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Nuclear fission and fusion pdf

All of the energy we produce comes from basic chemical and physical processes. That’s mostly been accomplished throughout history by burning carbon-based material like wood, coal and gas—or by harnessing power from the sun, wind, and water. Fission and fusion are two physical processes that produce massive amounts of energy from atoms. They yield millions of times more energy than other sources through nuclear reactions. You can check out the difference between the two in this video below. Video courtesy of the Department of Energy Fission occurs when a neutron slams into a larger atom, forcing it to excite and spilt into two smaller atoms—also known as fission products. Additional neutrons are also released that can initiate a chain reaction. When each atom splits, a tremendous amount of energy is released. Uranium and plutonium are most commonly used for fission reactions in nuclear power reactors because they are easy to initiate and control. The energy released by fission in these reactors heats water into steam. The steam is used to spin a turbine to produce carbon-free electricity. Fusion occurs when two atoms slam together to form a heavier atom, like when two hydrogen atoms fuse to form one helium atom. This is the same process that powers the sun and creates huge amounts of energy—several times greater than fission. It also doesn’t produce highly radioactive fission products. Fusion reactions are being studied by scientists, but are difficult to sustain for long periods of time because of the tremendous amount of pressure and temperature needed to join the nuclei together. Fusion of deuterium with tritium creating helium-4, freeing a neutron, and releasing 17.59 MeV of energy. Nuclear fusion is the reaction in which two or more nuclei combine, forming a new element with a 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 isotopes of hydrogen. 2 1Deuterium + 3 1Tritium = 42He + 10n + 17.6 MeV [Image:Fission-Reaction.svg|thumb|none|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 + 3n + 177 MeV Fission vs. Fusion Physics Atoms are held together by two of the four fundamental forces of nature: the weak and strong nuclear bonds. The total amount of energy held within the bonds of atoms is called binding energy. The more binding energy held within the bonds, the more stable the atom. Moreover, atoms try to become more stable by increasing their binding energy. The nucleon of an iron atom is the most stable nucleon found in nature, and it neither fuses nor splits. This is why iron is at the top of the binding energy curve. For atomic nuclei lighter than iron and nickel, energy can be extracted by combining iron and nickel 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. The notion of splitting the atom arose from New Zealand-born British physicist Ernest Rutherford's work, which also led to the discovery of the proton. Conditions for Fission and Fusion Fission can only occur in large isotopes that contain more neutrons than protons in their nuclei, which leads to a slightly stable environment. Although scientists don't yet fully understand why this instability is so helpful for fission, the general theory is that the large number of protons create a strong repulsive force between them and that too few or too many neutrons create "gaps" that cause weakening of the nuclear bond, leading to decay (radiation). These large nucleii with more "gaps" can be "split" by the impact of thermal neutrons, so called "slow" neutrons. Conditions must be right for a fission reaction to occur. For fission to be self-sustaining, the substance must reach critical mass, the minimum amount of mass required; falling short of critical mass limits reaction length to mere microseconds. If critical mass is reached too quickly, meaning too many neutrons are released in nanoseconds, the reaction becomes purely explosive, and no powerful release of energy will occur. Nuclear reactors are mostly controlled fission systems that use magnetic fields to contain stray neutrons; this creates a roughly 1:1 ratio of neutron release, meaning one neutron emerges from the impact of one neutron. As this number will vary in mathematical proportions, under what is known as Gaussian distribution, the magnetic field must be maintained for the reactor to function, and control rods must be used to slow down or speed up neutron activity. Fusion happens when two lighter elements are forced together by enormous energy (pressure and heat) until they fuse into another isotope and release energy. The energy needed to start a fusion reaction is so large that it takes an atomic explosion to produce this reaction. Still, once fusion begins, it can theoretically continue to produce energy as long as it is controlled and the basic fusing isotopes are supplied. The most common form of fusion, which occurs in stars, is called "D-T fusion," referring to two hydrogen isotopes: deuterium and tritium. Deuterium has 2 neutrons and tritium has 3, more than the one proton of hydrogen. This makes the fusion process easier as only the charge between two protons needs to be overcome, because fusing the neutrons and the proton requires overcoming the natural repellent force of like-charged particles (protons have a positive charge, compared to neutrons' lack of charge) and a temperature — for an instant — of close to 81 million degrees Fahrenheit for D-T fusion (45 million Kelvin or slightly less in Celsius). For comparison, the sun's core temperature is roughly 27 million F (15 million C).