Radioactivity and Nuclear Reactions

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INTRODUCTION

On March 1, 1896, Henry Becquerel made one of the most important discoveries of our time by accident. Becquerel put a couple of photographic plates that were completely sealed in paper in a drawer next to a rock, identified as uranium ore, and left them there. After a few days, he developed the plates and discovered strange bright spots. Becquerel discovered that uranium gives off invisible rays. Although we cannot see these rays, they will cause photographic material to react, just as visible light causes film to be exposed. The invisible rays from the uranium ore were able to pass directly through paper and cause the bright spots that formed on Becquerel's photographic plate. Materials that give off such invisible rays are said to be radioactive.

Radioactivity was the first of many starting discoveries that led the way into the world of nuclear reactions. Today, radioactive materials help us to look inside ourselves, and radioactive dating gives us clues into eras long past. Research in radioactivity has also opened the door to one of the most powerful forces known to the human race. Today, it is more important than ever that we learn how to use this power constructively.

OBJECTIVES

Objective 1: Radioactive Isotopes

Deep inside the atom, past the electrons, in the nucleus, the secret to radioactivity is found. Recall that the nucleus of an atom is composed of protons and neutrons. Protons are positively charged and neutrons have no charge. The protons and neutrons make up nearly all of the mass of the atom. For example, the nucleus of an isotope of hydrogen can be represented by the formula shown below. The subscript one ($_1$) is the *atomic number*, or the number of protons in the nucleus. The superscript two (^{2}) is equal to the *atomic mass*, which is the number of protons and neutrons in the nucleus. Hydrogen atoms always have an atomic number of one. In other words, an atom is not hydrogen unless it has only one proton in its nucleus.

Hydrogen can have mass numbers of one, two and three, which means it can have no neutrons, one neutron, or two neutrons. These different versions of hydrogen are called *isotopes*. Isotopes are forms of the same element that have different number of neutrons. They have the same atomic number, but different mass numbers. Most elements have two or more isotope forms. For example, carbon-12 has six protons and six neutrons. Carbon-14 has six protons and eight neutrons.

In most nuclei, positively charged protons sit close together. The repelling force between these positively charged protons is very powerful. The protons in the nucleus do not fly apart because protons and neutrons are held together in the nucleus by an even more powerful force, called the *strong nuclear force*. When a nucleus gets overloaded, nuclear particles escape. When these particles break free of the nucleus, energy is produced. This spontaneous release of nuclear particles and energy is called *radioactivity*. Radioactive isotopes are *unstable*. An unstable isotope may release nuclear particles and are not radioactive. All isotopes with atomic numbers of 83 or greater are unstable and, therefore, radioactive. For example, Radon-222 with an atomic number of 86 is radioactive.

Only some isotopes of elements with atomic numbers from 1 to 82 are unstable. There is no easy rule to determine whether these isotopes will be radioactive or not. For example, Carbon-12 is a stable isotope, but Carbon-14 is unstable and therefore radioactive.

Objective 2: Types of Radioactive Emissions

Radioactive substances emit invisible particles and energy. What is the nature of these emissions? Because of the work of early scientists, an experiment can be performed which will reveal the properties of radioactive emissions. A radioactive substance is placed at the bottom of a deep hole in a solid lead block. The radiation escapes only through the hole and forms a thin beam. A photographic plate is placed beyond the lead block to record the radiation. Positively and negatively charged plates are positioned on either side of the radioactive beam in front of the photographic plate.

