THERMONUCLEAR FUSION[26]

Natural abundance of isotopes:

hydrogen	$n_D/n_H = 1.5 \times 10^{-4}$
helium	$n_{\mathrm{He}^3}/n_{\mathrm{He}^4} = 1.3 \times 10^{-6}$
lithium	$n_{\mathrm{Li}^6}/n_{\mathrm{Li}^7} = 0.08$

Mass ratios:

$$
\begin{aligned}
m_e/m_D &= 2.72 \times 10^{-4} = 1/3670 \\
(m_e/m_D)^{1/2} &= 1.65 \times 10^{-2} = 1/60.6 \\
m_e/m_T &= 1.82 \times 10^{-4} = 1/5496 \\
(m_e/m_T)^{1/2} &= 1.35 \times 10^{-2} = 1/74.1
\end{aligned}
$$

Absorbed radiation dose is measured in rads: 1 rad = $10^2\,\mathrm{erg\,g^{-1}}$. The curie (abbreviated Ci) is a measure of radioactivity: 1 curie = 3.7×10^{10} counts sec^{-1}.

Fusion reactions (branching ratios are correct for energies near the cross section peaks; a negative yield means the reaction is endothermic):[27]

$$
\begin{array}{lll}
\text{(1a)} & \mathrm{D + D} & \xrightarrow[50\%]{} \mathrm{T}(1.01\,\mathrm{MeV}) + \mathrm{p}(3.02\,\mathrm{MeV}) \\
\text{(1b)} & & \xrightarrow[50\%]{} \mathrm{He}^3(0.82\,\mathrm{MeV}) + \mathrm{n}(2.45\,\mathrm{MeV}) \\
\text{(2)} & \mathrm{D + T} & \xrightarrow{} \mathrm{He}^4(3.5\,\mathrm{MeV}) + \mathrm{n}(14.1\,\mathrm{MeV}) \\
\text{(3)} & \mathrm{D + He}^3 & \xrightarrow{} \mathrm{He}^4(3.6\,\mathrm{MeV}) + \mathrm{p}(14.7\,\mathrm{MeV}) \\
\text{(4)} & \mathrm{T + T} & \xrightarrow{} \mathrm{He}^4 + 2\mathrm{n} + 11.3\,\mathrm{MeV} \\
\text{(5a)} & \mathrm{He}^3 + \mathrm{T} & \xrightarrow[51\%]{} \mathrm{He}^4 + \mathrm{p} + \mathrm{n} + 12.1\,\mathrm{MeV} \\
\text{(5b)} & & \xrightarrow[43\%]{} \mathrm{He}^4(4.8\,\mathrm{MeV}) + \mathrm{D}(9.5\,\mathrm{MeV}) \\
\text{(5c)} & & \xrightarrow[6\%]{} \mathrm{He}^5(2.4\,\mathrm{MeV}) + \mathrm{p}(11.9\,\mathrm{MeV}) \\
\text{(6)} & \mathrm{p + Li}^6 & \xrightarrow{} \mathrm{He}^4(1.7\,\mathrm{MeV}) + \mathrm{He}^3(2.3\,\mathrm{MeV}) \\
\text{(7a)} & \mathrm{p + Li}^7 & \xrightarrow[20\%]{} 2\ \mathrm{He}^4 + 17.3\,\mathrm{MeV} \\
\text{(7b)} & & \xrightarrow[80\%]{} \mathrm{Be}^7 + \mathrm{n} - 1.6\,\mathrm{MeV} \\
\text{(8)} & \mathrm{D + Li}^6 & \xrightarrow{} 2\mathrm{He}^4 + 22.4\,\mathrm{MeV} \\
\text{(9)} & \mathrm{p + B}^{11} & \xrightarrow{} 3\ \mathrm{He}^4 + 8.7\,\mathrm{MeV} \\
\text{(10)} & \mathrm{n + Li}^6 & \xrightarrow{} \mathrm{He}^4(2.1\,\mathrm{MeV}) + \mathrm{T}(2.7\,\mathrm{MeV})
\end{array}
$$

