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P6_1 Fusion For Breakfast

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Abstract

In this paper, an investigation is conducted to determine whether the human jaw is strong enough to fuse two hydrogen atoms together. It is found that the human jaw could bite down and successfully fuse 14 pairs of hydrogen atoms simultaneously. Given the energy generated via this fusion, it is then determined that it would take a human 3.204×10^{10} yrs - 8.520×10^{10} yrs to induce a sufficient number of fusion reactions to meet the average human's daily energy requirements, thus implying that a human could not hypothetically sustain themselves solely on hydrogen fusion.

Introduction

Nuclear fusion is currently seen as the goldmine of limitless, clean energy. This proposed form of future power generation produces electricity by using the heat energy released from the fusion of light nuclei. Developments in the technology of fusion reactors has lead to operating times of up to 20 s in the case of Korean Superconducting Tokamak Advanced Research [1]. Given the possibility of fusion revolutionising the way we power our lives, it begs the question: could it *literally* power our lives?

Assumptions

For this investigation, we consider two hydrogen nuclei at a distance of 2.500 fm from each other, with no initial kinetic energy. At this distance, both the effects of electrostatic repulsion and the attractive strong nuclear force drop off and become negligible. Their motion is restricted to the vertical direction to avoid the inevitable consequence of the particles deflecting along a different axis. The force applied by the upper and lower second molars (the point at which the most force can be applied [2]), assumed to be uniformly distributed onto the nuclei by approximating that the surfaces of the teeth at the point of contact are flat and have the same area as the cross section of a hydrogen nucleus. The final assumption made is given that the work done by the jaw is small compared to the energy intake of a human, we are assuming this daily energy intake takes into account the energy used by the jaw to chew.

Method

We begin by calculating the work done by the Coulomb force between two like-charged particles. This force, F, is given by:

$$F = \frac{kq^2}{r^2} \tag{1}$$

where $k = \frac{1}{4\pi\epsilon_0}$, (the Coulomb constant), q is the charge of the particles and r is the distance between the two particles. The force applied by the tooth is in the opposite direction to that of the repulsion thus: $F_{Tooth} = -F_{Repulsion}$. This can be seen in Figure 1.

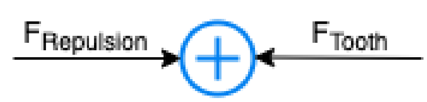

Figure 1: A schematic representation of the force vectors acting on one of the hydrogen nuclei.

The minimum work done required by the jaw, is equal to the work done to overcome the Coulomb force:

$$W_{req} = -\int_{r_1}^{r_2} \frac{kq^2}{r^2}\, dr \tag{2}$$

where, $r_2 = 2.500$ fm, $r_1 = 1.000$ fm (the scale at which the nuclear strong force overcomes Coulomb repulsion [5]), $q = 1.602 \times 10^{-19}$ C. Following this, we calculate the maximum work done the jaw could provide, using a constant force, $F = 1317\,\mathrm{N}$, (the maximum theoretical bite force possible from a human jaw [2]) over the same distance:

$$W_{max} = F\Delta x \tag{3}$$

where $\Delta x = 1.500\,\mathrm{fm}$. To calculate the number of reactions a human jaw could induce in one bite, n, we calculate the ratio of the W_{max} to W_{req}:

$$n = \frac{W_{max}}{W_{req}} \tag{4}$$

The energy is produced from the fusion of two hydrogen nuclei via:

$$H_1^1 + H_1^1 \rightarrow D_1^2 + \beta^+ + \nu_e + energy \tag{5}$$

where D_1^2 represents deuterium, β^+ is a positron and ν_e is an electron neutrino. Typically, the positron annihilates with a local electron, so the process can be rewritten as:

$$H_1^1 + H_1^1 + e^- \rightarrow D_1^2 + \nu_e + energy \tag{6}$$

The energy of the neutrino is not accounted for due to the rarity at which neutrinos interact with matter. This energy, ΔE, comes from the difference in binding energy between hydrogen and deuterium nuclei and is calculated via:

$$\Delta E = \Delta mc^2 \tag{7}$$

where Δm is the change in mass (for this reaction $\Delta m = 2.619 \times 10^{-30}\,\mathrm{kg}$ and c is the speed of light ($2.998 \times 10^8\,\mathrm{m\,s^{-1}}$). The average person needs a minimum 2000 calories (kcal) to maintain their body weight and be healthy [3]. With a conversion of 1 kcal = $4.184\,\mathrm{kJ}$, we divide this energy requirement, E_{req}, by the energy produced, E, in Eq.6, which provides the number of reactions, N, needed to produce this energy requirement.

$$N = \frac{E_{req}}{E} \tag{8}$$

With this value, we obtain the number of 'bites' a person would have to perform, l, to produce the energy, E_{req}, by dividing this by the number of reactions possible in one bite calculated in Eq.4. Divide this by the range of chewing frequencies, f, of humans: $0.940\,\mathrm{s^{-1}}$ - $2.500\,\mathrm{s^{-1}}$[4], we get the range of time, τ, it will take to complete the number of reactions required, N:

$$\tau = \frac{l}{f_{1,2}} \tag{9}$$

where $f_1 = 0.940\,\mathrm{s^{-1}}$ and $f_2 = 2.500\,\mathrm{s^{-1}}$.

Results

Using Eq.2, we calculate the work required, W_{req} = $1.384 \times 10^{-13}\,\mathrm{J}$. Following this, the maximum work the jaw could do over this distance is $W_{max} = 1.976 \times 10^{-12}\,\mathrm{J}$ using Eq.3. The number of reactions possible in one bite was found to be $n = 14$ using Eq.4. Eq.7 yields $\Delta E = 2.358 \times 10^{-13}\,\mathrm{J}$. This along with the energy required by an average person (E_{req} = $8.368\,\mathrm{MJ}$) per day, substituted into Eq.8 yields the number of reactions required, $N = 3.555 \times 10^{19}$ Provided these values, l (the number of bites required to produce this energy) = 2.539×10^{18} Finally, substituting l into Eq.9 produces a range of time to complete this task:

$$\tau = 3.220 \times 10^{10}\,\mathrm{yrs} - 8.565 \times 10^{10}\,\mathrm{yrs} \tag{10}$$

Conclusion

We conclude that mastication induced hydrogen fusion is not a viable method of sustaining one's self. The investigation has found that the force exerted by the human jaw is capable of hypothetically fusing 14 pairs of hydrogen nuclei simultaneously. However, it would take 3.220×10^{10} yrs - 8.565×10^{10} yrs to 'chew' the number of nuclei pairs required to provide the average human's daily energy requirements. Future research could consider the human jaw's capability of fusing heavier nuclei, such as Deuterium and/or Tritium, which will yield a larger magnitude of energy per reaction.

References

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