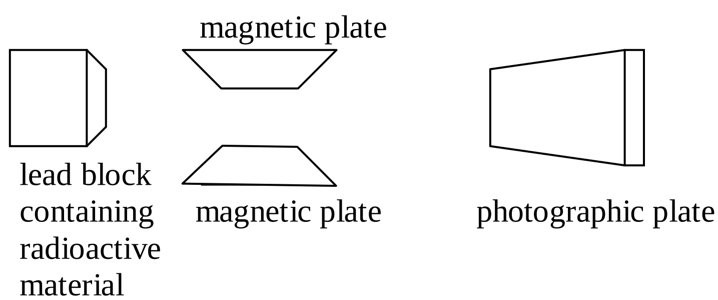


Diagram 1

The positive and negative plates will tell if the radioactive emissions have a charge. If the emissions have no charge, they will pass between the charged plates without bending and hit the photographic plate dead center. If they have a positive charge, they will bend toward the negative plate, since opposites attract, and strike the photographic plate off-center. Negative rays will bend toward the positive plate and hit the photographic plate on the other side of the center. Here is the developed photographic plate. There are three separate points of light. What does this tell us about the radioactive emissions?

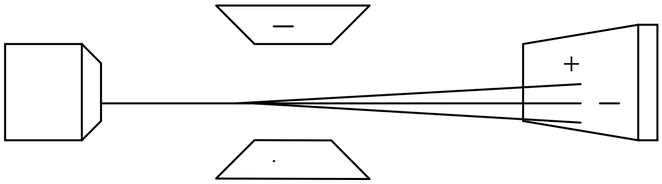


Diagram 2

The diagram of the result of the experiment shows there at least three types of radioactive radiation. The English scientist, Curie, who first performed a similar experiment, named the emissions *alpha rays*, *beta rays*, and *gamma rays*. Alpha rays are actually made up of alpha particles. Likewise, beta rays are made up of beta particles. But gamma rays rate not composed of particles; they are a form of energy, like X-rays.

Notice that the path of the beta particles bends toward the positive plate. This shows that alpha particles have a negative charge. Gamma rays do not bend toward either plate, which indicates that they are neutral or have no charge.

In the next experiment, barriers of paper, aluminum and lead are set up between the charged plates and photographic plate. The barriers will show us the penetrating powers of the rays. Alpha particles have the least penetrating power. They are stopped by only a sheet of paper. Beta particles are more penetrating than alpha particles, but less than gamma rays. They pass right through paper, but are stopped by thin sheet of aluminum. Gamma rays have the most penetrating power and are, therefore, the most dangerous. They can pass through paper and aluminum sheets. Only thick sheets of lead or concrete can stop them. Both beta and gamma rays will penetrate the skin into living tissue unless stopped. That is why people handling radioactive materials wear lead suits.

Now, lets look at the mass speed and compositions of these of radiation. Notice in Diagram 2 that the alpha particles have more mass than beta particles. What could explain this difference? Alpha particles have more mass than beta particles. Imagine alpha particles as baseballs and beta particles as ping-pong balls moving down an incline through a strong cross wind. Baseball are not blown off course as much as ping-pong balls. Likewise, the more massive alpha particles are not forced off course by the electrical field as much as the beta particles.

Scientists have discovered that an alpha particle is actually the nucleus of a helium atom. That is, it has two protons and two neutrons, which gives it an atomic weight of four and a charge of 2^+. These heavy alpha particles travel at approximately one-tenth of the speed of light, the slowest of the three. Following is the alpha particle symbol.

$${}^{4}_{2}He$$

The beta particle is simply a free electron. It has very little mass compared to an alpha particle or even a proton. The symbol below, which is for beta particles, is the same as the symbol for the electron.

$$^{0}_{-1}e$$

The superscript (^{0}) refers to its atomic weight and the subscript ($_{-1}$) refers to its charge. Because these particles have so little mass, they travel close to the speed of light.

A beta particle is thought to be created when a neutron splits into a proton and an electron. This means a beta particle comes from inside the nucleus, not from the electrons surrounding the nucleus.

The gamma ray is a form of energy. It has no mass, so it travels at the speed of light.

Objective 3: Nuclear Charge

When a radioactive isotope, such as uranium-238, spontaneously release nuclear particles and energy, it changes dramatically. It becomes a completely different element. This process is called radioactive decay. Radioactive decay occurs anytime a radioactive element changes into a different element through the spontaneous release of nuclear particles and energy. Uranium-238 emits an alpha particle when it decays. How does this affect its atomic number?

