Nuclear Fusion

How are elements created in stars?

About the Activity

This simple and engaging activity explains nuclear fusion and how radiation is generated by stars, using marshmallows as a model.

Topics Covered

- What is cosmic radiation and where does it come from?
- How are the elements in the universe generated?

Participants

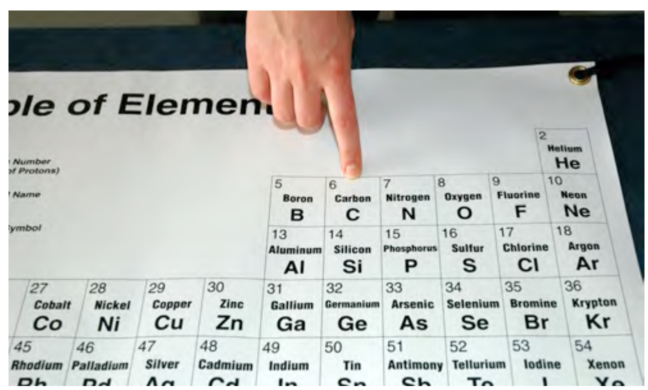
Activities are appropriate for families, the general public, and school groups ages 10 and up. Any number of visitors may participate.

Materials Needed

- Marshmallows (mini multi-colored ones are best. White and full-sized marshmallows also work.) Or substitute small balls of playdough.
- Uncooked salad pasta
- Bowls for the marshmallows and hard pasta
- A Periodic Table of the Elements (provided below)
- *(Optional)* Copies of the Electromagnetic Spectrum for advanced audiences (See Activity Description for a link)
- *(Optional)* Napkins for the marshmallows

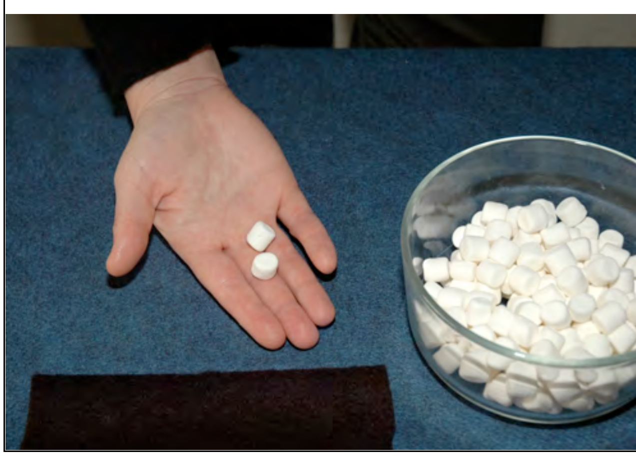
Location and Timing

This activity can be used at or before a star party, in a classroom, with youth groups or the general public. It takes about 5 - 8 minutes.



Detailed Activity Description

Nuclear Fusion

<table>
<tr><th>Leader's Role</th><th>Participants' Role (Anticipated)</th></tr>
<tr><td colspan="2">Objective:
Allow visitors to have an introduction to nuclear fusion and the energy it releases.</td></tr>
<tr><td><u>To Do:</u>
Display the Table of Elements side of the banner and/or pass out the Table of Elements handouts.
<u>To say:</u>
Throughout its life, a star generates new elements by fusing atoms together in its core,
What's fuse mean?
Stars are mostly hydrogen and helium.
<u>To Do:</u>
Point to Hydrogen and Helium on the Table of Elements.
Hold up a marshmallow (or small ball of clay).
<u>To say:</u>
This represents a proton. The number of protons an atom has in its nucleus determines what kind of element it is. [pointing to Hydrogen on banner or handout] A Hydrogen atom has one proton in its nucleus. So how many hydrogen atoms does this represent?
<u>To Do:</u>

Have each person take 2 marshmallows out of the bowl.</td><td>Join together.

One.</td></tr>
</table>

<table>
<tr><td>
To say:
Take two protons representing the nucleus of two Hydrogen atoms. Generally fusion happens with two atomic nuclei at a time.

What element has two protons in its nucleus? [point to Helium on handout or banner]

Let’s see how a star makes helium.

To do:
Put your hands together with the marshmallows inside.

