Nuclear Reaction and Energy Production

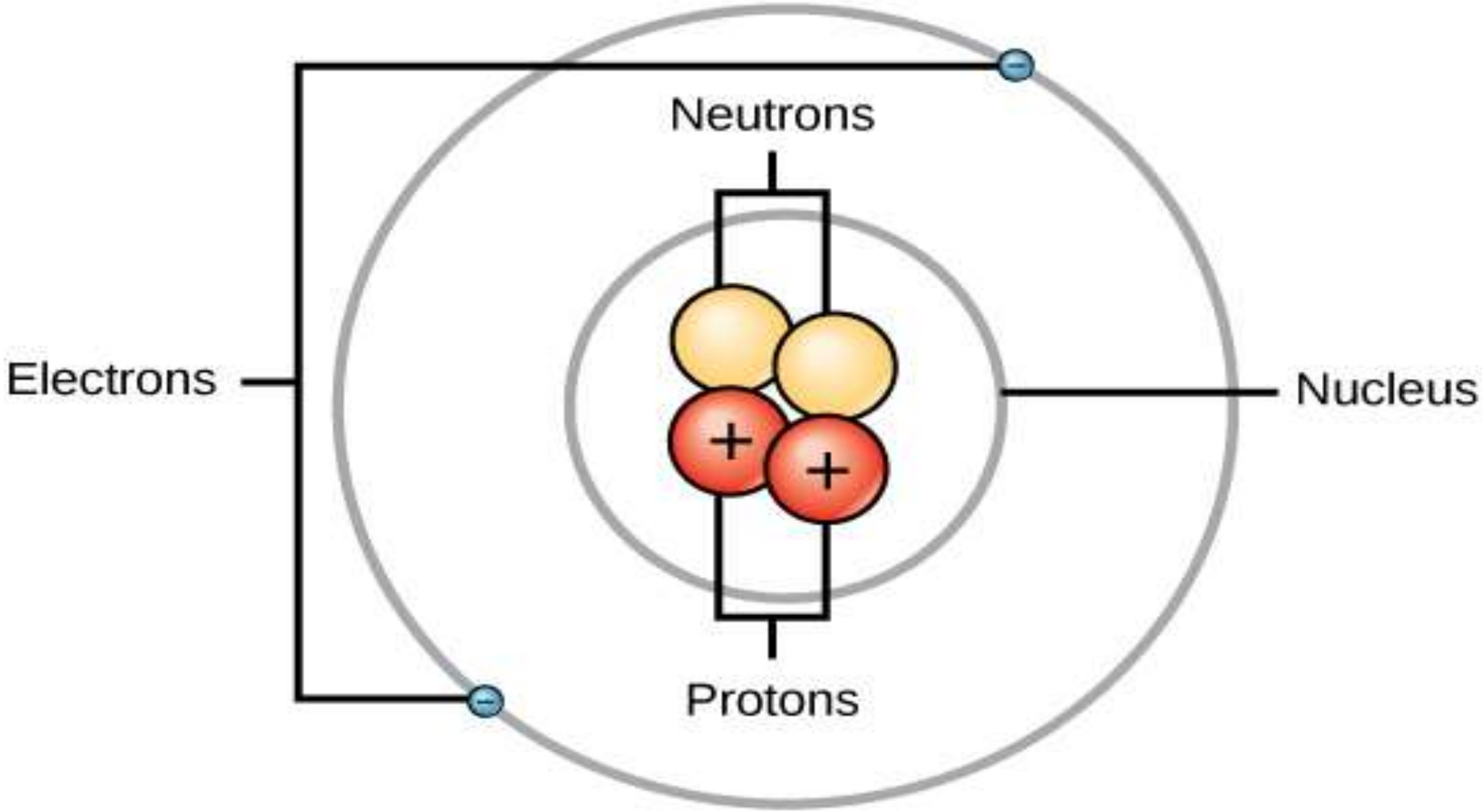
Acknowledgement:

By combined effort of group 4 members and a little bit of assistance from our beloved physics teacher we were able to complete this presentation that deals with several topics about nuclear energy and its realms. We want to thank everyone who helped us achieve this goal!!

Introduction:

All matter is composed of atoms: incredibly small structures that house different combinations of three particles, known as protons, neutrons, and electrons. At the center of each atom is a “nucleus” (the plural of which is “nuclei”), where neutrons and protons are bound in close proximity together. Most nuclei are relatively stable; meaning the makeup of their neutrons and protons is comparatively static and unchanging.

Structure of Atom



Nuclear energy

Energy in the nucleus, or core, of an atom. Atoms are tiny units that make up all matter in the universe, and energy is what holds the nucleus together. There is a huge amount of energy in an atom's dense nucleus. In fact, the power that holds the nucleus together is officially called the ”strong force. Human beings can make use of this immense source of power in different ways.

Nuclear energy

Nuclear energy can be used to create electricity, but it must first be released from the atom. In the process of nuclear fission, atoms are split to release that energy.

Nuclear energy

A nuclear reactor, or power plant, is a series of machines that can control nuclear fission to produce electricity. The fuel that nuclear reactors use to produce nuclear fission is pellets of the element uranium.

Nuclear energy

Nuclear energy is crucial for ensuring a reliable, low-carbon, and sustainable energy future. Its role in reducing greenhouse gas emissions, enhancing energy security, fostering economic growth, and driving technological innovation underscores its importance in the global energy landscape

Types of nuclear reaction

There are two antagonistic way of reaction. Fusion and fission are two fundamental nuclear processes that release energy, and also they operate in opposite ways.

Types of nuclear reaction

Nuclear fission

Nuclear fission is a reaction where the nucleus of an atom splits into two or more smaller nuclei, while releasing energy.

