Science Behind Atomic Bomb

Introduction:

This project is about some of the scientific concepts and history behind nuclear weapons (Atomic Bomb). The first section is the theory that paved the way for the usage of nuclear power, followed by an explanation of how a nuclear weapon works. The next section discusses the results and the both sides of effects of radiation for humanity. In the end there is some statistics about the distribution of nuclear power in the world.

Theory

Let a system of plane waves of light, referred to the system of coordinates (x, y, z), possess the energy l; let the direction of the ray (the wave-normal) make an angle ϕ with the axis of x of the system. If we introduce a new system of coordinates (ξ , η , ζ) moving in uniform parallel translation with respect to the system (x, y, z), and having its origin of coordinates in motion along the axis of x with the velocity v, then this quantity of light measured in the system (ξ , η , ζ) possesses the energy;

$$l^* = l\frac{1 - \frac{v}{c}cos\phi}{\sqrt{1 - v^2/c^2}}$$

where c denotes the velocity of light. We shall make use of this result in what follows.

Let there be a stationary body in the system (x, y, z), and let its energy referred to the system (x, y, z) be E_0. Let the energy of the body relative to the system (ξ , η , ζ) moving as above with the velocity v, be H_0.

Let this body send out, in a direction making an angle ϕ with the axis of x, plane waves of light, of energy $\frac{1}{2}$ L measured relatively to (x, y, z), and simultaneously an equal quantity of light in the opposite direction. Meanwhile the body remains at rest with respect to the system (x, y, z). The principle of energy must apply to this process, and in fact (by the principle of relativity) with respect to both systems of co-ordinates. If we call the energy of the body after the emission of light E_1 or H_1 respectively, measured relatively to the system (x, y, z) or (ξ , η , ζ) respectively, then by employing the relation given above we obtain.

$$E_0 = E_1 + \frac{1}{2} L + \frac{1}{2} L$$

$$H_0 = H_1 + \frac{1}{2} L \left(\frac{1 - \frac{v}{c}cos\,\varphi}{\sqrt{1-v^2/c^2}} \right) + \frac{1}{2} L \left(\frac{1 + \frac{v}{c}cos\,\varphi}{\sqrt{1-v^2/c^2}} \right) = H_1 + \frac{L}{\sqrt{1-v^2/c^2}}$$

By subtraction we obtain;

$H_0 - E_0 - (H_1 - E_1) = L \{ \frac{1}{\sqrt{1-v^2/c^2}} - 1 \}$

The two differences of the form H − E occurring in this expression have simple physical significations. H and E are energy values of the same body referred to two systems of co-ordinates which are in motion relatively to each other, the body being at rest in one of the two systems (system (x, y, z)). Thus it is clear that the difference H − E can differ from the kinetic energy K of the body, with respect to the other system (ξ , η , ζ), only by an additive constant C, which depends on the choice of the arbitrary additive constants of the energies H and E. Thus we may place;

$H_0 - E_0 = K_0 + C$

$H_1 - E_1 = K_1 + C$

since C does not change during the emission of light. So we have;

$K_0 - K_1 = L \{ \frac{1}{\sqrt{1-v^2/c^2}} - 1 \}$

The kinetic energy of the body with respect to (ξ , η , ζ) diminishes as a result of the emission of light, and the amount of diminution is independent of the properties of the body. Moreover, the difference $K_0 - K_1$, like the kinetic energy of the electron, depends on the velocity.

Neglecting magnitudes of fourth and higher orders we may place;

$K_0 - K_1 = \frac{1}{2} \frac{L}{c^2} v^2$

From this equation it directly follows that:

If a body gives off the energy L in the form of radiation, its mass diminishes by ($\frac{L}{c^2}$).The fact that the energy withdrawn from the body becomes energy of radiation evidently makes no difference, so that we are led to the more general conclusion that

The mass of a body is a measure of its energy-content; if the energy changes by L, the mass changes in the same sense by ($\frac{L}{9 * 10^{20}}$), the energy being measured in ergs, and the mass in grams.

It is not impossible that with bodies whose energy-content is variable to a high degree (e.g. with radium salts) the theory may be successfully put to the test.

If the theory corresponds to the facts, radiation conveys inertia between the emitting and absorbing bodies.

We also can relate the total energy E of a particle (kinetic energy plus rest energy) directly to its momentum by combining the equation of relativistic momentum (p = $\frac{mv}{\sqrt{1-v^2/c^2}}$). The simplest procedure is to rewrite the total energy equation in the following form;

$E^2 = m^2 c^4 + m^2 p^2$

Atomic Bomb

A bomb whose violent explosive power is due to the sudden release of energy resulting from the splitting of nuclei of a heavy fissile chemical element (such as plutonium ${}_{244}Pu^{94}$ or uranium ${}_{238}U^{92}$) by neutrons in a very rapid chain reaction, called also atom bomb. Einstein equation, proved already, is used for explaining how a tiny amount of matter contains a tremendous amount of energy.

