Introduction

There are many forms of energy in the world. As you learned in the last unit, many of these are derived from the forces of electromagnetism. Gasoline that burns, muscles that contract, and electrons that flow are all the result of this electromagnetic force. Although we use this force constantly, it is relatively weak when compared to nuclear forces. Just as with electromagnetic forces, nuclear forces produce energy. The sun is the ultimate source of almost all our energy. The energy of the sun comes from **nuclear energy**.

Nuclear energy involves the nuclei of atoms. Subatomic particles in the **nucleus** of atoms are called *neutrons* and *protons*. These particles are matter. In "Unit 8: Chemical Equations," you learned that matter cannot be created nor destroyed. What about energy? Energy can change form, but can never be destroyed. This is called the *law of conservation of energy*. (Covered in "Unit 13: Forms of Energy"). This law applies to the energy you use every day.

Electromagnetic forces provide us with most of the energy we use on a daily basis. Most of this energy has originated in sunlight. For example, sunlight is used by plants. Wheat plants store this energy as chemical energy. The chemical energy comes to you as flour or bread. You use the chemical energy for many purposes. You will produce heat, may make sound, or use mechanical energy. The energy you use, though, originated in the sun's light. This unit discusses how nuclear reactions only appear to break the laws of conservation of mass and energy and how the result is all the energy you use.

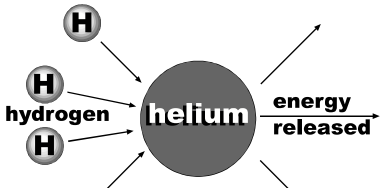
What Is Nuclear Energy?

Most of the electromagnetic energy we know comes from the outer portions of atoms, the electrons. Within the center of the atom, however, is the nucleus. The energy that holds tightly together the nucleus of atoms is nuclear energy. Compared to the electromagnetic forces of the atom, the nuclear energy is immense. By releasing some of this energy, the sun creates light. The sun's light gives us energy that runs the world.

Most of the energy sources we use today are derived from sunlight. Oil and natural gas, and even wood for fires, are the products of sunlight. Unfortunately, this is not a very efficient way to use the sun's energy. Much of the energy of the sun is lost as heat. Because the world’s population grows every day, we find that we need more and more energy. Nuclear energy may be one way of providing that energy. With the use of nuclear energy also comes the serious risk of the escape of harmful radiation, such as in the disaster in 1986 at a nuclear power plant in Chernobyl, in the Ukraine. Many safeguards must be taken to prevent accidents.

How Does the Sun Work?

There are two main ways to release nuclear energy. The sun uses a process known as **fusion**. The sun is made of light gases being held together by gravity. Most of this gas is the lightest of elements, hydrogen. In the center of the sun, the hydrogen gas is being pushed together by gravity. This pressure is incredibly high. Because of this pressure, there is also a large amount of heat. Under the pressure and heat, the hydrogen changes. Four hydrogen atoms will combine to form one helium atom! When this happens, energy is released.



4 hydrogen atoms combine to form 1 helium atom - energy released

You should remember that the law of conservation of energy says energy can neither be created nor destroyed. From where did the energy come? When the four hydrogen atoms were changed into one helium atom, a small part of their mass was lost. Compare the mass of four hydrogen atoms to one helium atom. The hydrogen atoms have a mass of 4.03188. The mass of the helium is 4.0026. In this case, it looks like we lost a mass of 0.02928. What has actually happened is that this mass has been changed to nuclear energy. The mass was not destroyed, and the energy was not created. They were just changed. The small amount of mass becomes the large amount of energy that comes from the sun.

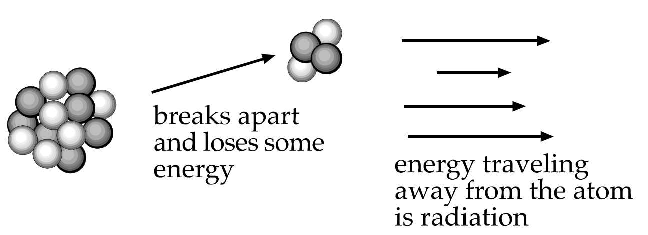
The process of taking these lighter elements and making a heavier element is called fusion. Fusion powers the sun and releases large amounts of energy. Because of the heat and pressure needed, however, scientists have not been able to control fusion. So far, the only use of fusion by humans has been to create highly destructive weapons. No one knows if we will ever find a peaceful use for fusion.

What Is Fission?

