Module 5
Radiation around Us

What this module is about

Did you know that an effective way of treating cancer nowadays is with the use of radiation? Radiation therapy is now being practiced by some hospitals in Metro Manila like St. Luke's Medical Center, Makati Medical Center and Cardinal Santos Medical Center. The process is very well expressed as **radioactivity** – the transformation of an atom.

In this module you will learn many things about Physics, particularly about radiation. This module includes four (4) lessons such as:

- **Lesson 1 - Brief Account of Radioactivity**
- **Lesson 2 - Radioactivity**
- **Lesson 3 - Nuclear Reactions: A Menace?**
- **Lesson 4 - Applications of Radioactivity and their Implications**

Read, enjoy, and discover the secrets of Physics!

What you are expected to learn

After going through the module, you are expected to:

1. discuss the contributions of Becquerel, Pierre and Marie Curie on radioactivity;
2. discuss and compare the types and properties of ionizing radiation;
3. interpret equations on nuclear reactions;
4. explain Einstein's matter-energy equivalence; and
5. recognize the significance of the contributions of scientists in nuclear energy and related technology.

How to learn from this module

Here's a simple guide for you in going about the module.

1. Read and follow the instructions very carefully.
2. Take the pretest. It is a simple multiple-choice test provided at the start to determine how much you know about the content of this module.
3. Check your answers against the answer key provided at the last page of the module.
4. Be very honest in taking the test so you know how much knowledge you already have about the topic.
5. Read the different lessons about the earth, sun and moon.
6. Perform all the activities, as these will help you have a better understanding of the topic.
7. Take the self-tests at the end of each lesson for you to determine how much you remember about the lesson.
8. Finally, take the post test at the end of this module.

Good Luck and have fun!

What to do before (Pretest)

Direction: Choose the letter of the best answer. Write your answer on a separate sheet of paper.

1. What is the process by which elements change to other elements by the emission of ionizing particles?
    a. Radioactivity
    b. Chemical Change
    c. Physical Change
    d. None of these

2. Who is the polish chemist who received 2 Nobel prizes-one in physics and another in chemistry for his/her success in the field of radioactivity?
    a. Marie Curie
    b. William Roentgen
    c. Ernest Rutherford
    d. Henry Becquerel

3. Which of the following is INCORRECT?
   a. Atoms are made of subatomic particles called electrons, protons and neutrons.
   b. The electrons are distributed in space like a cloud around the nucleus.
   c. The nucleus of the atom consists of protons and neutrons.
   d. The electrons are found inside the nucleus of the atom.

4. What do you call the force that holds the nucleus together?
   a. nucleonic force
   b. gravitational force
   c. strong nuclear force
   d. electromagnetic force

5. Helium is 4x as massive as hydrogen. Compared to the size of hydrogen, helium is ___________.
   a. smaller
   b. of the same size
   c. twice as large
   d. four times as large

6. Which among the ionizing radiation can penetrate the farthest into a material?
   a. a beta particle
   b. a gamma ray
   c. an alpha particle
   d. All have the same penetrating capability.

7. The reason alpha rays are easy to stop is that they _____________.
   a. are relatively big
   b. slow down easily
   c. are doubly changed
   d. All of the above.

8. Large nuclei, like uranium, are radioactive because ____________.
   a. they have too much mass
   b. there are too many protons
   c. there are too many isolated neutrons
   d. they can hold extra particles, like beta rays

9. When Uranium (90 protons) ejects an alpha particle, how many protons does the remaining nucleus have?
   a. 92 protons
   b. 90 protons
   c. 88 protons
   d. 86 protons

10. What happens to the atomic number of an element which emits 1 alpha particle and 3 beta particles?
    a. increases by 1
    b. stays the same
    c. decreases by 2
    d. decreases by 1

11. What happens to the atomic number of an element which emits 1 alpha particle and 2 beta particles?
    a. increases by 1
    b. stays the same
    c. decreases by 2
    d. decreases by 1

