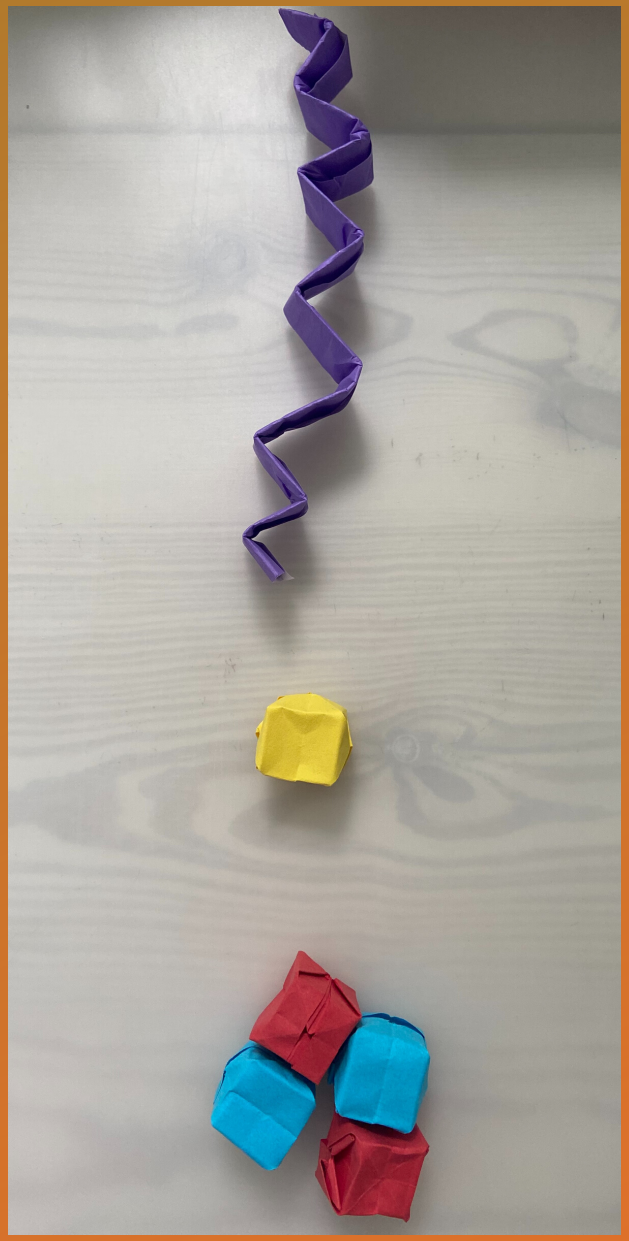
Radioactivity



Liam Teel

Introduction

Radioactivity. What does it mean? Is it good, or is it bad? Exploding bombs, creating power, and so much more - what exactly is it? At the beginning of my sixth grade school year, I had no idea what I was going to study. Towards the middle, when we were thinking about our topics, I came across a book that was all about chemistry and what it is. I got hooked on it. My favorite section of all was the part about radioactivity. I found it so fascinating, how such tiny specks of matter could do such big things. A little later in the year, when we were actually picking our topics, I was convinced that Chemistry had to be mine. Unfortunately, I could not think of a reason why studying Chemistry would be related to sustainability and what my goal would be when I understood it. So in the end, I settled on radioactivity. Radioactivity overlaps with the theme of sustainability because it can destroy the environment, but it can also create great things that can benefit the world. And I don't regret anything.



This Book

This paper is all about radioactivity and what it is. How is it bad and how is it good? But before I tell you about radioactivity, I'm going to have to talk about an atom.