The atomic number of uranium-238 is decreased by two since an alpha particle consists of two protons and two neutrons. The new element now has an atomic number of 90. Uranium has become thorium. The following equation is the nuclear equation for the change that takes place when uranium decays into thorium.

$$^{238}_{92}U \rightarrow {}^{234}_{90}To + {}^{4}_{2}He + \text{energy}$$

It is called a nuclear equation because it represents a change in the atom's nucleus. A nuclear equation differs from a chemical equation. In a chemical equation, the same elements appear on both sides of the equation in equal numbers. In a nuclear equation, the atomic symbols often change from one side of the equation to the other, because the identity of the elements has changed. Like chemical equations, nuclear equations must be balanced. Can you see how this equation is balanced?

$$^{238}_{92}U \rightarrow {}^{234}_{90}To + {}^{4}_{2}He + \text{energy}$$

The sum of the mass number of thorium and helium equals uranium's mass number. The same goes for the atomic numbers. In a nuclear equation, the subscripts and superscripts on both sides of the equation are balanced. Thorium is also radioactive. When it emits radiation, it loses a beta particle. Remember that the beta particle is a free electron that comes from the nucleus. A neutron splits in to an electron and a proton. The electron is emitted, but the proton stays in the nucleus. The atomic number goes up by one. Thorium becomes the element protactinium. Here is the nuclear equation for this change.

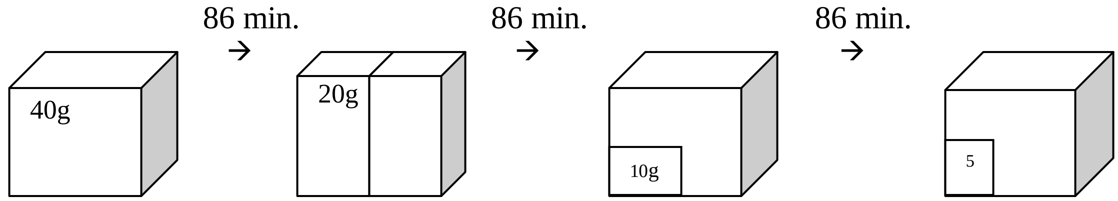
$$^{238}_{92}\text{U} \rightarrow \text{Th} \rightarrow {}^{234}_{91}\text{Pa} + {}^{0}_{1}\text{e} + \text{energy}$$

Protactinium is also radioactive. It loses a beta particle and changes into another element. After 14 such changes, a stable element, lead-206, is finally reached. Each change is accompanied by a release of energy. This long decay process is called a *decay chain*. All radioactive elements decay. If the new isotope is radioactive, it will also decay. When a stable isotope is formed, the decay process stops and energy is no longer released.

Objective 4: Half-life of Radioactive Decay

In the 1950s a tropical island, Bikini Atoll, was the site for a series of tests by the United States government. Several nuclear bombs were exploded. Today, the natives of Bikini Atoll are still not allowed to return. The reason is because dangerous radioactive isotopes left on the island by the explosion have not decayed into safe, stable isotopes. How long will it take for these radioactive isotopes to decay? The rate of decay for each isotope is different. The decay time can range from seconds to billions of years. The rate at which an element decays is related to it is *half-life*. Half-life is the time it takes for one-half of the atoms in a radioactive substance to decay into another element. For example, polonium-216 has a half-life of 0.16 seconds, sodium-24 has a half-life of hours, carbon-14 has a half-life of 5700 years, and uranium-238 has a half-life of 4.5 billion years. You can see that the decay rates vary tremendously.