12. A sample of a certain radioactive material has a half-life of 1 year. How much of this radioactive material will be left at the end of 3 years?
    a. one sixteenth
    b. one eighth
    c. one quarter
    d. one half

13. The half-life of most radioactive isotopes is about _________.
    a. 5700 years
    b. a few years
    c. a few seconds
    d. half lives range from very short to very long

14. The half life of a certain isotope is 1 day. At the end of 2 days, how much of the isotope remains?
    a. one half
    b. one quarter
    c. one eighth
    d. none of it

15. Energy released by the sun results from atomic nuclei __________
    a. combining
    b. breaking apart
    c. None of the above
    d. Needs more information to say

16. Splitting helium would yield ___________.
    a. a net release of energy
    b. a net absorption of energy
    c. neither absorption nor release
    d. Not enough information to say

17. Which shape uses the smallest amount of material when creating a critical mass?
    a. cube
    b. cone
    c. sphere
    d. elongated box

18. If gold were used as nuclear fuel, it would be best ____________.
    a. fused
    b. split
    c. either
    d. neither

19. Suppose hydrogen bombs were exploded in a box that could contain all the energy released by the explosion, the weight of the box after the explosion would be __________.
    a. less
    b. more
    c. the same
    d. none of the above

20. What technique is used by archeologist to determine the age of wooden artifacts?
    a. Carbon dating
    b. Radium dating
    c. Uranium dating
    d. Polonium dating

Key to answers on page 27

Lesson 1 A Brief Account of Radioactivity

Read this!

Do you still remember the word 'atom'? Atom is the smallest particle of matter. Its era began during Becquerel's time. Becquerel's discovery of radioactivity marked the beginning of the modern understanding of the atom.

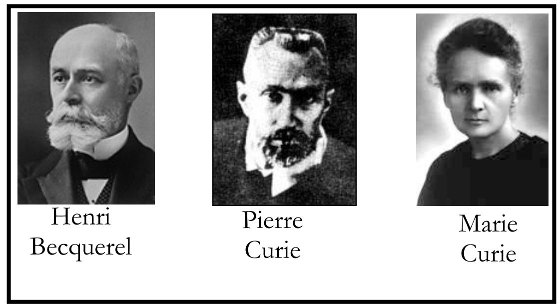


Fig. 1.1 Scientists who discovered radiation

Antoine Henri Becquerel was a physicist and an expert in the field of fluorescence. While studying a fluorescent compound that included an element called uranium; he noticed that the material was giving out a type of a ray that passes through foil which he used to wrap the material. He later discovered that this event only happens to uranium compound and not with others. Further experiments showed that there were 2 distinct types of radiation: the alpha and beta radiation, which consisted of electrically changed particles. Later, a third type, gamma radiation was discovered which proved to be a form of electromagnetic radiation.

Know this!

☆ Nobel Prize – prestigious award given to a person who has done extraordinary things.

☆ Electromagnetic waves – waves that do not need medium in order to propagate.

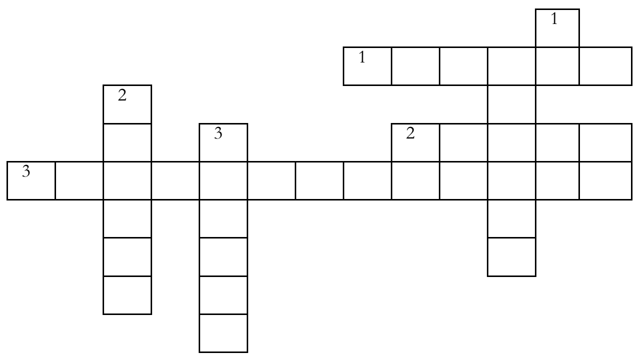
Marya Sklodowska (Marie Curie) was born on November 7, 1867 in Warsaw, Poland. She left for Sorbonne in Paris to study chemistry where he met and married another chemist, **Pierre Curie** (1859-1906).