[History] The U.S. developed two types of atomic bombs during the Second World War. The first, Little Boy, was a gun-type weapon with a uranium core. Little Boy was dropped on Hiroshima. The second weapon, dropped on Nagasaki, was called Fat Man and was an implosion-type device with a plutonium core.


Little Boy

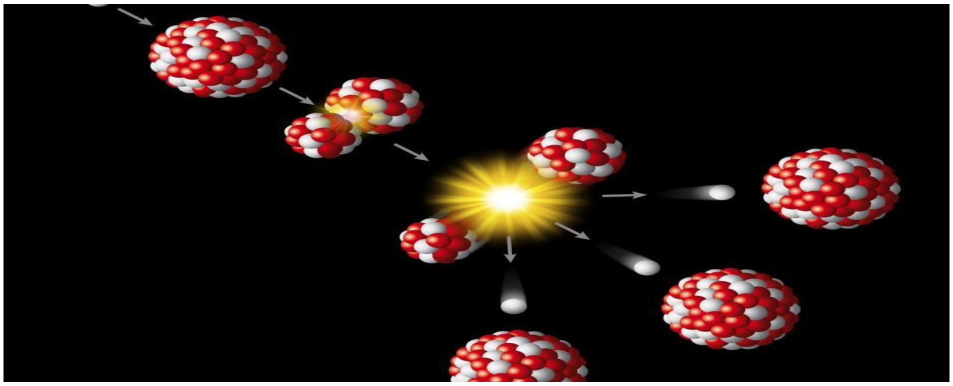

Fat Man

How they work: All nuclear/atomic weapons use fission to generate an explosion.

Fission;

The isotopes ${}_{235}U$ and ${}_{239}Pu$ were selected by the atomic scientists because they readily undergo fission which occurs when a neutron strikes the nucleus of either isotope, splitting the nucleus into fragments and releasing a tremendous amount of energy. (Isotopes of an element possess the same number of protons in their nuclei but have different numbers of neutrons).

The fission process becomes self-sustaining as neutrons produced by the splitting of atom strike nearby nuclei and produce more fission. This is known as a chain reaction and is what causes an atomic explosion.



When a $_{235}U$ atom absorbs a neutron and fissions into two new atoms, it releases three new neutrons and some binding energy. Two neutrons do not continue the reaction because they are lost or absorbed by a $_{238}U$ atom. However, one neutron does collide with an atom of $_{235}U$, which then fissions and releases two neutrons and some binding energy. Both of those neutrons collide with $_{235}U$ atoms, each of which fission and release between one and three neutrons, and so on. This causes a nuclear chain reaction.

Criticality

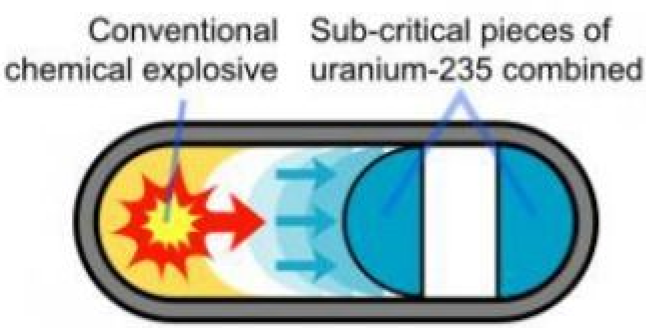
In order to detonate an atomic weapon, you need a critical mass of fissionable material. This means you need enough $_{235}U$ or $_{239}Pu$ to ensure that neutrons released by fission will strike another nucleus, thus producing a chain reaction. The more fissionable material you have, the greater the odds that such an event will occur. Critical mass is defined as the amount of material at which a neutron produced by a fission process will, on average, create another fission event.

In fission weapons, a mass of fissile material, either enriched uranium or plutonium, is assembled into a supercritical mass the amount of material needed to start an exponentially growing nuclear chain reaction. This is accomplished either by shooting one piece of sub-critical material into another, termed the “gun” method, or by compressing a sub-critical sphere of material using chemical explosives to many times its original density, called the “implosion” method.

