

# NUCLEAR REACTION AND ENERGY PRODUCTION

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June 5, 2024

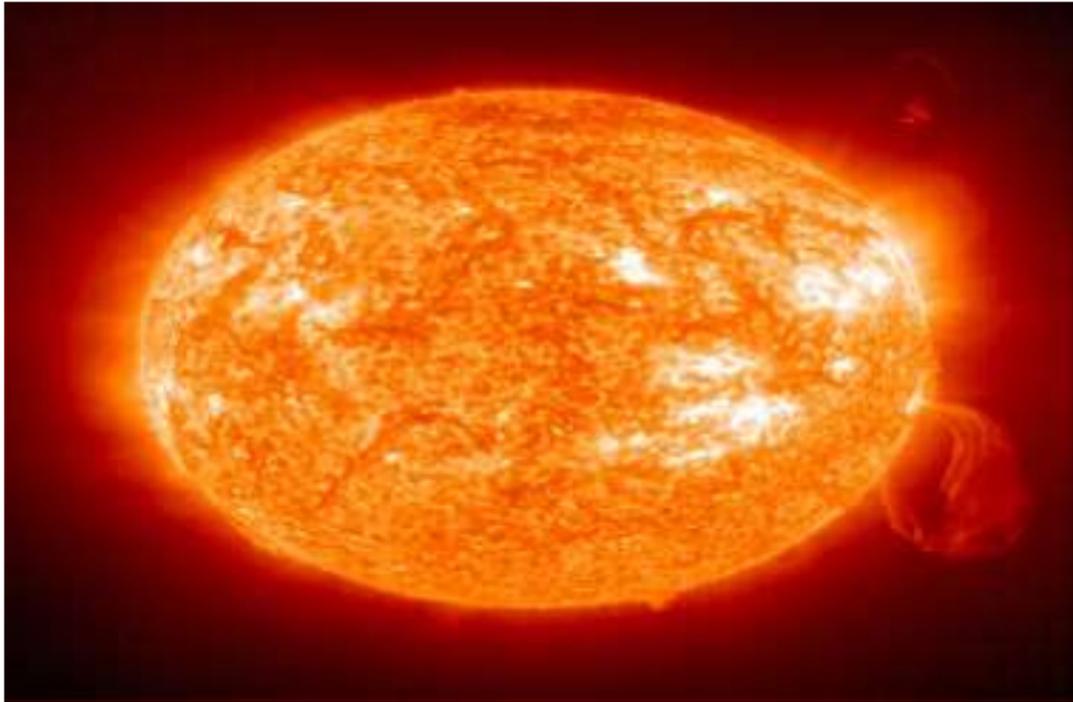
## Outline

- NUCLEAR FISSION REACTION
- APPLICATION OF NUCLEAR FISSION
- NUCLEAR PLANTS AND RESEARCH REACTOR
- PROBLEMS POSTED BY NUCLEAR WASTE OF REACTOR
- NUCLEAR FUSION REACTION
- STELLAR ENERGY GENERATION
- HYDROGEN BOMBS Vs ATOMIC BOMBS

# INTRODUCTION

- Nuclear -means the process that involves the nucleus.
- Reaction -Atomic Nucleus Interplay.
- Fission -Atom Splitting Process.
- Fusion -Uniting Nuclei.

