

THE LAST HOMEWORK SET 28: FUSION POWER

Due Friday, May 2, 2025

PROBLEMS FROM TZDII

17.54) The Sun's energy comes from the proton-proton cycle which begins with the reaction

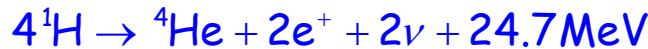


This reaction is exceedingly improbable, since it requires conversion of a proton to a neutron by β^+ decay during the brief collision of the two protons. Estimate the probability that a p^+p^+ collision will lead to this reaction as follows: Estimate the time that the first proton (with about 70 keV) is within range of the second (time to traverse about 10 fm, say). Take the mean life for a β decay of this kind to be of order 1 minute, and find the probability that the decay will occur while the protons are within range. [Hint: Recall Eq. (17.7) and the definition of r .]

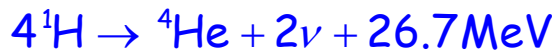
TZDII get the probability = $r t_{\text{passage}} = 4.6 \times 10^{-23}$

PROBLEMS FROM AOD

1) On p. 598, TZDII writes the fusion of hydrogen to helium as



Then explains that the annihilation of the two positrons results in another 2 MeV of energy so that the total reaction is



a) The Sun's luminosity is 3.827×10^{26} W. How many kilograms of hydrogen does the Sun fuse into helium each second to produce this luminosity? State your answer in Nimitz Class aircraft carrier masses of 98.6 Gg.

b) Two neutrinos are released in each fusion reaction in the Sun. Use this to calculate the flux of solar neutrinos at the distance of Earth in ν/cm^2 and compare this to the $6 \times 10^{10} \nu/\text{cm}^2$ I gave you in class.

2) According to the US Energy Information Administration, the US consumed 32.1×10^{15} BTU of electric power in 2023. If we could build a nuclear fusion reactor to supply that electricity at 100% efficiency, how many kilograms of hydrogen would have to be fused into helium to provide this power? Comment on how this compares to your answer to problem 1. Are you impressed by the local star?

U.S. energy consumption by source and sector, 2023
quadrillion British thermal units (Btu)