Types of nuclear reaction

Nuclear fission

For instance, when hit by a neutron, the nucleus of an atom of uranium-235 splits into two smaller nuclei, for example a barium nucleus and a krypton nucleus and two or three neutrons. These extra neutrons will hit other surrounding uranium-235 atoms, which will also split and generate additional neutrons in a multiplying effect, thus generating a chain reaction in a fraction of a second.

Types of nuclear reaction

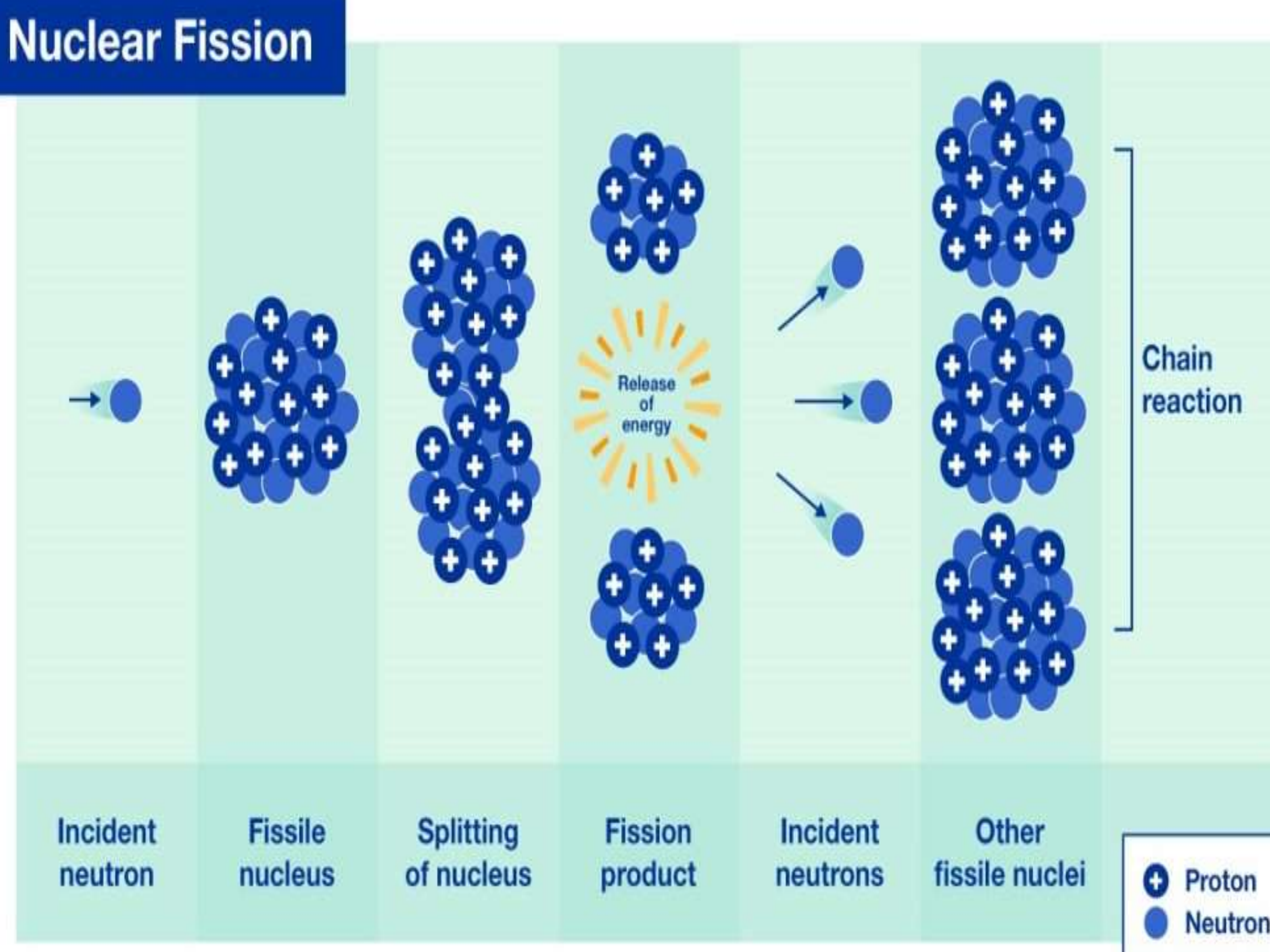
Nuclear fission:

This can sometimes occur spontaneously, but can also, in certain nuclei, be induced from outside. A neutron is shot at the nucleus and is absorbed, causing instability and fission

Types of nuclear reaction

Nuclear fission:

In some elements—such as certain isotopes of uranium and plutonium—the fission process also releases excess neutrons, which can trigger a chain reaction if they're absorbed by nearby atoms.


Nuclear Fission
Release of energy
Chain reaction
Incident neutron
Fissile nucleus
Splitting of nucleus
Fission product
Incident neutrons
Other fissile nuclei
Proton
Neutron

Types of nuclear reaction

Nuclear fusion:

Fusion works in reverse: when exposed to extremely high temperatures and pressures, some lightweight nuclei can fuse together to form heavier nuclei, releasing energy in the process.

Types of nuclear reaction

Nuclear fusion::

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. The leftover mass becomes energy.

Types of nuclear reaction

Nuclear fusion::

Einstein's equation ($E=mc^2$), which says in part that mass and energy can be converted into each other, explains why this process occurs. If scientists develop a way to harness energy from fusion in machines on Earth, it could be an important method of energy production.

