58 Energy from the Nucleus – Fusion ♡

The methods needed for working out the energy released are explained in full on Energy from the Nucleus – Radioactivity & Fission ♡ - P165.

The most promising fusion reaction, as far as power stations are concerned, is this:

$$^{2}_{1}\text{H} + ^{3}_{1}\text{H} \longrightarrow ^{4}_{2}\text{He} + ^{1}_{0}\text{n}$$

The masses of some nuclei are given in the table below:

$^{1}_{0}\text{n}$	1.6749×10^{-27} kg	$^{2}_{1}\text{H}$	3.3436×10^{-27} kg
$^{3}_{1}\text{H}$	5.0074×10^{-27} kg	$^{4}_{2}\text{He}$	6.6447×10^{-27} kg

58.1 Consider the reaction $^{2}_{1}\text{H} + ^{3}_{1}\text{H} \longrightarrow ^{4}_{2}\text{He} + ^{1}_{0}\text{n}$.

(a) Calculate the total mass of the reactants.

(b) Calculate the total mass of the products.

(c) The mass ‘lost’ is the energy lost to the nuclei. This energy is released in the form of kinetic energy. Calculate the lost mass.

(d) Use the equation $E = mc^2$ to work out how much energy has been lost from the nuclei (and gained in kinetic energy). Take $c = 3.00 \times 10^8$ m/s.

(e) A 1.0 kg sample of fusion fuel contains equal numbers of ^{2}H and ^{3}H nuclei. How many ^{2}H nuclei would the sample contain? Ignore the mass of the electrons which would also be in the fuel.

(f) The energy you calculated in (d) was released when one fusion occurred. Use your answers to the previous questions to work out how much energy you could get out of 1.0 kg of fusion fuel (with ^{2}H and ^{3}H in equal numbers) if you fused it all.

(g) A nuclear power station has a power output of 3.0×10^9 W. Calculate how much energy is generated in one year of continuous operation.

(h) Use your answers to (f) and (g) to calculate how many kilograms of fusion fuel you need to fuel the power station for a year.

To answer the next two questions, you will need your answers to the Energy from the Nucleus – Radioactivity & Fission ♡ worksheet questions, P166.

58.2 Compare your answers to 56.2d and 58.1d to find out which produces more energy – one fission or one fusion.

58.3 Compare your answers to 56.2e and 58.1f to find out which produces more energy per kilogram of fuel – fission or fusion.

58.4 Why is radioactive waste not as big a problem with fusion as it is with fission?

${}^{0}_{1}e$	9.1094×10^{-31} kg		${}^{12}_{6}C$	1.99210×10^{-26} kg
${}^{1}_{0}n$	1.6749×10^{-27} kg		${}^{14}_{7}N$	2.32463×10^{-26} kg
${}^{1}_{1}H$	1.6726×10^{-27} kg		${}^{15}_{8}O$	2.49059×10^{-26} kg
${}^{2}_{1}H$	3.3436×10^{-27} kg		${}^{24}_{12}Mg$	3.98172×10^{-26} kg
${}^{3}_{1}H$	5.0074×10^{-27} kg		${}^{56}_{26}Fe$	9.28585×10^{-26} kg
${}^{3}_{2}He$	5.0064×10^{-27} kg		${}^{111}_{52}Te$	18.41405×10^{-26} kg
${}^{4}_{2}He$	6.6447×10^{-27} kg			

58.5 Using the nuclear masses above, calculate the energy released in each of the following fusion reactions.

(a) ${}^{2}_{1}H + {}^{2}_{1}H \longrightarrow {}^{3}_{2}He + {}^{1}_{0}n$

(b) ${}^{3}_{1}H + {}^{3}_{1}H \longrightarrow {}^{4}_{2}He + 2\,{}^{1}_{0}n$

(c) $4{}^{1}_{1}H \longrightarrow {}^{4}_{2}He + 2{}^{0}_{1}e$

(d) ${}^{1}_{1}H + {}^{14}_{7}N \longrightarrow {}^{15}_{8}O$

(e) ${}^{12}_{6}C + {}^{12}_{6}C \longrightarrow {}^{24}_{12}Mg$

(f) ${}^{56}_{26}Fe + {}^{56}_{26}Fe \longrightarrow {}^{111}_{52}Te + {}^{1}_{0}n$

(g) What is different about the last reaction?