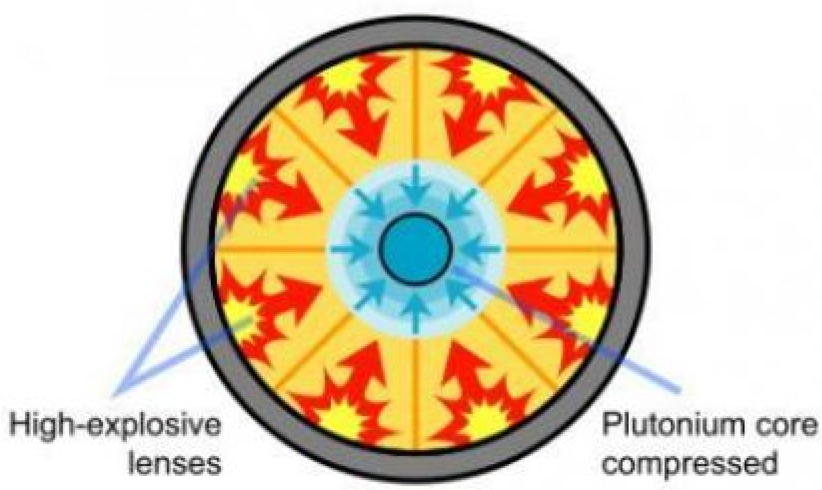
The implosion method is considered more sophisticated than the gun method and only can be used if the fissile material is plutonium. The inherent radioactivity of uranium will then release a neutron, which will bombard another atom of $_{235}U$ to produce the unstable $_{236}U$, which undergoes fission, releases further neutrons, and continues the process. The uranium atom can split any one of dozens of different ways, as long as the atomic weights add up to 236 (U plus the extra neutron). The following equation shows one possible split, namely into strontium-95 ($_{95}Sr$), xenon-139 ($_{139}Xe$), and two neutrons (n), plus energy;

$$^{235}\mathrm{U} + ^{1}_{0}\mathrm{n} \rightarrow \; ^{95}\mathrm{Sr} + ^{139}\mathrm{Xe} + 2\,^{1}_{0}\mathrm{n} + 180\mathrm{MeV}$$

The immediate energy release per atom is about 180 million electron volts (Me). Of the energy produced, 93% is the kinetic energy of the charged fission fragments flying away from each other, mutually repelled by the positive charge of their protons. This initial kinetic energy imparts an initial speed of about 12,000 kilometers per second. However, the charged fragments’ high electric charge causes many inelastic collisions with nearby nuclei, and thus these fragments remain trapped inside the bomb’ s uranium pit. Here, their motion is converted into X-ray heat, a process which takes about a millionth of a second. By this time, the material in the core and tamper of the bomb is several meters in diameter and has been converted to plasma at a temperature of tens of millions of degrees. This X-ray energy produces the blast and fire which are normally the purpose of a nuclear explosion.



Gun-type assembly method



Implosion assembly method

Fission bomb assembly methods: Two methods have been applied to induce the nuclear chain reaction that produces the explosion of an atomic bomb. The gun-type assembly uses a conventional explosive to compress from one side, while the implosion assembly compresses from all sides simultaneously.

And there is a piece of equipment in which nuclear chain reactions can be harnessed to produce energy in a controlled way, which called 'Nuclear Reactor'.

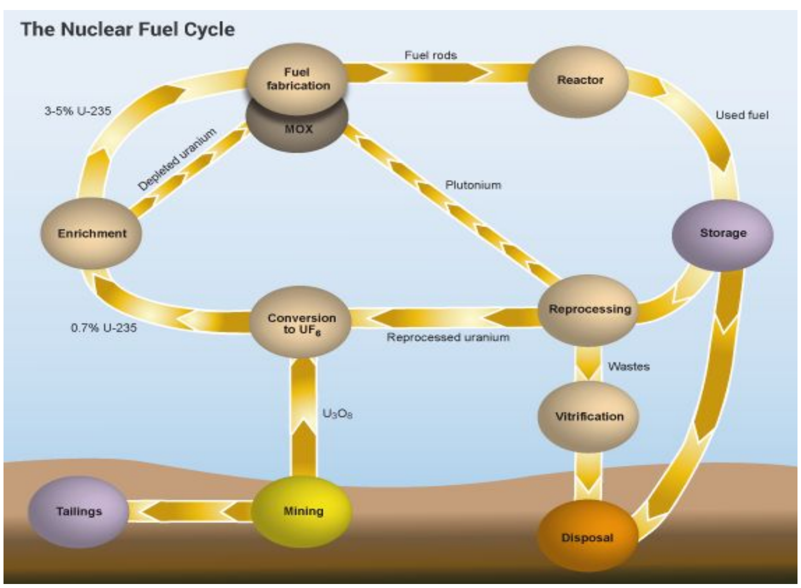
Results

1- The scourge of wars; These two bombings resulted in the deaths of approximately 200,000 Japanese people—mostly civilians. The role of the bombings in Japan's surrender, and their ethical status, remain the subject of scholarly and popular debate.

