898.

Problem 55.56 (RHK)

In a hydrogen bomb the fusion fuel is lithium deuteride (LiD). *The high temperature, particle density, and neutrons to induce fusion are provided by an atomic* (*fission*) *bomb "trigger." The fusion reactions are*

$$^{6}\text{Li} + \text{n} \rightarrow {}^{3}\text{H} + {}^{4}\text{He} + Q$$

and

$$^{2}\text{H} + {}^{3}\text{H} \rightarrow {}^{4}\text{He} + \text{n} + 17.59 \text{ MeV},$$

The tritium $\left({}^{3}\text{H}\right)$ *produced in the first reaction fusing with the deuterium* (D) *in the fuel. By calculating Q for the first reaction, we have to find the mass of* LiD *required to produce a fusion yield of* 1 megaton *of* TNT $\left(= 2.6\times10^{28} \text{ MeV}\right)$. *Needed atomic masses are*

^{6}Li	6.015121 u	^{4}He	4.002603 u
^{3}H	3.016049 u	n	1.008665 u.

Solution:

In a hydrogen bomb the fusion fuel is lithium deuteride (LiD). The high temperature, particle density, and neutrons to induce fusion are provided by an atomic (fission) bomb “trigger.” The fusion reactions are

$$^{6}\mathrm{Li} + \mathrm{n} \rightarrow {}^{3}\mathrm{H} + {}^{4}\mathrm{He} + Q$$

and

$$^{2}\mathrm{H} + {}^{3}\mathrm{H} \rightarrow {}^{4}\mathrm{He} + \mathrm{n} + 17.59 \text{ MeV},$$

The tritium ($^{3}\mathrm{H}$) produced in the first reaction fusing with the deuterium (D) in the fuel.

We calculate the Q value for the reaction

$^{6}\mathrm{Li} + \mathrm{n} \rightarrow {}^{3}\mathrm{H} + {}^{4}\mathrm{He}$.

It will be

$$= \left(6.015121 + 1.008665 - 3.016049 - 4.002603\right) \text{ u}c^{2}$$

$$= 0.005134 \text{ u}c^{2} = 0.005134 \times 931.5 \text{ MeV}$$

$$= 4.782 \text{ MeV}.$$

Therefore, the combined energy released in both fusion reactions in which one nucleus of $^{6}\mathrm{Li}$ and one nucleus of $^{2}\mathrm{H}$ undergo fusion using a neutron from the trigger fissions will be $\left(17.59 + 4.78 = 22.37\right)$ MeV.

We are required to estimate the amount of LiD required to produce a fusion yield of 1 megaton of TNT $\left(= 2.6 \times 10^{28} \text{ MeV}\right)$. The number of LiD molecules required for producing fusion yield of 1 megaton of TNT will be

$$N_{\mathrm{LiD}} = \frac{2.6\times10^{28}\ \mathrm{MeV}}{22.37\ \mathrm{MeV}} = 11.62\times10^{27}.$$

Therefore, the amount of LiD required in the hydrogen bomb will be

$$M_{\mathrm{LiD}} = \frac{8.0\times11.62\times10^{27}}{6.02\times10^{23}}\ \mathrm{g} = 154.4\ \mathrm{kg}.$$