If you know the original mass of a substance and its half-life, you can determine how much radioactive material will have decayed after a certain amount of time. Barium-139 has a half-life of 86 minutes. If you start with 40 grams of pure barium-139, and one-half of the atoms decay after 86 minutes, 20 grams of barium will remain. After another 86 minutes, half of the remaining 20 grams decay, leaving only 10 grams of barium-139. Can you determine, from Diagram 4, how many are left after another 86 minutes?



Five grams of barium-139 remain. Thirty-five grams have decayed.

The half-life of radon-222 is four days. If you start out with a 64-gram sample of radon-222, how much would remain after 20 days? First, divide the amount of time that has elapsed by the half-life to determine the number of half-lives.

$$20 \div 4 = 5 \text{ half-lives}$$

Then reduce the mass by half five times.

How much Rn-222 has decayed? There are two grams of radon-222 remaining after 20 days. Sixty-two grams of radon-222 have decayed into a new element.

Practice problem

Sodium-24 has a half-life of 15 hours. Given 36 grams of sodium-24, how much will have decayed after 2.5 days?

Solution

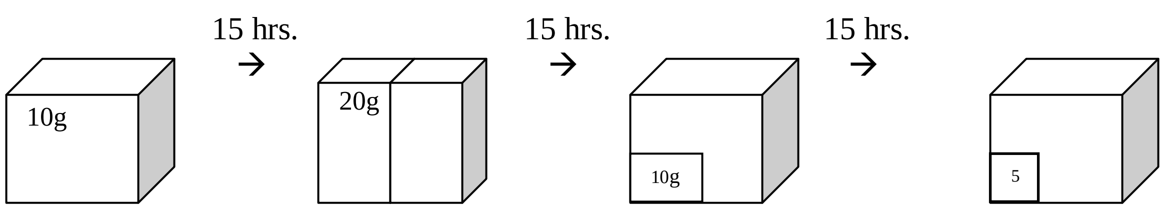
First, convert days into hours.

$$2.5 \text{ days} * \frac{12 \text{ hours}}{1 \text{ day}} = 60 \text{ hours}$$

Since the half-life of sodium-24 is 15 hours, divide the number of hours passed by the half-life.

$$\frac{60 \text{ hours}}{15 \text{ hrs/half-life}} = 4 \text{ half-lives}$$

Then reduce the mass by half four times.



Objective 5: Detection Devices

When radioactive particles penetrate matter, they smash into atoms and molecules, stripping electron from them. When these atoms or molecules make up living cells, the cells may start to malfunction or die. Exposure to high doses of radiation will cause serious burns. Radioactive particles penetrate living tissue and disrupt the normal functioning of cells. White blood cells, which are very important for protecting us against infections, are particularly vulnerable to radiation. When the number of white cells drops, radiation victims lose their natural ability to fight infection or disease. Since radiation from radioactive materials cannot be seen, heard, tasted, or smelled, how could you detect if radiation is leaking out of a container? There are, however, several devices that detect the presence of radioactive radiation.

Common radiation detection devices include a *cloud chamber*, a *Geiger counter*, and a *film badge*. Recall that radioactive particles strip electrons from anything they encounter. Any matter that is hit by radiation becomes electrically charged or ionized. These devices tell us when ionization is taking place.

A cloud chamber contains air that is supersaturated with water vapor, like a very thick fog. When radioactive material is place inside the chamber, particles zip through the fog, ionizing everything in their path. Water vapor condenses around the ions, creating a visible vapor trail across the chamber, much like the vapor trail of a jet across the sky.

A Geiger counter consists of a tube filled with argon gas and an electric wire running through the gas. The wire is connected to a small speaker. Each time a nuclear particle goes through the argon gas, gas particles become ionized or electrically charged. An electric current is then sent up the wire to the speaker, which causes the speaker to click. The more click per second, the greater the amount of radiation.

Radioactivity was first discovered from its effect on photographic film. When nuclear radiations come from into contact with film, they ionize the chemicals in the film. For this reason, film badges are worn by people who work around radioactive material on a daily basis. At the end of a given hour, the film in the badges is developed. Spots on the film show the level of radiation exposure for each badge.