The total cross section in barns (1 barn = $10^{-24}\,\mathrm{cm}^2$) as a function of E, the energy in keV of the incident particle [the first ion on the left side of Eqs. (1)–(5)], assuming the target ion at rest, can be fitted by[28]

$$
\sigma_T(E) = \frac{A_5 + \left[(A_4 - A_3E)^2 + 1\right]^{-1} A_2}{E\left[\exp(A_1E^{-1/2}) - 1\right]}
$$

where the Duane coefficients A_j for the principle fusion reactions are as follows:

	D–D (1a)	D–D (1b)	D–T (2)	D–He^3 (3)	T–T (4)	T–He^3 (5a–c)
A_1	46.097	47.88	45.95	89.27	38.39	123.1
A_2	372	482	50200	25900	448	11250
A_3	4.36×10^{-4}	3.08×10^{-4}	1.368×10^{-2}	3.98×10^{-3}	1.02×10^{-3}	0
A_4	1.220	1.177	1.076	1.297	2.09	0
A_5	0	0	409	647	0	0

Reaction rates $\overline{\sigma v}$ (in cm^3 sec^{-1}), averaged over Maxwellian distributions:

Temperature (keV)	D–D (1a + 1b)	D–T (2)	D–He^3 (3)	T–T (4)	T–He^3 (5a–c)
1.0	1.5×10^{-22}	5.5×10^{-21}	10^{-26}	3.3×10^{-22}	10^{-28}
2.0	5.4×10^{-21}	2.6×10^{-19}	1.4×10^{-23}	7.1×10^{-21}	10^{-25}
5.0	1.8×10^{-19}	1.3×10^{-17}	6.7×10^{-21}	1.4×10^{-19}	2.1×10^{-22}
10.0	1.2×10^{-18}	1.1×10^{-16}	2.3×10^{-19}	7.2×10^{-19}	1.2×10^{-20}
20.0	5.2×10^{-18}	4.2×10^{-16}	3.8×10^{-18}	2.5×10^{-18}	2.6×10^{-19}
50.0	2.1×10^{-17}	8.7×10^{-16}	5.4×10^{-17}	8.7×10^{-18}	5.3×10^{-18}
100.0	4.5×10^{-17}	8.5×10^{-16}	1.6×10^{-16}	1.9×10^{-17}	2.7×10^{-17}
200.0	8.8×10^{-17}	6.3×10^{-16}	2.4×10^{-16}	4.2×10^{-17}	9.2×10^{-17}
500.0	1.8×10^{-16}	3.7×10^{-16}	2.3×10^{-16}	8.4×10^{-17}	2.9×10^{-16}
1000.0	2.2×10^{-16}	2.7×10^{-16}	1.8×10^{-16}	8.0×10^{-17}	5.2×10^{-16}

For low energies ($T \lesssim 25\,\mathrm{keV}$) the data may be represented by

$$(\overline{\sigma v})_{DD} = 2.33 \times 10^{-14} T^{-2/3} \exp(-18.76 T^{-1/3})\ \mathrm{cm}^3\,\mathrm{sec}^{-1};$$

$$(\overline{\sigma v})_{DT} = 3.68 \times 10^{-12} T^{-2/3} \exp(-19.94 T^{-1/3})\ \mathrm{cm}^3\,\mathrm{sec}^{-1},$$

where T is measured in keV.

The power density released in the form of charged particles is

$$P_{DD} = 3.3 \times 10^{-13} {n_D}^2 (\overline{\sigma v})_{DD}\ \mathrm{watt\,cm}^{-3}\ \text{(including the subsequent D–T reaction);}$$

$$P_{DT} = 5.6 \times 10^{-13} n_D n_T (\overline{\sigma v})_{DT}\ \mathrm{watt\,cm}^{-3};$$

$$P_{D\mathrm{He}^3} = 2.9 \times 10^{-12} n_D n_{\mathrm{He}^3} (\overline{\sigma v})_{D\mathrm{He}^3}\ \mathrm{watt\,cm}^{-3}.$$