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Problem 55.54 (RHK)

Ordinary water consists of 0.015% *by mass of "heavy water," in which one of the two hydrogen atoms is replaced with deuterium,* $^{2}\mathrm{H}$. *We have to estimate the average fusion power that could be obtained if we "burned" all the* $^{2}\mathrm{H}$ *in* 1 *litre of water in* 1 *day through the reaction* $^{2}\mathrm{H}+{}^{2}\mathrm{H}\rightarrow{}^{3}\mathrm{He}+\mathrm{n}+3.27\ \mathrm{MeV}$.

Solution:

Ordinary water consists of 0.015% by mass of "heavy water," in which one of the two hydrogen atoms is replaced with deuterium, $^{2}\mathrm{H}$. Therefore, mass of "heavy water" in 1 litre of water will be

$=1000\times 0.00015\ \mathrm{g}=0.15\ \mathrm{g}$.

Number of molecules of "heavy water" in 0.15 g, which will also be the number of $^{2}\mathrm{H}$, will be

$$N_{^{2}\mathrm{H}}=\frac{6.02\times 10^{23}\times 0.15}{19}=4.75\times 10^{21}.$$

In fusion of two $^{2}\mathrm{H}$ nuclei through the process

$^{2}\mathrm{H}+{}^{2}\mathrm{H}\rightarrow{}^{3}\mathrm{He}+\mathrm{n}$, 3.27 MeV energy is released. Therefore, the total energy that can be released by burning off all $^{2}\mathrm{H}$ nuclei contained in 1 litre of water will be

$$E = \frac{3.27 \times 4.75 \times 10^{21}}{2}\ \mathrm{MeV}$$

$$= 7.77 \times 10^{21} \times 1.6 \times 10^{-13}\ \mathrm{J} = 12.42 \times 10^{8}\ \mathrm{J}.$$

If the burning of $^{2}\mathrm{H}$ nuclei contained in 1 litre of water occurs in 1 day $\left(8.60 \times 10^{4}\ \mathrm{s}\right)$, the average fusion power that will be available will be

$$P = \frac{12.42 \times 10^{8}\ \mathrm{J}}{8.60 \times 10^{4}\ \mathrm{s}} = 1.44 \times 10^{4}\ \mathrm{W}.$$