The Lifetime of the Sun

DF (1)

Data

The Sun fuses four Hydrogen nuclei (protons) to form each Helium nucleus. Eventually, when the supply of Hydrogen runs out, this process will stop. You can estimate when this stage is reached from the information below.

- The energy released when four protons fuse, ΔE, = 4.0×10^{-12} J.
- The luminosity of the Sun = 3.9×10^{26} ($W = J s^{-1}$).
- The mass of the Sun, $M_\odot$ = 2×10^{-30} kg
- The mass of the proton, M_p = 1.7×10^{-27} kg
- Approximate age of the Sun = 5×10^9 years (1 year $\approx 3 \times 10^7$ s)

Assume that the Sun was made entirely of protons, when it condensed from the Interstellar Matter (I.S.M.) and that proton fusion will stop when 10% of the protons have been consumed.

The number of protons in the Sun = $\dfrac{M_\odot}{M_p}$

$= \dfrac{2 \times 10^{30}\ \text{kg}}{1.7 \times 10^{-27}\ \text{kg}}$

$= 1.1(8) \times 10^{57}$

Each Helium nucleus is made from the fusion of four protons, and only 10% of the total number protons take part; so the number of Helium nuclei produced

$= \dfrac{\text{number of protons in the Sun}}{40}$

$= \dfrac{1.1(8) \times 10^{57}}{40}$

$= 2.9(4) \times 10^{55}$

The total energy released = number of Helium nuclei produced × energy released in the production of a single Helium nucleus

$= 2.9(4) \times 10^{55}$ nuclei $\times$ 4×10^{-12} J nucleus^{-1}

$= 1.1(8) \times 10^{44}$ J

The time taken to release the energy

$= \dfrac{\text{total energy output}}{\text{luminosity of the Sun}}$

$= \dfrac{1.1(8) \times 10^{44}\ \text{J}}{3.9 \times 10^{26}\ \text{J s}^{-1}\ (\text{W})}$

$= 3.0(2) \times 10^{17}$ s

$\approx 10^{10}$ years

The Sun will continue to fuse Hydrogen for approximately 5×10^9 years from now (that is, the Sun is roughly half-way through its Hydrogen fusion).

This answer is an example of a calculation the steps of which can be performed simply on your R.T.C., without the need to write intermediate answers or to re-key complicated numbers.

My turbo-assisted, Castell slide rule is truly luxurious in its provision of two (yes, two) decimal places... How could anyone demand a greater luxury?

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