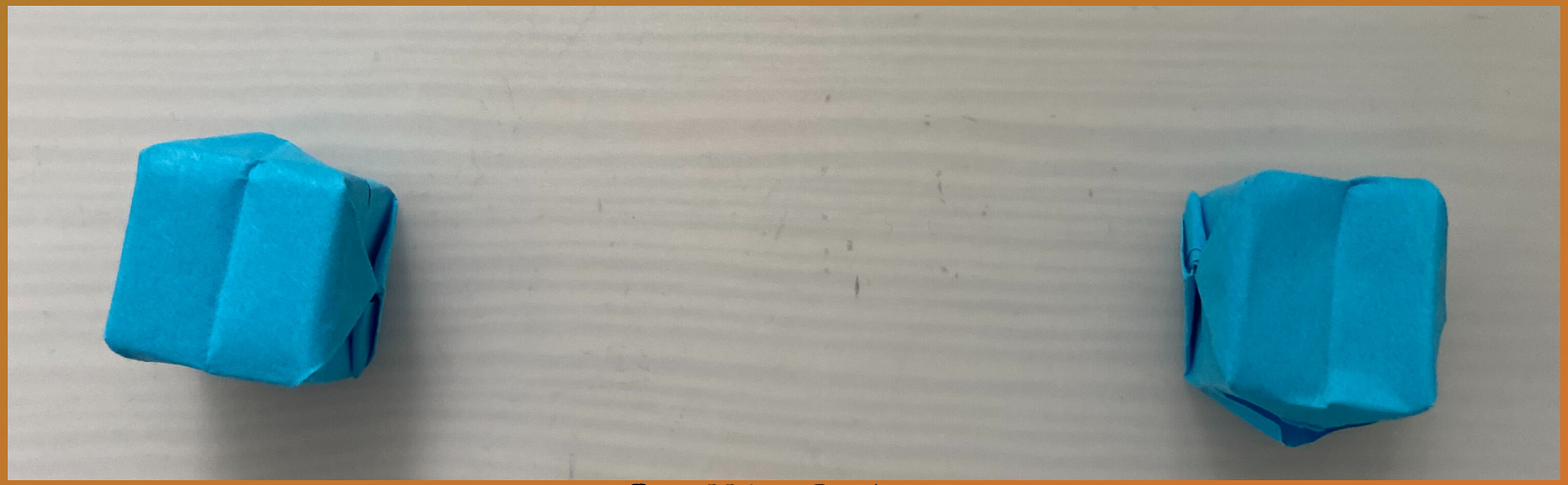
The Atom

An atom makes up everything on the planet - under our feet, these words, and even us. Can you imagine that we are a trillion different tiny little things? Fascinating. But why are the atoms staying together to hold us up? Are they packed up super tightly? No, they would fall apart, and we would disappear. The answer is an invisible force called electromagnetism. This force is critical, as without it, we would sink into the ground, never to be seen again. It is a mixture of magnetism and electricity. The “rule” that electromagnetism follows is that atoms with like charges repel each other, while atoms with opposite charges attract, like a normal magnet that you could find at your home. But why do the atoms have electrical charges? We need to go into the atom.

Inside the atom are even smaller particles inside the tiny atoms, which are called subatomic particles. These particles are usually charged electrically. Where are some of the charged particles? There are different parts of the atom; one of them, the nucleus, is located in the middle of an atom. The nucleus contains two kinds of particles, protons and neutrons. Protons are positively charged, and neutrons have a neutral charge, or no charge, hence their name. Neutrons are bigger than protons. These particles in the nucleus - protons and neutrons - are called nucleons.

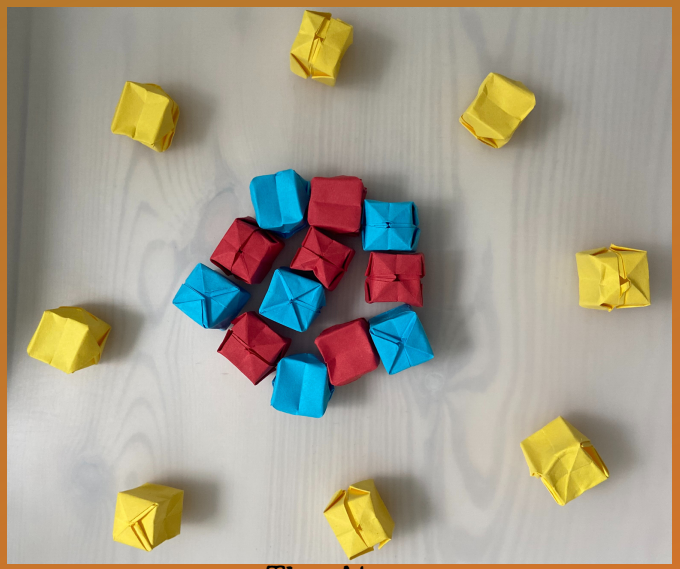


The Nucleus



Repelling Protons

Inside the nucleus there is almost always more than one proton (except in a hydrogen atom). These protons repel each other because they have the same charge. Neutrons help a little to balance the particles in the nucleus, but you still need another force to keep the nucleons together and to stop protons from flying off into infinity. And luckily, there is something that can do that. It is called the strong nuclear force, a super strong force that is stronger than electromagnetism such that the nucleus can be happily comfortable and stable.