# THE SUN'S RADIANT NUCLEAR REACTION

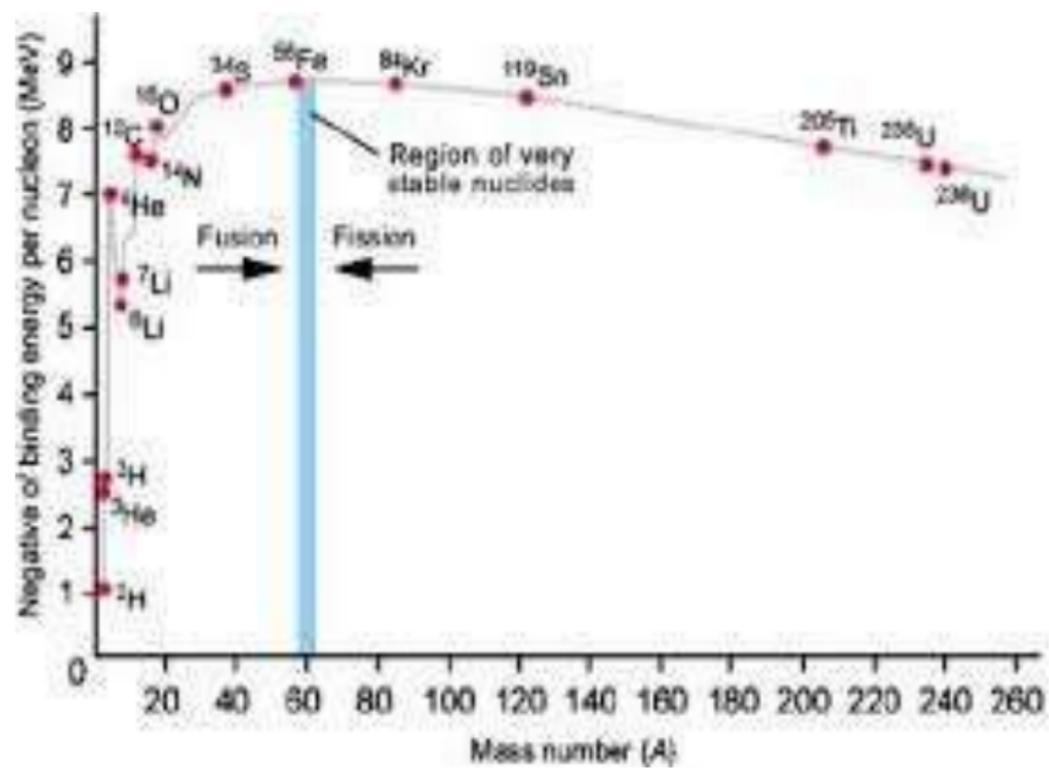


Within the sun's core, nuclear fusion orchestrates a symphony of immense energy that sustains the sun's brilliant glow and fuels the stellar processes that forge heavier elements.

# NUCLEAR REACTION

A nuclear reaction is an event where two atomic nuclei, or a nucleus and a subatomic particle from outside, collide to form one or more new nuclides.

- A process to be classified as a nuclear reaction, it must transform at least one nuclide into another. If they part ways without altering the nature of any nuclide, this process is termed nuclear scattering rather than a nuclear reaction. Mainly there are two types of nuclear reaction. Those are
  - FISSION REACTION
  - FUSION REACTION



# FISSION REACTION

- The alchemy of atoms, a marvel of scientific discovery, where the unimaginable power held within the heart of the atom is unleashed through controlled division.
- It is a decay in which the heavy nucleus splits into smaller parts (lighter nuclei) after being bombarded by a neutron. The fission process often produces free neutrons, photons (in the form of gamma rays) and releases a large amount of energy.

## Fissile and Fertile elements

### **fissile**

elements that sustain a nuclear chain reaction by undergoing fission with low-energy neutrons including thermal neutrons (neutrons with low energy levels).

### **Example**

uranium-235 (U-235), plutonium-239 (Pu-239), and uranium-233 (U-233).

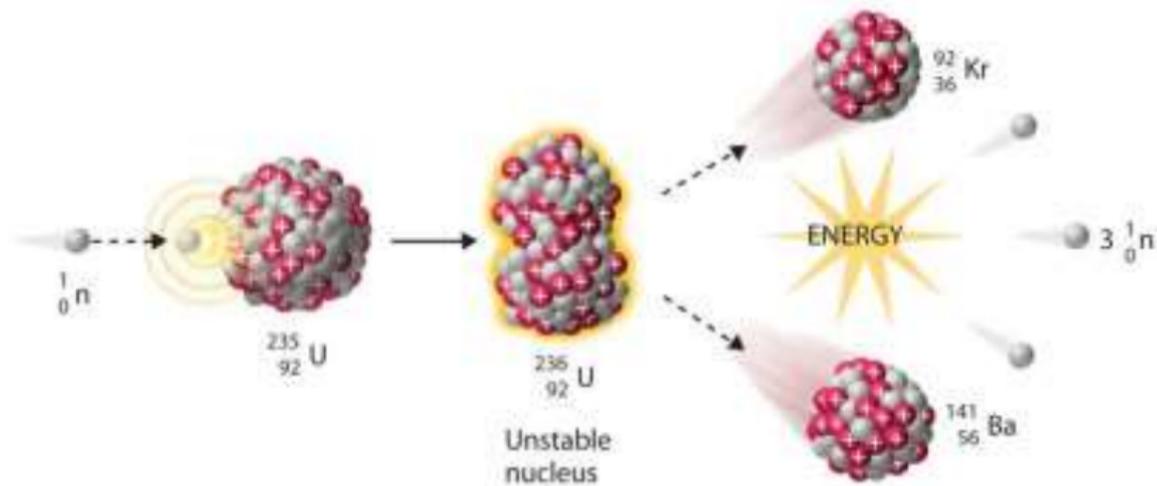
### **fertile**

are those that can undergo nuclear fission when bombarded by high-energy neutrons. Unlike fissile materials, fissionable materials may not sustain a chain reaction with low-energy (thermal) neutron.

