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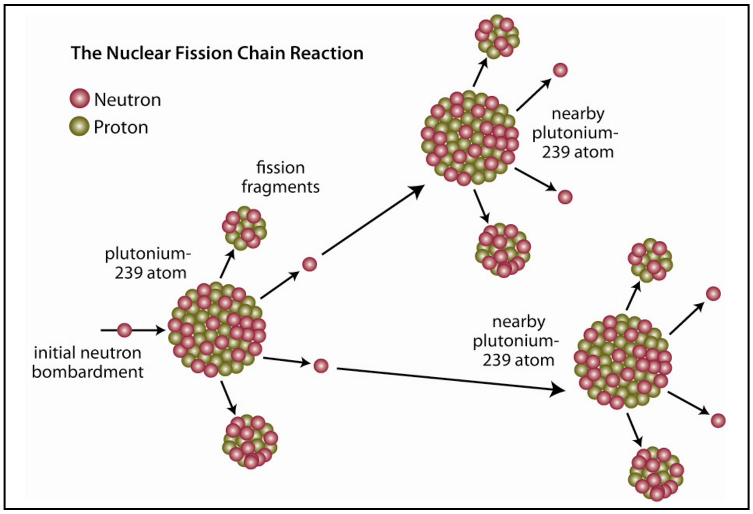
Nuclear Weapons: How They Work

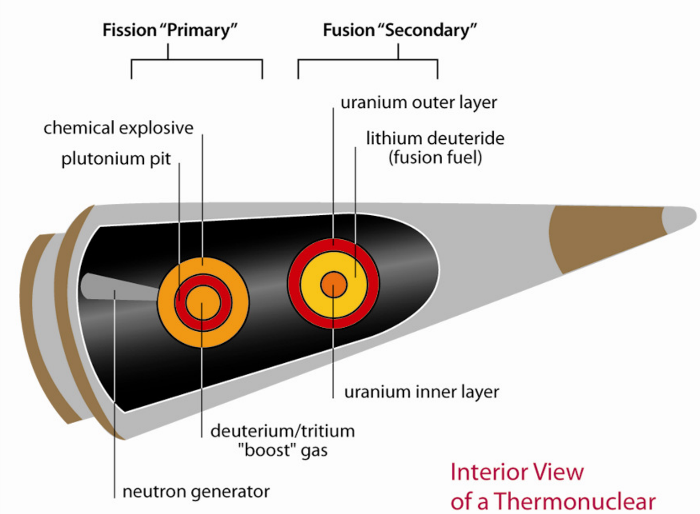
Most nuclear weapons today—including those in the U.S., Russian, British, French, and Chinese arsenals—are two-stage thermonuclear weapons that derive their explosive energy from the combined power of nuclear fission and fusion. An initial fission reaction generates the high temperatures needed to trigger a secondary—and much more powerful—fusion reaction (hence the term "thermonuclear"). Israel, India, and Pakistan are generally believed to possess nuclear weapons that utilize only nuclear fission, although some of these nations may also have some thermonuclear weapons. North Korea first tested a fission-based weapon in 2006, and tested another in 2009.



Nuclear Fission and Atomic Weapons

The nuclei of atoms consist of two types of particles: positively charged protons and neutrons with no electric charge. (All atoms of the same element have the same number of protons, but the number of neutrons can vary.) The nuclei of some radioactive elements can split—or fission—if bombarded with fast-moving neutrons. The by-products of this fission are two lighter nuclei, one or more free neutrons, and energy in the form of heat and light.

Certain isotopes of radioactive elements (i.e., variations of the same element with different numbers of neutrons in the nucleus) such as plutonium-239 or uranium-235 can emit two neutrons when they fission. These secondary neutrons then collide with other nearby nuclei, causing them to fission and release two more neutrons. Each fission reaction doubles the amount of neutrons and energy released, causing a chain reaction. After only a few microseconds, this chain reaction can produce an explosion equivalent to the detonation of many thousands of tons (or kilotons) of TNT. The so-called atomic (or A-) bombs dropped on Hiroshima and Nagasaki, Japan, in 1945 were fission-based, and had explosive yields equivalent to about 15 and 20 kilotons of TNT, respectively. Similar fission processes (though controlled) generate the energy in nuclear reactors.



Interior View of a Thermonuclear Weapon

Thermonuclear Weapons

Thermonuclear weapons can produce much larger explosions than fission weapons; the first thermonuclear test explosion had a yield of about 10,000 kilotons (or 10 megatons). Today, U.S. warheads commonly have explosive yields of several hundred kilotons.

Essentially, the destructive energy produced by such weapons is the result of three separate but nearly simultaneous explosions. The first is the detonation of chemical explosives that surround a hollow sphere (or "pit") of plutonium-239 metal. The force from this blast is directed inward, compressing the pit and bringing its atoms closer together. When the plutonium pit becomes dense enough to sustain a fission chain reaction (a condition termed "supercritical"), a neutron generator injects neutrons into the pit to initiate the fission chain reaction. Together, these chemical and fission explosions are known as the nuclear "primary."

The primary produces the high temperatures and pressures required to ignite fusion reactions in the "secondary," which actually produces the third explosion. In fusion, two or more atomic nuclei fuse into one heavier nucleus and, in the process, release a great deal of energy. In a thermonuclear weapon, isotopes of hydrogen undergo fusion, which is why these weapons are commonly called hydrogen or H-bombs.

In practice, a thermonuclear weapon (such as that illustrated in the diagram) is even more complicated than the description above suggests.

First, a pure fission primary is inefficient since the plutonium pit will blow itself apart before much of the available plutonium-239 fissions. To reduce the amount of plutonium needed, the fission reaction can be "boosted" so that a higher fraction of the plutonium fissions. For boosted primaries, hydrogen gas (consisting of the isotopes deuterium and tritium, which have one and two neutrons, respectively, in addition to the one proton that all hydrogen atoms have) is placed inside the hollow center of the pit. As the plutonium fissions, enough heat is produced to cause the "boost" gas to undergo fusion, releasing a burst of high-energy neutrons that, in turn, induce additional fissions in the pit.

The fusion fuel in the secondary takes the form of lithium deuteride (a solid compound of lithium and deuterium). Inside the layer of fusion fuel is a fission "spark plug" consisting of either plutonium-239 or uranium-235. As the primary explosion compresses the fusion fuel from the outside, the spark plug material becomes supercritical and fissions, heating the fusion fuel from the inside and helping to initiate the fusion reactions. Finally, a layer of uranium that surrounds the fusion fuel undergoes fission in response to the neutrons released by the fusion reactions, generally contributing more than half of the total explosive yield of a thermonuclear weapon.

The Non-Nuclear Components

In addition to the primary and secondary nuclear components that constitute the "nuclear explosive package," a thermonuclear weapon typically has thousands of non-nuclear components. These perform a variety of functions such as preventing the accidental detonation and unauthorized use of the weapon, arming the weapon by removing these barriers to detonation, determining the altitude of the weapon during its delivery so that it detonates at the correct location, and initiating the detonation by setting off the chemical explosives.

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