To Say:
We’ll pretend your hands are the core of a star. Temperatures are so hot and pressures so great inside stars that the atoms are moving tremendously fast and crashing into one another. And sometimes they fuse. Can you make your protons fuse?
Let’s say the magic words: Nuclear fusion!
To do:
Crush the marshmallows together.

To say:
The two hydrogen atoms have fused to make the nucleus of what element?

Now nuclear fusion doesn’t generate just new, heavier atoms. Each time two atoms lighter than iron fuse, the reaction releases energy. In the form of gamma-ray radiation. We’re using this to represent the released gamma-ray.
</td>
<td>
Helium.

NUCLEAR FUSION!

Helium!
</td></tr>
</table>

To do:
Set a short spool (or one piece of salad macaroni) representing a gamma ray on the table.

Presentation Tip:

If you have a more advanced audience:

It might be helpful here to point to a picture of the Electromagnetic Spectrum and point out that gamma-rays are the highest energy radiation. You can find one here: http://www.teachersdomain.org/asset/phy03_img_lpaemspect/

You might also want to explain that it is the atomic nuclei that fuse, not the whole atom – which would include its electrons. Temperatures are so high in the core of the star that the nuclei have all been stripped of their electrons. The nucleus of an atom contains only protons and neutrons. In the core of a star, the atomic nuclei and the electrons are moving about independent of each other.

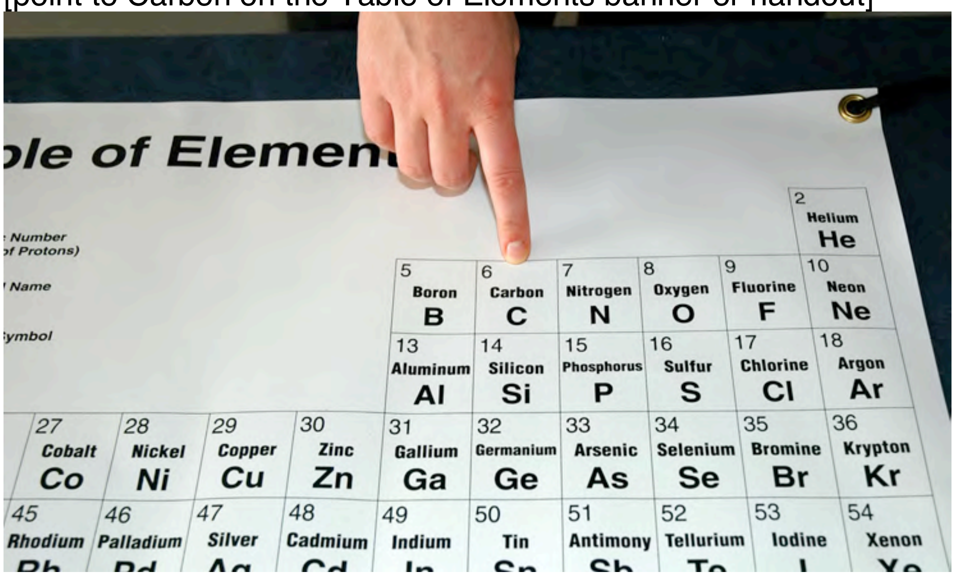
To Say:
Let's make another Helium.
Take two more marshmallows – I mean, Hydrogen!
To do:
Pick up and smash two more marshmallows.
To Say:
Say the magic words: Nuclear fusion!

NUCLEAR FUSION!

To do:
Set out a gamma-ray piece.
To Say:
And another.
To do:
Pick up and smash two more marshmallows.

NUCLEAR FUSION!

Set out a gamma-ray piece.
To Say:
Now we have three helium atoms – how many protons are

here? Let’s smash two of these together. Magic words?	 Six. NUCLEAR FUSION!
To do: Smash two of the Helium marshmallows together. Set out a gamma-ray piece. *To Say:* Then smash your other helium atom into this and … Say it again! We have . . . an atomic nucleus with how many protons? What element is that? [point to Carbon on the Table of Elements banner or handout]   	 NUCLEAR FUSION! Six. Carbon.