Types of nuclear reaction

Nuclear fusion:

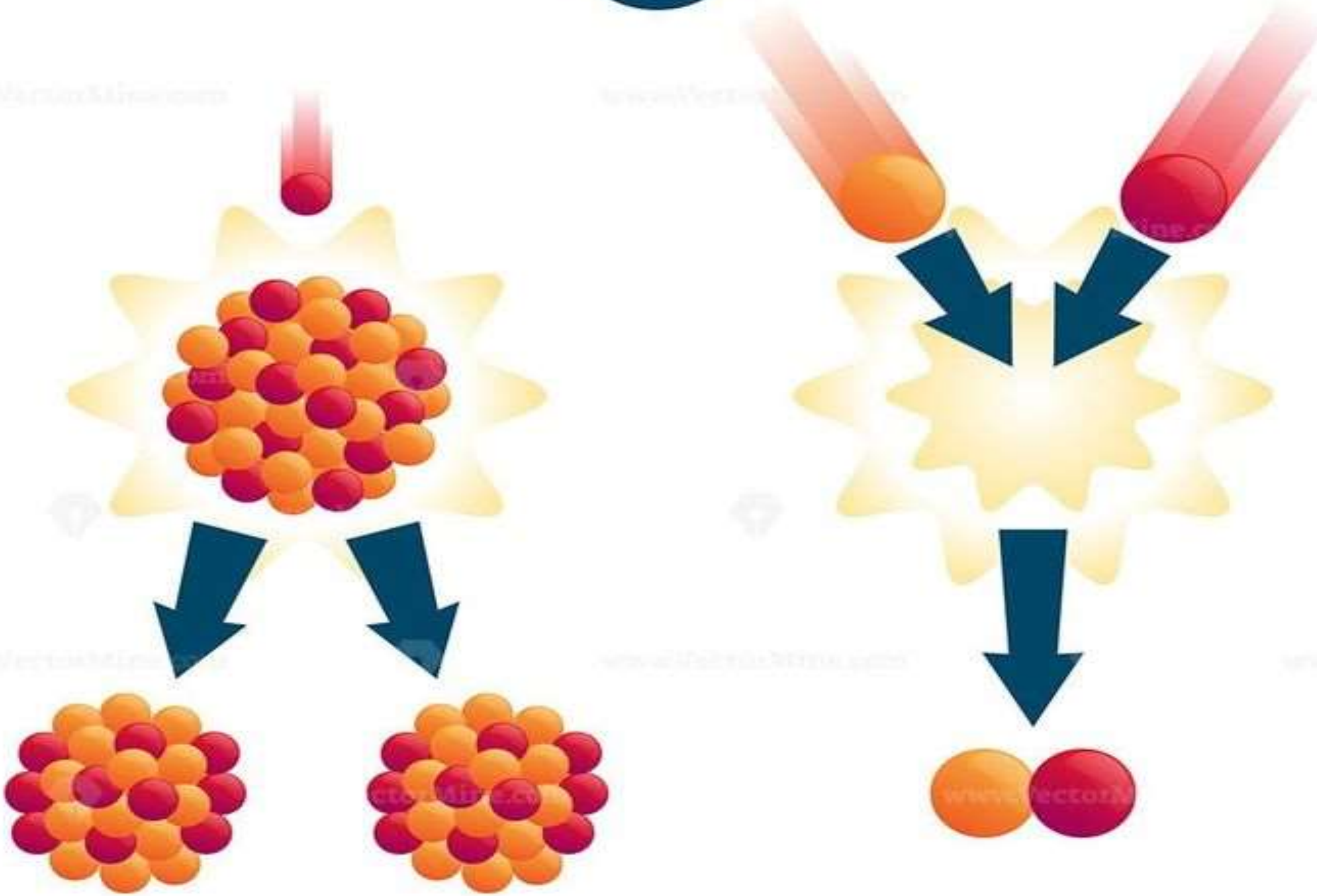
Fusion can involve many different elements in the periodic table. However, researchers working on fusion energy applications are especially interested in the deuterium-tritium (DT) fusion reaction. DT fusion produces a neutron and a helium nucleus. In the process, it also releases much more energy than most fusion reactions.

Types of nuclear reaction

Nuclear fusion:

