Demystify Nuclear Bomb - How It Works and Why It Is Destructive

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In our attempts to harness the energy of atoms, humans have built the most destructive weapons in the history - the nuclear bombs. These weapons are believed to be powerful enough to wipe out the entire human race if used carelessly. As more and more countries have built their nuclear weapons, most people now live under the fear of nuclear attack. To better protect ourselves, this article will demystify the working mechanism of nuclear bombs and explain what to do if there is a nuclear threat.

How Do Nuclear Bombs Work?

There are two major types of nuclear bombs: fission bombs and fusion bombs. Fission bombs are also known as atomic bombs as they generate explosive energy from nuclear fission in which a heavy atomic nucleus is split into lighter nuclei [8]. The most widely used nuclear fuels for fission bombs is uranium-235 (U-235). Figure 1 illustrates the process of fission reaction with U-235. When a U-235 nucleus absorbs a neutron, it splits into two smaller nuclei, krypton and barium, and produces energy in the form of heat and kinetic energy of particles. Meanwhile, three neutrons are released and can be absorbed by other U-235 nuclei to trigger further nuclear fission. This chain reaction is what makes a fission bomb a "bomb". If we bring a sufficient number of U-235 nuclei together, even a single neutron could trigger millions of nuclear fission reactions, releasing enormous amount of energy in a second.

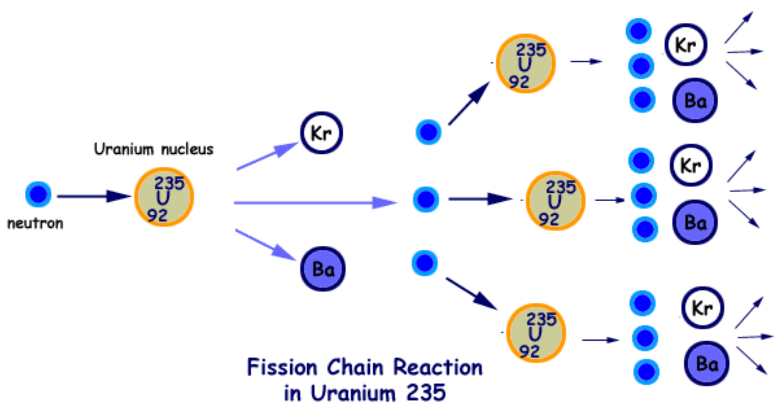

Figure 1: fission reaction with uranium-235

Credit: https://www.citycollegiate.com/fissionXc.gif

The other type of nuclear bomb is fusion bombs, also called hydrogen bombs, since part of their explosive nature is from fusion reaction between isotopes of hydrogen, deuterium and tritium [8], which is demonstrated in Figure 2. A common misconception is that fusion bombs draw their energy entirely from fusion reaction. In fact, the nuclear reaction inside a hydrogen bomb usually goes through a fission-fusion-fission process [1]. As fusion reaction requires high temperature and high pressure, the bomb creates such conditions by first initiating fission reaction. The neutrons released from fusion reaction are then used to cause a uranium container to undergo secondary fission reaction. The energy released from this whole process is way more than that released from the fission reaction alone using the same amount of fuels.

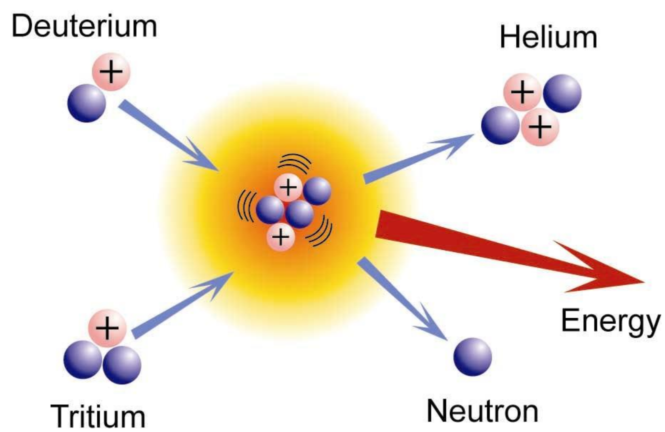

Figure 2: fusion reaction by deuterium and tritium

Credit: https://www.universetoday.com/52696/nuclear-fusion-power-closer-to-reality-say-two-separate-teams/

The theory above implies several requirements for nuclear bombs to work. As the general principles work similarly for both kinds of nuclear bombs, I will focus on fission bombs in the following discussion.