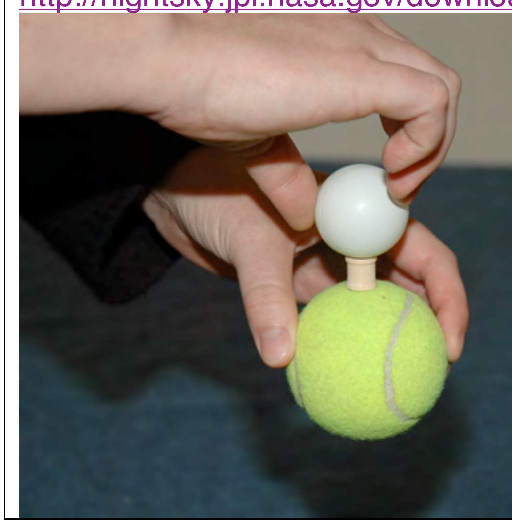
Presentation Tips:

1. Two Helium nuclei fuse to form Beryllium (with 4 protons in its nucleus). But Beryllium is so unstable that it will disintegrate in a tiny fraction of a second. However, when another Helium nucleus hits it before it disintegrates, Carbon is formed (6 protons). This is referred to as the "triple-alpha" process. Helium nuclei are also called "alpha particles."

2. *"We are stardust":* If your audience had clean hands while they were making the Helium and Carbon, when they get to Carbon, you can let them eat the Carbon marshmallow atomic nucleus, adding to their understanding that they are made of material that was made inside stars. "Living things, like you and me, have carbon in them. So if you want to eat your carbon atom, you can see that you are made of atoms that were made in stars."

3. Follow this activity with the "Protecting the Earth from Cosmic Radiation" to see how these elements and the radiation associated with a supernova are expelled into space. Find that here:
http://nightsky.jpl.nasa.gov/download-search.cfm

Presentation Tip:
You can also use the ping-pong ball & tennis ball demo ("Let's Make a Supernova!"), this time placing a "gamma-ray" piece between the tennis ball and the ping-pong ball (see photo below) and dropping it all. Both the ping-pong ball and the gamma-ray will go flying, simulating the concept of cosmic radiation spreading out into the universe. Find the activity and more here:
http://nightsky.jpl.nasa.gov/download-earch.cfm



Helpful Hints

IMPORTANT DEFINITION Cosmic Radiation: We are limiting the use of the scientific term "cosmic rays" and instead using the more descriptive term "fast-moving (or accelerated) atomic particles." This is to reduce confusion with the term "**cosmic radiation**" which is used here to refer to the combination of electromagnetic radiation (particularly the high-energy x-rays and gamma-rays) AND accelerated atomic particles coming from space. Atomic particles can be atomic nuclei or individual protons, neutrons, or electrons.

Background Information

For more information on gamma-ray and x-ray astronomy, gamma-ray bursts, and Earth's atmosphere and magnetic field as a shield from cosmic radiation:

http://imagine.gsfc.nasa.gov/docs/science/science.html

For background on nuclear fusion and nucleosynthesis, review the booklet "What is your Cosmic Connection to the Elements?" included in the ToolKit or download the PDF from:
http://imagine.gsfc.nasa.gov/docs/teachers/elements/

For more information about exposure to radioactivity and its effects on the body, search the Internet for "radiation sickness".

NASA Missions studying high-energy radiation

Swift (http://swift.gsfc.nasa.gov) is a first-of-its-kind multi-wavelength observatory dedicated to the study of gamma-ray burst (GRB) science. It was launched into a low-Earth orbit in November of 2004 and has detected hundreds of bursts.
For downloadable information and handouts related to the Swift Mission:
http://swift.sonoma.edu/resources/multimedia/pubs/
For downloadable animations on the Swift mission and GRBs:
http://swift.sonoma.edu/resources/multimedia/animations/index.html

The **Gamma-Ray Large Area Space Telescope** (GLAST: http://www.nasa.gov/glast) is an international and multi-agency mission studying the cosmos looking at objects that emit the highest energy wavelengths of light. Launched in 2008 into low-Earth orbit, its main mission objectives include studying active galaxies, supernovae, pulsars, and gamma-ray bursts.
For downloadable images, animations, and posters on the GLAST Mission: http://glast.sonoma.edu/resources/