### **Example**

uranium-238 (U-238) and thorium-232 (Th-232).

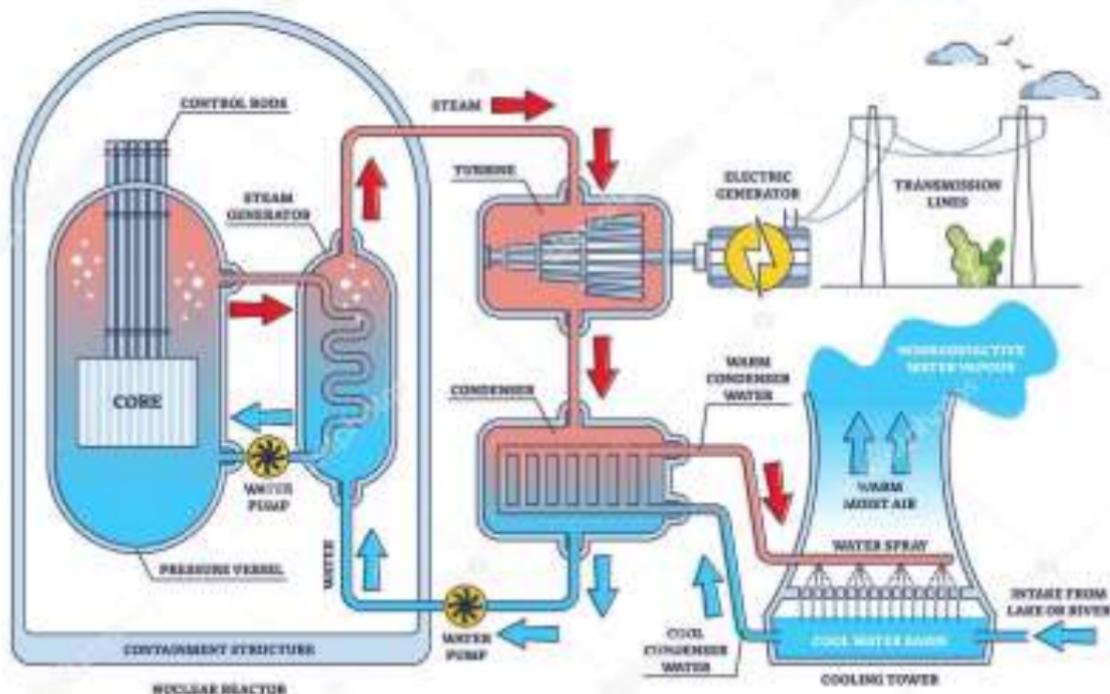
# fission of Uranium-235



# APPLICATION OF FISSION REACTION



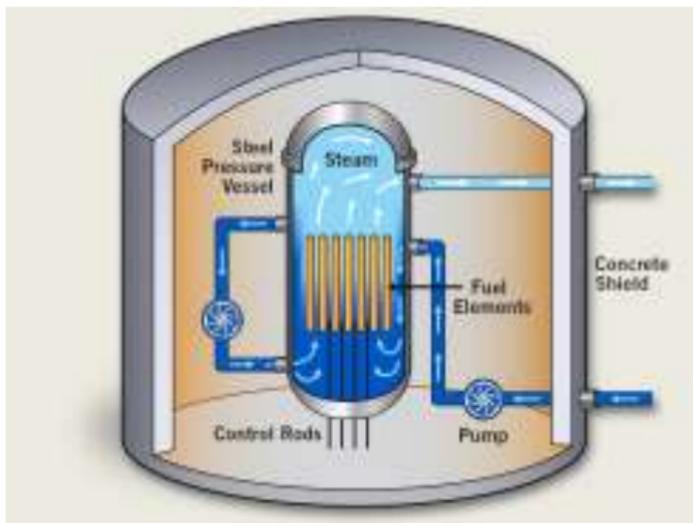
## NUCLEAR POWER STATION



- A nuclear power plant (NPP) is a thermal power station in which the heat source is a nuclear reactor.

