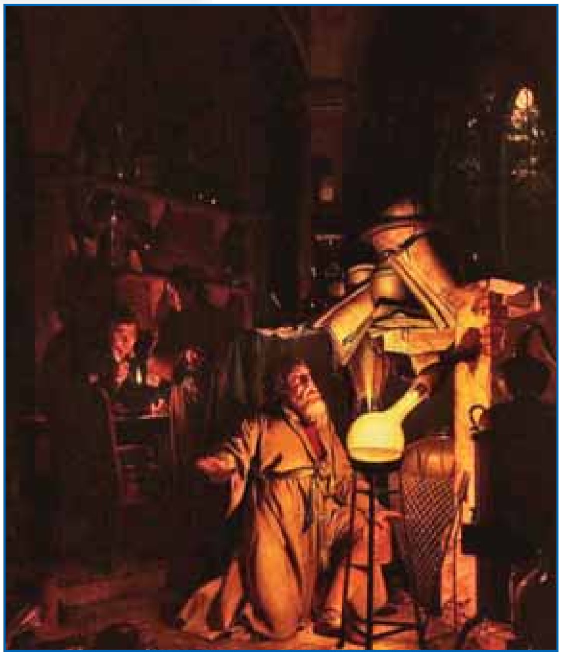
LEARNING ABOUT OTHER IDEAS

Activity 12
Isotopes and Radioactivity



Part of painting by Joseph Wright of Derby, 1734-1797: The Alchemist in Search of the Philosopher's Stone Discovers Phosphorus.

Purpose

More than a thousand years ago, people thought that it was possible to change one substance into a different substance. For hundreds of years chemists tried to make a "philosopher's stone." This was a substance that could convert other metals, like lead, into bright, valuable gold. They heated metals, cooled metals, and added acids to metals. They ground metals into a powder and mixed it with everything they could think of. Nothing worked. Physical and chemical interactions do not convert one element into another element.

Even so, some elements do change into other elements. Atoms of carbon can become atoms of nitrogen. Atoms of iodine can become atoms of antimony. A uranium atom can become a thorium atom. These changes occur because of nuclear reactions. Unfortunately, atoms of lead never become atoms of gold! The key questions for this activity are:

1. What are isotopes of an element?
2. What are nuclear reactions and radioactivity?

Record the key questions for the activity on your record sheet.

Learning the Ideas

Isotopes of an Element

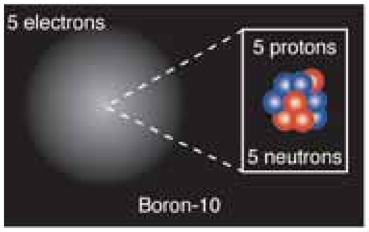
Your teacher will show a periodic table that contains some different information. Notice that the atomic mass numbers are not whole numbers. For example, the atomic mass number of hydrogen (H) is 1.008 instead of 1, and the atomic mass number for iron (Fe) is 55.85 instead of 56. How can this be? Is it possible to have fractions of a proton or neutron?

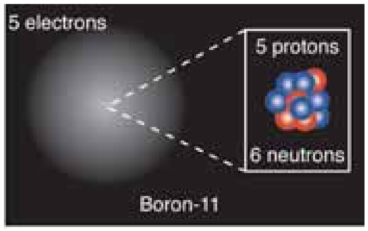
It turns out that the atoms of elements do not always have the same number of neutrons. They do always have the same number of protons. An element that has different numbers of neutrons is called an **isotope** (EYE-suh-tohp) of the element.

Science Word

Isotope: An element that has different numbers of neutrons.

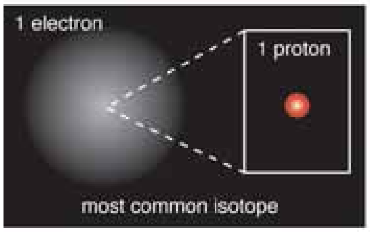
Suppose you have a sample of the element boron. Boron, a metalloid, is usually a grey powder. All boron atoms have 5 protons in the nucleus. But there are two different isotopes of boron. Each has a different number of neutrons.

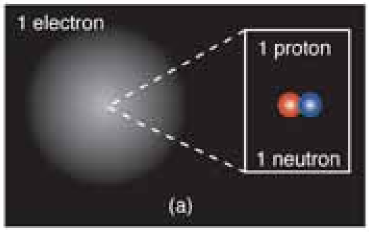


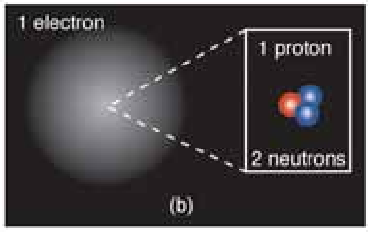


The isotopes are identified by the name of the element followed by the atomic mass number of the isotope. For example, one isotope of boron is called *boron-10* because it has an atomic mass number of 10 (5 protons plus 5 neutrons). The other isotope of boron is called *boron-11* because it has an atomic mass number of 11 (5 protons plus 6 neutrons).

