Generation of energy in the core from of the sun

Sun's Energy Source

The Sun as a Star: the Sun is a typical star, in terms of mass, size, surface temperature, chemical composition.

The Sun is the main source of light and heat in the solar system. Without the light (energy) from the Sun, there would be no life on Earth.

The sun's core, or center, nuclear fusion makes enormous amounts of energy

Each second the sun converts about 600,000,000 tons of hydrogen nuclei into helium nuclei. When hydrogen atoms combine with each other, In these reactions change the atoms' mass (4 million tons) into energy and release it as heat and light into our solar system

Processes of Nuclear Energy

Thermonuclear Fusion

Nuclear Fission

- A heavy nucleus splits into two smaller nuclei
- The total mass of the products is more than the original mass of the heavy nucleus

Nuclear Fusion

Nuclear fusion occurs when two light nuclei combine to form a heavier nucleus

- The mass of the final nucleus is less than the masses of the original nuclei
- This loss of mass is accompanied by a release of energy

The Sun's energy is generated by thermonuclear reactions in its core

- All stars generate energy through fusion
- The Sun, fuses hydrogen

- **Two conditions must be met before fusion can occur in a star**

- **Thermonuclear fusion can take place only at extremely high temperature and high pressure: These two conditions (high temp. and high press. are required for the positively charged nuclei to overcome the repulsive forces and fuse together**

1905: Albert Einstein discovered from his special theory of relativity predicted that matter can be converted to energy according to this equation $E = mc^2$

where m is the mass in kg and $c = 3 \times 10^8 \ \frac{m}{sec}$ **is the speed of light in empty space**

- **Thermonuclear fusion: fusing together of two light nuclei to form a heavier nuclei.**