Background Radiation

Background radiation is a low-level radiation that is all around us. It is usually not dangerous. The sun and other natural sources, such as cosmic rays, which come from the deepest reaches of the universe, contribute to background radiation. The decay of naturally radioactive substances in the ground adds to the background radiation. Granite, for example, contains very low amounts of radioactive radon-222. Man-made sources also contribute to background radiation. Nuclear testing is one such source.

Objective 6: Fission and Fusion Reactions

Fission Reaction

The destructive power of an atomic bomb comes from the tremendous amount of energy released during nuclear reactions. How is this energy released? Radioactive substances naturally release energy when they decay, but this energy is released over long periods of time and is extremely small compared to the energy of an atomic bomb.

Scientists discovered that energy could be "manufactured" by bombarding the nucleus of various elements with nuclear particles. In 1939, European scientists bombarded uranium with neutrons and found that uranium split into two different elements, barium and krypton. They also discovered that when the nucleus split, a sudden burst of energy and three neutrons were released. The splitting of a nucleus into two fragments of approximately equal mass is called *nuclear fission*.

Scientists then realized something startling, that if each of the three neutrons produced by the uranium fission collided with three more uranium atoms, how many more neutrons would be emitted? Nine uranium atoms would release 27 neutrons. If each of *these* neutrons struck other uranium atoms, 81 neutrons would be released, and so on. A chain reaction would occur, getting bigger and bigger as long as there were enough uranium atoms nearby.

In a nuclear chain reaction, each time a neutron is emitted, energy is released. If the chain reaction is allowed to continue uncontrolled, a tremendous amount energy is released is a mater of seconds.

Can a nuclear chain reaction be controlled? Yes. Today, nuclear power plants generate electricity produced by controlled chain reactions of radioactive substances undergoing nuclear fission. The nucleus is the source of all this power.

How could something so small produce so much energy? The answer is found in the difference between the amount of matter before and after a nuclear reaction. Careful measurements reveal that a very small amount of matter disappears.

One tenth of one cent of the mass of the reactants vanishes during a fission reaction. Where does the mass go?

Einstein understood that the mass does not disappear. It is converted directly into energy. Einstein's equation told him how much energy. It shows that a tremendous amount of energy is locked within a very tiny amount of mass. Is there a conflict between Einstein's ideas and the Law of Conservation of Matter?

Einstein demonstrated that while mass is not always conserved, energy and mass are. The mass before nuclear reaction equals the mass and energy after the reaction. The Law of Conservation of Matter was changed to the Law of Conservation of Matter and Energy.

Fusion Reaction

There is another type of nuclear reaction more powerful than fission. It is called *nuclear fusion*. A fusion reaction occurs when two light atoms, such as two hydrogens, form one heavier atom, such as helium. Think of fusion as two nuclei that are fused together. How are fusion and fission different?

Fusion is the merging of two nuclei into one. Fission is the splitting a party of one nucleus into two. During a fusion reaction, one-half of one percent of the mass of the reactants is converted directly to energy as compare to one-tenth of one percent during a fission reaction. The fusion reaction produces five times more energy than fission reaction.

Fusion is a very important reaction to the Earth. Our sun is a gigantic fusion reactor. Every second, millions of tons of hydrogen nuclei are being fused into helium and other light elements. Without fusion, the Earth would be thrown into an endless night. Scientists today are trying to make fusion reactors generate electricity. Fusion reactors are still in the experimental stage.

One of the biggest problems with fusion reactors is that they require tremendous amounts of energy to work. To get hydrogen atoms to fuse, they must be heated to the same temperatures that are found inside the sun. Imagine heating up your oven to 100 million degrees Centigrade. At that temperature, any normal container would vaporize. When this and other problems are solved, there are several advantages of fusion over fission as a source of energy. Uranium, the reactant needed for fission, is scarce, while hydrogen, the reactant needed for fusion, is abundant. One problem with fission reactors is that they produce radioactive material, which is extremely harmful. The waste from a fission reactor can be dangerous to handle for hundreds of years. Fusion does produce radioactive materials, but they are less dangerous.

