The Science behind Nuclear Bomb

Why in news?

Christopher Nolan's film "Oppenheimer" has ignited conversation around nuclear weapons.

What is the basis of nuclear weapon?

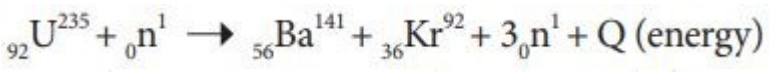
- Atoms are the *basic building blocks* of all matter, such that they cannot be "broken down" further by simple chemical processes.
- Atom comprises of *three sub-atomic particles*.
    - Positively charged proton
    - Negatively charged electron
    - Neutral neutron
- The protons and neutrons combine to form the atom's nucleus, around which circle a "*cloud" of electrons*.
- The number of protons in an atom determines the element, and the number of neutrons determines the isotope of that element.
- Different isotopes of the same element have the same chemical properties, but very different nuclear properties.

The Manhattan Project was a research and development undertaking led by the United States with the support of the United Kingdom and Canada, during World War II to produce the first nuclear weapons.

What is nuclear fission?

- In 1939, German Scientist *Otto Hahn and F.Strassman* discovered that when a uranium nucleus is bombarded with a neutron, it breaks up into 2 smaller nuclei of comparable mass along with the emission of a few neutrons and energy.
- This process of breaking up of a *heavier nucleus into 2 smaller nuclei* with the release of a large amount of energy and a few neutrons is called 'nuclear fission'.

Example- Nuclear fission of a uranium



• The minimum mass of a fissile material necessary to sustain the chain reaction is called *critical mass.*
• If the mass of the fissile material is less than the critical mass, it is termed as *subcritical.*
• If the mass of the fissile material is more than the critical mass, it is termed as *supercritical*

How the atom bomb works?

- **Atom bomb** - The atom bomb is based on the principle of ***uncontrolled chain reaction***, in which the number of neutrons and the number of fission reactions multiply in a geometrical progression.
- This releases a huge amount of energy in a very small time interval and leads to an explosion.
- An atom bomb consists of a piece of fissile material whose mass is *subcritical*.
    - Example- Hiroshima and Nagasaki atom bomb explosion in 1945.
- **Uranium enrichment** - Approximately *99.3%* of naturally occurring uranium is of the isotope *U-238, which is not fissionable*.
- Naturally occurring uranium, therefore, cannot be used in a weapon, or nuclear power plants.
- Uranium ore is enriched in order to increase the concentration of U-235.
- Most nuclear power plants require an *enrichment of 3-4%* U-235 to sustain a chain reaction.
- Fission bombs on the other hand need *closer to 90% enrichment*.

J. Robert Oppenheimer is called as the father of atom bomb.

What is nuclear fusion?

- The process in which *two lighter nuclei combine to form a heavier nucleus* is termed as 'nuclear fusion'.

$$^{2}_{1}H + {}^{3}_{1}H \rightarrow {}^{4}_{2}He + {}^{1}_{0}n + energy$$

- Nuclear fusion is also called as ***thermonuclear reaction*** which is possible only at an extremly high temperature and high pressure to push the hydrogen nuclei closer to fuse with each other.

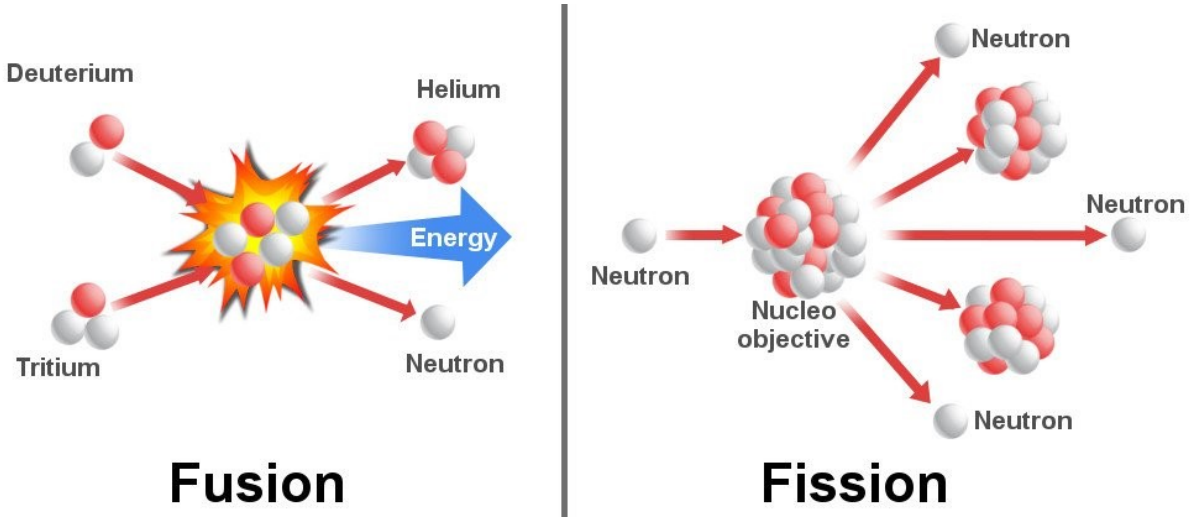
What is a hydrogen bomb?

- It is based on the principle of *nuclear fusion.*
- A hydrogen bomb is always designed to have an *inbuilt atom bomb* which creates the high temperature and pressure required for fusion when it explodes.
- Then, fusion takes place in the hydrogen core and leads to the release of a very large amount of energy in an uncontrolled manner.

The energy released in a hydrogen bomb (or fusion bomb) is much higher than that released in an atom bomb

What is the difference between nuclear fusion and nuclear fission?

Features	Nuclear Fusion	Nuclear Fission
About	Lighter nuclei will join together to prouce heavy nucleus	Heavy nucleus is divided into two fragments along with few neutrons
Temperature	Takes place at very high temperature (107 kelvin)	Take place even at room temperature
Conditions required	High density and high temperature	Critical mass of the substances and high speed neutrons
Need of neutrons	No need of external neutrons	To start fission atleast one thermal neutron from outside is compulsory
Energy	Energy released per unit mass is high, nearly 7 times more than fission	Energy released per unit mass is less
Reaction	No control on fusion reaction	Can be controlled Example- Nuclear reactor
Emissions	Alpha rays, positrons, and neutrinos	Alpha, beta and gamma radiations
Example	Hydrogen bomb	Atomic bomb



What happens during the explosion of nuclear device?

- **Shockwave-** A blast or a shock wave that can flatten and obliterate any physical structures in the blast radius.
- **Bright light-** It can cause permanent blindness even many kilometres away.
- **Intense heat-** It can literally turn human bodies into ashes in an instant.
- **Radiation-**It includes both initial radiation, produced within a minute of detonation and residual (or delayed) nuclear radiation, which is emitted over a period of time.

Reference

1. Indian Express- Science behind nuclear weapon