## Components of Nuclear reactor

### 1. reactor core



- fuel elements-enriched uranium
- control rod- Boron or cadmium
- moderator-most of the time purified water

**2.steam generator**-is a heat exchanger used to convert water into steam from heat produced in a nuclear reactor core.

**3.Turbines**-receives high pressure and temperature steam from nuclear reactor and converts the heat energy into mechanical energy.

**4.generator**-converts the mechanical energy to electrical energy.

## Uses of nuclear power plant

1. Nuclear power is primarily utilized for generating electricity.
2. nuclear power plants have the potential to produce clean hydrogen for ammonia and nitrogen in fertilizers.
3. In steel refining and in creating synthetic fuels for cargo ships, significantly reducing carbon emissions.
4. Space Exploration: a great deal of what we know about deep space has been made possible by radioisotope power systems

# RESEARCH REACTORS

- Research reactors are nuclear fission reactors primarily used as neutron sources, operating at lower temperatures and requiring less fuel than power reactors.
- production of radioisotopes
- neutrone scattering
- neutron transmutation doping

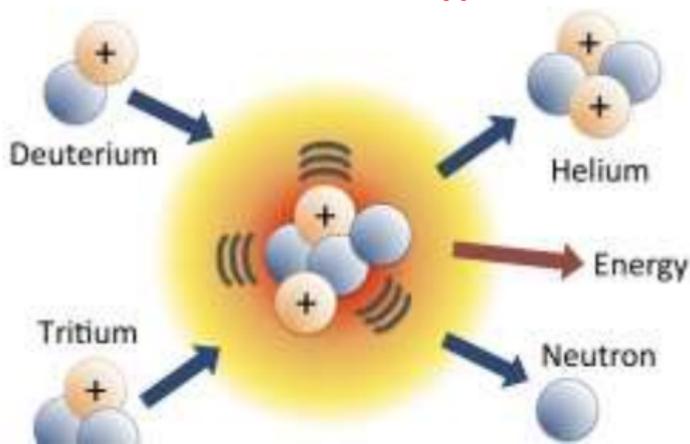
# PROBLEMS POSTED BY NUCLEAR WASTE OF REACTORS

- Long term Radioactivity(nuclear waste) - Nuclear waste is radioactive waste that emits radiation spontaneously. It primarily comes from the by-products of nuclear reactions and degrades over time, emitting alpha, beta, and gamma radiation, which pose significant health risks.
- The controversy surrounding nuclear technology largely stems from the radioactive waste it generates, which includes elements with extremely long half-lives, like plutonium-239 and uranium-235, requiring isolation from humans and the environment for thousands to millions of years.

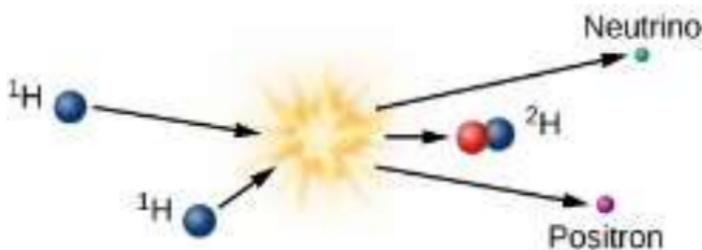
# FUSION REACTION

- Nuclear Fusion reactions power the Sun and other stars. In a fusion reaction, two light nuclei merge to form a single heavier nucleus.
- The process releases energy because the total mass of the resulting single nucleus is less than the mass of the two original nuclei.