In their own research on radiation, they were able to discover that a mineral uranium, is 4x as radioactive as pure uranium. This led them to conclude that the mineral must contain some unknown radioactive element. By 1902, they successfully separated 0.1 gram of the unknown element and called it radium. This breakthrough led them to a Nobel Prize in Physics in 1903 and a Nobel Prize in Chemistry in 1911. The Curies were the first scientists who received 2 Nobel Prizes.

What you will do

Activity 1.1 Try Me!

Direction: Answer the crossword puzzle given below.



Across

1. Marie Curie's husband
2. Becquerel's first name or given name
3. Process of atom transformation

Vertical

1. Element discovered by Becquerel to be radioactive
2. Radioactive element discovered by the Curies
3. Home town of Marie Curie.

Key to answers on page 27

The Nucleus of the Atom

Before we go on, identify the following parts of an atom

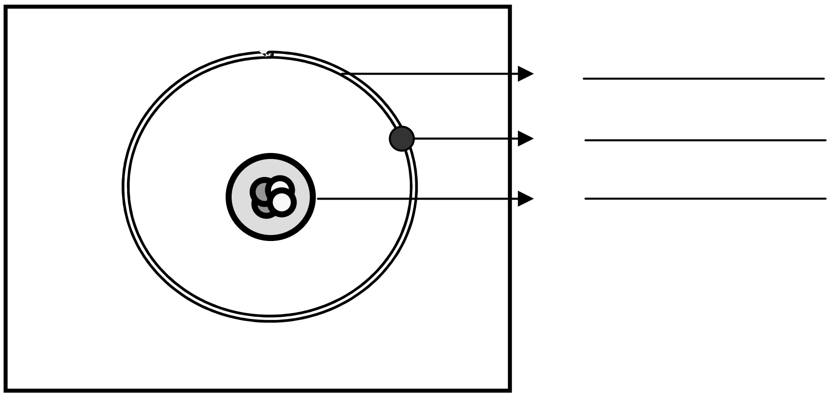


Fig 1.2 The Atom

Key to answers on page 27

Read this!

The atomic nucleus is a very tiny structure of an atom which is composed of particles called **nucleons.** Electrically charged nucleons are the protons and the neutrally charged nucleons are the neutrons. On the average, nucleons have nearly 2000 times the mass of the electron. This means that the mass of an atom is practically equal to the mass of its nucleus alone!

Electrons are held close to the nucleus by the protons. The neutrons, on the other hand, hold the nucleus together. Nucleons are bound by an attractive force known as the **strong nuclear force**, which holds the protons and neutrons together inside the nucleus.

$^{1}_{1}H$ Hydrogen $^{2}_{1}H$ Deuterium

$^{3}_{1}H$ Tritium

Fig 1.3 Isotopes of Hydrogen

In an electrically neutral atom, the number of protons inside the nucleus is equal to the number of electrons in the atomic orbital. A difference in the number of protons and electrons makes the atom a charged particle and is known as an **ion**. The number of neutrons in the nucleus, however, has no effect on the number of electrons an atom may have. This means that any change in the number of neutrons will not affect the chemical properties of an element. Elements having different numbers of neutrons but have the same number of protons have the same chemical properties and are called **isotopes.**

The common form of hydrogen has a bare proton as its nucleus. There are however different kinds of hydrogen as seen in figure 1.2. They all have the same number of protons but different number of neutrons. Thus, they are known as the isotopes of hydrogen: **deuterium** and **tritium.**

$^{1}_{1}H$ is a stable element. This means that it has no excess nuclear energy. On the other hand, $^{2}_{1}H$ and $^{3}_{1}H$ which are isotopes of hydrogen are unstable atoms. They have excess nuclear energy which is released when the neutrons inside their nuclei decay.

What you will do

Self-Test 1.1

Direction: Answer the following briefly.