Most elements have more than one isotope. The atomic mass numbers on the *Periodic Table of the Elements* are stated as decimal numbers because each number is an average of the mixture of isotopes for each element. For example, about two out of every 10 atoms of boron are boron-10. About eight out of every 10 atoms are boron-11. The average mass number for boron is 10.81.







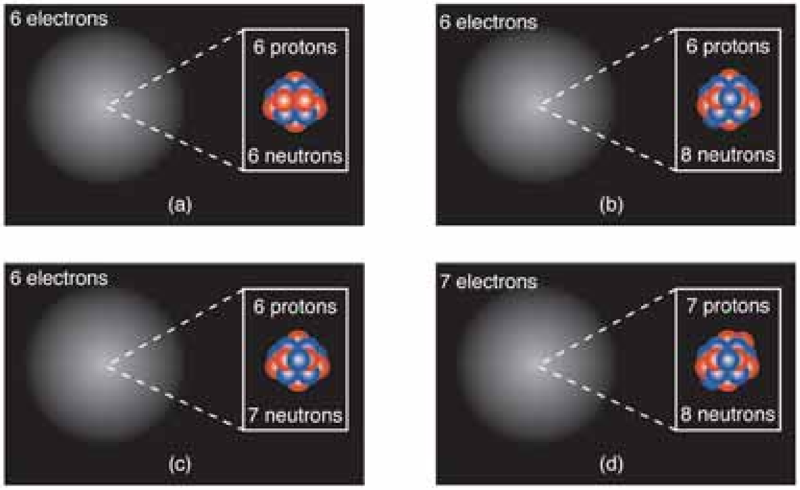
All hydrogen atoms have one proton in the nucleus. There are three isotopes of hydrogen. The first isotope, hydrogen-1, has one proton and no neutrons. The other isotopes of hydrogen are hydrogen-2 (deuterium) and hydrogen-3 (tritium). All are shown in the diagrams above.

1. Which diagram, (a) or (b), shows the hydrogen-2 isotope. Explain your reasoning.

2. Which diagram, (a) or (b), shows the hydrogen-3 isotope. Explain your reasoning.

Your teacher will review answers to these questions with the class.

The most abundant isotope of hydrogen is hydrogen-1. Out of thousands of hydrogen atoms, only a few are hydrogen-2 and hydrogen-3. The average atomic mass number for hydrogen is 1.008.



3. The element carbon has many isotopes.The isotope used in the dating fossils is carbon-14. Which diagram, (a), (b), (c) or (d), shows the carbon-14 isotope? Explain your reasoning.

Radioactive Decay

Interactions involving the particles of a nucleus (protons and neutrons) are called *nuclear reactions*. Some isotopes of elements are unstable. The nucleus of an unstable atom does not hold together well. It breaks apart, sometimes forming atoms with a different number of protons or neutrons. When an unstable atom beaks apart (decays), the nucleus emits fast-moving particles and energy. This process is called *radioactive decay*.

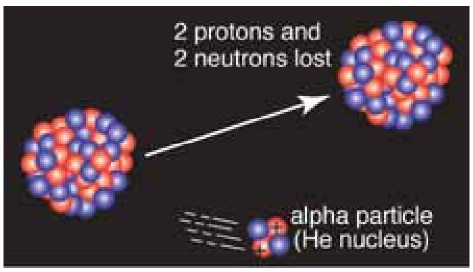
Technology Connection

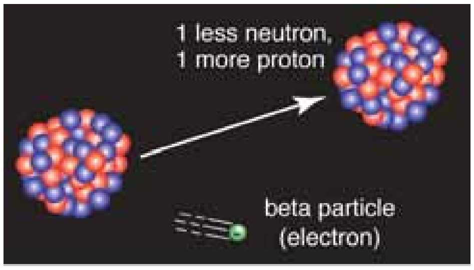
Barbara Askins, a former teacher, was hired by NASA in 1975 to find a way to make images taken in space more clear. She used radioactive materials to enhance the pictures. Her method was so successful that it was also used to help restore old photographs. The process pioneered by Askins might have been used to improve the quality of the pictures in your history book.

All the isotopes of some elements are radioactive, such as element 43, technetium, or element 86, radon. No stable samples of those elements exist in nature. Element 92, uranium, is another example of an element in which no stable isotopes exist. However, uranium decays so slowly that it is still found in the Earth's crust.

There are three types of radioactive decay.

