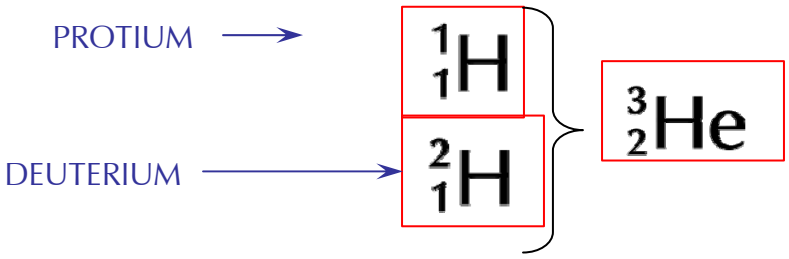
15:4a Nuclear Fusion

Nuclear Fusion

The combination of two light nuclei to form one larger nucleus



The energy produced by our sun and other stars results from fusion processes like those shown above

Here is another example of a fusion reaction within a star:

$$^{3}_{1}H + {}^{2}_{1}H \longrightarrow {}^{4}_{2}He + {}^{1}_{0}n$$

Notice that tritium and deuterium nuclei of hydrogen combine to produce a helium nucleus and a neutron

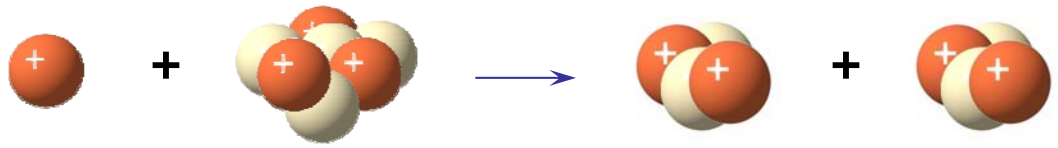
This reaction also releases
1.7×10^{12} J *for each mole of* He *produced*

1 700 000 000 000 J / mol

15:4b $E=mc^2$ and the Nuclear Mass Defect

Nuclear reactions such as fusion convert small amounts of mass into energy

Here is an example:



Proton	Lithium-7 nucleus	Helium-4	Helium-4
Mass	**Mass**	**Mass**	**Mass**
1.00728	7.01601	4.00620	4.00620

Total Initial Mass 8.02329

Combined Mass of Products 8.01240

Notice that 0.01809 *mass units* ***<u>are missing</u>***

We refer to this missing mass as the
NUCLEAR MASS DEFECT

$$E = mc^2$$

$$E = (0.01809) (299{,}792{,}458 \text{ km/sec})^2$$

or about (186,282 miles/sec)^2

The missing mass from one gram of Lithium-7 as above yields 230,000,000,000 Joules

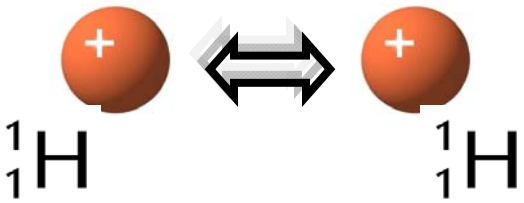
15:4c $E=mc^2$ and the Nuclear Mass Defect

If one kg of matter were completely converted into energy, 9×10^{16} Joules ***of energy would be released***

*Equivalent to burning approximately three **billion** kilograms of coal*

Atomic nuclei do not readily undergo fusion reactions in ordinary circumstances

For example, the positive charges of two hydrogen nuclei would ordinarily be expected to repel each other



Only extraordinarily high temperatures and pressures can force them together

The only places in nature where such high temperatures and pressures routinely occur are inside stars

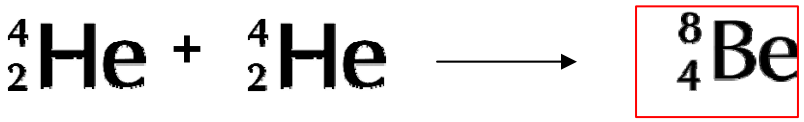
15:4d Stellar Nucleosynthesis

Stellar Nucleosynthesis

Stellar = "star" **Nucleo** = "nucleus" **Synthesis** = "to make"

Production of heavier nuclei by fusion reactions within stars

We can think of a star as a nuclear furnace where heavier atomic nuclei are synthesized



Crushing interior pressures force atomic nuclei closer together

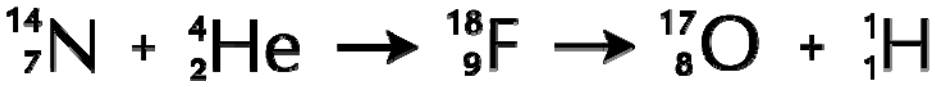
And interior temperatures of 15 or 20 million degrees Celsius provide the required kinetic energy

In each fusion event, tiny amounts of mass are converted into enormous amounts of energy

15:4e Stellar Nucleosynthesis

Notice that a star eventually begins to exhaust its supply of nuclear fuel as all of its hydrogen nuclei are utilized

With the exhaustion of their hydrogen fuel, stars shift to begin using ever heavier nuclei in their nuclear reactions



And produce every heavier nuclei as a result of a process called STELLAR NUCLEOSYNTHESIS

The Fluorine-18 nucleus depicted above is an unstable transitory intermediate