The Atom

At this point, we have only discussed positive and neutral charges. The neutral charge cancels itself out and you are left with a positively charged atom. Are all atoms positively charged? What about electrons? Electrons are negatively charged particles that hang out outside the nucleus and are orbiting it freely. If the electron's negative charge is balanced with the proton's positive charge, you get a neutral charge. Usually an atom is neutrally charged, which allows it to hang out with other atoms.

But why do these tiny atoms kill?

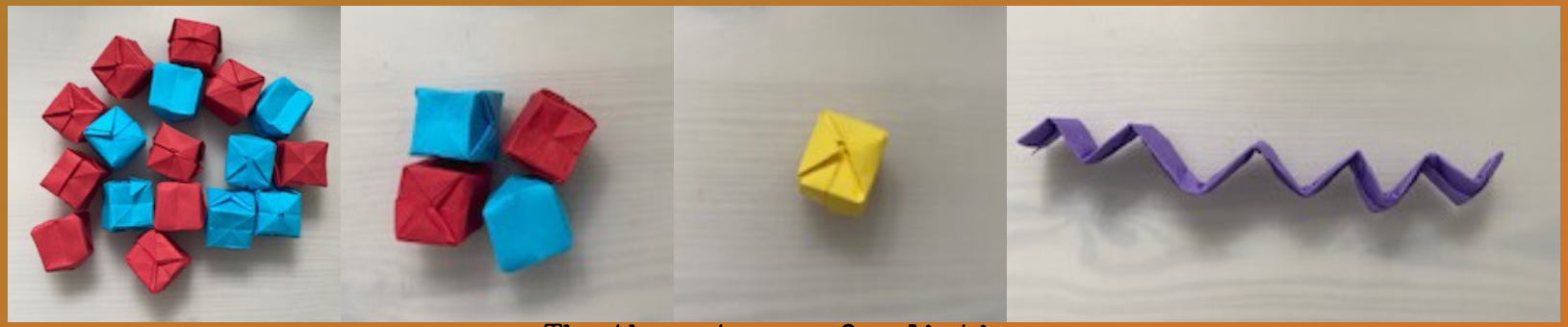
They kill?

You bet. That's what radioactivity is.



A broken down atom

Radioactivity is when an atom wants to break down because it is too heavy, meaning it has too many protons or neutrons in the nucleus, having naturally formed that way; the strong nuclear force cannot keep it together for long. When this atom breaks down, it creates more atoms which have different numbers of particles in them. They also emit electromagnetic waves and subatomic particles.



The three types of radiation

Usually there are three types of radiation: Alpha, Beta, and Gamma. They are named after the first three letters in the Greek alphabet. Alpha radiation, the biggest form of radiation, has two neutrons and two protons. An atom releases this type of radiation until it takes a stable form that isn't radioactive. Beta radiation is much smaller and lighter, which is an electron or a positively charged positron. This happens when another force called the weak nuclear force changes a neutron into a proton to try to make an atom more stable, or as a positron when a proton changes into a neutron. This form of making the atom more stable can also release other types of radiation. Gamma rays are photons, particles that act as waves that travel at the speed of light. All of these forms of radiation are harmful to your body and can give you cancer or radiation sickness by destroying cells it passes by.



An isotope

An atom can have different forms called isotopes. Different isotopes have different numbers of neutrons. Sometimes isotopes are stable, but some are radioactive. These isotopes are called radioisotopes. For example, Cesium-137, with 55 protons and 82 neutrons, is radioactive. The amount of time that it takes for half of the nucleons to radioactively decay is called the half-life. For example, some isotopes of plutonium have a half-life of 20,000 years.

