**Nuclear Fission vs Nuclear Fusion**

Nuclear fusion and nuclear fission are two different types of energy-releasing reactions in which energy is released from high-powered atomic bonds between the particles within the nucleus. The main difference between these two processes is that fission is the splitting of an atom into two or more smaller ones while fusion is the fusing of two or more smaller atoms into a larger one.

**Comparison chart**

|  | **Nuclear Fission** | **Nuclear Fusion** |
| --- | --- | --- |
| **Natural occurrence of the process:** | Fission reaction does not normally occur in nature. | Fusion occurs in stars, such as the sun. |
| **Byproducts of the reaction:** | Fission produces many highly radioactive particles. | Few radioactive particles are produced by fusion reaction, but if a fission "trigger" is used, radioactive particles will result from that. |
| **Energy Ratios:** | The energy released by fission is a million times greater than that released in chemical reactions; but lower than the energy released by nuclear fusion. | The energy released by fusion is three to four times greater than the energy released by fission. |
| **Nuclear weapon:** | One class of nuclear weapon is a fission bomb, also known as an atomic bomb or atom bomb. | One class of nuclear weapon is the hydrogen bomb, which uses a fission reaction to "trigger" a fusion reaction. |
| **Definition:** | Fission is the splitting of a large atom into two or more smaller ones. | Fusion is the fusing of two or more lighter atoms into a larger one. |
| **Conditions:** | Critical mass of the substance and high-speed neutrons are required. | High density, high temperature environment is required. |
| **Energy requirement:** | Takes little energy to split two atoms in a fission reaction. | Extremely high energy is required to bring two or more protons close enough that nuclear forces overcome their electrostatic repulsion. |

**Definition of nuclear fission and fusion**

Nuclear fusion is the reaction in which two or more nuclei combine together to form a new element with higher atomic number (more protons in the nucleus). The energy released in fusion is related to E = mc 2 (Einstein’s famous energy-mass equation). On earth, the most likely fusion reaction is Deuterium–Tritium reaction. Deuterium and Tritium are both isotopes of hydrogen. 2 1Deuterium + 3 1Tritium = 42He + 10*n* + 17.6 MeV



Fusion of deuterium with tritium creating helium-4, freeing a neutron, and releasing 17.59 MeV of energy.



Fission Reaction

Nuclear fission is the splitting of a massive nucleus into photons in the form of gamma rays, free neutrons, and other subatomic particles. In a typical nuclear reaction involving 235U and a neutron:

23592U + *n* = 23692U

followed by

23692U = 14456Ba + 89 36Kr + 3*n* + 177 MeV

**Physics behind both fission and fusion processes**

The more the binding energy held within the bonds of an atom, more stable is an atom. Binding energy is the amount of energy held within the bonds of the atoms. The most stable is the nucleon of iron atom, which neither fuses nor splits. That’s why iron is at the top of the binding energy curve. Each atom tries to become more stable by increasing its binding energy. For atomic nuclei lighter than iron and nickel, energy can be extracted by combining these nuclei together through nuclear fusion. In contrast, for atomic nuclei heavier than iron or nickel, energy can be released by splitting the heavy nuclei through nuclear fission.

**Conditions for fission and fusion**

For a fission reaction, two conditions need to be satisfied:

* Critical mass of the substance (the minimum amount of mass is required for fission to be self-sustaining). A relatively slow neutron is required to initiate the process.

For a nuclear fusion reaction to occur it is necessary to bring two nuclei so close that nuclear forces become active and glue the nuclei together. Nuclear forces are small-distance forces and have to act against the electrostatic forces where positively charged nuclei repel each other. This is the reason why nuclear fusion reactions occur mostly in high density, high temperature environment.

**Natural occurrence of fusion and fission**

In nature, fusion occurs in stars. On Earth, nuclear fusion was first achieved in the explosion of the Hydrogen bomb. In a non-destructive manner, fusion has also been reached in different experimental devices aimed at studying the possibility of producing energy in a controlled fashion.

