Math/Science Studio
Astronomy Workshop: 'Stardust'
Liana Tsigaridi, PhD

Nucleosynthesis Activity

Introduction: Nuclear fusion is a process by which atoms of low mass elements are combined to make new elements under conditions of very high temperatures and pressures. This yields a large amount of energy, due to a process by which mass is converted to energy. In this exercise you will explore two fusion pathways that actually occur in stars.

Masses: H = 1.0079u He = 4.0026u C = 12.011u

1. Four nuclei of hydrogen combine to make one nucleus of helium:

$$H + H + H + H \rightarrow He$$

a) What is the exact mass of one H? _____
b) Multiply this (part a) by 4: _____
c) What is the exact mass of one He? _____
d) Subtract c from b: _____

This answer (part d) is known as the mass defect. It ***becomes energy*** during the nuclear fusion process.

2. Einstein's equation of Energy-Mass Equivalence is: $E = mc^2$
Where E is energy (in joules), m is mass (in kg), and
c is the speed of light, which is 3 x 10^8 m/s

The mass of 1u = 1.66 x 10^{-27} kg

You will now calculate the energy released by the fusion process that creates one He nucleus.

a) Change the mass defect of the $H \rightarrow He$ reaction (from #1. part d) from u into kg.
Show your work:

b) Multiply your answer in kg (part a) by c^2. The unit for your answer is joules. This gives the amount of energy produced for one He nucleus.

3. The Sun produces 9.5 x 10^{38} He nuclei every second. Calculate the amount of energy produced by the Sun <u>each second</u>.

4. A hydrogen bomb releases 1 x 10^{17} joules. How many bomb explosions are equal to the Sun's energy output each second?

5. There are a variety of nucleosynthesis reactions that form the heavy elements inside of stars. Below are two potential methods of forming carbon:

(A) $H + H + H + H + H + H + H + H + H + H + H + H \rightarrow C$

(B) $He + He + H + H + H + H \rightarrow C$

Calculate the mass defect of each reaction.

a) (A) m = _____ (B) m = _____

b) Which reaction produces more energy? _____

c) Based on this example, do lighter or heavier elements produce more energy per fusion reaction? _____

6. Calculate the mass defect of this reaction:

$He + He + He \rightarrow C$ m = _____

a) What is unusual about it? _____

b) Does this reaction release or absorb energy? _____

c) Would fusion proceed for this reaction? _____