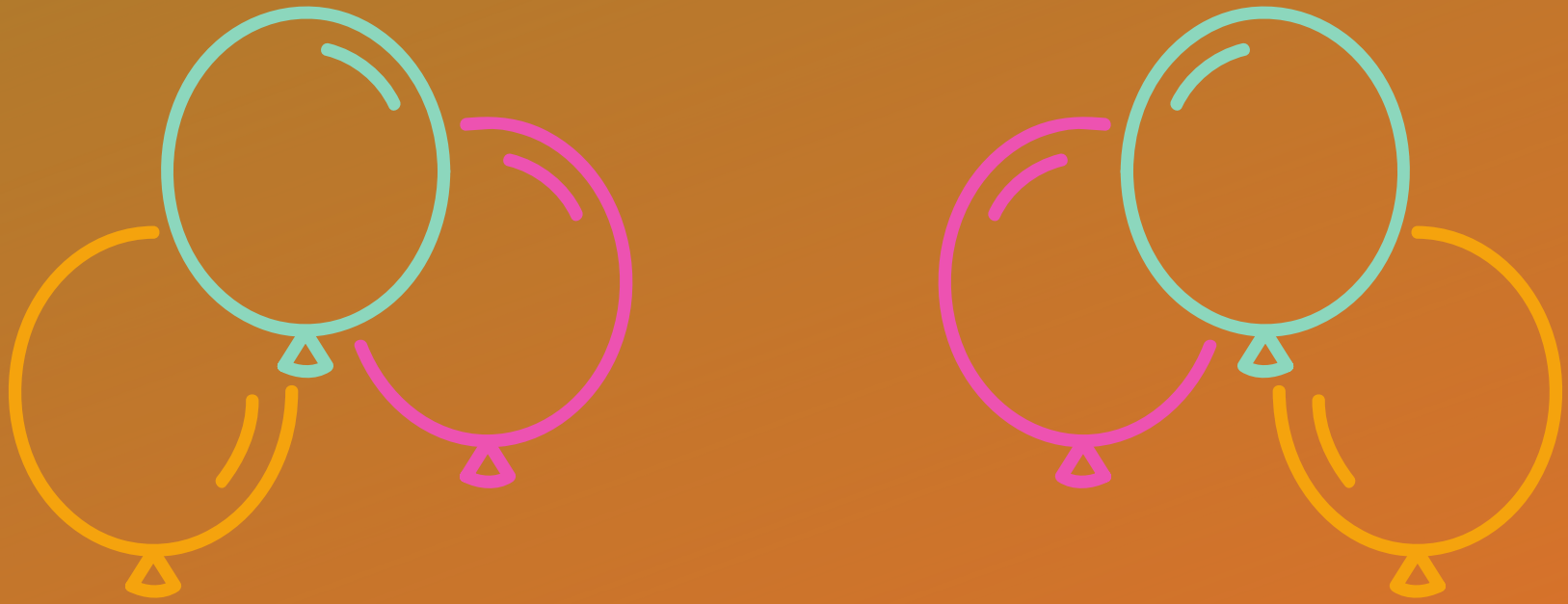
The Nuclear Bomb

As you can see, radioactivity is very dangerous and just a little dose of it may kill many people. But can we use it in some way? Otto Hahn and Lise Meitner, two successful chemists, were working in a lab one day in 1939. And in that lab, an amazing discovery happened. When they were working with Uranium-235, they set it down on a table next to another radioactive element. When it was placed beside the other element, the uranium atoms were split in half, releasing lots of energy. They studied this more thoroughly and found out what was actually happening. The radioactive particles of the decaying element interfered with the nucleus and caused it to break in two, and in the process allowed all that strong force holding the nucleus together fly everywhere. It was so powerful, scientists knew it could cause an explosion if not used carefully. They named this process fission.

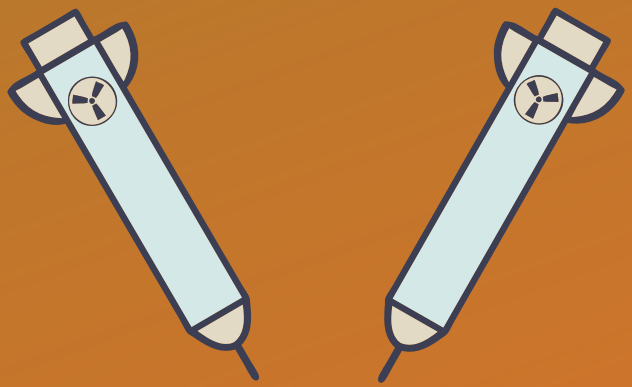


It was the middle of World War II and the Nazis were busy taking over Europe. They seemed invincible, and no one knew how to defeat them. Luckily, this uranium-splitting phenomenon had just been discovered and many scientists had an idea. They were going to create a bomb.

