SAINT JOHN BAPTIST DE LA SALLE CATHOLIC SCHOOL.

# Nuclear Reaction and Energy Production

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By group 4,11A

**Submitted to Sir Aaron Girmaye**

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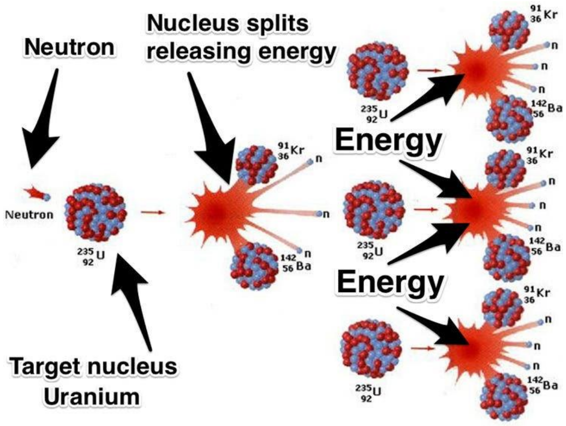
By combined effort of group 4 members and a little bit of assistance from our beloved physics teacher we were able to complete this manuscript that deals with several topics about nuclear energy and its realms. We want to thank everyone who helped us achieve this goal!!




## Nuclear Reaction and Energy Production

**Introduction**:

**What is Nuclear energy?**

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.

Nuclear energy is the 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 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.

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 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.

### What is nuclear fission?

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

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. 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 and electricity consequently.

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. 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.

### What is 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.

**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. 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.**

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. 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.

**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.

## 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. 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.

The heat created by nuclear fission warms the reactor's cooling agent. A cooling agent is usually water, but some nuclear reactors use liquid metal or molten salt. The cooling agent, heated by nuclear fission, produces steam. The steam turns turbines, or wheels turned by a flowing current. The turbines drive generators, or engines that create electricity.

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 nuclear fission. 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.

As of 2011, about 15 percent of the world's electricity is generated by nuclear power plants. The United States has more than 100 reactors, although it creates most of its electricity from fossil fuels and hydroelectric energy. Nations such as Lithuania, France, and Slovakia create almost all of their electricity from nuclear power plants.

The first nuclear reactor to produce electricity was located near Arco, Idaho. The Experimental Breeder Reactor began powering itself in 1951. The first nuclear power plant designed to provide energy to a community was established in Obninsk, Russia, in 1954.

## 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.

## Mining, enrichment and disposal of uranium

**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.

Although some of the uranium the United States uses is mined in this country, most is imported. The U.S. gets uranium from Australia, Canada, Kazakhstan, Russia, and Uzbekistan. Once uranium is mined, it must be extracted from other minerals. It must also be processed before it can be used.

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. The treaty promotes the peaceful use of nuclear fuel, as well as limiting the spread of nuclear weapons.

To make natural uranium more likely to undergo fission, it is necessary to increase the amount of uranium-235 in a given sample through a process called uranium enrichment. Once the uranium is enriched, it can be used effectively as nuclear fuel in power plants for three to five years.

A typical nuclear reactor uses about 200 tons of uranium every year. Complex processes allow some uranium and plutonium to be re-enriched or recycled. This reduces the amount of mining, extracting, and processing that needs to be done.If it is still radioactive and has to be disposed of following stringent guidelines to protect people and the environment. Used fuel, also referred to as spent fuel, can also be recycled into other types of fuel for use as new fuel in special nuclear power plants.

## Nuclear Power Plants: Design, Operation, and Challenges

As tried to explain in the above paragraph nuclear power plants are complex facilities designed to harness nuclear reactions for electricity generation.

**Design and Components**:

- Nuclear power plants consist of several key components, including the reactor core, control rods, coolant systems, and turbines.
- The reactor core contains fuel rods (usually enriched uranium) where nuclear fission occurs.
- Control rods regulate the reaction by absorbing neutrons.
- Coolant (often water) circulates to transfer heat from the reactor core to steam generators.