There are two basic types of nuclear fusion reaction those are

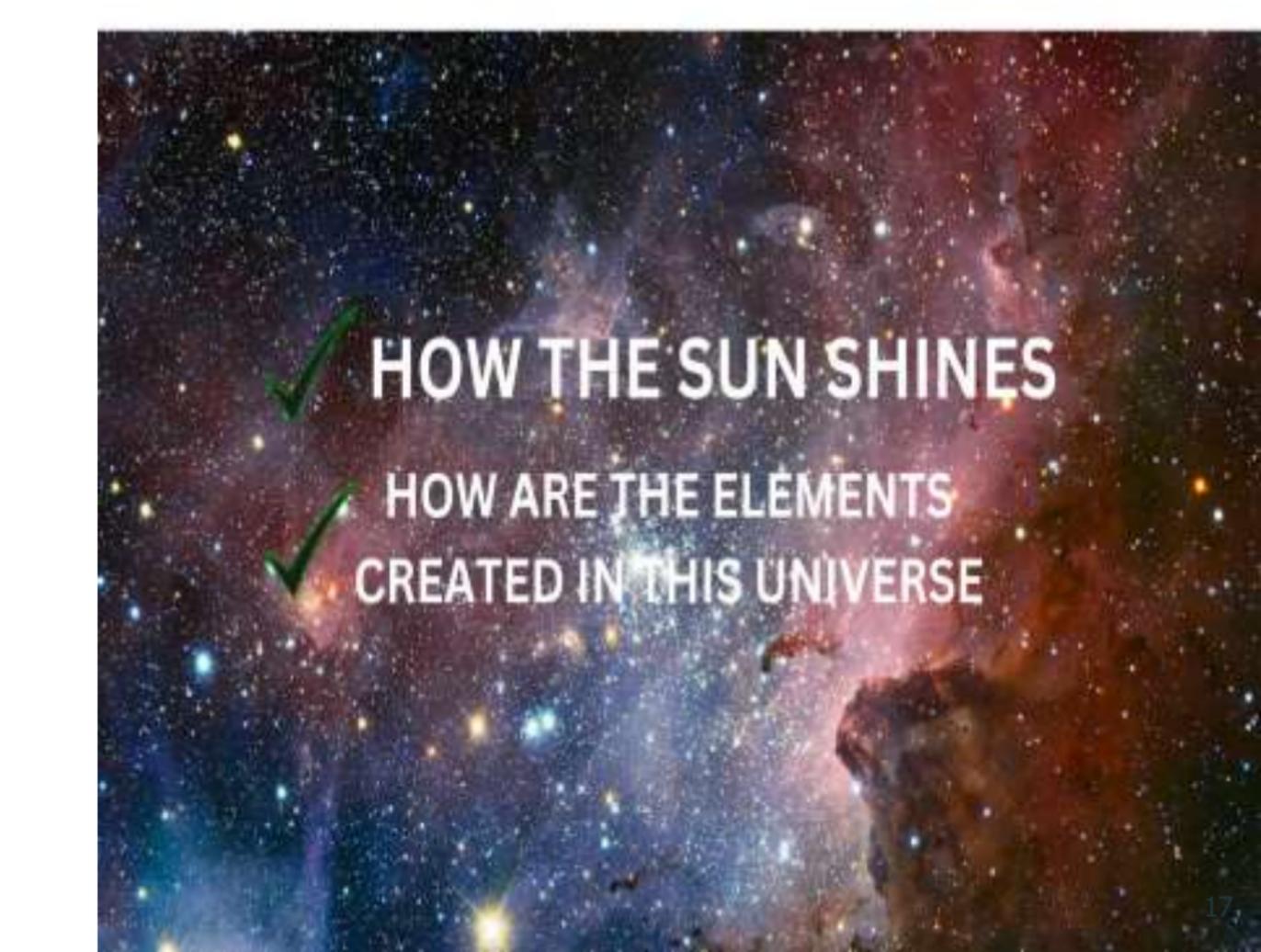


1. one that preserve the number of protons and neutrons and (D-T fusion)



2. those that involve a conversion between protons and neutrons (H-H fusion).

1. Reactions of the first type are most important for practical fusion energy production, whereas those of the second type are crucial to the initiation of star burning.