1. What is the major contribution of the Curies in the field of radiation that gave them two Nobel prizes?
2. Who initiated the research on radiation?
3. Between what subatomic particles does the strong nuclear force act?
4. How does the number of electrons in an electrically neutral atom compare with the number of protons in its nucleus?
5. What do different isotopes of a given element have in common? How are they different?

Key to answers on page 28

Lesson 2 Radioactivity

Read this!

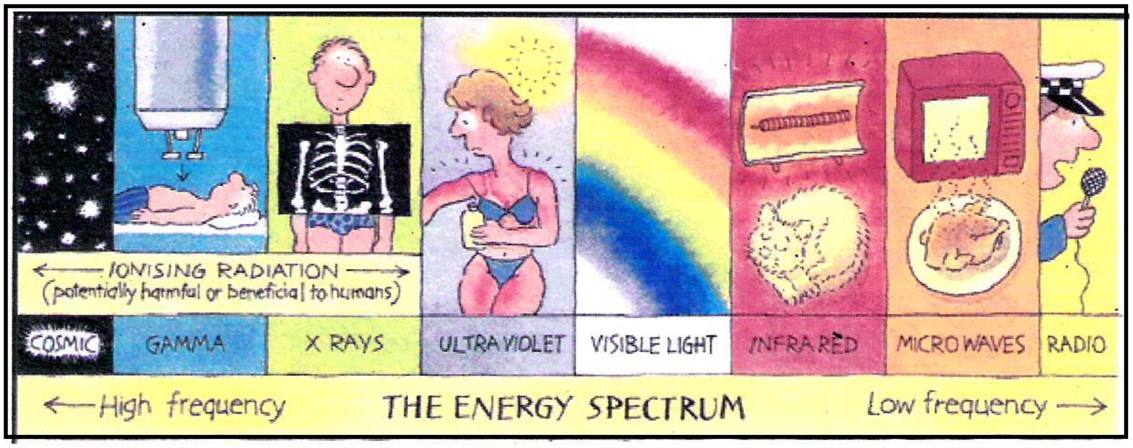


Fig 2.1 The Electromagnetic Spectrum

Radiation is energy in transit in the form of high speed particles and electromagnetic waves as seen in Figure 2.1. There are basically 2 types of radiation: the ionizing radiation and the non-ionizing radiation.

Take a look at figure 2.1. The electromagnetic waves that we often encounter such as visible light, radio waves, infrared, microwaves and UV are electromagnetic waves that do not carry enough energy to separate molecules or remove electrons from an atom. Such waves are called **non-ionizing radiation.**

The electromagnetic waves, on the other hand, such as x-rays, gamma rays and cosmic rays are known as **ionizing radiation**. These are the rays that carry amounts of energy large enough to remove electrons from the atom, thus making the atom a charged or an ionized particle. In the same manner, some atoms are unstable and are called radioactive. These atoms eventually disintegrate into a totally new atom. This process of spontaneous transformation of an unstable atom which results in the emission of radiation is called **radioactivity**.

Take a look at Figure 2.2. A single or lone neutron is an unstable neutron. While a neutron with a proton is a stable one. Neutrons without nearby protons decay into a proton and an electron (Figure 2.2). All nuclei that decay in this manner are known to be radioactive. Radioactive atoms decay and emit three distinct types of rays. These are the alpha particle (α) for an alpha decay, a beta particle (β) for a beta decay, and gamma ray (γ) for a gamma decay.