2. **Operation and Maintenance**:

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

**Research Reactors: Advancing Science and Innovation**

Research reactors serve scientific and experimental purposes:

1. **Facilities and Capabilities**:

- Research reactors are smaller than power reactors and operate at lower power levels.
- They facilitate neutron-based experiments, isotope production, and materials testing.

- Universities, laboratories, and medical institutions use research reactors for various studies.

2. **Experimental Uses**:
   - Neutron scattering experiments help study materials at the atomic level.
   - Isotope production supports medical imaging, cancer treatment, and industrial applications.
   - Research reactors contribute to understanding nuclear physics and radiation effects.

## 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. They can be situated in both urban and rural locations without significantly altering the surrounding environment.The steam that drives the turbines and generators is eventually recycled. It is cooled down in a cooling tower, where it condenses back into water and can be reused to generate more electricity. Any excess steam is released into the atmosphere as harmless water vapor.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.

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. Such waste remains radioactive for thousands of years. Government regulations ensure these materials are disposed of safely to prevent contamination. Used fuel and rods of nuclear poison are extremely radioactive. The used uranium pellets must be stored in special containers that look like large swimming pools. Water cools the fuel and insulates the outside from contact with the radioactivity. Some nuclear plants store their used fuel in dry storage tanks above ground.

The storage sites for radioactive waste have become very controversial in the United States. For years, the government planned to construct an enormous nuclear waste facility near Yucca Mountain, Nevada, for instance. Environmental groups and local citizens protested the plan. They worried about radioactive waste leaking into the water supply and the Yucca Mountain environment, about 130 kilometers (80 miles) from the large urban area of Las Vegas, Nevada. Although the government began investigating the site in 1978, it stopped planning for a nuclear waste facility in Yucca Mountain in 2009.

**Storage and Disposal Challenges:**

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

This is what happened in Chernobyl, Ukraine, in 1986. 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.

The environmental impact of the Chernobyl disaster was immediate. 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.

The storage and disposal of radioactive waste are complex and multifaceted challenges that require careful planning, robust technology, and long-term commitment. Inorder to prevent such incidents like **Chernobyl** Addressing these challenges is crucial for the sustainable and safe use of nuclear energy, ensuring that the benefits of nuclear power do not come at the expense of future generations.

**Comparison Summary** of the topics so far.

| 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

- **What are atomic bombs?**
- **How does they work?**
- **Historical development and impacts.**

### ✍What Are Atomic Bombs?

☞Atomic bomb, or A-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. For this reason, this type of bomb is also known as a fission bomb. The word “atomic” isn't strictly accurate since it's just the nucleus of the atom that is involved in fission (its protons and neutrons), rather than the entire atom or its electrons.

### ✍How Does It Work?

☞ All nuclear weapons use fission to generate an explosion. “Little Boy”—the first nuclear weapon ever used during wartime—worked by shooting a hollow uranium-235 cylinder at a target “plug” of the same material.

**Nuclear fuel**

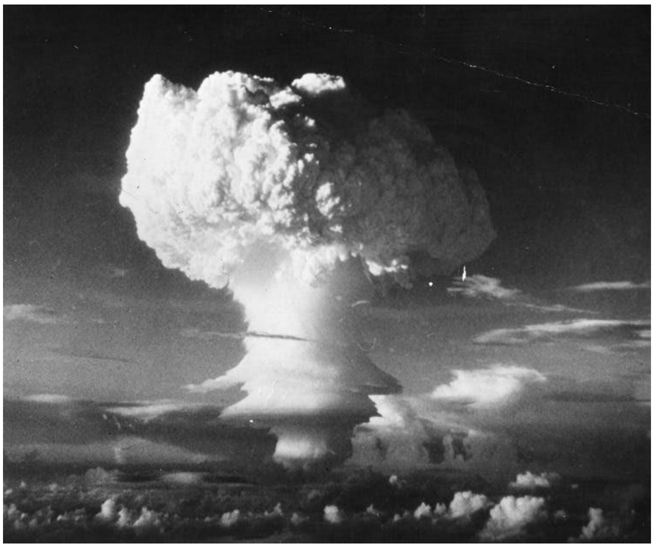
Only certain isotopes of certain elements can undergo fission (an isotope is a variation of the same element with different numbers of neutrons in the nucleus). Plutonium-239 and uranium-235 are the most common isotopes used in nuclear weapons.