In the previous section, you learned about one way to release nuclear energy, fusion. This section will examine another way of releasing nuclear energy, **fission**. Fission occurs when the nucleus of an atom splits and releases some of its nuclear energy. To understand how and why this happens, we need to look at the nucleus of atoms.

Remember that the nucleus is made of neutrons and protons. In any given element, the number of protons in a nucleus never changes. This is not true of the number of neutrons. Consider carbon. Most atoms of carbon have six neutrons as well as six protons. This will give the nucleus a mass of 12. Because the chemical symbol of carbon is C, then this type of atom is called C12. Some carbon atoms, however, may have seven neutrons. The nucleus of such an atom would have a mass of 13 and is called C13. The element is still carbon, but the atom is a little heavier. Other than that, the atom behaves just like an atom with six neutrons, C12. However, if we add another neutron, for a total of eight, the atom will behave differently. This atom will have a nucleus with a mass of 14, but it will still be carbon. It is known as C14. How is C14 different? If left by itself, the nucleus will break apart and lose some energy. The energy will travel away from the atom, and we know this as **radiation**. Radiation is any form of energy that travels in a wave. Nuclear radiation, however, is sometimes dangerous because it has such high energy.

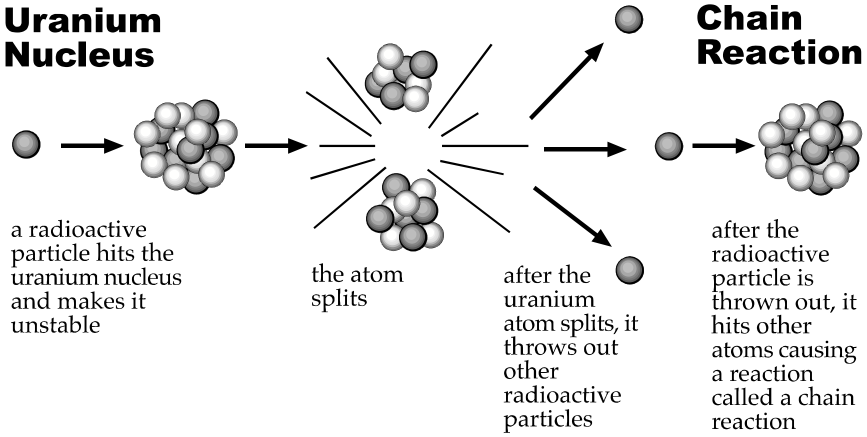
Carbon Atom or C14



You may be wondering if there is a special name for atoms with a different number of neutrons. The name for these are **isotopes**. We discussed three isotopes of carbon. Most isotopes of atoms are harmless. Some are

radioactive. That is, some isotopes, like the C14 isotope, spontaneously produce radiation. Radioactive material has nuclei that break down and release energy and neutrons. The element uranium is naturally radioactive and constantly releases energy and radioactive particles. These radioactive particles are made from the protons, neutrons, and electrons of the atom.

Where do the particles go? The particles travel outward. When the uranium nucleus is hit with a particle, it becomes unstable. Eventually it will split in two. Splitting an atom is called fission. When the atoms split they lose a small amount of matter that is changed into a large amount of energy. Not all elements have atoms that can be split. When the uranium atom splits, it throws out more radioactive particles. These particles will split other atoms. This will continue to happen. This reaction is called a **chain reaction**. Besides uranium, there are many other elements that spontaneously produce radiation. These include plutonium, radium, and cesium.

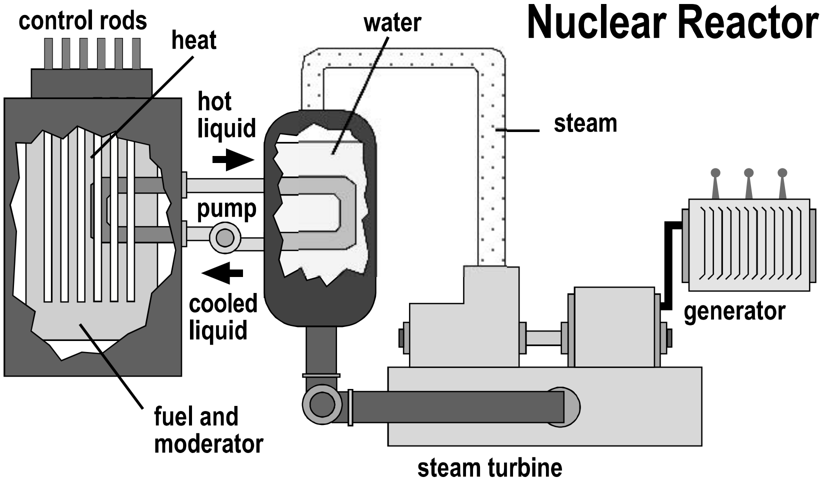


Controlling Nuclear Reactions

Large amounts of energy are released by fission and fusion reactions. Why can't this energy be used to run generators? It can, but first it must be controlled. After learning how to use nuclear energy to destroy, scientists found ways to control it.