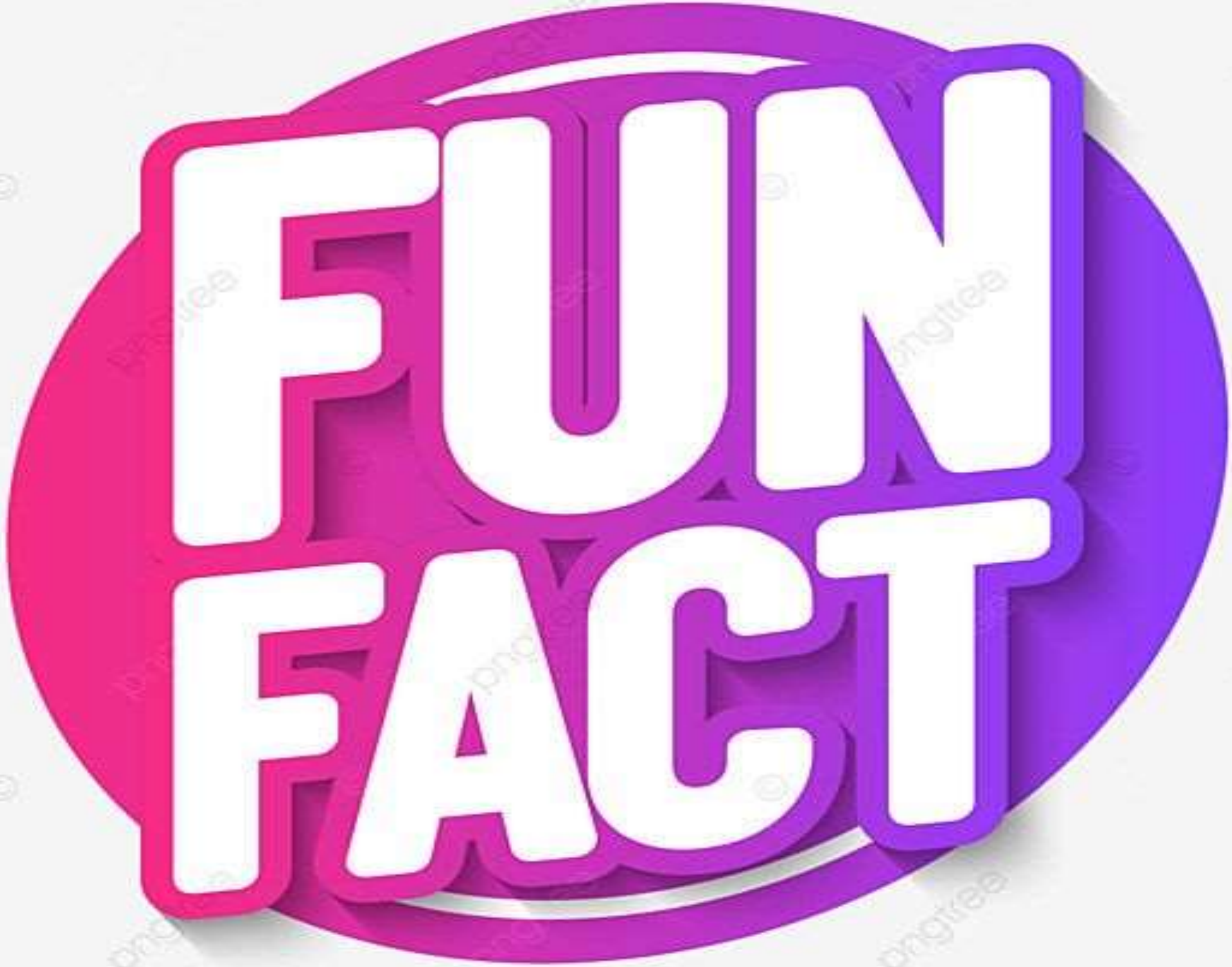
In a potential future fusion power plant such as a tokamak or stellarator, neutrons from DT reactions would generate power for our use. Researchers focus on DT reactions both because they produce large amounts of energy and they occur at lower temperatures than other elements.

FISSION VS FUSION



SPLITS a larger atom into 2 or more smaller ones

JOINS 2 or more lighter atoms into a larger one


FUN
FACT

Fun fact:

(this actually might not be funny), in modern nuclear weapons, which use both fission and fusion, a single warhead can release more explosive energy in a fraction of a second than all of the weapons used during World War II combined—including Fat Man and Little Boy, the two atom bombs dropped on Japan.
e who helped us achieve this goal!!

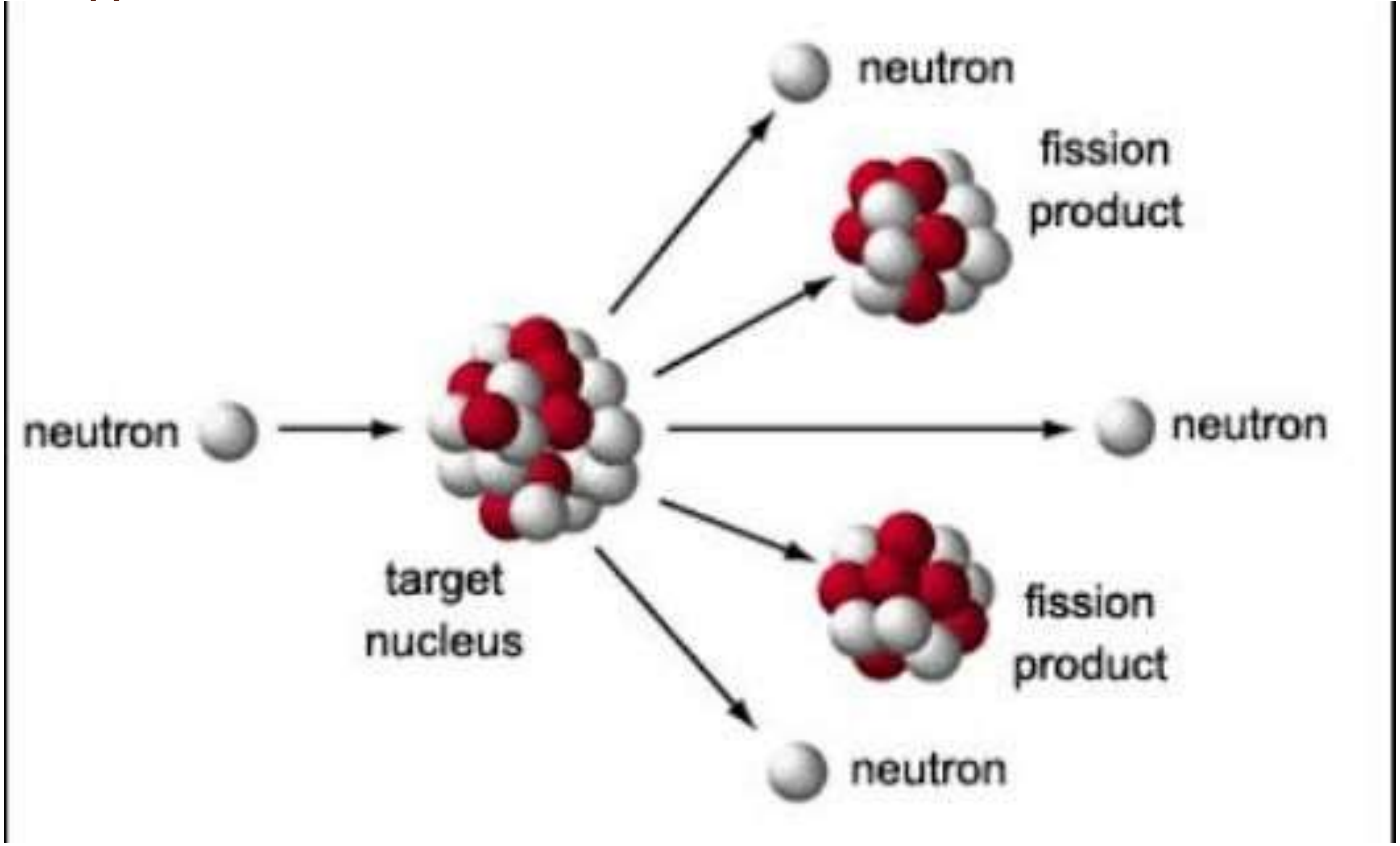
Applications of Nuclear Fission Reaction

