Principles of Chemistry | (3rd Edition)

Chapter 19, Problem 54E | Bookmark | Show all steps: ON

Problem

The overall hydrogen burning reaction in stars can be represented as the conversion of four protons to one *a* particle. Use the data for the mass of H-1 and He-4 to calculate the energy released by this process.

Step-by-step solution

Step 1 of 3

The nuclear reaction representing the fusion of four protons to form an alpha particle is as follows:

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

$$\text{Mass of the reactant} = 4(\text{mass of proton})$$
$$= 4(1.00783\,\text{amu})$$
$$= 4.03132\,\text{amu}$$

$$\text{Mass of the product} = (\text{mass of } {}^{4}_{2}\mathrm{He})$$
$$= 4.00260\,\text{amu}$$

Comment

Step 2 of 3

In the nuclear reaction process, only the nucleus is involved and not the electrons. But the atomic mass includes the mass of electrons. So, the mass of electrons is to be deducted from the mass of the reactant and the product.

So, the equation for the mass defect becomes as follows:

$$\text{Mass of the product} = (\text{mass of } {}^{4}_{2}\mathrm{He})$$
$$= 4.00260\,\text{amu}$$

$$4(\text{Mass}_{\text{H}}) - 4e^{-} = \text{Mass}_{\text{He}} - \cancel{2e^{-}} + \cancel{2e^{-}}$$

$$\left[4(\text{Mass}_{\text{H}}) - 4e^{-}\right] - \text{Mass}_{\text{He}} = \text{Mass defect}$$

$$\text{Mass defect} = 4(\text{Mass}_{\text{H}}) - \text{Mass}_{\text{He}} + 4e^{-}$$

Comment

Step 3 of 3

Now substitute the values to calculate the mass defect as follows:

$$\text{Mass defect} = 4.03132 - 4.00260 + 4(0.000548)$$
$$= 0.0309\,\text{amu}$$

Convert amu to MeV. The conversion factor is as follows:

$$0.0309\,\text{amu} = 0.0309\,\text{amu} \times \frac{}{1\,\text{amu}}$$

$$= 28.794\,\text{MeV}$$

Convert MeV to J. The conversion factor is as follows:

$$\frac{1.6\times10^{-13}\,\text{J}}{1\,\text{MeV}}\,(or)\,\frac{1\,\text{MeV}}{1.6\times10^{-13}\,\text{J}}$$

$$28.794\,\text{MeV} = 28.794\,\text{MeV} \times \frac{1.6\times10^{-13}\,\text{J}}{1\,\text{MeV}}$$

$$= 4.61\times10^{-12}\,\text{J}$$

Therefore, the energy produced in this process is $\boxed{4.61\times10^{-12}\,\text{J}}$.

Comment

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Recommended solutions for you in Chapter 19

Chapter 19, Problem 10SAQ

Which problem is not associated with nuclear power generation? a) danger of overheated nuclear core b) waste disposal c) global warming d) none of the above (All of the above are problems associated with nuclear power generation.)

See solution

Chapter 19, Problem 6SAQ

Iron-59 is a beta emitter with a half-life of 44.5 days. If a sample initially contains 132 mg of iron-59, how much iron-59 is left in the sample after 265 days? a) 0.00 mg b) 2.13 mg c) 33.2 mg d) 66.0 mg

See solution