Figure 1. A neutron strikes a 235U nucleus and causes a fission event. This releases more neutrons. Unlike in the figure, on average one new fission event happens as a result of these released neutrons. A nuclear chain reaction occurs when the output of one nuclear reaction causes more nuclear reactions to occur. These chain reactions are almost always a series of fission events, which give off excess neutrons. It is these excess neutrons that can go on to cause more fission events to occur, hence the name chain reaction. Nuclear chain reactions are essential to the operation of nuclear power plants. Chemical reactions involve different chemical species recombining. Nuclear reactions involve different flavours of nuclei (called nuclear species) interacting. Many chemical reactions are also chain reactions, with many similarities to nuclear chain reactions. These similarities include: That the reactions are sustained when chemical or nuclear species available to react. The chain reaction stops when the species are removed or are used up. That the chain reactions are controlled (starting, speeding up, slowing down and stopping) by adding or removing chemical or nuclear species in that chain. Energy is often released as the reactions occur. Released energy is often output as thermal energy, becoming heat that can be harnessed by heat engines to do useful work like make electricity. While these similarities exist, there are some important differences as well. Nuclear reactions release roughly one million times as much energy as chemical reactions. This means that chemical chain reactions occur much more easily than nuclear reactions. For example, fire is a chemical chain reaction. Nuclear chain reactions require careful engineering and as far as we know, a natural nuclear chain reaction has only occurred once.[1] Nuclear chain reactions require an abundance of careful planning. When they do occur, there is substantially more energy available, leading to nuclear having a much higher energy density for its fuel. In order to sustain a nuclear chain reaction, every fission event must lead to exactly one more fission event. The most convenient nuclear species to use for nuclear chain reactions is a fissile isotope of uranium, 235U. When 235U undergoes fission, it gives off, on average, ~2.5 neutrons per fission event. Careful engineering must go into having those neutrons go on to create more fission events. Contrary to what one may expect, difficulties arise in getting enough neutrons to go on and make a sustained nuclear reaction, rather than having too many nuclear reactions. If every fission event leads to exactly one more fission event, the nuclear chain reaction is said to be critical. Figure 2 shows a simplification of the fission chain reaction. Figure 2. A nuclear fission chain reaction of uranium-235 atoms.[2] In a real nuclear reactor, most of the released neutrons are lost, rather than leading to another fission event. The video below has a member of the Energy Education team explaining nuclear chain reactions: For Further Reading References This simulation is intended to understand the principle of fission, and the proportions of the model presented may not match the reality. The nucleus was exaggerated and drawed large. The electrons around the nucleus were not shown. When neutrons split a uranium nucleus, it gives off 2×108eV of energy. Compared to one TNT molecule producing 30 eV of energy, it is a huge amount (about 6.66 million times difference). After fission, the mass of the fission byproduct plus the neutron's mass is less than the original mass of uranium. Mass before division > Mass after division The mass decreases slightly but produces a lot of energy by Einstein's famous formula E=mc2. The energy from nuclear fission comes as the kinetic energy of the fission byproduct. And part of it is used to generate neutrons, and the remaining part comes out as gamma rays (r -ray). Scientists were shocked by this fission. This is because nuclear fission not only produces tremendous energy but also generates neutrons. Usually, when one neutron causes nuclear fission, there are about two to three neutrons emitted. If a newly released neutron causes fission in another nucleus, it can produce 8 to 27 neutrons again, causing a nuclear chain reaction. Does nuclear fission often occur in nature? Nuclear fission does not occur in nature. In fact, the chain reaction is only possible with the rare isotope of uranium, 235U, because only 0.7% of the uranium metal is present. 238U, which makes up most uranium metal, absorbs neutrons. Therefore, the chain reaction becomes impossible. Critical mass If the fission reaction occurs in a small mass, the chain reaction cannot continue because many neutrons escape through the surface. This is because small objects have a large surface area compared to their volume. There is a minimum size of a substance that can cause a chain reaction, which is called the 'critical size,' and the mass is called the 'critical mass.' Atomic bombs were created using rapid fission. Masses smaller than the critical mass do not explode. Multiple chunks of 235U are suddenly merged to detonate a bomb. Then, the total mass becomes more than the critical mass, so it explodes rapidly.(Chemistry-The Central Science) Nuclear power plants are places that allow nuclear fission to occur slowly. For fission to occur, a nucleus must first absorb one neutronThe nucleus splits into two smaller nuclei (called daughter nuclei) of roughly equal size as well as two or three neutrons which move away at high speedEach of these new neutrons can start another fission reaction, which again creates further excess neutronsThis process is called a chain reactionThe neutrons released by each fission reaction can go on to create further fissions, like a chain that is linked several times – from each chain comes two moreIn a nuclear reactor, a chain reaction is required to keep the reactor runningThe kinetic energy of the fission products is transferred to water, causing it to boilThe steam from this is used to generate electricityFor the reactor to work safely in a stable state, the number of free neutrons in the reactor needs to be kept constantThis means some neutrons must be removed from the reactorTo do this, nuclear reactors contain control rodsThe overall purpose of the reactor is to transfer the energy released from nuclear reactionsControl rods are made of a material, such as boron, which can absorb neutrons without becoming dangerously unstable The number of neutrons absorbed is controlled by varying the depth of the control rods in the fuel rodsLowering the rods further decreases the rate of fission, as more neutrons are absorbedRaising the rods increases the rate of fission, as fewer neutrons are absorbedThis is adjusted automatically so that, on average, only one neutron produced by each fission event goes on to cause another fission eventIn the event the nuclear reactor needs to shut down, the control rods can be lowered all the way to absorb all of the neutrons so no further reactions can take placeBecause each new fission reaction transfers energy, uncontrolled chain reactions can be dangerousThe number of neutrons available increases quickly, so the number of reactions does tooA nuclear weapon uses an uncontrolled chain reaction to release a huge amount of energy in a short period of time as an explosionThe diagram shows the nuclear fission process for an atom of uranium-235.Complete the diagram to show how the fission process starts a chain reaction.Answer:Step 1: Draw the neutrons to show that they hit other U-235 nucleiIt is the neutrons hitting the uranium-235 nuclei which causes the fission reactionsThe daughter nuclei do not need to be shown, only the neutrons and uranium-235 nucleiStep 2: Draw the splitting of the U-235 nuclei to show they produce two or more neutronsThe number of neutrons increases with each fission reactionEach reaction requires one neutron but releases twoMore reactions happen as the number of neutrons increasesYou need to be able to draw and interpret diagrams of nuclear fission and chain reactions. Generally, things move to the right as time goes on in these diagrams, but it is important to read all the information carefully on questions like this. If you have to draw a diagram in an exam remember that the clarity of the information is important, not how pretty it looks!Did this page help you?