Electricity Generation Process:

A nuclear reactor, or power plant, is a series of machines that can control nuclear fission to produce electricity. The fuel that nuclear reactors use to produce nuclear fission is pellets of the element uranium.

Applications of Nuclear Fission Reaction

In a nuclear reactor, atoms of uranium are forced to break apart. As they split, the atoms release tiny particles called fission products. Fission products cause other uranium atoms to split, starting a chain reaction. The energy released from this chain reaction creates heat.



Applications of Nuclear Fission Reaction

Rods of material called nuclear poison can adjust how much electricity is produced. Nuclear poisons are materials, such as a type of the element xenon, that absorb some of the fission products created by is nuclear fssion.

Applications of Nuclear Fission Reaction

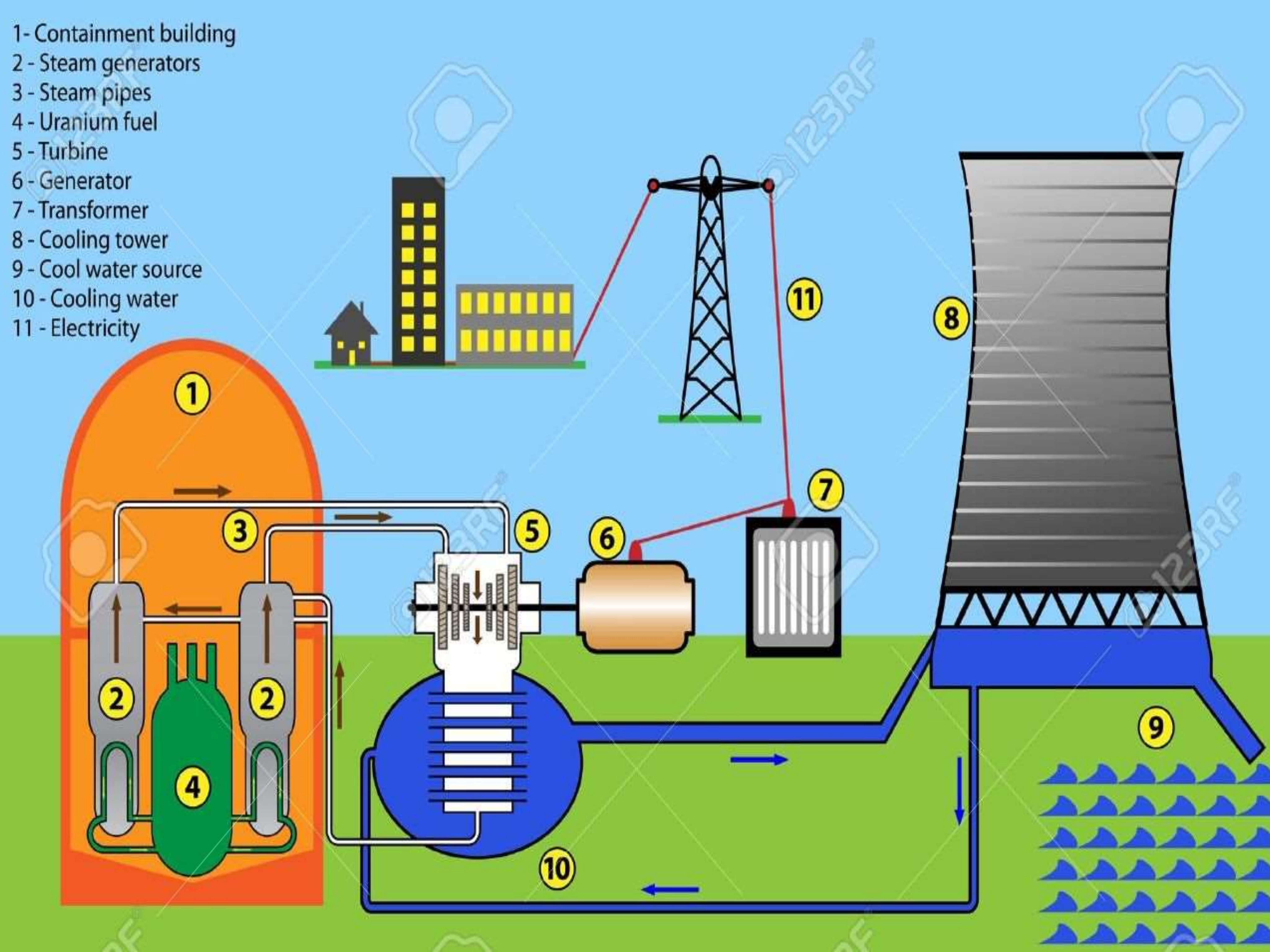
The more rods of nuclear poison that are present during the chain reaction, the slower and more controlled the reaction will be. Removing the rods will allow a stronger chain reaction and create more electricity.

Applications of Nuclear Fission Reaction

As of 2011, about 15 percent of the world's electricity is generated by nuclear power plants.

How does a nuclear power plant work?