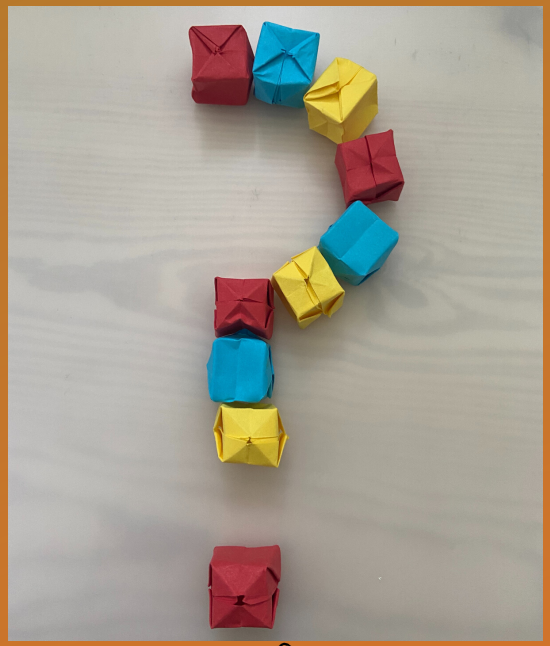
A team of chemists, assembled at Los Alamos, New Mexico, was designing the bomb to drop on the Nazis. This plan was called the Manhattan Project. But as they got deeper into their work, they figured something out: this bomb was going to be incredibly hard to create and it would take a long time, which was inconvenient because the Nazis had allied with Japan. And yet, as they were building it, more bad news kept coming. The Nazis were also building a bomb. The Los Alamos scientists had to work quickly and carefully. The only form of uranium that would undergo fission was U-235, which was rare. They had to make mills, sort of like a windmill, to separate the uranium into U-235 and U-238, the much more common isotope which would not fission. They found out that a new element that they had artificially made, plutonium, could also undergo fission, but would not make as big of an explosion, even though it fissioned faster than the uranium. For the first bomb, they used uranium.



A couple of months later, a bomb had been successfully made, and the scientists were all very proud of the outcome. But there was one more thing: they didn't actually know if it would work. They had to run a test. They tested this bomb near Alamogordo, New Mexico, on July 16, 1945. It exploded with a boom, and all the Manhattan Project employees celebrated.



The team of scientists had to make another and use it on the cities of Nazi allies. They constructed one in several weeks that still used uranium, and they decided to drop it on Hiroshima, Japan. When they dropped it, it instantly became the most powerful bomb in history. It injured or killed somewhere between 90,000 and 146,000 people, some killed the moment the bomb exploded, or they died later because of the strong radiation. A few months later, the US scientists had constructed a plutonium bomb the team had chosen to drop on Nagasaki, Japan. This bomb injured or killed between 40,000 and 85,000 people, almost half the people in the Hiroshima bomb.

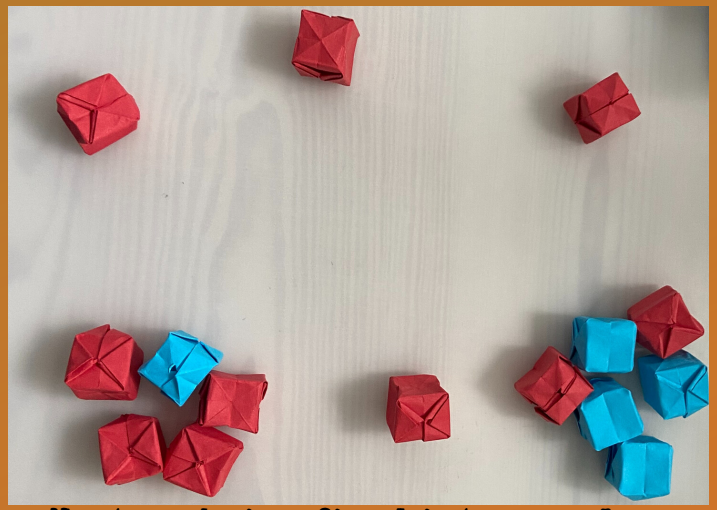


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Adolf Hitler, the tyrannical leader of the Nazis, commited suicide on April 30, 1945. The war was over. The US had won, and lots of the credit went to radioactivity. The bomb had ended the war, but it still had annihilated two cities and killed hundreds of thousands of people. Maybe we could find out a way to make radioactivity into something wonderful that everyone would appreciate? This dream later came true!