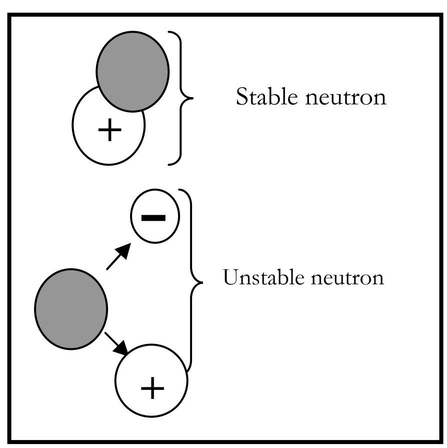


Fig 2.2 Stable and Unstable Neutron

Alpha particles consist of two protons and two neutrons in the form of atomic nuclei. They carry a positive electrical charge and are emitted from naturally occurring heavy elements such as uranium. Since alpha particles are relatively large they collide readily with matter and quickly loses this energy, thus they have little penetrating power. Sheets of paper and skin can easily block or stop alpha particles.

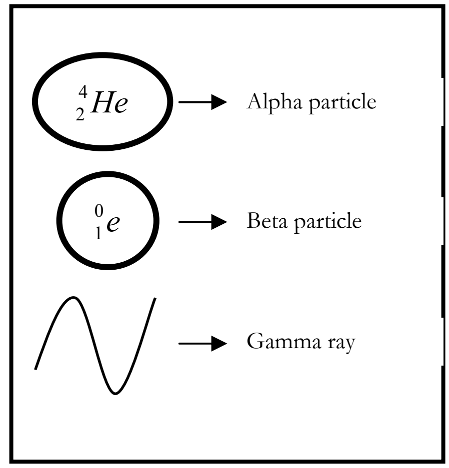


Fig 2.3 Ionizing particles and radiation

Beta particles, on the other hand, are fast moving electrons ejected from the nuclei. They are smaller than the alpha particle, thus they have greater penetrating capability. They can penetrate up to 2 cm of water or human flesh and can only be stopped by a sheet of aluminum.

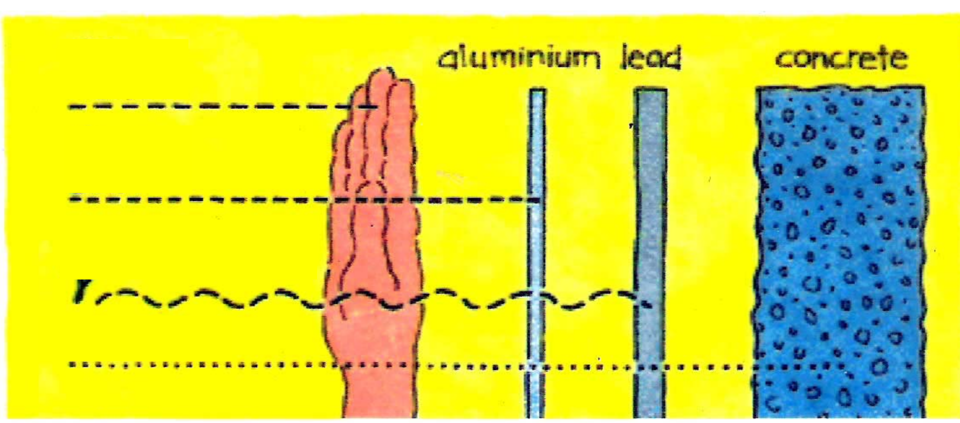
X-rays and gamma rays are transmitted through waves. X-rays are generally artificially produced while gamma rays are generally emitted from the atomic nucleus. Both have high penetrating power and can easily pass through the human body. Only thick barriers of concrete, lead or water can be used to stop them.

Neutrons are particles, that are highly penetrating. They usually originate from the splitting (nuclear fission) of atoms in a nuclear reaction. Water and concrete are the most common shields against neutron radiation.

What you will do

Activity 2.1 Ionizing Radiation

Direction: Identify the ionizing radiation that can penetrate the given materials.