Inside nuclear power plants, nuclear reactors and their equipment contain and control the chain reactions, most commonly fueled by uranium-235, to produce heat through fission. The heat warms the reactor's cooling agent, typically water, to produce steam. The steam is then channeled to spin turbines, activating an electric generator to create low-carbon electricity.


1- Containment building
2 - Steam generators
3 - Steam pipes
4 - Uranium fuel
5 - Turbine
6 - Generator
7 - Transformer
8 - Cooling tower
9 - Cool water source
10 - Cooling water
11 - Electricity
1
2
2
3
4
5
6
7
8
9
10
11

How does a nuclear power plant work?

Nuclear Food: Uranium

Uranium is the fuel most widely used to produce nuclear energy. That's because uranium atoms split apart relatively easily. Uranium is also a very common element, found in rocks all over the world. Uranium has several naturally occurring isotopes, which are forms of an element differing in mass and physical properties but with the same chemical properties. However, the specific type of uranium used to produce nuclear energy, called U-235, is rare. U-235 makes up less than one percent of the uranium in the world.

How does a nuclear power plant work?

Once uranium is mined, it must be extracted from other minerals. It must also be processed before it can be used.

How does a nuclear power plant work?

Because nuclear fuel can be used to create nuclear weapons as well as nuclear reactors, only nations that are part of the Nuclear Non-Proliferation Treaty (NPT) are allowed to import uranium or plutonium, another nuclear fuel.

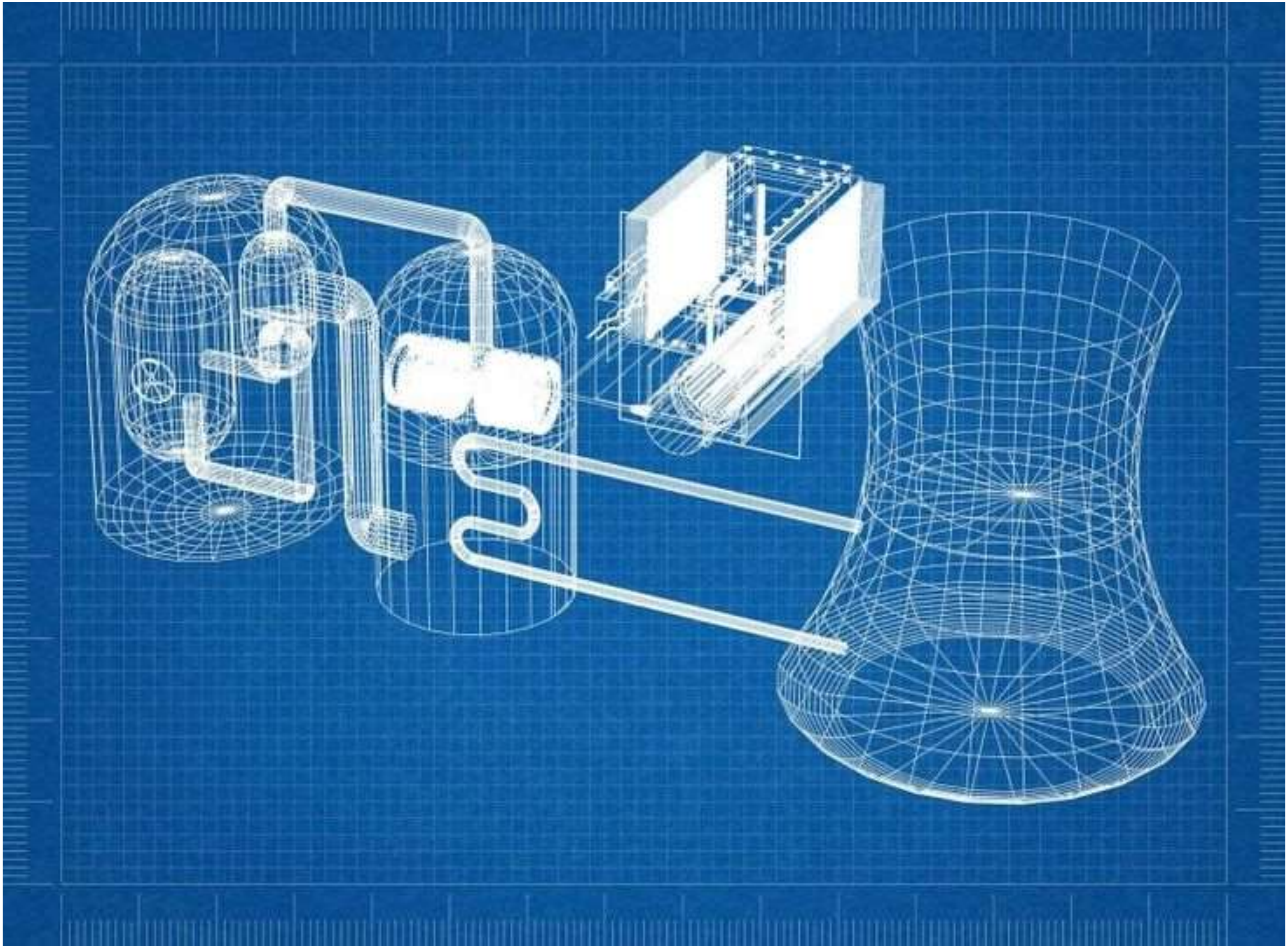
Nuclear Power Plants: Design, Operation, and Challenges

Design:

o Nuclear power plants consist of several key components, including the reactor core, control rods, coolant systems, and turbines.
o The reactor core contains fuel rods (usually enriched uranium) where nuclear fission occurs.

oControl rods regulate the reaction by absorbing neutrons.

o Coolant (often water) circulates to transfer heat from the reactor core to steam generators.



Nuclear Power Plants: Design, Operation, and Challenges

Operation and Maintenance:

- o Nuclear reactors operate by maintaining a controlled chain reaction.
- o Heat generated from fission converts water into steam, which drives turbines connected to generators.
- o Rigorous safety protocols ensure smooth operation and prevent accidents.