Objective 7: Nuclear Fission Reactor

The reactor core is the heart of a nuclear fission reactor. The fuel used by most reactors is uranium-235. A tiny pellet of uranium-235 about the size of your little fingernail will produce as much energy as a pile of coal two meters tall. In a nuclear reactor, pellets of uranium-235 undergo a controlled chain reaction. The intensity of the reaction is adjusted by control rods made of dense materials such as boron steel or cadmium. Control rods take away neutrons before they can collide with the uranium-235 atoms. Because there are fewer neutrons available to collide with uranium atoms, the rate of nuclear reaction drops.

By raising or lowering the control rods, the rate of nuclear reaction in the reactor core be increased or decreased. If all the control rods are lowered, so many neutrons are absorbed that there aren’t enough left to keep the chain reaction going, and the reactor shuts down. To start the reactor up, the control rods are raised. Because uranium-225 is radioactive, enough neutrons are released through natural decay to get the chain reaction going. The neutrons again bombard the uranium, and the chain reaction heats up the reactor core. A shield around the reaction core prevents leakage of radiation. The shield is usually made of thick blocks of lead and concrete.

The reactor core is surrounded by a *coolant*, usually water. The intense energy from the chain reaction heats the water to extremely high temperatures. Because the water is under a great deal of pressure, it remains a liquid at these high temperatures. This super hot water, which is also highly radioactive, is piped out of the reactor to the *heat exchanger*.

Objective 8: Evaluate the Use of Nuclear Reactors as an Energy Source

In summary, nuclear fission heats water, which is then pumped to the heat exchanger. Steam is formed, which in turn, powers a stream turbine. The turbine drives an electrical generator, which provides electricity to homes and businesses. An advantage of nuclear reactors is that they generate lots of energy. And, under normal conditions, they do not release pollutants into the air. But a major problem with nuclear reactors is that they produce radioactive waste. Radioactive fuel takes hundreds of years to decay. Today a lot of radioactive waste is being temporarily stored until a decision is made on how to best dispose of it. Another problem is how to service parts of the reactor that have become radioactive, such as coolant pipes.

Even though the industry does have a good long-term safety record, accidents have occurred. A nuclear plant cannot explode like an atomic bomb. Nuclear reactors do not contain the amount of fissionable uranium required for an atomic bomb. The accident that occurred in 1986 at a nuclear power plant in Chernobyl, Soviet Union, was caused by a steam explosion. The reactor core overheated and steam pressure built up until it exploded. This sent a cloud of radioactive steam and smoke into the atmosphere. This is a danger situation because radioactive materials that rise into the atmosphere are carried by the wind until they ball back to the earth as radioactive fallout. If the fallout is inhaled or lands on food that is eaten, people run the danger of getting radiation sickness.

Objective 9: Medical and Archaeological Uses of Radioactivity

Some of the best uses of radioactivity are in the fields of medicine and archaeology. In medicine, radioactive isotopes help us a great deal. Doctors use radioactive isotopes to diagnose and treat a number of illnesses.

For instance, a very small amount of radioactive material is placed in a patient. It is not enough to hurt the patient, but it is enough to produce an image of internal organs. Radioactive isotopes machine is called a *Gamma camera*. It is a kind of video camera that sees the gamma rays from the radioactive material inside the patient and records an image. To get this image, the patient is injected with radioactive technetium-99; this allows us to see inside the patient and find the problem.

Iodine-131, a radioactive form of iodine, is taken by patients with overactive thyroid glands. The gland, which in this case is malfunctioning, absorbs the iodine-131. Radiation given off by the iodine then destroys the tissue that is causing the problem. The reason iodine-131 is used is because it has a very short half-life. Once it does what we want it to do in the gland, it quickly decays into a stable, non-radioactive isotope. The reason radioactive isotope are so valuable in the treatment of illnesses, and why patients do not mind using them, is that if the technetium or the isotopes do its job, surgery may not be required.