Frist, we need enough amount of U-235 to sustain chain reaction. The term to describe this is "critical mass", which is defined as "the minimum mass of fissionable material required to sustain a nuclear fission reaction" [3]. If the amount of U-235 is below the critical mass, then it is unlikely to initiate the chain reaction and to generate devastating power. Second, we do not want a nuclear bomb to explode accidently. The safest approach is to keep the nuclear materials in separate subcritical masses before detonation. Third, we need a neutron to initiate the nuclear reaction. Fourth, we want the nuclear fuels to fission as much as possible before the bomb explodes. This is achieved by confining the nuclear reaction inside a dense material called tamper, which is typically made of uranium-238 [2]. As the tamper is heated and expanded by the fission core, it exerts pressure on the core and slows down the core's expansion. Neutrons emitted from the nuclear reaction are also reflected back into the core by the tamper, promoting the overall efficiency of nuclear reaction.

Curious readers may wonder if we separate nuclear fuels in critical mass before detonation, how do we bring the subcritical masses together? Ingenious engineers have come up with two solutions. The first one is called the "gun-type assembly" method (see Figure 3) and is used in the Little Boy, the bomb dropped on Hiroshima during World War II [1]. Two subcritical masses of U-238 fuels are stored at the two ends of the bomb. When the nuclear bomb is launched, a barometric-pressure sensor inside the bomb determines the altitude for detonation and triggers the following series of events. The chemical explosive on the left fires and shoots one piece of the fuels into the other like a bullet. Meanwhile the neutron generator inside the bomb releases neutrons to initiate the fission reaction. Within 600 billionths of a second, the fission core generates an immense amount of energy and the bomb explodes [2].

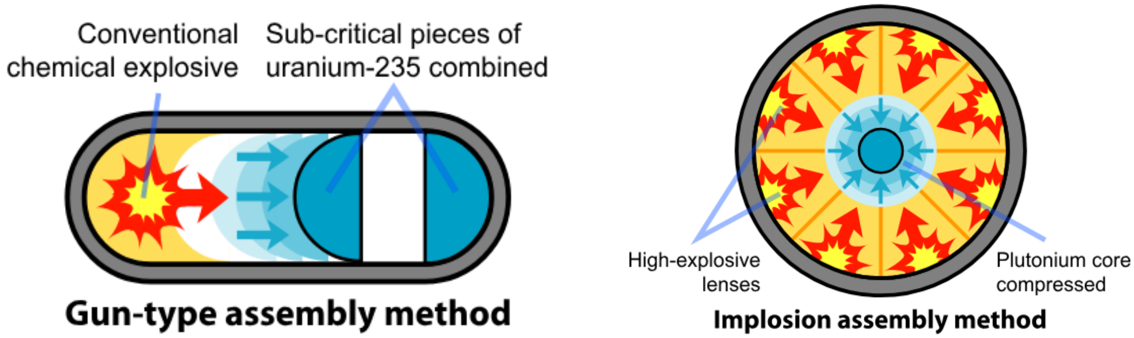

Figure 3: gun-type assembly method and implosion assembly method

Credit: https://en.wikipedia.org/wiki/Nuclear_weapon

Another method of detonation is called "implosion assembly" method and is used in the Fat Man, the bomb dropped on Nagasaki (see Figure 3) [2]. This method stores subcritical pieces of fission fuels at the center of a sphere. When the chemical explosive surrounding the sphere fires, the firing creates a shock wave and compresses the fission core, allowing the nuclear fuels to reach supercritical mass [2]. The neutron generator inside the sphere releases neutrons at the same time to start off nuclear reaction.