2- Waste: The enormous difference in the quantities of fuel used also directly affects the quantities of waste that remain after the electricity has been generated or after the usage of nuclear energy in general.

3- Generating Electricity: just as many conventional thermal power stations generate electricity by harnessing the thermal energy released from burning fossil fuels, nuclear power plants convert the energy released from nuclear fission. The heat is removed from the reactor core by a cooling system that generates steam. The steam drives a turbine which runs a generator to produce electricity.

4- Using Nuclear fuel: space shuttles and stations can use nuclear energy.



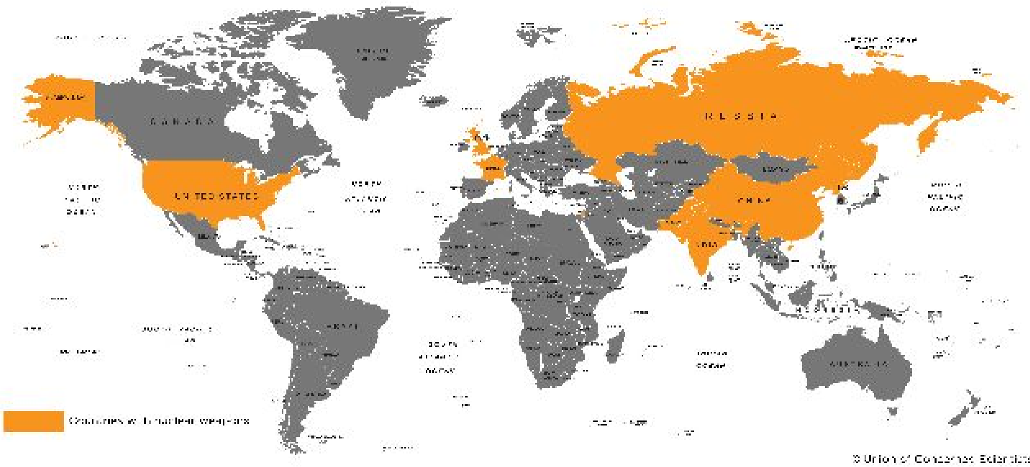
5- Economics: The difference in fuel requirements between coal fired and nuclear power stations also affects their economics. The cost of fuel for a nuclear power station is very much less than for an equivalent coal fired power station, usually sufficient to offset the much higher capital cost of constructing a nuclear plant.

6- Reprocessing: used fuel still contains about 96% of its original uranium, of which the fissionable $_{235}U$ content has been reduced to less than 1%. About 3% of the used fuel comprises waste products and the remaining 1% is plutonium produced while the fuel was in the reactor and not 'burned' then.

Conclusion

The distribution of nuclear power in the world

Russia's modern day arsenal includes an estimated 7,300 warheads. France (~300 warheads), China (~260), the United Kingdom (~215), Pakistan (~130), and India (~120) also have nuclear weapons. Israel has not officially acknowledged its nuclear capabilities. Estimates of its arsenal have typically been around 80 warheads, although some estimates are significantly larger . North Korea's capabilities are largely unknown. It's suspected it may have a limited arsenal of 5-10 fission weapons, but may have material to build twice that many .



Nuclear power plants provided 11% of the world's electricity production in 2014. In 2016, 13 countries relied on nuclear energy to supply at least one-quarter of their total electricity. As of April 2017, 30 countries worldwide are operating 449 nuclear reactors for electricity generation and 60 new nuclear plants are under construction in 15 countries.

References

1- “DOES THE INERTIA OF A BODY DEPEND UPON ITS ENERGY-CONTENT?” By A. EINSTEIN. September 27, 1905. (Reviewed and coordinated at December 2017)

2- “University Physics with Modern Physics 14th edition”. Chapter 37, section 8. (Reviewed and coordinated at December 2017)

3- “Union of Concerned Scientists (science for a healthy planet and safer world)” titled by ‘How Do Nuclear Weapons Work?’--, [Ucsusa.org] scientific webpage.

4- “Lumenlearning.com” Study webpage. “Nuclear Fission, The Atomic Bomb, Nuclear Reactors”. (Reviewed and coordinated at December 2017)

5- “Nature; Physics” Scientific Magazine. Titled by ‘’Physics, physicists and the bomb’’. (Reviewed and coordinated at December 2017)

6- “Atomic Heritage Foundation” scientific webpage, Titled by “Science Behind the Atom Bomb”. (Reviewed and coordinated at December 2017)

7- “Nuclear Energy Institute NEI, (Knowledge Center)” Scientific Webpage titled by “World Statistics {Nuclear Energy Around the World}”. (Reviewed and coordinated at December 2017)