[1] Once this temperature is reached, the resulting fusion has to be contained long enough to generate plasma, one of the four states of matter. The result of such containment is a release of energy from the D-T reaction, producing helium (a noble gas, inert to every reaction) and spare neutrons than can "seed" hydrogen for more fusion reactions. At present, there are no secure ways to induce the initial fusion temperature or contain the fusing reaction to achieve a steady plasma state, but efforts are ongoing. A third type of reactor is called a breeder reactor. It works by using fission to create plutonium that can seed or serve as fuel for other reactors. Breeder reactors are used extensively in France, but are prohibitively expensive and require significant security measures, as the output of these reactors can be used for making nuclear weapons as well. Chain Reaction Fission and fusion nuclear reactions are chain reactions, meaning that one nuclear event causes at least one other nuclear reaction, and typically more. The result is an increasing cycle of reactions that can quickly become uncontrolled. This type of nuclear reaction can be multiple splits of heavy isotopes (e.g. 235 U) or the merging of light isotopes (e.g. 2H and 3H). Fission chain reactions happen when neutrons bombard unstable isotopes. This type of "impact and scatter" process is difficult to control, but the initial conditions are relatively simple to achieve. A fusion chain reaction develops only under extreme pressure and temperature conditions that remain stable by the energy released in the fusion process. Both the initial conditions and stabilizing fields are very difficult to carry out with current technology. Energy Ratios Fusion reactions release 3-4 times more energy than fission reactions. Although there are no Earth-based fusion systems, the sun's output is typical of fusion energy production in that it constantly converts hydrogen isotopes into helium, emitting spectra of light and heat. Fission generates its energy by breaking down one nuclear force (the strong one) and releasing tremendous amounts of heat than are used to heat water (in a reactor) to then generate energy (electricity). Fusion overcomes 2 nuclear forces (strong and weak), and the energy released can be used directly to power a generator; so not only is more energy released, it can also be harnessed for more direct application. Nuclear Energy Use The first experimental nuclear reactor for energy production began operating in Chalk River, Ontario, in 1947. The first nuclear energy facility in the U.S., the Experimental Breeder Reactor-1, was launched shortly thereafter, in 1951; it could light 4 bulbs. Three years later, in 1954, the U.S. launched its first nuclear submarine, the U.S.S. Nautilus, while the U.S.S.R. launched the world's first nuclear reactor for large-scale power generation, in Obninsk. The U.S. inaugurated its nuclear power production facility a year later, lighting up Arco, Idaho (pop. 1,000). The first commercial facility for energy production using nuclear reactors was the Calder Hall Plant, in Windscale (now Sellafield), Great Britain. It was also the site of the first nuclear-related accident in 1957, when a fire broke out due to radiation leaks. The first large-scale U.S. nuclear plant opened in Shippingport, Pennsylvania, in 1957. Between 1956 and 1973, nearly 40 power production nuclear reactors were launched in the U.S., the largest being Unit One of the Zion Nuclear Power Station in Illinois, with a capacity of 1,155 megawatts. No other reactors ordered since have come online, though others were launched after 1973. The French launched their first nuclear reactor, the Phénix, capable of producing 250 megawatts of power, in 1973. The most powerful energy-producing reactor in the U.S. (1,315 MW) opened in 1976, at Trojan Power Plant in Oregon. By 1977, the U.S. had 63 nuclear plants in operation, providing 3% of the nation's energy needs. Another 70 were scheduled to come online by 1990. Unit Two at Three Mile Island suffered a partial meltdown, releasing inert gases (xenon and krypton) into the environment. The anti-nuclear movement gained strength from the fears the incident caused. Fears were fueled even more in 1986, when Unit 4 at the Chernobyl plant in Ukraine suffered a runaway nuclear reaction that exploded the facility, spreading radioactive material throughout the area and a large part of Europe. During the 1990s, Germany and especially France expanded their nuclear plants, focusing on smaller and thus more controllable reactors. China launched its first 2 nuclear facilities in 2007, producing a total of 1,866 MW. Although nuclear energy ranks third behind coal and hydropower in global wattage produced, the push to close nuclear plants, coupled with the increasing costs to build and operate such facilities, has created a pull-back on the use of nuclear energy for power. France leads the world in percentage of electricity produced by nuclear reactors, but in Germany, solar has overtaken nuclear as an energy producer. The U.S. still has over 60 nuclear facilities in operation, but ballot initiatives