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 & Impact

☞On 6 and 9 August 1945, the United States detonated two atomic bombs over the Japanese cities of Hiroshima and Nagasaki. The bombings killed between 129,000 and 226,000 people, most of whom were civilians, and remain the only use of nuclear weapons in an armed conflict. Japan surrendered to the Allies on 15 August, six days after the bombing of Nagasaki and the Soviet Union's declaration of war against Japan and invasion of Japanese-occupied Manchuria. The Japanese government signed the instrument of surrender on 2 September, effectively ending the war.

## Hydrogen bombs



- **What are HYDROGEN BOMBS?**
- **How does they work?**
- **Development and Deployment.**
- **Global security concerns.**
- **Non-proliferation efforts.**

## ✍What Are 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.

## ✍How Does It Works?

☞ 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. 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.
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).

The explosions used in thermonuclear weapons are often described as a **primary** (the chemical and fission explosions) and **secondary** (the subsequent fusion blast). However, the actual mechanisms are considerably more complicated.

## ✍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, as well as by non-state actors and, thus, nuclear terrorism or an accidental use of these weapons may occur. Just as the risks of a world nuclear war are real today, this emphasizes the need to continue international processes of disarmament and non-proliferation.

## ✍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. It has also been noted that arms race has also led to drain of resources from development of social welfare as well as economic infrastructures thereby widening the inequalities in the international community.

## ✍Non-Proliferation Efforts

☞ Measures to contain the use of nuclear weapons have been in practice since the period that synthesized Nuclear Age. For instance, the Treaty on the Non-Proliferation of Nuclear Weapons many years has attempted to put a halt of spread in nuclear weapons and call for their elimination among the countries that possess them. However, certain difficulties can be observed in fulfilling compliance requirements with the modern innovative approach to work.

# Atomic bomb Vs Hydrogen bomb

Both bombs are extremely lethal and have the power to kill people within seconds, as well as hours later due to radiation. Blasts from both bombs would also instantly burn wood structures to the ground, topple big buildings and render roads unusable.

“With the [atomic] bomb we dropped in Nagasaki, it killed everybody within a mile radius,” Morse told that, adding that a hydrogen bomb’s reach would be closer to 5 or 10 miles. “In other words, you kill more people,” he said.

Hall, director of the University of Tennessee’s Institute for Nuclear Security, called the hydrogen bomb a “city killer” that would probably annihilate between 100 and 1,000 times more people than an atomic bomb.

“It will basically wipe out any of modern cities,” Hall said. “A regular atomic bomb would still be devastating, but it would not do nearly as much damage as an H-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.<br>✓ 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** |

## Future of Nuclear Energy

Nuclear reactors use fission, or the splitting of atoms, to produce energy. Nuclear energy can also be produced through fusion, or joining (fusing) atoms together. The sun, for instance, is constantly undergoing nuclear fusion as hydrogen atoms fuse to form helium. Because all life on our planet depends on the sun, you could say that nuclear fusion makes life on Earth possible.

Nuclear power plants do not have the capability to safely and reliably produce energy from nuclear fusion. It's not clear whether the process will ever be an option for producing electricity. Nuclear engineers are researching nuclear fusion, however, because the process will likely be safe and cost-effective.

FAST FACT

**Nuclear Tectonics**

The decay of uranium deep inside the Earth is responsible for most of the planet's geothermal energy, causing plate tectonics and continental drift.

FAST FACT

**Three Mile Island**

The worst nuclear accident in the United States happened at the Three Mile Island facility near Harrisburg, Pennsylvania, in 1979. The cooling system in one of the two reactors malfunctioned, leading to an emission of radioactive fallout. No deaths or injuries were directly linked to the accident.

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