Nuclear Energy

Remember that discovery that Lise Meitner and Otto Hahn made? Fission? That was the next step into the present. When the uranium fissioned, it created lots of energy. Then an idea popped into physicist Enrico Fermi's head. What if we could use this energy from the splitting of atoms to power people's homes? People all around the world were weighing the pros and cons. Could electricity become free? Or were countries going to be secretly building nuclear weapons instead?



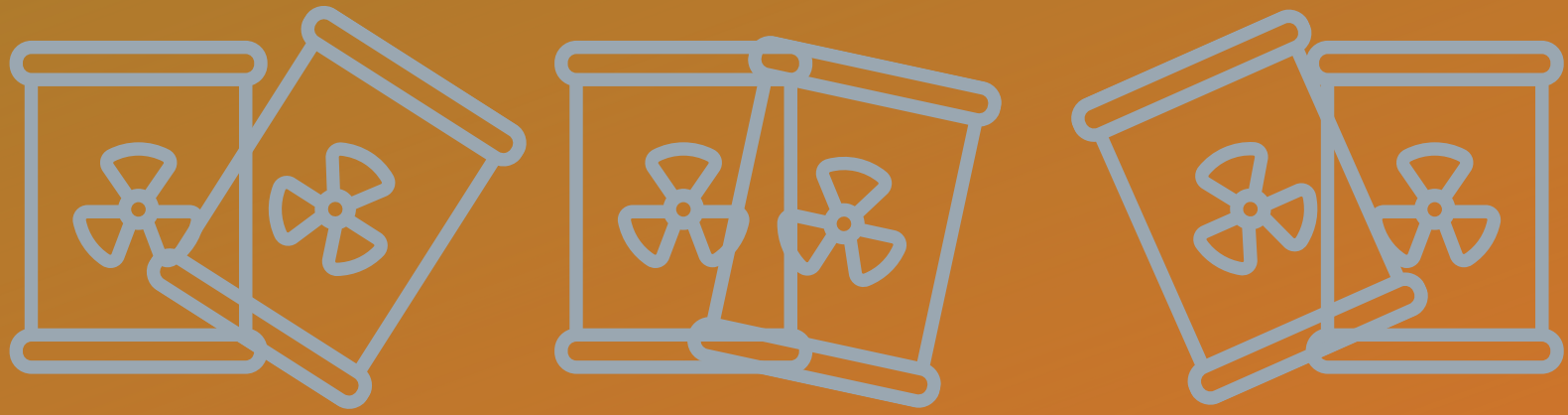
Neutron being fired into a nucleus

Scientists designed nuclear reactors, the equipment that would be used to generate the power. They thought that building them would be easy and it wouldn't take many years to create. But doing this was tricky in real life. Plus, lots of companies thought it was too risky and wanted to rely on burning fossil fuels. Fossil fuels are made from materials that were alive millions of years ago, that sunk into the earth and were crushed and boiled by pressure and heat. When burned, they produce energy. Later, the Yom Kippur War in 1973, another fight for justice, caused a scarcity of fossil fuels, making their prices rise dramatically worldwide and that left an open spot in peoples' minds for nuclear energy.





Lots of scientists from all around the world teamed up and each came up with a way that we can use this fission energy. In the end they settled on one called the Light Water Reactor. Scientists didn't think it was very innovative, but it had its advantages. It was available, it actually worked, and it was cheap compared to all the others. The idea of the Light Water Reactor was that nuclear fission would heat up the water in the reactor and make steam, triggering a generator that created electricity. Control rods inside the reactor made of barium or boron absorb extra neutrons without them becoming radioactive. Nuclear fission would generate lots of energy which would not be held back by the design or the other methods of the power plant. Also, it would be hard for the fission to go haywire because the water in the reactor would cool it down enough.