In archaeology radioactive isotopes can be used to determine when certain species of animals roamed the earth. A technique called *radiocarbon dating* provides a way to find the answer. While alive, the animal ingested plants, which absorbed carbon dioxide from the atmosphere. The carbon dioxide contained a harmless radioactive isotope, carbon-14, along with the more common, non-radioactive carbon-12. Since the animal ate the plant, it also took in the carbon compounds. While it was living, the animal maintained a fixed ratio between carbon-12 and carbon-14. After it died, however, the carbon-14 content decreased because carbon-14 is radioactive. Since we know that the half-life of carbon-14 is 5700 years, we can tell, from the amount of carbon-14 left, just how long ago the animal died.

BACKGROUND

I have used the Texas Learning and Technology Group (TLTG) Integrated Physics & Chemistry courseware to teach my students. The course is an intricate weaving of a technology-based delivery system and of student-teacher interactions designed as a level 111 interactive Videodisc System. Students who have difficulty learning often do not know what information is important to learn and what strategies are helpful in learning how to learn.

Several teaching strategies have been found to be effective in helping students to acquire key concepts. Several of the strategies, such as note taking and cooperative learning, are also advantageous to students with average and above average learning skills.

GOALS

Major Goals Addressed by the TLTG Integrated Physics and Chemistry Science Project to Be Taught in the Unit of Radioactivity and Nuclear Reactions.

1. To increase student understanding of radioactivity and nuclear concepts in science.

2. To increase scientific literacy with emphasis on science, technology, and society.
3. To increase student interest in science.
4. To increase activities, which are challenging activities, designed for the student who is kinesthetic, visual-spatial, logical-mathematical, interpersonal, intrapersonal, linguistic, and auditory-musical.
5. To increase activities and allow students an opportunity for reinforcement of the concepts presented by teachers.

My Motto: Education for All Students. All Students Can and Will Learn, Succeed and Achieve.

This proposed curriculum unit will be taught to ninth through twelfth grade high school students.

The videodisc instruction may be led by the teacher, involve the entire class, or include small group practice activities, allowing three to five students to work together cooperatively.

The electronic system captures student interest by presenting radioactivity and nuclear reactions with entertaining scenarios and animation. The activities allow groups of three to five students to work at their own pace as they apply the principles they learned during the teacher-led instruction.

The remainder is devoted to laboratory activities, independent practice, enrichment and remediation activities, special projects and testing.

LESSON PLANS

Day 1 Lesson Strategy:

1. Review discoveries of Becquerel and the Curies
2. Relate radioactivity to changes in atomic nucleus
3. Apply term binding energy to radioactive decay

Day 2 Lesson Strategy:

1. Relate the term *decay series* to *radioactive decay*
2. Compare alpha, beta, and gamma decay
3. Review use of equation to describe nuclear decay
4. Define and discuss half-life

Day 3 Lesson Strategy:

1. Read and discuss pre-lab
2. Graph the data obtained in the simulation (half-life and original mass of a radioactive isotope)
3. Component of fission reaction

Day 4 Lesson Strategy:

1. Lab: Simulating the half-life of an unknown element. Students will work in lab. Groups. Six groups, with four students per group.

Day 5 Lesson Strategy:

1. Lab: Identifying components of a Fission Reactor. Students will work in lab. Groups. Six groups, with four students per group.

In This Activity You Will:

1. Simulate radioactive decay of an isotope using water;
2. Graph the data obtained in the simulation;
3. Operationally define half-life.