Why Is Nuclear Bomb Destructive?

Of the total energy released from nuclear explosion, 50% is the kinetic energy of shock wave, 35% is the thermal radiation, and the last 15% constitutes the nuclear radiation [1]. At the center of detonation, the temperature could reach several thousand Celsius degrees, enough to incinerate anything nearby. The spread of shock wave produces sudden changes in air pressure and destroys most buildings along its way. In addition, the thermal radiation could cause skin burn for people miles away [5]. Figure 4 illustrates the range of various effects if a nuclear bomb was detonated in San Francisco.

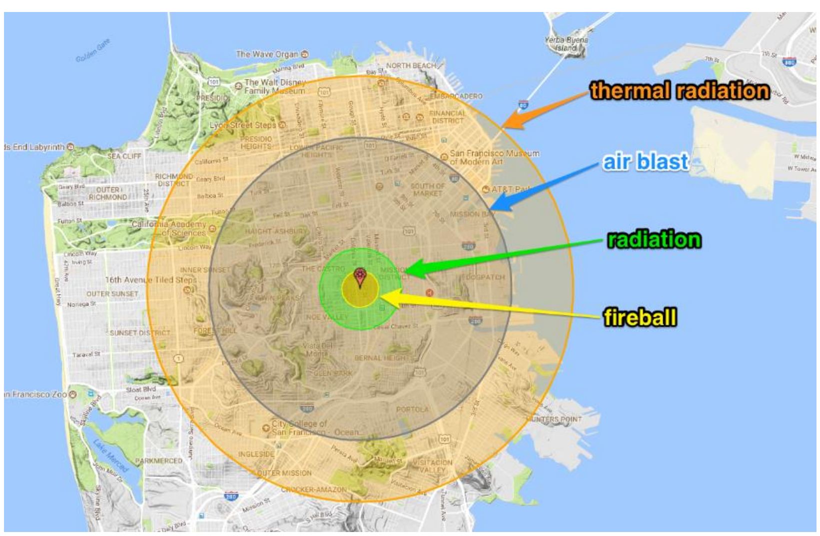

Figure 4: range of various effects after detonation of nuclear bombs

Credit: https://static.businessinsider.com/image/59c03ce09803c524008b72d7/image.jpg

The effects mentioned above occur in the first few minutes of detonation. What makes nuclear bombs lethal in the long term is the radioactive fallout produced during the explosion. The fallout consists of radioactive particles with various half-life, ranging from one day to several months. Exposure to fallout could cause mild or serious health problems in the long run, including hair loss, blood disorder, and cancer [4].

How to Protect Yourself When There Is Nuclear Threat?

The various effects of nuclear bombs discussed above may sound terrifying, and you might wonder how to survive from a nuclear attack. When a nuclear bomb is detonated, the first thing you would observe is a strong flash of light [5]. When you see a nuclear flash, get behind a barrier immediately because the shock wave would come very soon. If you can, get inside and go underground to avoid radiation. Ideally, you should find a shelter that is protected by several layers of concrete walls, as strong radiation could penetrate thin layers of walls. Underground shelters would be the best because buildings could be destroyed by shock wave.

Once you make through the shock wave and thermal radiation, you need to protect yourself from radioactive fallout. During the first few hours after detonation, fallout is at the most dangerous level as it gives the highest amount of radiation during this period [5]. The good news is that it usually takes 15min before fallout reaches ground level after detonation, so there is time for you to find a better shelter. Also, make sure you stay inside for at least 48 hours before a significant proportion of the fallout has decayed.

Conclusion

Now you understand how nuclear bombs work and how to protect yourself under nuclear attack. Although there is no guarantee that nuclear threats would go away any sooner, we could still make the world a better place by sharing this knowledge with friends and families. In the end, we wish everyone can make rational decisions and protect themselves when it comes to nuclear threats.

Reference

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