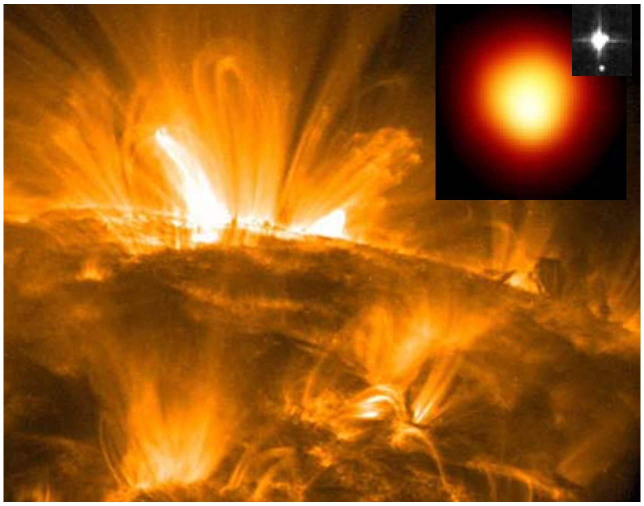

Stellar Chemistry

Every star you see in the night sky is a distant sun. A sun, for part of its life, is a ball of plasma (ionized gas) that fuses atoms into larger ones, converting small amounts of mass into enormous quantities of energy, as dictated by $E = mc^2$.

Recall that in chemical reactions, mass is conserved. One could also find the same elements on both sides of the equation. They just combine to become parts of different compounds. In nuclear equations, different elements can be formed without conserving mass. But from looking at a nuclear equation, you get the *false* impression that mass is still unchanged because *the sum of the mass numbers on both sides is the same*. But keep in mind that the true mass of an atom is not exactly equal to its mass number. Nuclear reactions also *conserve total atomic numbers*.

<u>Example</u>: The overall reaction for what occurs in the sun is:

$$4\,{}^{1}_{1}H \rightarrow {}^{4}_{2}He + 2\,{}^{0}_{1}e$$

	Left Hand Side of the Equation	**Right Hand Side of the Equation**
Total mass number	4(1) = 4	4 + 2(0) = 4
Total of atomic numbers	4(1) = 4	2 + 2(1) = 4

The ***e*** is not an electron, but a **positron**. Positrons, components of antimatter, are quickly destroyed as soon as they are formed as they encounter electrons, but during their brief existence they are the electron's counterpart: they have very little mass (mass number = 0) but hold a positive charge (same atomic number as hydrogen).

Stars of different sizes go on to produce elements. The greater their gravity, the higher the temperature of their cores, allowing different fusions to occur.

When stars like our sun are about to die, they go through a red giant stage. Elements crucial for life such as oxygen and carbon are produced: (γ = gamma rays)

$${}^{4}_{2}He + {}^{4}_{2}He \rightarrow {}^{8}_{4}Be$$

$${}^{8}_{4}Be + {}^{4}_{2}He \rightarrow {}^{12}_{6}C + \gamma$$

$${}^{12}_{6}C + {}^{4}_{2}He \rightarrow {}^{16}_{8}O + \gamma$$

Again check out how mass number-total and atomic number-total are conserved, even though new elements are being synthesized.

Strangely, most of the elements of the periodic table, especially those with atomic numbers greater than iron's, are synthesized when stars explode as supernovae. Only then does the energy that is needed to fuse such elements become available.

Examples with $E = mc^2$.

Given:
positron's molar mass = $5.485802368 \times 10^{-4}$ g/mole
^{1}H = 1.007825035 g/mole
^{4}He = 4.00260324 g/mole
c = speed of light = 2.99792458×10^{8} m/s

calculate the Δm and energy released for the following nuclear reaction:

$$4\,{}^{1}_{1}H \rightarrow {}^{4}_{2}He + 2\,{}^{0}_{1}e$$

Answer:

$\Delta m = 4.00260324 + 2(5.485798670 \times 10^{-4}) - 4(1.007825035) = -0.027599740$ g/mole

= 0.000027599740 kg/mole of He. The mass lost will be converted into energy. So for every mole of He produced, the sun releases:

$E = mc^2 = (0.000027599740 \text{ kg/mole}) (2.99792458 \times 10^{8} \text{ m/s})^2 =$
$2.480540926 \times 10^{12}$ J /mole
= 689039.1461 kWh/mole , (over $40 000 worth of electricity)

Note that we convert grams into kg since the unit of energy, $J = kg{*}m^2/s^2$.

For a more detailed discussion, click here.