✓ HOW THE SUN SHINES

✓ HOW ARE THE ELEMENTS  
CREATED IN THIS UNIVERSE

# STELLAR NUCLEOSYNTHESIS

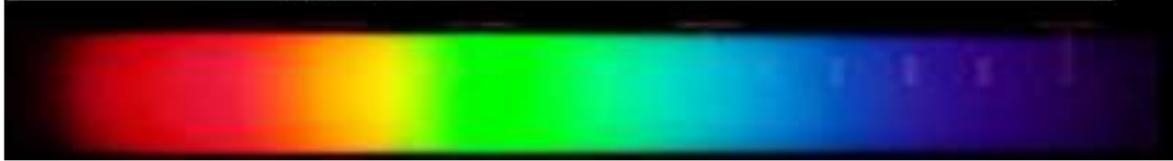
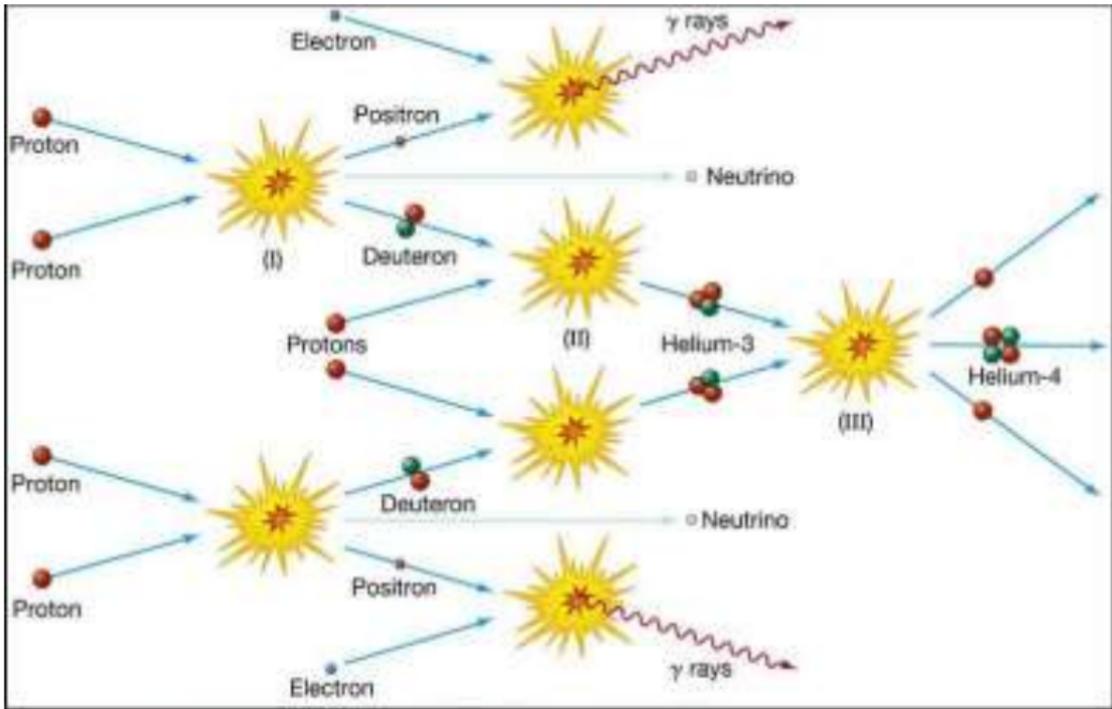
- The word "**stellar**" means star and the formation of elements in the core of the star is called stellar nucleosynthesis.

- **Big Bang nucleosynthesis** - refers to the production of light elements such as hydrogen (H), helium (He), and small amounts of lithium (Li) and beryllium (Be) that occurred in the first few minutes after the Big Bang when the universe was very hot and dense.
- **Supernova nucleosynthesis** - occurs during a supernova explosion, when a massive star reaches the end of its life and undergoes a catastrophic collapse. During this process, fusion reactions create elements heavier than iron.

## Proton-Proton chain

- The sun, a colossal sphere of hydrogen gas, fuels solar nuclear fusion for billions of years, continuously producing immense energy.
- The proton-proton chain, the primary source of the sun's energy, involves hydrogen nuclei fusing into helium within the sun's core.
- The first step in all the branches is the fusion of two protons into a deuterium.
- As protons fuse one of them undergo beta plus decay, converting into a neutron by emitting a positron and an electron neutrino.
- This chain reaction, driven by both the weak and strong nuclear forces, rapidly converts deuterium into helium-3.

- There are multiple branches, including p–p I, p–p II, and the rare p–p III and IV, culminating in the conversion of 0.7
- This energy, in the form of gamma rays, kinetic energy, and neutrinos, heats the sun's interior and sustains its structure against gravitational collapse.



- The formation of He-4 from He-3 nucleus occurs in 4 possible paths.