On the other hand, fission is a nuclear process which does not normally occur in nature. The reason for this is that it requires a large mass and an incident neutron to initiate the process. But there have been examples where nuclear fission has occured in natural reactors. This was discovered in 1972 wherein uranium deposits were found at one location which could self sustain a natural chain reaction. 16 deposits have been discovered of these deposits at this lone site.

**Effects of fusion vs. fission**

If accidentally, a fission reaction goes out of control as a result of not controlling the emission of neutrons, a nuclear meltdown can happen which can then release highly radioactive particles in the atmosphere. In contrast, in case of nuclear fusion if the reaction goes out of control, the reaction would stop automatically as it it’ll cool down. In addition, in case of nuclear fusion reaction, the amount of radioactive materials produced as waste is very small and the maximum damage which could happen is the vaporization of anything in the immediate vicinity of the reaction.

With regards to these factors it can be said that a fusion reaction is a more environmentally friendly method of producing nuclear power. Energy requirement: It takes less energy to split two atoms with fission than it does to fuse two atoms, which is why fission reactors were developed first, and why fusion reactors have not been developed yet.

**History of human-engineered fusion/fission**

While an atom bomb is an example of nuclear fission, a hydrogen bomb is an example of nuclear fusion. The testing of a hydrogen bomb arising out of fusion was first conducted in 1951 though the idea of such nuclear fusion had been proposed as early as 1941. This bomb was tested at full scale in 1952.

Atom Bombs based on nuclear fission were tested first in World War II. The first atomic bomb used as a weapon was detonated by the United States in 1945 on the Japanese city of Hiroshima. The first test detonation of an atomic bomb was conducted in New Mexico state in 1945.

**Chain Reaction in fusion vs. fission**

Both fission and fusion nuclear reactions are chain reactions. A nuclear chain reaction occurs when one nuclear reaction causes an average of one or more nuclear reactions, thus leading to a self-propagating number of these reactions. The specific nuclear reaction may be the fission of heavy isotopes (e.g. 235 U) or the fusion of light isotopes (e.g. 2H and 3H).

Fission chain reactions occur because of interactions between neutrons and fissile isotopes and a fusion chain reaction occurs under extreme pressure and temperature conditions, which are maintained by the energy released in the fusion process.

**Nuclear weapons**



Two methods of assembling fission bombs

One class of nuclear weapons, a fission bomb, otherwise known as an atomic bomb or atom bomb, is a fission reactor designed to liberate as much energy as possible and as rapidly as possible, before the released energy causes the reactor to explode (and the chain reaction to stop).

Another class is the hydrogen bomb, which functions by fusion of lighter nuclei into the heavier one. Hydrogen bomb or H-bomb is a weapon deriving a large portion of its energy from the nuclear fusion of hydrogen isotopes. Extremely high temperatures are required in order to initiate a fusion reaction which also gives the hydrogen bomb the name of a thermonuclear bomb.

**Cost of fission vs. fusion**

Nuclear fission: The inefficiency of cost comes into play when it is considered that nuclear fuel creates heat and this heat is used to boil the water and the steam produced is used to turn turbine to generate electricity. This transformation from heat energy to electrical energy is cumbersome and expensive. A second source of inefficiency is that clean-up and storage of nuclear waste is very expensive because the waste is radioactive and finally security issues add to the cost of nuclear energy.

Nuclear fusion: For fusion to occur the atoms must be confined in the magnetic field and raised to a temperature of 100 million Kelvin or more. This takes lot of electricity and hence cost inefficiency comes in the picture. Hence both are cost inefficient logically for productive and non destructive purpose.

**Advantage of nuclear fusion over nuclear fission**

In case of fusion reactions, fusion reactors cannot sustain a chain reaction so they can never melt down like fission reactors. Fusion reaction produces very less or, if the right atoms are chosen, no radioactive waste. In case of nuclear fission large radioactive waste is produced and disposal of radioactive waste is a complicated problem. For nuclear power, fusion is the better choice.

**Energy ratios in fission and fusion**

The energy released by fusion is three to four times greater than the energy released by fission. This is because the amount of mass transformed into energy is that much greater in a fusion reaction than in a fission reaction.