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A4_5 Nuclear Explosion

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Abstract
Nuclear atomic bombs release a large amount of energy when they explode (through uncontrolled fission). They go through a chain reaction where the splitting of uranium atoms induce further splitting. The aim of this paper was to calculate the amount of energy released if all the nuclear bombs in the world were to explode together. We found a lower boundary of 2.586×10^{19} J would be released, assuming that every warhead is involved in the same continuous chain reaction.

Introduction

Nuclear fission is a great source of energy, but it can also be terribly destructive when used in atomic bombs. There are currently 14570 nuclear warheads in the world [1]. In this paper, we assumed that all nuclear weapons are atomic bombs which produce nuclear energy through the same atomic fission process of a neutron splitting a uranium atom [2]. This produces a barium atom, a krypton atom and three neutrons as can be seen in equation (1).

$$^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{144}_{56}\mathrm{Ba} + {}^{89}_{36}\mathrm{Kr} + 3\,{}^{1}_{0}\mathrm{n} \qquad (1)$$

Assumptions

Equation (1) is one of the possible chain reactions for splitting a uranium atom. We assumed that only ^{235}U was used as it is the most abundant isotope in a fission bomb (there is 90% of ^{235}U and 10% of ^{238}U [3]).

We will also assume that all fission bombs completely use the 55 lbs (24.9476 kg) of uranium [4], which is the mass of uranium required to build an atomic bomb. This is a low value of uranium, meaning that our calculated answer would be an estimation for the minimum amount of energy that would be released if all the atomic bombs were to fission at once.

Theory

To calculate the energy released by all atomic bombs together, we first need to determine the energy released by a single bomb.

The mass defect (m_D) of a nuclear reaction can be calculated by subtracting the sum of the masses of each element before the reaction (m_B) with the sum of the masses of the elements after the reaction (m_A), shown in equation (2).

$$m_D = m_B - m_A \qquad (2)$$

The energy released (E) per uranium atom can then be calculated as shown in equation (3) by multiplying m_D by the speed of light (c) squared.

$$E = m_D \times c^2 \qquad (3)$$

We then determine the number of atoms (N) that there are in 24.9476 kg of uranium, using equation (4).

$$N = \frac{m_{U,\ bomb}}{m_{U,\ atom} \times amu} \qquad (4)$$

Where $m_{U,\ bomb}$ represents the total mass of uranium per atomic bomb, $m_{U,\ atom}$ is the atomic mass of uranium and amu is one atomic mass unit. This gives 6.39133×10^{25} atoms.

Then multiplying the answers to equations (3) and (4) we find the total energy released per bomb. This is shown in equation (5).

$$E_{bomb} = N \times E \tag{5}$$

By multiplying the result from equation (5) with the number of atomic bombs in the world we can find the total energy released per bomb.

Results

The masses in atomic mass units (amu) of each element can be found in table (1).

Element	Mass (amu)
^{235}U	235.0439299
n	1.0086654
^{144}Ba	143.9229529
^{89}Kr	88.9176306

Table 1: Atomic masses in amu to 7 d.p. for use in equation (2), [5][6]

By substituting the values in table (1) into equation (2), we get a mass defect of $3.0878590 \times 10^{-28}$ kg. Using a mass of uranium of 24.9476 kg we calculate that there are 6.39133×10^{25} atoms which release a total energy of 1.775×10^{15} J per atomic bomb. This gives a result of 2.586×10^{19} J released if all the atomic bombs in the world were to detonate simultaneously.

Discussion

The actual energy released if all nuclear warheads were to explode simultaneously would probably be far greater than our result due to our many assumptions. To make our results more accurate, it could be assumed that half of the nuclear warheads in the world are H-bombs and half are atomic bombs. The mass of uranium used per atomic bomb could be based of a bomb that has already been detonated, such as the Hiroshima bomb. Different chain reactions could also be considered to give a result of better accuracy. The amount of energy released from our calculated value is 6.9% of the world's total energy consumption in 2014 [7]. We are purely discussing energy released in this paper, but it should be noted that there would also be further damage due to nuclear fallout to the Earth and other repercussions. Therefore, we can assume that if the premise of this paper were to happen then there would be irreversible changes to the global ecosystem.

Conclusion

The detonation of all the atomic bombs at once would be greatly destructive as it would generate at least 2.586×10^{19} J, but there would also be catastrophic ecological damages.

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