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A1_5 Atomising Death Ray

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Abstract

This report examines the weapons commonly found in science fiction movies which are able to completely atomise a human being, leaving nothing visible behind. To atomise a human body, this report uses the approximation that every bond connecting their atoms must be broken simultaneously. The energy required from such a device is found to be ~3.75 GJ and it is found that it would require 11.06 mg of Deuterium-Tritium to undergo fusion to provide this energy. It is also found that targets will glow deep violet in the visible spectrum shot.

Introduction

Since the early days of science fiction movies there have been many versions of the famous ray gun. Over the years these many different versions have been shown to perform a wide variety of outcomes on their target, from miniaturization to disappearance in a flash of light. For the purpose of this report we shall consider a common design which is well portrayed in the 2005 remake of '*The War of the Worlds*' and also in the '*Star Trek*' TV series. This is a device which is capable of completely atomising a human and leaving either very little or no remaining residue behind.

This report will assume that these futuristic weapons atomise their targets by delivering energy which breaks the bonds between all of their atoms. This energy is assumed to be applied in a uniform distribution throughout the body and it will also be assumed that these bonds do not reform immediately so that once broken there is enough time for the atoms to disperse effectively.

Discussion

The first task in this analysis was to calculate an estimate for the number of molecular bonds in the human body. To do this we use the approximation that 70% of the human body is comprised of water and that the other 30% consists of long chain carbon based molecules. Water molecules are held together by $\mathrm{H-O}$ bonds and to calculate the number of these bonds in the body ($N_{\mathrm{H-O}}$), we use the following equation

$$N_{\mathrm{H-O}} = 0.7 \times \frac{2W}{m_{\mathrm{H_2O}}} N_{\mathrm{A}}, \qquad (1)$$

where W is the mass of the human target which we take to be $70\,\mathrm{kg}$, $m_{\mathrm{H_2O}} = 18\,\mathrm{g\,mol^{-1}}$ is the molecular mass of water, N_{A} is Avogadro's number and the factor of 2 arises because there are two $\mathrm{H-O}$ bonds in each water molecule. It follows from this that there are $N_{\mathrm{H-O}} = 3.28 \times 10^{27}$ bonds in the average human body.

Next it was necessary to calculate the number of different carbon based bonds in the body. There are many different forms of these molecules, so to simplify the calculation we consider only the backbone structure - similar to the form of a hydrocarbon. This simplification is acceptable as the bond energies of every bond in a carbon based molecule are of the same order as the $\mathrm{C-C}$ and $\mathrm{C-H}$ bond energies present in a hydrocarbon [1]. We use the structure of a basic hydrocarbon polymer, represented below in Figure 1.

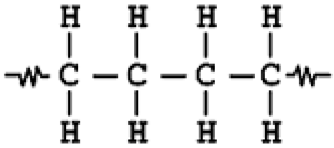

Figure 1. "The basic backbone of a hydrocarbon polymer". [2]

From this, we can consider a unit cell for a hydrocarbon as consisting of three bonds: two $\mathrm{C-H}$ bonds and one $\mathrm{C-C}$ bond. The number of these bonds is then calculated using Equation 1, but substituting the molecular molar mass of water with that of a simple hydrocarbon unit cell ($14\ \mathrm{g\ mol^{-1}}$) and using a mass percentage of 30%. This gives the number of $\mathrm{C-H}$ bonds, $N_{\mathrm{C-H}} = 1.81 \times 10^{27}$, and the number of $\mathrm{C-C}$ bonds, $N_{\mathrm{C-C}} = 9.03\ \times 10^{26}$.

Now that the total number of bonds in the body is known, the total minimum energy E required to break all of these bonds is

$$E_{\mathrm{min}} = \frac{1}{N_A} \sum_{x=0}^{2} E_x N_x, \qquad (2)$$

where $N_0 = N_{\mathrm{H-O}},\ N_1 = N_{\mathrm{C-H}},\ N_2 = N_{\mathrm{C-C}}$; and where $E_0 = 366\ \mathrm{kJ\ mol^{-1}}$, $E_1 = 413\ \mathrm{kJ\ mol^{-1}}$, and $E_2 = 348\ \mathrm{kJ\ mol^{-1}}$ are the energies required to break $\mathrm{H-O}$, $\mathrm{C-H}$, and $\mathrm{C-C}$ bonds respectively [1]. From Equation 2 we find that $E_{\mathrm{min}} \geq 3.75\ \times 10^9\ \mathrm{J} = 3.75\ \mathrm{GJ}$. For an assumed exposure time of $t = 5$ s, this would require a ray gun with a very high power of $P = E/t = 751\ \mathrm{MW}$. The only perceivable way to achieve a power of this magnitude is through nuclear fusion. A typical fusion reaction is the standard Deuterium-Tritium fusion reaction

$$^2_1\mathrm{D} + ^3_1\mathrm{T} \rightarrow ^4_2\mathrm{He} + ^1_0\mathrm{n}, \qquad (3)$$

which releases $E_f = 17.58\ \mathrm{MeV}$ per reaction [3]. The number of reactions n can then be calculated as,

$$n = \frac{E_{\mathrm{min}}}{E_f} = 1.33 \times 10^{21}. \qquad (4)$$

This gives a total mass of the Deuterium-Tritium mixture which has fused as $m = nM/N_{\mathrm{A}} = 11.06\mathrm{mg}$, where $M = 5\ \mathrm{g\ mol^{-1}}$ (taken from their atomic mass numbers) is the total molar mass of the deuterium and tritium reactants.

If the human body is approximated as a black body emitter, the wavelength λ_{max} of light at which it glows moments before atomisation can be calculated via Wien's displacement law

$$\lambda_{\mathrm{max}} = \frac{b}{T}, \qquad (5)$$

where $b = 2.898 \times 10^6\ \mathrm{K\ nm}$ is Wien's displacement constant and T is the temperature of the black body. If the specific heat of a human is assumed to be $c_{\mathrm{H_2O}} = 4.18\ \mathrm{J\ g^{-1}\ K^{-1}}$ [4], the temperature rise caused by the ray gun is

$$\Delta T = \frac{E_{\mathrm{min}}}{W c_{\mathrm{H_2O}}} = 12.83 \times 10^3\ \mathrm{K}. \qquad (6)$$

Using an initial temperature of $T = 310\ \mathrm{K}$ this gives $\lambda_{\mathrm{max}} = 225.9\ \mathrm{nm}$, which is in the UV part of the EM spectrum, indicating that the person would glow deep violet moments before atomisation.

Conclusion

This paper has found that to completely atomise a human, a ray gun would have to have a minimum power of $P = 751\ \mathrm{MW}$. This is a very large amount of power, although if fusion was available it would require $11.06\ \mathrm{mg}$ of fuel per shot, which may become a realistic amount in the future. It has also been shown that, when shot, targets will glow deep violet in the visible spectrum.

References

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[4] Paul A. Tipler & Gene Mosca. 2007. "*Physics for Scientists and Engineers*", Sixth Edition.