Problems Posed by Nuclear Waste of Reactors

The operation of nuclear power plants produces waste with varying levels of radioactivity. These are managed differently depending on their level of radioactivity and purpose. Nuclear power plants generate clean, renewable energy without polluting the air or emitting greenhouse gases.

It is cooled down in a cooling tower, where it condenses back into water and can be reused to generate more electricity.

Problems Posed by Nuclear Waste of Reactors

However, nuclear energy production results in radioactive material as a byproduct. This material consists of unstable atomic nuclei that release energy, potentially affecting nearby materials, organisms, and the environment. Radioactive material is highly toxic and can cause burns, increase cancer risk, and lead to blood diseases and bone decay.

Problems Posed by Nuclear Waste of Reactors

Radioactive waste is the residual material from the operation of a nuclear reactor. This waste primarily includes protective clothing worn by workers, tools, and other items that have come into contact with radioactive dust.

Storage and Disposal Challenges:

An example worth mentioning here is the famous Chernobyl, Ukraine, in 1986.

Storage and Disposal Challenges:

A steam explosion at one of the power plants four nuclear reactors caused a fire, called a plume. This plume was highly radioactive, creating a cloud of radioactive particles that fell to the ground, called fallout. The fallout spread over the Chernobyl facility, as well as the surrounding area. The fallout drifted with the wind, and the particles entered the water cycle as rain. Radioactivity traced to Chernobyl fell as rain over Scotland and Ireland. Most of the radioactive fallout fell in Belarus.

Storage and Disposal Challenges:

For kilometers around the facility, the pine forest dried up and died. The red color of the dead pines earned this area the nickname the Red Forest. Fish from the nearby Pripyat River had so much radioactivity that people could no longer eat them. Cattle and horses in the area died.

More than 100,000 people were relocated after the disaster, but the number of human victims of Chernobyl is difficult to determine.

Table of comparison

Feature	Nuclear Fission	Nuclear Fusion
Primary Use	Electricity generation in power plants	Potential future electricity generation
Secondary Uses	Medical isotopes, nuclear weapons, industrial	Space propulsion, medical neutron sources
Waste	Radioactive fission products	Minimal radioactive waste
Current Status	Commercially viable and widely used	Experimental, not yet commercially viable
Advantages	Established technology, high energy yield	Abundant fuel, less radioactive waste
Challenges	Radioactive waste management, safety concerns	Technical difficulties, achieving sustained reactions

Atomic bombs:

A-bomb or fission bomb, is a nuclear weapon that explodes due to the extreme energy released by nuclear fission, 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.

How Does Atomic bombs work:

Plutonium-239 and uranium-235 are the most common isotopes used in nuclear weapons. Each piece by itself was not enough to constitute a critical mass (the minimum amount of nuclear material needed to maintain fission)—but by colliding the pieces, critical mass was reached and a fission chain reaction occurred.

🏌️‍♂️Historical Development and Impacts:

On 6 and 9 August 1945, the United States detonated two atomic bombs over the Japanese cities of Hiroshima and Nagasaki.

Name: Little Boy

Type: gun-assembly fission bomb

In a gun-assembly bomb, a mass of uranium-235 is fired down a "gun barrel" toward another mass of U-235 to start a chain reaction.

TNT equivalent: 15,000 tons (estimated)

Deployment: B-29 bomber Enola Gay, airburst at 580 m (1,900 ft) above the city

JAPAN

Tokyo

Hiroshima

*Nagasaki

AUGUST 6, 1945, about 8:15 AM

Hiroshima is a city, capital of Hiroshima ken (prefecture), near the southwestern end of Honshu island, Japan. It lies at the head of Hiroshima Bay, an embayment of the Inland Sea. On August 6, 1945, Hiroshima became the first city in the world to be struck by an atomic bomb.


1945
Google Earth

Name: Fat Man

Type: implosion fission bomb

In an implosion bomb, a sphere of plutonium-239 is surrounded by high explosives that compress the plutonium.

TNT equivalent: 21,000 tons (estimated)

Deployment: B-29 bomber Bockscar, airburst at 500 m (1,650 ft)
above the city

AUGUST 9, 1945, 11:02 AM

In the early 20th century the city became a major shipbuilding
centre; it was this industry that led to Nagasaki's being chosen JAPAN as a target for the second atomic bomb dropped on Japan by the United States in World War II. The bomb destroyed the innermost portion of Nagasaki.

3 days after Hiroshima was destroyed.

🏊‍♂️Impacts Durning WWII:

On the aide of Hiroshima

☞27% of total population outright or shortly after the blast.

☞ 55% of total population dead by year's end.

☞ Hiroshima became a spiritual center of the peace movement.

☞Radiation injuries.

☞Genetic mutation.

☞ Cataract, due to beta - particles?

On the side of Nagasaki

☞36% of total population dead by year's end.

☞40% of buildings completely destroyed or severly damaged

☞20% of total population outright or shortly after the blast.

Hydrogen Bombs

Hydrogen bombs are another type of nuclear bomb……

Hydrogen Bombs

A hydrogen bomb, or H-bomb, is a type of nuclear weapon that explodes from the intense energy released by nuclear fusion. Hydrogen bombs may also be called thermonuclear weapons. The energy results from the fusion of isotopes of hydrogen: deuterium and tritium.

Hydrogen Bombs

Modern nuclear weapons work slightly differently. Critical mass depends on the density of the material: as the density increases, the critical mass decreases. Instead of colliding two sub-critical pieces of nuclear fuel, modern weapons detonate chemical explosives around a sub-critical sphere (or "pit") of uranium-235 or plutonium-239 metal.