1. The p-p I branch

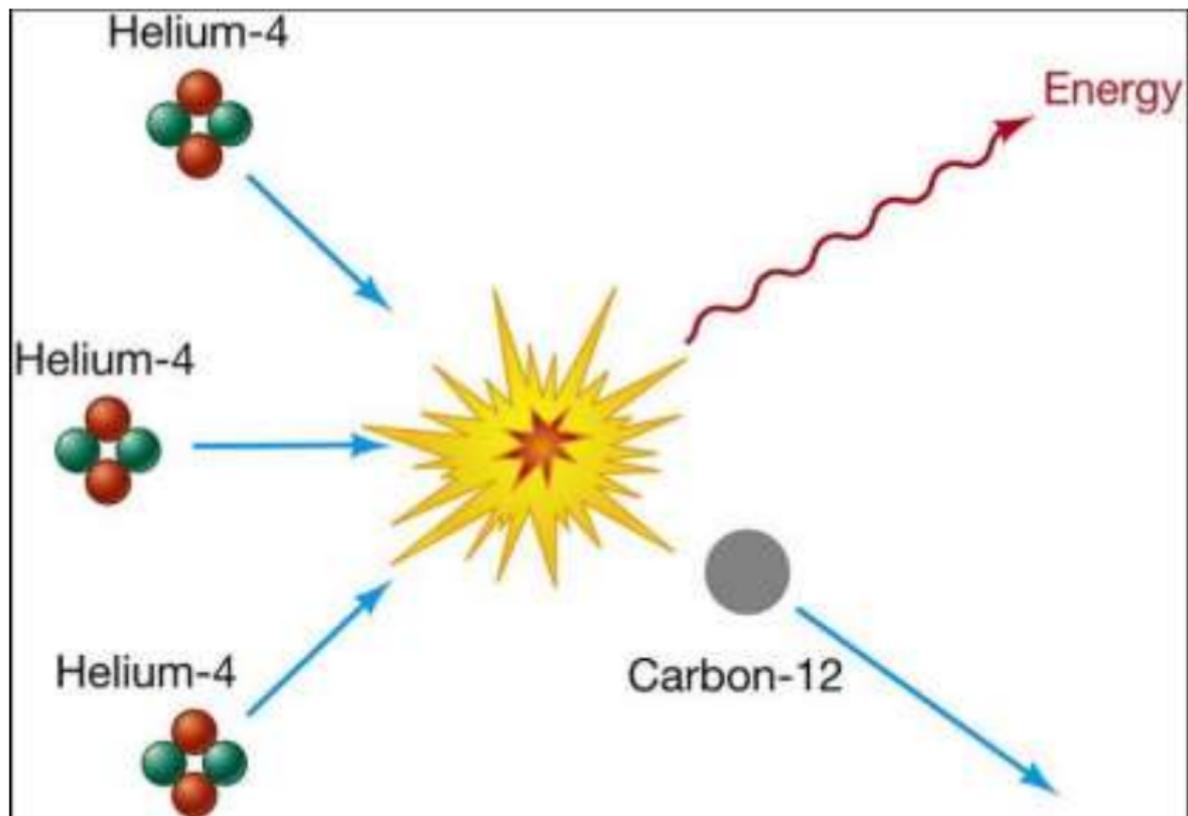


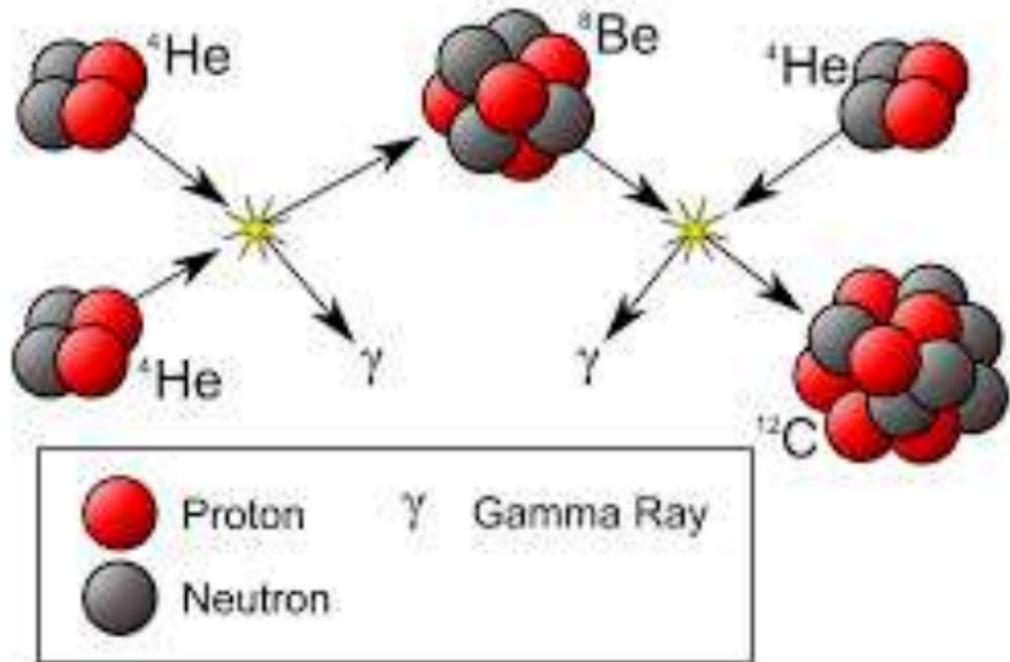
2. The p-p II branch

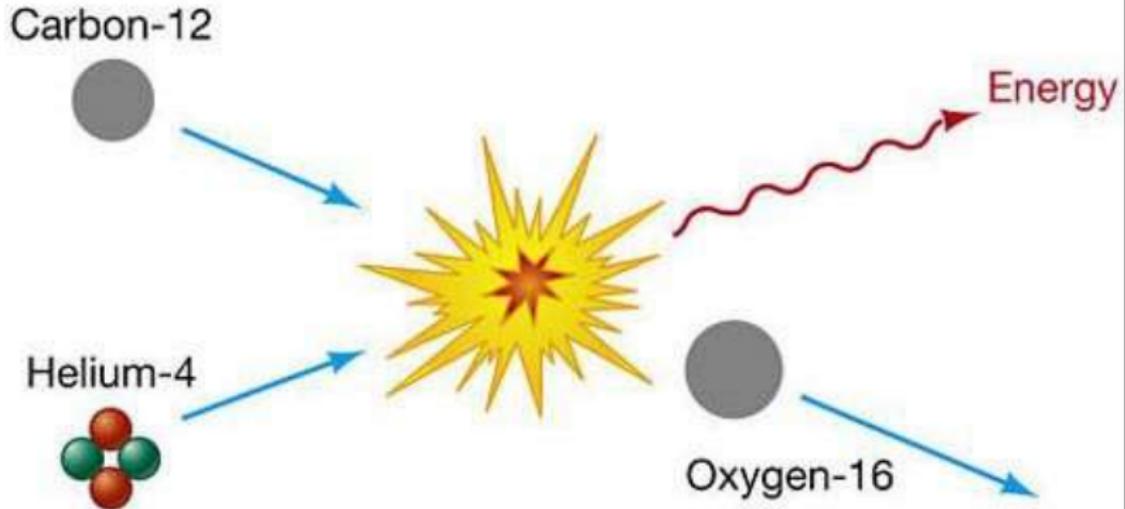


3. The p-p IV branch









"The process of alpha capture continues on to the heaviest elements fused in the core of the star"

## Energy produced with in the sun



- 4,000,000 tons of matter is converted to energy in 1 sec according to the relativity theory( $E = mc^2$ )

$$E = 3.24 \times 10^{26}$$

The stellar nucleosynthesis is only up to the formation of Iron.

**Why?**

## Hydrogen Bomb Explosion-1950



- *In 1950, the hydrogen bomb's cataclysmic detonation unleashed an unparalleled tempest of energy, forever altering the landscape of human power and technological prowess.*

- The mechanism of making hydrogen bombs involves a combination of three bombs in one.
- It includes an ordinary chemical bomb, a fission bomb similar to the one dropped on Nagasaki and a fusion bomb.
- The chemical bomb initiates the fission bomb, which then initiates the fusion bomb.
- Hydrogen bombs are much more powerful than atomic bombs, releasing energy through the fusion of atoms.
- The process of fusion in a hydrogen bomb involves combining protons and neutrons to form a Helium nucleus and a free neutron.
- The casing of the hydrogen bomb is lined with beryllium, which acts as a mirror to reflect neutrons back into the casing.