Fission can be controlled. It must take place slowly, but at a steady speed. In this way, fission can be used to produce useful energy. A **nuclear reactor** is used to control a nuclear chain reaction. All reactors currently running are **fission reactors**. These use uranium atoms for fuel. They are hit with neutrons. When the reaction begins, a **control rod** is used. A control rod is made of a substance that absorbs neutrons. Control rods can be used to slow down fission reactions. By absorbing some of the neutrons, the chain reaction does not become explosive. If the reaction must be speeded up, the rods are removed.

A nuclear reactor produces heat. This heat can be used to run generators. It takes a very small amount of nuclear fuel to produce large amounts of energy. Is this the answer to man's energy needs? There are nuclear power plants being used today. Unfortunately, nuclear fission creates some problems. **Radioactive wastes** is one of these problems.



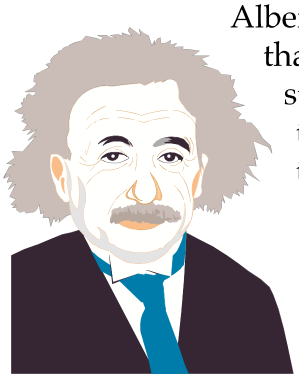
Radioactive Material

Radioactive wastes are no longer useful as fuel, but they are still radioactive. **Radioactivity** can damage or kill living cells. Large doses of radiation can cause severe burns. On the other hand, radiation also has helpful uses. It can be used to kill cancer cells. Low levels of radiation can be used to find tumors in people.

Think about the nuclear reactor. It uses uranium for fuel. Uranium is radioactive. A nuclear reactor produces waste that is radioactive. This radioactive waste is harmful to living things. What happens to this waste? It cannot be destroyed. Some radioactive material may require millions of years to decay. A measure of time required for substances to decay is called *half-life*. The half-life is the amount of time it takes for half of the atoms in the radioactive substance to decay. Some of the radioactive waste is stored in underground tanks. Some is sunk deep in the ocean. People worry that these methods of disposal might leak.

Fusion reactors would not produce radioactive waste. Remember that fusion needs high temperatures. Scientists have not yet figured out how to produce and control these high temperatures. It is hoped that in the future, man may be able to solve some of the problems of nuclear energy.

Albert Einstein and Nuclear Power



Albert Einstein

Albert Einstein was a physicist. He created the theory that stated mass and energy were related. His theory stated that the energy of matter was equivalent to the mass of the object multiplied by the square of the speed of light. This equation is written as:

$$E=mc^2$$

E represents energy. The *m* stands for mass. The speed of light is represented by a *c*. This theory led to many outcomes.

When Einstein first conceived of this theory, it was not seen as a formula for making energy. At first, there was resistance to the concept. Had the theory not shown itself to be accurate, it would surely have been rejected. Yet, the **theory of relativity** was not rejected. Despite this, it took decades before the theory could be applied. Its first application was in the creation of atomic bombs. Many other scientists had to add theories and knowledge. Sometimes such knowledge is expected. At other times, it is unexpected.

Again, the application of the theory for bombs was not what Einstein had envisioned. He simply developed a theory. The development of bombs and nuclear reactors and an understanding of the sun were not necessarily expected. Although Albert Einstein made these things possible, he did not have them in mind when working on the theory of relativity.

Summary

Atoms store huge amounts of energy. This energy can be released by fission or fusion. Fusion is the combining of light elements into heavier elements. The sun uses fusion. Nuclear reactors control the speed of fission reactions. Fission is the splitting of atoms. Nuclear power plants produce energy and dangerous radioactive waste. Scientists are searching for ways to eliminate the problems of using nuclear energy. As Einstein's theory of relativity demonstrates, ideas in science are limited by the purpose for which they are conceived, are sometime rejected, may grow from unexpected discoveries, and often grow slowly from many contributors.