XMM-Newton (http://xmm.sonoma.edu/) is a joint NASA-European Space Agency (ESA) orbiting observatory, designed to observe high-energy x-rays emitted from exotic astronomical objects such as pulsars, black holes and active galaxies. It was launched in 1999 from the ESA base at Kourou, French Guiana.
For more information on the XMM-Newton Mission: http://xmm.esac.esa.int/

The **Suzaku** (http://suzaku-epo.gsfc.nasa.gov/) satellite provides scientists with information to study extremely energetic objects like neutron stars, active and merging galaxies, black holes, and supernovae in the x-ray energy range. Astronomers hope it will help answer several important questions: When and where are the chemical elements created? What happens when matter falls onto a black hole? How does nature heat gas to x-ray emitting temperatures? Suzaku was launched in July 2005 and is a collaboration between Japanese and US institutions including NASA.
For more information on the Suzaku Mission: http://www.nasa.gov/mission_pages/astro-e2/main/index.html

Table of Elements

1 Hydrogen H																	2 Helium He
3 Lithium Li	4 Beryllium Be											5 Boron B	6 Carbon C	7 Nitrogen N	8 Oxygen O	9 Fluorine F	10 Neon Ne
11 Sodium Na	12 Magnesium Mg											13 Aluminum Al	14 Silicon Si	15 Phosphorus P	16 Sulfur S	17 Chlorine Cl	18 Argon Ar
19 Potassium K	20 Calcium Ca	21 Scandium Sc	22 Titanium Ti	23 Vanadium V	24 Chromium Cr	25 Manganese Mn	26 Iron Fe	27 Cobalt Co	28 Nickel Ni	29 Copper Cu	30 Zinc Zn	31 Gallium Ga	32 Germanium Ge	33 Arsenic As	34 Selenium Se	35 Bromine Br	36 Krypton Kr
37 Rubidium Rb	38 Strontium Sr	39 Yttrium Y	40 Zirconium Zr	41 Niobium Nb	42 Molybdenum Mo	43 Technetium Tc	44 Ruthenium Ru	45 Rhodium Rh	46 Palladium Pd	47 Silver Ag	48 Cadmium Cd	49 Indium In	50 Tin Sn	51 Antimony Sb	52 Tellurium Te	53 Iodine I	54 Xenon Xe
55 Cesium Cs	56 Barium Ba	57-71 *	72 Hafnium Hf	73 Tantalum Ta	74 Tungsten W	75 Rhenium Re	76 Osmium Os	77 Iridium Ir	78 Platinum Pt	79 Gold Au	80 Mercury Hg	81 Thallium Tl	82 Lead Pb	83 Bismuth Bi	84 Polonium Po	85 Astatine At	86 Radon Rn
87 Francium Fr	88 Radium Ra	89-103 **	104 Rutherfordium Rf	105 Dubnium Db	106 Seaborgium Sg	107 Bohrium Bh	108 Hassium Hs	109 Meitnerium Mt	110 Darmstadtium Ds	111 Roentgenium Rg	112 Ununbium Uub	113 Ununtrium Uut	114 Ununquadium Uuq	115 Ununpentium Uup	116 Ununhexium Uuh	117 Ununseptium Uus	118 Ununoctium Uuo

6 — Atomic Number (Number of Protons)

Carbon — Chemical Name

C — Chemical Symbol

*	57 Lanthanum La	58 Cerium Ce	59 Praseodymium Pr	60 Neodymium Nd	61 Promethium Pm	62 Samarium Sm	63 Europium Eu	64 Gadolinium Gd	65 Terbium Tb	66 Dysprosium Dy	67 Holmium Ho	68 Erbium Er	69 Thulium Tm	70 Ytterbium Yb	71 Lutetium Lu
**	89 Actinium Ac	90 Thorium Th	91 Protactinium Pa	92 Uranium U	93 Neptunium Np	94 Plutonium Pu	95 Americium Am	96 Curium Cm	97 Berkelium Bk	98 Californium Cf	99 Einsteinium Es	100 Fermium Fm	101 Mendelevium Md	102 Nobelium No	103 Lawrencium Lr