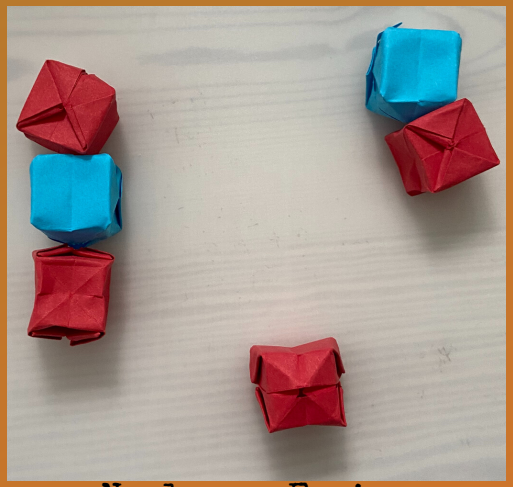
But in the end, a side effect of the fission was nuclear waste. Nuclear waste is made up of radioactive elements, usually uranium or plutonium isotopes, from the fission and the burned-up control rods, long tube-like objects that are made of barium, boron, or some other elements, that soaked up stray neutrons flying around. Nuclear reactors called Breeder Reactors created fuel for other types of nuclear reactor, but this was discontinued in 1979 by president Jimmy Carter because of the Three Mile Island accident (see later). This waste is a problem because it was very dangerous and radioactive and there is really no place to put it all. Could they let it decay? Some of the elements, like plutonium, had incredibly long half-lives (the amount of time it takes for half the particles in the atom to decay). And nuclear reactor employees can't dump it in the ocean, animals would get sick, or in a volcano, because when it erupts people would be showered with radioactive lava. One scientist thought that we could build a rocket filled with all the nuclear waste and send it to the sun, never to be seen again. But that still was very expensive, and a whole rocket would be wasted!



Usually nuclear chemists and engineers decide to dump it all in a deep hole in the ground, which is still probably not the best idea. One example of bad placement of nuclear waste is the Hanford Power Plant in Washington, USA. The waste had gotten into ponds and rivers. All this waste contaminated the soil and this power plant remains the most radioactive place in the US.

Nuclear fission became a great source of energy, beside the nuclear waste. But scientists wondered if there was another way, an even better method of getting energy from the cores of atoms. Maybe they could make more energy as well as less nuclear waste?

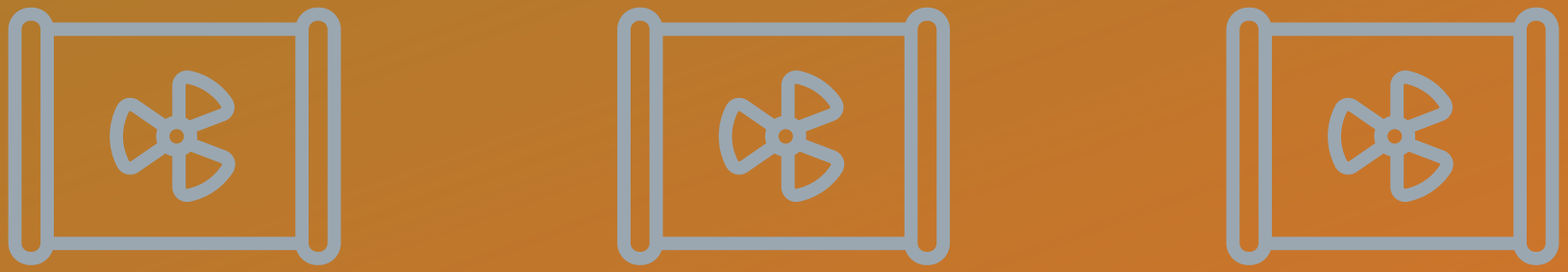
They did come up with another way, called nuclear fusion. Instead of splitting atoms, they joined them together to create even more energy than fission would produce. And yes, less nuclear waste was made. Not even any waste! But even now, no one has been able to really successfully do this. One, it is very expensive, and two, it is incredibly hard to achieve.