and reactor ages have closed plants in Oregon and Washington, while dozens more are targeted by protesters and environmental protection groups. At present, only China appears to be expanding its number of nuclear plants, as it seeks to reduce its heavy dependence on coal (the major factor in its extremely high pollution rate) and seek an alternative to importing oil. Concerns The fear of nuclear energy comes from its extremes, as both a weapon and power source. Fission from a reactor creates waste material that is inherently dangerous (see more below) and could be suitable for dirty bombs. Though several countries, such as Germany and France, have excellent track records with their nuclear facilities, other less positive examples, such as those seen in Three Mile Island, Chernobyl, and Fukushima, have made many reluctant to accept nuclear energy, even though it is much safer than fossil fuel. Fusion reactors could one day be the affordable, plentiful energy source that is needed, but only if the extreme conditions needed for creating fusion and managing it can be solved. Nuclear Waste The byproduct of fission is radioactive waste that takes thousands of years to lose its dangerous levels of radiation. This means that nuclear fission reactors must also have safeguards for this waste and its transport to uninhabited storage or dump sites. For more information on this, read about the management of radioactive waste. Natural Occurrence In nature, fusion occurs in stars, such as the sun. On Earth, nuclear fusion was first achieved in the creation of the hydrogen bomb. Fusion has also been used in different experimental devices, often with the hope of producing energy in a controlled fashion. On the other hand, fission is a nuclear process that does not normally occur in nature, as it requires a large mass and an incident neutron. Even so, there have been examples of nuclear fission in natural reactors. This was discovered in 1972 when uranium deposits from an Oklo, Gabon, mine were found to have once sustained a natural fission reaction some 2 billion years ago. Effects In brief, if a fission reaction gets out of control, either it explodes or the reactor generating it melts down into a large pile of radioactive slag. Such explosions or meltdowns release tons of radioactive particles into the air and any neighboring surface (land or water), contaminating it every minute the reaction continues. In contrast, a fusion reaction that loses control (becomes unbalanced) slows down and drops temperature until it stops. This is what happens to stars as they burn their hydrogen into helium and lose these elements over thousands of centuries of expulsion. Fusion produces little radioactive waste. If there is any damage, it will happen to the immediate surroundings of the fusion reactor and little else. It is far safer to use fusion to produce power, but fission is used because it takes less energy to split two atoms than it does to fuse two atoms. Also, the technical challenges involved in controlling fusion reactions have not been overcome yet. Use of Nuclear Weapons All nuclear weapons require a nuclear fission reaction to work, but "pure" fission bombs, those that use a fission reaction alone, are known as atomic, or atom, bombs. Atom bombs were first tested in New Mexico in 1945, during the height of World War II. In the same year, the United States used them as a weapon in Hiroshima and Nagasaki, Japan. Since the atom bomb, most of the nuclear weapons that have been proposed and/or engineered have enhanced fission reaction(s) in one way or another (e.g., see boosted fission weapon, radiological bombs, and neutron bombs). Thermonuclear weaponry — a weapon that uses both fission and hydrogen-based fusion — is one of the better-known weapon advancements. Though the notion of a thermonuclear weapon was proposed as early as 1941, it was not until the early 1950s that the hydrogen bomb (H-bomb) was first tested. Unlike atom bombs, hydrogen bombs have not been used in warfare, only tested (e.g., see Tsar Bomba). To date, no nuclear weapon makes use of nuclear fusion alone, though governmental defense programs have put considerable research into such a possibility. Cost Fission is a powerful form of energy production, but it comes with built-in inefficiencies. The nuclear fuel, usually Uranium-235, is expensive to mine and purify. The fission reaction creates heat that is used to boil water for steam to turn a turbine that generates electricity. This transformation from heat energy to electrical energy is cumbersome and expensive. A third source of inefficiency is that clean-up and storage of nuclear waste is very expensive. Waste is radioactive, requiring proper disposal, and security must be tight to ensure public safety. 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 an enormous amount of energy to initiate fusion (atom bombs and lasers are thought to provide that "spark"), but there's also the need to properly contain the plasma field for long-term energy production. Researchers are still trying to overcome these challenges because fusion a safer and more powerful energy production system than fission, meaning it would ultimately cost less than fission. References Share this comparison: If you read this far, you should follow us: "Nuclear Fission and Fusion." Diffen.com. Diffen LLC, n.d. Web. 10 Jun 2021. < >