899.

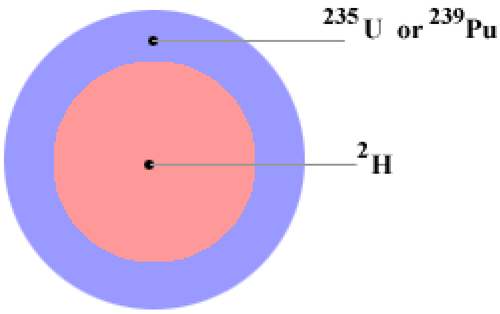
Problem 44.51P (HRW)

In the figure an early proposal for a hydrogen bomb has been shown. The fusion fuel is deuterium, $^{2}\mathrm{H}$. *The high temperature and particle density for fusion are provided by an atomic bomb* "*trigger*," *which involves a* $^{235}\mathrm{U}$ *or* $^{239}\mathrm{Pu}$ *fission fusion that is arranged to impress an imploding, comprehensive shock wave on the deuterium. The operative fusion reaction is*

$$5\,^{2}\mathrm{H} \rightarrow {}^{3}\mathrm{He} + {}^{4}\mathrm{He} + {}^{1}\mathrm{H} + 2\mathrm{n}\ .$$

We have to calculate (a) *the* Q *for the fusion reaction*; (b) *we have to calculate the rating of the fusion part of the bomb if it contains* 500 kg *of deuterium*, 30.0% *of which undergoes fusion. Needed atomic masses are*

$^{1}\mathrm{H}$	1.007825 u	$^{2}\mathrm{H}$	2.014 102 u
$^{3}\mathrm{He}$	3.016029 u	$^{4}\mathrm{He}$	4.002 603 u
n	1.008665 u.		



Solution:

The Q for the fusion reaction

$$5\,{}^{2}\text{H} \rightarrow {}^{3}\text{He} + {}^{4}\text{He} + {}^{1}\text{H} + 2\text{n}$$

will be

$$= \left(5 \times 2.014\,102 - 3.016029 - 4.002\,603 - 1.007825 - 2 \times 1.008665\right)\text{u}c^{2}$$

$$= 0.026723\ \text{u}c^{2} = 0.026723 \times 931.5\ \text{MeV}$$

$$= 24.89\ \text{MeV}.$$

Number of ^{2}H atoms in 500 kg of deuterium will be

$$N_{^{2}\text{H}} = \frac{6.02 \times 10^{23} \times 500 \times 10^{3}\ \text{g}}{2\ \text{g}} = 15.05 \times 10^{28}.$$

It is given that the design of the hydrogen bomb is such as allows 30.0% of deuterium to undergo fusion. As in each fusion reaction 5 nuclei of ^{2}H fuse, the total amount of energy that will be released in the bomb will be

$$E = \frac{15.05\times10^{28}\times0.3\times24.89\ \text{MeV}}{5}$$

$$= 22.47\times10^{28}\ \text{MeV} = 22.47\times10^{28}\times1.6\times10^{-13}\ \text{J}$$

$$= 35.96\times10^{15}\ \text{J}.$$

As one megaton of TNT is equivalent to $2.6\times10^{28}\ \text{MeV}$, the rating of the bomb in unit of megaton of TNT will be

$$\frac{22.47\times10^{28}\ \text{MeV}}{2.6\times10^{28}\ \text{MeV per megaton of TNT}} = 8.64 \text{ megaton of TNT.}$$