Materials:

Graduated 250-ml beaker
Solid substance, such as sand, salt, or sugar
Balance

Safety Equipment:

Goggles
Aprons

Procedure:

1. Weigh a clean dry beaker. Record the weight in Table 1

2. Pour 200 ml of the solid substance into the beaker. Weight and record the weigh in Table 1 and Trial 1.

3. Pour 100 ml of the solid out of the beaker. Your teacher will instruct you where to store the solid that is removed. Weigh the beaker and solid again. Record the weight as Trial 2.

4. Repeat Step 3, three more times pouring off half of the solid remaining each time. Weigh the beaker and the solid each time recording weights as Trials 3, 4, and 5.

5. Calculate the mass of the solid for each trial by subtracting the mass of the beaker from the mass of the beaker and solid. Record each mass in the appropriate space under the column labeled 'Mass of Solid' in Table 1.

6. Plot graph of the 'Number of Trials versus the Mass of the Solid.' The 'Number of Trials' (0-10) is on the X-axis and the 'Mass of the Solid' is on the Y-axis. Draw a smooth curve through the points.

Data Analysis:

1. What do the solid particles in the beaker represent?
2. What does the time between trials represent?
3. Why was half of the solid left in the beaker after each trial?
4. Can a projection be made from the graph of how many trials it would take to completely empty the beaker?
5. Why was the number of trials placed on the X-axis? Why was the mass of the solid placed on the Y-axis?
6. Using the information obtained in this activity, construct an operational definition of the term half-life.

Data Table 1

Number of trials	Mass of empty beaker	Mass of Beaker and Solid	Mass of solid
1.			
2.			
3.			
4.			
5.			

LAB ONE

Objective 7
Identifying Components of a Fission Reactor

Part A

Students will draw and label a diagram of a fission reactor. If necessary, they can use the information under the heading **Objective 7: Nuclear Fission Reactor**.

Part B

For each component labeled in Part A, describe its function.

Reactor Core
Cooling Tower
Control Rods
Coolant
Heat Exchange
Steam Turbine
Generator

LAB TWO

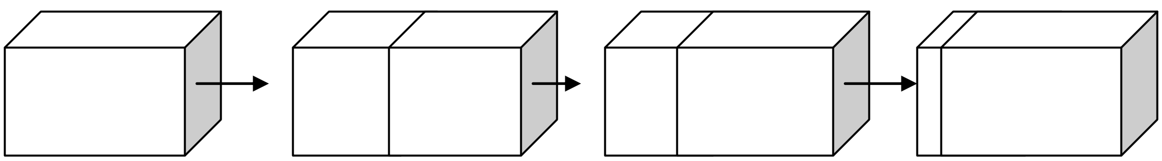
Objective 4
Laboratory 1: Simulating the Half-Life of an Unknown Element

Students will work in lab groups.

The half-life of a radioactive element is the time it takes for one half of the atoms in that element to decay into another element. Decay rates among radioactive elements vary tremendously. In this activity, you will simulate the decay of an element using water.

Radioactive Half-Life

½ decayed | ¾ decayed | $^{7}/_{8}$ decayed



First half-life | **Second half-life** | **Third half-life**

radioactive element | ½ radioactive element | ¼ radioactive element | $^{1}/_{8}$ radioactive element

BIBILOGRAPHY

Laboratory Manual. Prentice Hall, 1988.
The laboratory investigations in this laboratory manual provide you with the opportunity to investigate scientific problems in the same manner as that of a scientist. You may perform some of the same processes as you set up controlled experiments, construct models, and complete research.

O'Neill, Michael D., ed. *Chemistry*. Addison-Wesley Publishing Company, 1987.
Chemistry Laboratory Experiment

United States: Texas Learning Technology Group (TLTG) and the National Science Center Foundation, Inc. (NSCF), 1989.
This product was jointly developed by the TLTG, the NSCF, and the Texas Learning Association of School Boards. Major goals addressed by the TLTG Physical Science Projects are to increase student understanding of Integrated Physics and Chemistry; to increase scientific literacy with emphasis on science, technology, and society; and to increase student interest in science.