Hydrogen Bombs

The force from the blast is directed inward, compressing the pit and bringing its atoms closer together. Once dense enough to reach the critical mass, neutrons are injected, initiating a fission chain reaction and producing an atomic explosion.

Hydrogen Bombs

In fusion weapons (also called "thermonuclear" or "hydrogen" weapons), the energy from an initial fission explosion is used to "fuse" hydrogen isotopes together. The energy released by the weapon creates a fireball that reaches several tens of million degrees—temperatures in the same range as the center of the sun (which also runs on fusion).

✍Development And Deployment

Hydrogen bombs were developed and deployed thereby making it a momentous step up in the actualisation of the arms race involving nuclear powers. These weapons provided the capability of massive devastation and this quickened the fears of a doomsday in case these weapons were to be used in any combat. Civilian governments' testing and stockpiling of high powered hydrogen bombs made the situation worse during Cold War.

✍Global Security Concerns

☞ Hydrogen and atomic bombs have fared increase the insecurity in the world due to the rise of nuclear weapons. The risks also emerge from accessing by countries with different geopolitical agenda

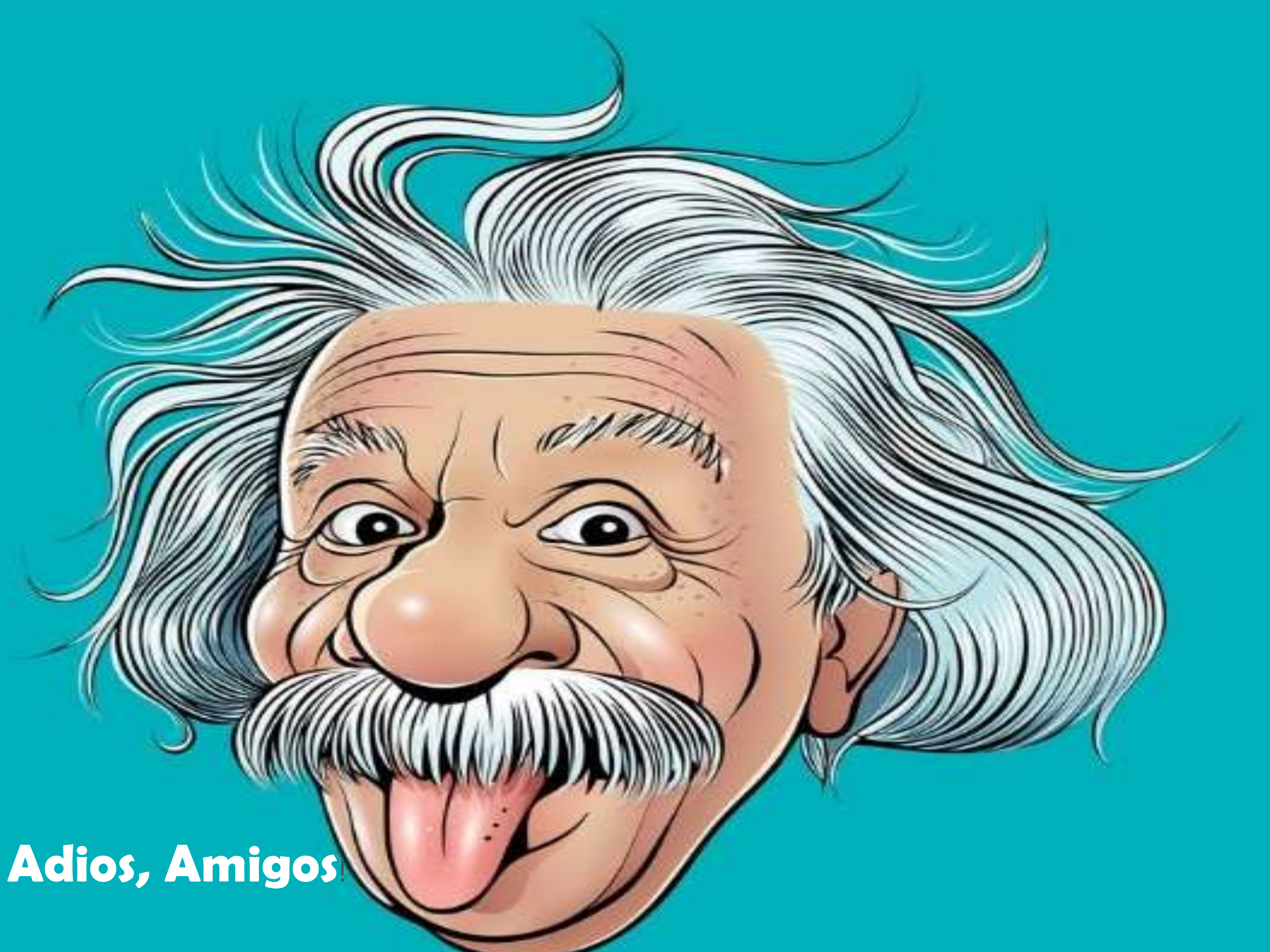
Arms Race Implications

☞ The invention of hydrogen and atomic bombs created a race between major powers to secure the element as it ensures that nations have an edge over their rivals. There are challenges with nuclear-armed states vying for power in various regions thus precipitating conflicts through efforts to develop more advanced and potent nuclear arsenals.

Atomic bomb Vs Hydrogen bomb

Atomic bomb	Hydrogen bomb
✓ It is a fission device relies on the splitting, or fission, of heavy atomic nuclei.	✓ Utilizes both fission and fusion reactions to generate explosions. ✓ It cause a bigger explosion
✓ Less Powerful than H-bomb	✓ Hydrogen bomb has the potential to be 1,000 times more powerful than an atomic bomb,
✓ **Less expensive than H-bomb**	✓ **Expensive**


Thank y'all for listening


Adios, Amigos!