proved to be a daunting scientific and engineering challenge. One of the methods used to confine fusion

on earth is the tokamak, first designed by the Russians. A tokamak is in the shape of a torus or a “doughnut.” Isotopes of hydrogen — deuterium and tritium — are introduced into the hollow torus. Various methods are then used to heat the plasma which include neutral beams, lasers, microwaves, and resistive heating. The physical characteristics of a plasma (it is charged and conducts electricity) allow it to be constrained magnetically. Since no physical material can withstand the 100 to 200 million Kelvin fireball of a fusion reaction, powerful magnetic fields surrounding the torus are used to keep the plasma in place.

The simulation shows:

1. Two pieces of cookie dough fusing into one cookie with enough heat.

In real fusion, two lighter elements fuse together through heat and pressure.

2. Loss of mass when the cookie dough cooks and water is lost.

In real fusion, 0.4% (0.004) of the initial mass is “lost” as mass is converted into energy.

3. Use of a microwave to heat the cookie dough.

Microwaves are actually used to help heat fusion fuels to millions of degrees in tokamaks.

Procedures

1. While commercial cookie dough which comes in tubes is recommended because of ease of use, any homemade dough will work.
2. Have students use plastic knives to cut the dough from the tube.
3. A mass of cookie dough of approximately 15 g is sufficient to get good results, i.e., the loss of mass will be very apparent after cooking in the microwave oven.

4. We have recommended the use of a microwave oven for this activity because (1) convection ovens are typically not found in many schools anymore, (2) it cooks the dough in 20 to 30 seconds compared to 10 to 15 minutes in a convection oven, and (3) it is actually used to heat fusion fuel in a tokamak. The “fusion” cookie which results from cooking in the microwave will be cooked and edible, but it may not look very edible.

Hints and Tips

1. “Fusion Cookies” is a simulation and therefore represents an analogy to the real fusion reaction. While there are several similarities between baking cookies and the fusion reaction, students must realize what is analogy and what is real. Keep reminding students to use the science terms throughout the activity. Otherwise, students who are asked what they learned from this activity will answer, “We nuked cookie dough in the microwave.” Have students creatively name their new element — microwavium, meltedcookieum, nukedcookieum, etc.