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# P3_4 Honey, I Shrunk the Tank!

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**Abstract**

In the 2015 film "Ant-Man", a Russian T-34 tank is shrunk down to the size of a keychain, during which its mass remains constant. By estimating the change in inter-atomic spacing, and the resulting increase in Coulomb repulsion between atomic nuclei, the energy required for this compression is found to be approximately $7.08 \times 10^{15}$ $J$. This an extremely large amount of energy, making the possibility of such a situation infeasible.

## Introduction

The Pym particle is a fictional particle isolated by Dr. Hank Pym in the film "Ant-Man"[1]. Harnessing these particles allows the user to alter the inter-atomic spacing (which we are taking as the distance between atomic nuclei) within objects, resulting in the object growing or shrinking in size. While the size of objects are altered, their masses are said to remain constant.

In one scene of the film, a T-34 tank is expanded from the size of a keychain up to full scale. Considering the tank is fully operational and is driven through walls, we can infer that the tank was initially shrunk from normal size to only a few centimetres in length. To investigate the possibility of such shrinking, the energy required to move the atomic nuclei closer to one another is calculated.

## Theory and Results

The tank shown in the film is a Russian T-34, which has a mass of $2.65 \times 10^4$ $kg$ [2]. While it is constructed from various materials, primarily steel, for the sake of simplicity we will consider it to be made entirely of iron. This is because iron has a near-identical density to steel (being an alloy of iron and carbon) [3], and the inter-atomic spacing of steel is hard to calculate due to atoms of different sizes and charges being present within the lattice structure.

Iron has an atomic mass of 55.9 $u$, and a density of $7.9 \times 10^3$ $kgm^{-3}$ [4]. Knowing this and the mass of the tank, we are able to estimate the volume of the full-sized tank, $V_{large}$, which is found to be 3.35 $m^3$. The number of atoms, $n$, is also calculated, and found to be $2.86 \times 10^{29}$. For simplicity, the tank will be considered as a cube of solid iron, with side length 1.5 $m$, and the nuclei are considered as points with negligible radius. Knowing the volume of the cube and the number of atoms allows the area occupied by a single atom to be approximated, which we calculate as being $1.2 \times 10^{-29}$ $m^3$. If we treat this volume as cubic in nature, the inter-atomic spacing, $r_1$, is given by the side length, 2.3 $\mathring{A}$.

The keychain-sized tank is also considered as a cube for simplicity, this time using a side length of 4 $cm$. The ratio between the large and small side lengths gives the scale factor for the shrinking, which will also apply the inter-atomic spacing. The ratio is found to be 37.5 : 1, giving a new inter-atomic spacing, $r_2$, of 0.061 $\mathring{A}$.

In this simplified model, we consider the main force being opposed to be the Coulomb repulsion between the charged nuclei of the iron atoms. This force, $F$, is given by the following equation;

$$F = \frac{q_1 \times q_2}{4\pi\epsilon_0 r^2}. \quad (1)$$

In this equation, $q_1$ and $q_2$ are the respective charges of the two nuclei, $\epsilon_0$ is the permittivity of free space, and $r$ is the separation between the two nuclei. To estimate the energy required for the stated compression, the change in potential energy, $\Delta U$, can be calculated. This is given by the integral of Eq. 1;

$$\Delta U = -\int_{r_1}^{r_2} \frac{q_1 \times q_2}{4\pi\epsilon_0 r^2} dr = \frac{q_1 \times q_2}{4\pi\epsilon_0}(\frac{1}{r_2} - \frac{1}{r_1}). \quad (2)$$

By taking $r_1$ and $r_2$ to be the values for the inter-atomic spacing obtained earlier, the change in potential energy when one atom is moved by a factor 37.5 closer to another is $2.47 \times 10^{-14}$ $J$. To convert this to the total change in energy, which is the energy required to be put into the system, we multiply by the number of atoms $n$; this gives $\Delta U_{total}$ as $7.08 \times 10^{15}$ $J$.

**Discussion**

The value obtained for the total energy required to shrink the tank is likely an underestimate. As stated, this is a simplified model of the forces at work; we have only considered the forces between nearest-neighbour atoms and have neglected the presence of electrons. Including these would provide a greater force of repulsion, thus a greater energy would be required to compress the tank to its smaller size.

In addition to the glaring inconvenience of a 26-tonne keychain, shrinking the tank in the film down to such a small size presents a number of problems. One such problem is the incredible amount of energy required. This energy would need to be constantly applied in order to keep the tank in its shrunken state, as the atomic bonds would otherwise expand to a lower energy state. Modern portable forms of generating power, such as batteries, provide nowhere near the output required to sustain the high-energy state that the atoms would be in.

Another problem arises when the tank is returned to its normal size. If the expansion is not properly controlled, then all of the energy keeping the tank in its miniature state would be expelled rapidly, potentially resulting in an explosion. The energy calculated is the equivalent of approximately 1.7 megatons of TNT [5]. By comparison, the atomic bombs dropped on Hiroshima and Nagasaki during World War II had TNT equivalences of 16 kilotons and 21 kilotons respectively [6]. The resulting explosion would likely destroy a large area surrounding the tank as it expands, unless some method for containing this energy was used.

**Conclusion**

The compression of the inter-atomic spacing in the tank from the film "Ant-Man" would require an estimated $7.08 \times 10^{15}$ $J$ of energy. This amount of energy is far more than modern generation methods can sustain. Without proper containment, the release of this energy would cause major destruction to the surrounding area.

**References**


[1] `http://marvel.wikia.com/wiki/Pym_Particles` [Accessed 18 October 2017]

[2] `https://en.wikipedia.org/wiki/T-34` [Accessed 18 October 2017]

[3] `https://www.engineeringtoolbox.com/metal-alloys-densities-d_50.html` [Accessed 18 October 2017]

[4] `https://en.wikipedia.org/wiki/Iron` [Accessed 18 October 2017]

[5] `https://en.wikipedia.org/wiki/TNT_equivalent` [Accessed 18 October 2017]

[6] `https://en.wikipedia.org/wiki/Atomic_bombings_of_Hiroshima_and_Nagasaki#Bombs` [Accessed 18 October 2017]