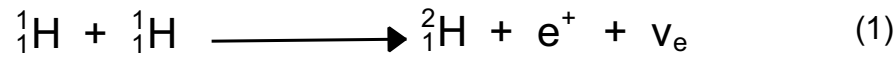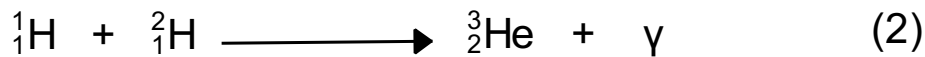# Nuclear reactions

*Verify that the fusion of four protons release 25 MeV for the **proton-proton fusion cycle**.*

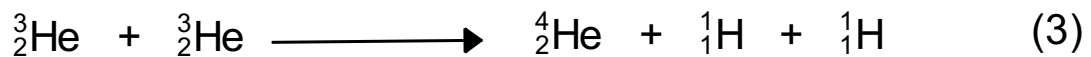## Solution:

The fusion of two hydrogen atoms produces one deuterium atom

$$^1_1H + {}^1_1H \longrightarrow {}^2_1H + e^+ + v_e \qquad (1)$$

The fusion of deuterium with hydrogen produces the helium atom

$$^1_1H + {}^2_1H \longrightarrow {}^3_2He + \gamma \qquad (2)$$

The fusion of helium with helium fives

$$^3_2He + {}^3_2He \longrightarrow {}^4_2He + {}^1_1H + {}^1_1H \qquad (3)$$
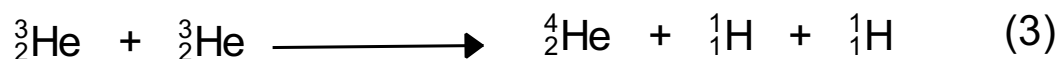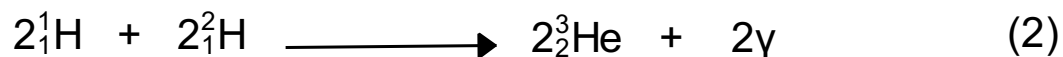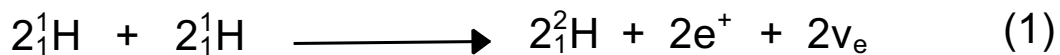
The chain of events (1), (2) and (3) is known as the proton-proton cycle, which is one of the schemes offered to describe the conversion of hydrogen atoms into helium atoms in stars.

If we multiply equations (1) and (2) by two and sum that with equation (3), we get

$$2{}^1_1H + 2{}^1_1H \longrightarrow 2{}^2_1H + 2e^+ + 2v_e \qquad (1)$$

$$2{}^1_1H + 2{}^2_1H \longrightarrow 2{}^3_2He + 2\gamma \qquad (2)$$

$$^3_2He + {}^3_2He \longrightarrow {}^4_2He + {}^1_1H + {}^1_1H \qquad (3)$$

$$6{}^1_1H + 2{}^2_1H + 2{}^3_2He \longrightarrow 2{}^1_1H + 2{}^2_1H + 2{}^3_2He + {}^4_2He + 2e^+ + 2v_e + 2\gamma$$

or $\qquad 4\,{}^1_1H \longrightarrow {}^4_2He + 2e^+ + 2v_e + 2\gamma$
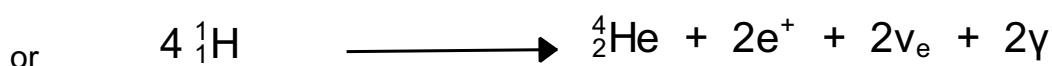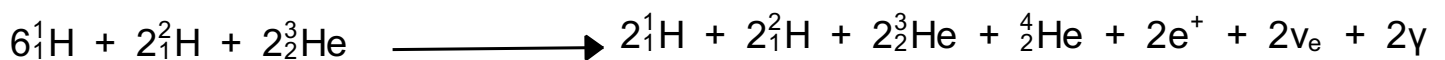
Before the reaction the total nuclear mass is:

4 x (Atomic mass of hydrogen) = 4 x 1.0073 amu

= 4.0292 amu

After reaction the total mass is

Atomic mass of ^{4}He + 2 x (mass of positron)

= (4.0015 + 2 x 0.0011) amu = 4.0026 amu

The energy released in the fusion reaction is equivalent to the difference in mass:

4.0292 - 4.0026 = 0

= (931 MeV/amu) (0.0266 amu) = 25 MeV