Nucleuses Fusing

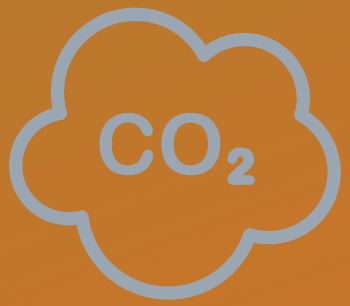
For the atoms to fuse inside a reactor, there needs to be space left for the fusion to happen. This whole area for fusion is surrounded by super strong magnets that keep a cube of salt water in the center. The water contains different hydrogen isotopes; normal hydrogen (one proton, no neutrons); deuterium (one proton, one neutron); and tritium (one proton, two neutrons). Tritium is best for the job, but it is hard to find, and it's radioactive. Then they heat the temperatures to be extremely hot such that the water disintegrates and particles bounce everywhere. The like-charged particles need to fuse, and the only way they will do that is if they are flying around at incredibly high speeds, fast enough to overcome electromagnetism. It needs to be millions of degrees!

Scientists got this idea from the sun, since it is constantly undergoing this process. The sun has so much pressure and it is so hot that the atoms in it are always fusing. This is why the sun is always shining and why the sun will die someday. When the sun runs out of hydrogen, it will burn out. Solar power is created by the sun's rays, which are pure energy. The energy comes from the atoms fusing, which is much more energy than nuclear fission releases. The water inside the reactor is perfect, since when heated enough, it can resemble and have the same characteristics of the sun. This method would be amazing to power our homes, but then again, this is extremely hard to do and it is very expensive. But scientists are still trying. If we could actually do this, then a small amount of seawater can get us enough energy for us to happily live in comfort in terms of energy. It would be convenient for the nuclear plant workers because there would be no waste, since the fuel is hydrogen and the outcome is helium. The negative impacts of fusion itself is that tritium releases. It could bond with the oxygen in the air to create radioactive water, which could harm animals and us. But luckily, there is only a small amount of tritium in use at some time, such that it would be quickly diluted.



Nuclear power held the promise of clean energy that would keep the peace in the world. But it is not all good. Nuclear power does have cons. There were a few nuclear disasters that shook the world. One of them was in 1986, Chernobyl, Ukraine, when a nuclear reactor blew up. It wiped out miles of people and animals, making the whole area for hundreds of miles radioactive. Chernobyl remains radioactive to this day. The next disaster was in Fukushima, Japan, in 2011. This accident was arguably less harmful than Chernobyl, but lots of people don't think so. The reactors had a meltdown when a hurricane struck. The city was evacuated, and while there were some deaths, not as many people died in the Fukushima accident than at Chernobyl. In 1979, the United States barely escaped a disaster when one of the reactors at Three-Mile Island melted, releasing toxic gases into the world. As you can see, the Light Water Reactor was not the safest nor the most efficient type of reactor. But still, most nuclear reactors are various types of Light Water Reactor.



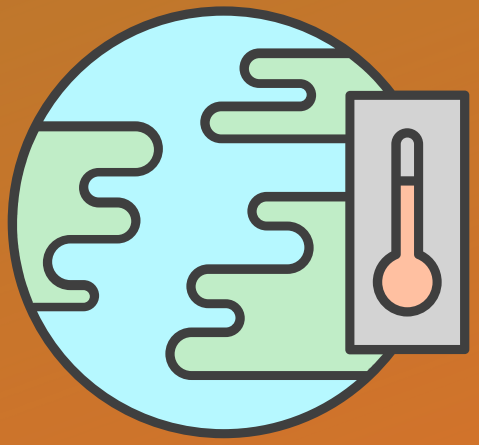




An advantage of nuclear power is that it does not pollute the world and cause problems like burning fossil fuels does. Fossil fuels are typically oil, coal, or natural gas that people burn to create energy. Burning these substances releases greenhouse gases into the atmosphere, including the notorious carbon dioxide. The greenhouse gases get trapped in the atmosphere and slowly make the earth a little warmer, leading to global warming. You may be thinking, “So what? The earth getting warmer, that sounds like a warmer winter!” However, this is a big problem. The ice in the Arctic and all the other places with ice are melting and people’s homes are slowly disappearing. And you don’t even need to be in an icy place; tiny islands are disappearing because of sea level rise from the ice melting! Would you like your home to disappear?







Now you have to decide on what you will have to deal with between those options: disappearing homes or radioactive disasters. If you think both of these decisions are terrible and you want to pick another one, remember that there is a downside and a waste product out of everything. Which will you choose?

Acknowledgements

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Thank You For Reading!