# Atomic Bomb Explosion-1945



- *1945, the atomic bomb detonations over Hiroshima and Nagasaki unleashed cataclysmic devastation, forever etching a somber legacy of unprecedented destructive power into human history*

## Atomic bomb

- A weapon with great explosive power that results from the sudden release of energy upon the splitting, or fission, of the nuclei of a heavy element such as plutonium or uranium.
- Plutonium is a fissile material(their atom splits) in to Xenon(Xe) and Zirconium(Zr).When a neutron collides with other plutonium atom splitting occurs and chain reaction is initiated.
- To make it sustain chain reaction it must be at critical mass.To do this it is compressed at 300,000 ATM increasing its density by two and a half .
- At normal density due to the large space the released neutron losses its energy before reaching another atom and chain reaction will not be sustained.

# HYDROGEN BOMB Vs ATOMIC BOMB

Hydrogen bombs	Atomic bombs
Uses uranium or plutonium as well as two other isotopes of hydrogen, called deuterium and tritium.	Uses either uranium or plutonium and relies on fission.
Get their power from a combination of fission and its opposite—nuclear fusion	Are powered solely by nuclear fission
Releases energy through both nuclear fission and nuclear fusion	Releases energy through the process of nuclear fission.
Needs the detonation of fission bomb to initiate the fusion reaction	the detonation mechanism involves the rapid assembly of a supercritical mass of fissionable elements