Journal of Physics Special Topics

An undergraduate physics journal

S1_2 Melting Mars

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October 26, 2017

Abstract

Unlike Earth, Mars lacks a fluid core to provide a global magnetic field to shield it against harmful solar winds. Mars is estimated to have a largely solid core of Iron, Nickel and Sulphur. We calculated 7.75×10^{13} kg of Uranium-235 would be needed in a theoretical bomb to liquify a proportion of Mars' core. The proportions used were a scaled imitation of Earth's core.

Introduction

Earth's magnetic field deflects solar winds that would otherwise strip away most of its atmosphere. Mars is believed to have origins similar to Earth before later evolution deviated, resulting in very different conditions today. Mars has no magnetic field to act as a shield, preventing an atmosphere from existing which could aid in terraforming Mars. A method suggested by S. Factor [1] to inaugurate a Martian magnetic field is to place a nuclear bomb near the core to create a partially fluid core similar to Earth. We investigate the proportions of a Martian fluid core and the mass of such a bomb.

Theory

Mars' core has a radius, R_M, of 1859 km [2]. Using the ratio of Earth's inner core to outer core of $\sim 1:2$ [3] we calculated an inner radius for Mars, r_M, as 620 km. From the core radii the volume, V_M, for a liquid outer core can be found by the equation

$$V_M = \frac{4\pi}{3}({R_M}^3 - {r_M}^3). \tag{1}$$

We identified the elemental percentage composition β_x, where x represents the element considered. The change in energy i.e. heat, ΔE, needed to melt V_M was then found. This was done by finding the mass of each element, m_x, via $m_x = \rho_x V_M \beta_x$.Where ρ_x repesents the density of each element. The heat capacities, c_x, and the change in temperature, ΔT required to reach an Earth-like molten core temperature were also found. Equation (2) shows how ΔE was found from these values for each element, which was then summed to find ΔE_{total} [4];

$$\Delta E = m_x c_x \Delta T. \tag{2}$$

From ΔE_{total}, the nuclear Q value relation in Equation (3) was used to find the total mass change, Δm_{total} during the fission of Uranium-235 [4];

$$Q = -(\Delta m_{total})c^2, \tag{3}$$

where c is the speed of light.

The number of U-235 atoms expended during the reaction was found by dividing Δm_{total} by the mass change during the fission of a single U-235 atom, Δm_s. Equation (4) shows the fission reaction route used to work out this value [4].

$$n_0^1 + U_{92}^{235} \rightarrow Ba_{56}^{141} + Kr_{36}^{92} + 3n_0^1. \tag{4}$$

The total mass of U-235 required for the bomb(s) was found by multiplying the amount of atoms by the mass of one atom.

Results

We took the percentage elemental composition of Earth's core [5] and made assumptions for Mars' composition, accounting for a greater Sulphur content [2].

	Iron	Nickel	Sulphur
β_x (%)	73	10	17
ρ_x (kgm^{-3})	7850	8908	2070
c_x (kJK^{-1}kg^{-1})	0.45	0.44	0.71

Table 1: Theorised elemental percentage composition of Mars' core and their properties [6][7][8][9].

We combined Equations (1), (2) and (3) and rearranged for Δm_{total} as shown below.

$$\Delta m_{total} = \frac{\Delta T V_M((\beta\rho c)_{Fe} + (\beta\rho c)_{Ni} + (\beta\rho c)_S)}{c^2}. \tag{5}$$

Mars' current core temperature is 1500 K [10] and Earth's molten core temperature is 5773 K [11] so ΔT was 4273 K, the difference between these two values. We found Δm_{total} to be 3.96×10^{12} kg. We divided this by $\Delta m_s = 2.00 \times 10^{-26}$ kg. This gave a total number of U-235 atoms of 1.98×10^{38}. Multiplying this by the mass of a single U-235 atom, 3.90×10^{-25} kg, we found the bomb(s) needed 7.75×10^{13} kg of nuclear fuel.

Conclusion

In this paper, we replicated Earth-like core proportions for Mars and calculated the mass of U-235 needed that could be used in a bomb to achieve a molten outer core. The molten core was calculated to begin at a distance of 620 km from the centre of the planet. The mass of U-235 needed to achieve this would be 7.75×10^{13} kg.

While it is unknown whether Mars requires a molten core of the same proportions as Earth, given the similarity in their formation history it is plausible for such conditions to allow Mars to develop and sustain a magnetic field. Whilst we discuss the mass of nuclear material needed to inaugurate these conditions, we have not proposed a method of transporting and detonating such a bomb or whether multiple bombs may be required. Samples from Mars' core could determine an accurate elemental composition, eliminating our assumption. Future work could investigate the exact proportions required for a Martian magnetic field to help build a future for Mars.

References

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