  $nucleus_1 + nucleus_2 \rightarrow nucleus_3 + energy$

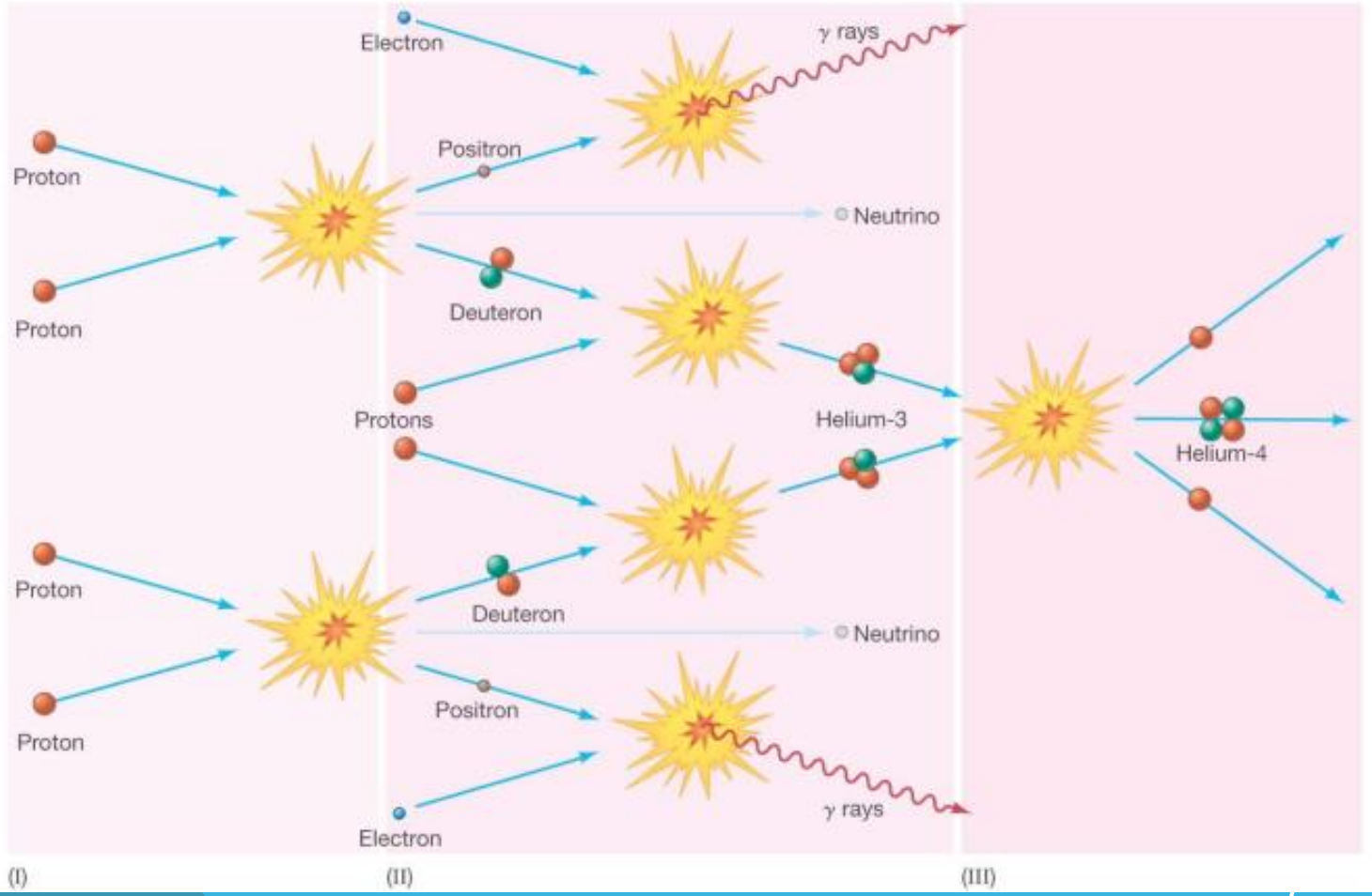
  In this a process

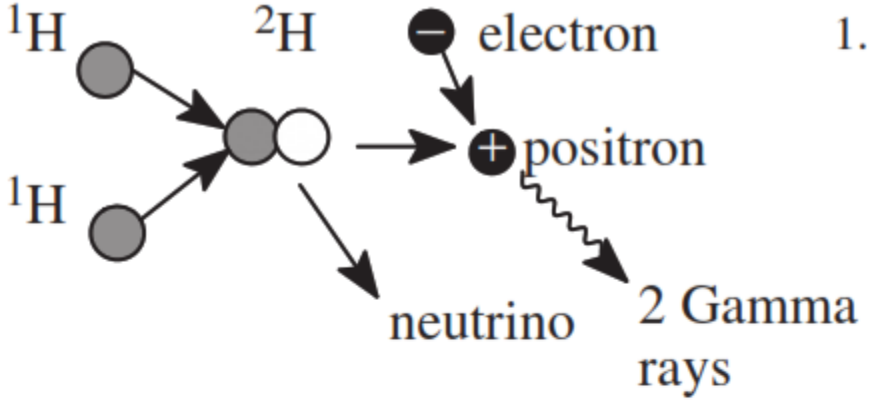
  $mass\ of\ nucleus_1 + mass\ of\ nucleus_2 > mass\ of\ nucleus_3$

  – Missing mass is converted to energy according to Einstein's mass-energy equation: $E = m\ c^2$

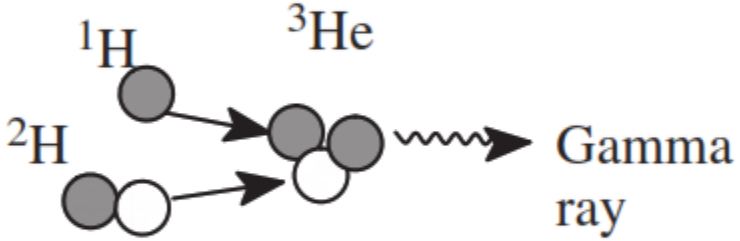
Proton-proton cycle:

This is the first step in a three-step fusion process that powers most stars. Study diagram to get a feel for the stages involved, but don't worry about memorizing the different reactions.