Alpha Decay An alpha particle consists of two protons and two neutrons. It is the same as a helium nucleus. The release of an alpha particle decreases the atomic number by two and the atomic mass by four. Alpha decay is not suitable for radiation therapy since its range is less than a tenth of a millimeter inside the body. It can cause a bad skin burn. A sheet of paper, a thin piece of metal foil, and clothing can stop alpha particles. Uranium, plutonium, thorium, and radon are typical alpha emitters.



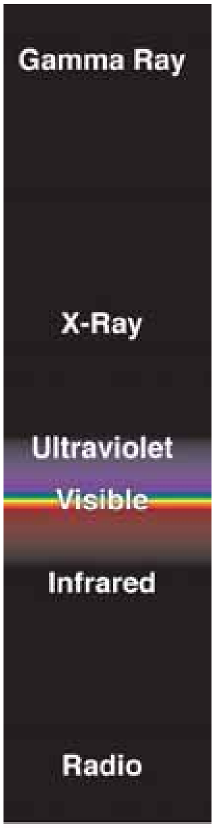


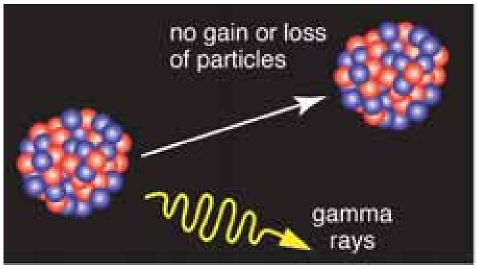
Beta Decay Beta particles are just electrons from the nucleus. The term "beta particle" was used in the early history of radioactivity. An electron is released when a neutron decays into a proton and an electron. The new proton stays inside the nucleus. This means that the nucleus now has one less neutron and one more proton. The mass number stays the same, but the atomic number increases. Cobalt-60 is used in medical practice. It decays to the more stable nickel-60. Tritium, krypton-85, and the potassium in fertilizers and food are also examples of beta emitters.

The beta particles (electrons) travel much faster than the alpha particles. Plastic, glass, or a sheet of metal such as aluminum can stop them.

Gamma Decay Alpha and beta decay are usually accompanied by gamma radiation. Gamma radiation is like infrared, visible light, and x-ray radiation, only much higher energy.

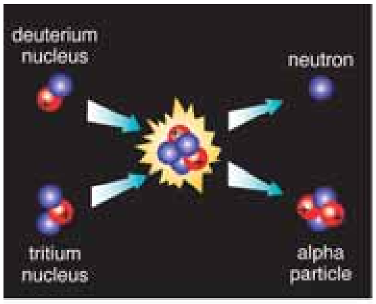
Gamma radiation (also called gamma rays) does not cause a change in either the atomic number or atomic mass of the decaying nucleus. However, the energy released is the most penetrating. You would need a piece of lead or steel several centimeters thick, or a concrete wall about a meter thick to stop this type of radiation

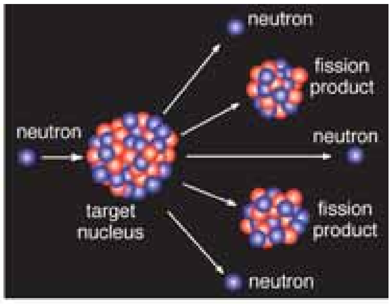




Neutrons in Nuclear Reactions

In addition to alpha, beta, and gamma decay, many nuclear reactions, like fusion and fission, produce neutrons. Fusion and fission reactions occur in stars. These reactions release enormous amounts of energy compared to chemical reactions. Nuclear fusion is the combing of two nuclei with low masses to produce one nucleus of larger mass and neutrons. In a fission reaction, a neutron collides with a large nucleus (atomic numbers larger than 90) to produce two smaller nuclei and some neutrons.





Neutrons are light and have no electric charge. They can penetrate into materials deeper than alpha particles, beta particles, and gamma rays. Neutrons can penetrate even lead. Materials with a high-hydrogen content, for example, water or plastics, provide the most effective shielding against neutrons.

4. What are four forms of nuclear radiation?
5. Which types of radioactive decay (alpha, beta, and/or gamma) results in a different element. Explain your reasoning.
6. Which type of radiation is the most penetrating, alpha particles, beta particles (electrons), gamma rays, or neutrons? Explain.

Your teacher will review answers to these questions with the class.

What We Have Learned

Think about the key questions for this activity:

1. What are isotopes of an element?
2. What are nuclear reactions and radioactivity?

Participate in a class discussion about the answers to the key questions.

Write the answers to the key questions on your record sheet.

Waste materials with low levels of radiation are stored in secure containers. Then they are buried in a landfill.

Radioactive products from nuclear power plants are very hazardous. The Waste Isolation Pilot Plant (WIPP) is a site in New Mexico where the United States government is developing safe storage for harmful radioactive wastes. Large rooms 2150 feet (almost one-half mile) underground house the waste in secure barrels.