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P2_4 Not So Spontaneous Combustion

T .Holesinsky, Z. Harrison, S. Mandhai, B. G. S. Harris

Department of Physics and Astronomy, University of Leicester, Leicester, LE1 7RH

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Abstract

In the X-Files TV series, a man is injected with a chemical that freezes him. When defrosted, his body starts producing exothermic reaction that sets him on fire. At normal metabolic rate, this reaction would take at least 4 days 15 hours and 24 minutes. In the time scale of the show the energy required to heat the individual would be 9.9 x 10^5 W.

Introduction

X-Files is a sci-fi series from the 90s where the main characters often encounter unexplainable or uncommon phenomena. In one episode, a man is injected with a serum that freezes him and upon raising his temperature to normal value his cells begin exothermic reaction. This causes him to combust in a matter of seconds. We investigate how long it would take for a normal metabolic rate to produce sufficient energy and whether it is feasible for the body to produce this amount of energy in such a short period of time.

Theory

In order to estimate the combustion of humans, we look at similar phenomena of spontaneous combustion. In this myth one theory suggests that fat in human body acts as wax in a candle, which allows this event to occur [1]. We estimate that in order for an individual to incinerate, he needs to reach the auto-ignition temperature of fat: 553.15 K for animal fat [2].

To evaluate the required energy we used the calorimetric equation [3]; Equation 1:

$$Q = mc\left(T_f - T_i\right) \tag{1}$$

We assume the mass of the person ,m, to be 70 kg. The initial and final body temperatures, T_i and T_f respectively, to be 309.15 K and 553.15 K. The specific heat capacity, c, of a human body is 3470 J kg^{-1}K^{-1} [4].

The rate at which humans emit heat, P_r, is 100 W [5]. We idealise the conditions and assume the person does not lose any energy to his surroundings. The time it would take to reach auto-ignition temperature can be found with [3]; Equation 2:

$$t = \frac{Q}{P_r} \tag{2}$$

Investigating further, we decided to calculate how the amount of fat in the body affects the energy requirements for auto-ignition. Simplifying the situation, we assume that the human body consists solely of fat and water.

Thereupon, we find that the heat capacities of fat and water are $c_f = 2348$ J kg^{-1}K^{-1} and $c_w = 4186$ J kg^{-1}K^{-1}, respectively [6][3]. We then calculate the heat required based on the percentage of fat and water in body. This is demonstrated by Equation 3;.

$$Q_t = xQ_f + yQ_w \tag{3}$$

Where Q_f is heat for fat, Q_w is heat for water, x is the fraction of fat in the body, y is the fraction of water in the body, and Q_t is the total heat required.

We then plot the relationship between Q_t and t to find that the higher the amount of fat the less energy is required. The red circle indicates the result found with usage of specific heat capacity of the body.

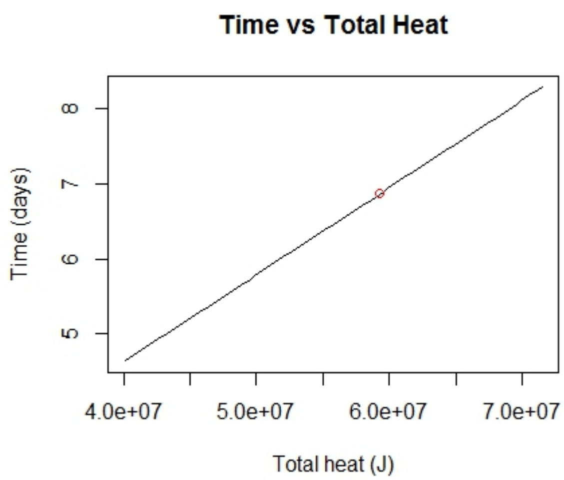

Figure 1: The time taken to heat up the body to autoignition point with changing heat based on the amount of fat and water in the body.

We estimate the time it takes for the individual to ignite in the episode as 60 s. Then we substitute into Equation 2 rearranged for P_r. Using the energy from the specific heat capacity of the human body we evaluate the power which the metabolism would have to produce autoignition in this time.

Discussion

The energy required to increase temperature of a person using the specific heat capacity of body was found to be 5.9 x 10^7 J. The time it would take for the body to produce such heat at rate of 100 W is about 6 days 20 hours and 38 minutes. From Figure 1 the specific heat of body approximates a ratio of 62% water and 38% fat. Furthermore, even if the individual consisted of fat it would take 4 days 15 hours and 24 minutes to heat him up.

In the scenario of the person autoigniting in 60 s we need to supply power of 9.9 x 10^5 W. As a comparison, the power consumed by a kettle is between 1200 and 3000 W [7].

Conclusion

Based on our evaluation of the problem we believe enough evidence is presented to prove that such a reaction cannot occur. Even in idealised conditions where no heat is lost to the surroundings, the time required for sufficient heat to be produced is in the order of days. In terms of power production, the body would need to turn into a small power plant to produce such power.

References

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