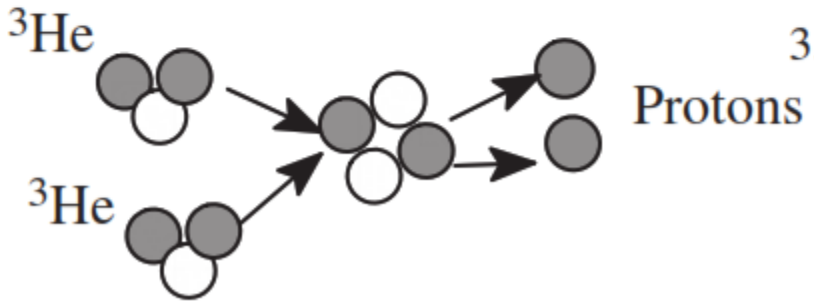




1. Two hydrogen nuclei (protons) collide and fuse. One proton turns into a neutron by the emission of a ***positron*** (which has a positive charge). The positron immediately encounters its anti-particle, the electron; the pair then annihilates, releasing two gamma rays. The result of this proton fusion is a ***deuterium*** nucleus, denoted ^{2}H.



2. A deuterium nucleus collides with a proton, and they fuse to form light helium, ^{3}He. Energy is released in the form of another gamma ray photon.



3. Finally, two ^{3}He nuclei collide and fuse into a nucleus of helium, ^{4}He. Two protons are released in this step.

The proton-proton fusion reaction which occurs in the core of the sun at a temperature of about 15,000,000 K. In this reaction 0.7% of the total mass disappears and is released energy.

The Proton-Proton Chain

Stars of mass similar to the sun and located on the main sequence of the HR Diagram derive their energy in their cores through a simple thermonuclear process called the proton-proton chain

The net result is that four protons (hydrogen nuclei) are converted to one helium nucleus plus two positrons (positively charged electrons that are annihilated when they combine with normal electrons to produce high-energy photons),

two neutrinos (tiny nearly massless particles that travel close to the speed of light), two high-energy gamma ray photons, and a whopping amount of heat energy.

Step One: $_1H^1 + {}_1H^1 \rightarrow {}_2H^1 + e^+ + \nu$

Step Two: $_2H^1 + {}_1H^1 \rightarrow {}_3He^2 + \gamma\text{-ray}$

Step Three: $_3He^2 + {}_3He^2 \rightarrow {}_4He^2 + {}_1H^1 + {}_1H^1$

Summarizing the thermonuclear reaction of hydrogen as follows:

$4\ H \rightarrow He + 2$ neutrinos + gamma ray photons.

Neutrinos(ν) are subatomic particles with no charge and little or no mass. (We will neglect the mass of the neutrino).

Most of the energy released in the thermonuclear fusion is in the form of gamma-ray photons

Energy of the sun in the proton proton chain

In this process four hydrogen atoms convert to helium and energy as following

$4\,H \rightarrow He + 2\,\nu + \gamma\text{-rays}$

- Amount of energy produced, (i.e. the energy of the gamma ray photons produced) is given by: Einstein equation

$\Rightarrow \; \boldsymbol{E = m\,c^2}$

- (note: ν and photons are massless)

- where m is the mass lost in one reaction:

m = mass of 4 H nuclei- mass of 1 He nucleus

$hydrogyen\ mass = 1.673 \times 10^{-27}$ kg

$\mathrm{h}elium\ \ mass = 6.645\ \times 10^{-27}$ kg

$4H = 4 \times 1.673 \times 10^{-27}$ kg=$6.693\ \times 10^{-27}$ kg

mass lost in one reaction is equal difference between masses of them

$four\ hydrogyen\ mass - one\ helium\ mass$

$= 6.693 \times 10^{-27} - 6.645 \times 10^{-27}$ kg

$= 0.048 \times 10^{-27}$kg

mass lost in one reaction is equal 0.048×10^{-27}kg

Thus the energy calculate by Einstein relationship

$$E=mC^2=0.048\times 10^{-27}\ \text{kg}\times\left(3\times 10^8\ \frac{m}{sec}\right)^2$$

$$E=mC^2=4.3\times 10^{-12}\ \text{J}$$

The fraction of the hydrogen mass that is lost is

$$fraction_{mass\ lost}=\frac{0.048\times 10^{-27}\ \text{kg}}{6.693\times 10^{-27}\ \text{kg}}=0.007$$

Which means that only 0.7% of the hydrogen mass has been converted to energy?

The actual energy produced from this reaction (for a given 4 Hydrogen atoms) can be found by

$$E=(0.007)(mas\ of\ 4H)C^2$$

$$E=0.063\times 10^{16}\ \text{J}$$

Thank you