Key to answers on page 28

Did you know that Uranium-238 can decay and become Thorium- 234? When a nucleus of an atom emits an alpha or a beta particle, a different element is formed. This changing of one element to another is called **transmutation.**

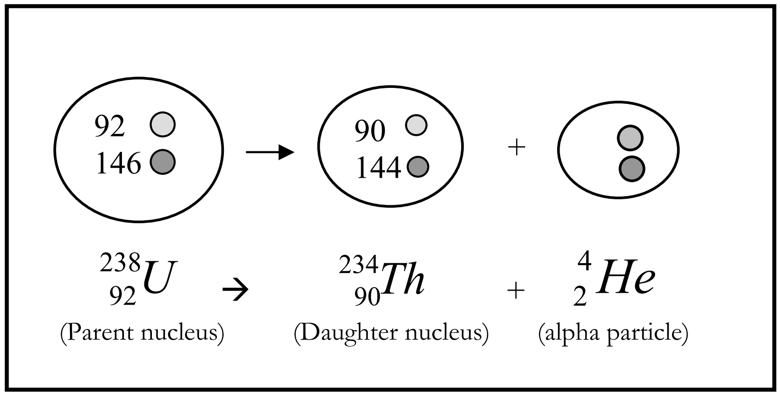


Fig 2.4 Transmutation of a radioactive element

Take a look at figure 2.4. Uranium-238 has 92 protons and 146 neutrons. The sum of the protons and neutrons is 238. This is known as the atom's mass number. **The mass number of an atom** is the total number of particles inside the atomic nucleus. If an alpha particle ($^{4}_{2}He$) is emitted then the mass number of Uranium is decreased by 4 while the number of protons is decreased by 2. This results to a nucleus with a mass number of 234 (*238-4=234*) 90 and protons (*92-2=90*). If we consult the periodic table of elements, the element with 90 protons and a mass number of 234 is Thorium. This means that Uranium (parent nucleus) has become thorium (daughter nucleus) when an alpha particle is emitted. This radioactive decay is particularly called **alpha decay**. When this happens, energy is then released in three forms: *gamma radiation, kinetic energy of the alpha particle and kinetic energy of the thorium.*

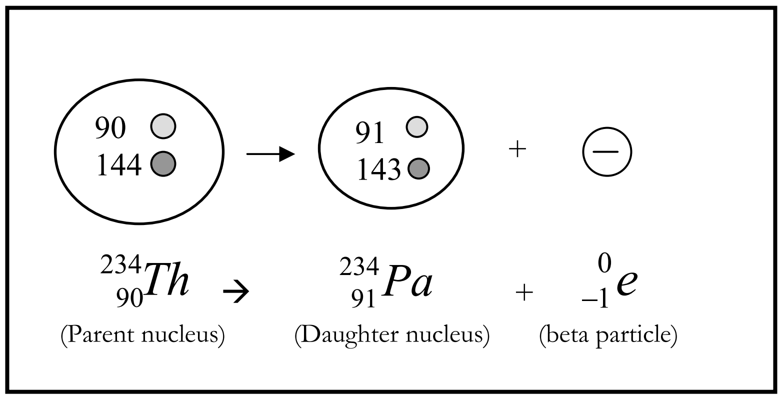


Fig 2.5 Beta Decay of Thorium-234

Take a look at figure 2.5. Thorium is still radioactive and can possibly emit a beta particle. Remember that a beta particle is an electron ejected from the nucleus. When a beta particle is ejected, a neutron changes into a proton. For thorium, beta emission leaves its initially 90 protons with fewer neutrons and an additional proton. Thus, the new nucleus has 91 protons and 143 neutrons. In the periodic table of elements the element which has 91 protons and 143 neutrons is Protactinium.

Gamma emission has no effect on the mass number or on the number of protons. Thus, for Thorium, gamma decay results to Thorium of lesser energy.

$$^{234}_{90}Th \rightarrow \; ^{234}_{90}Th + \gamma$$

Fig 2.6 Gamma decay of Thorium-234

Remember this!

The number of nucleons on the left side of the equation (reactants) must always equal the number of nucleons on the right side of the equation (products).

What you will do

Activity 2.2 Ionizing Radiation

Direction: Identify the nucleus of the new element designated by X in each of the following reactions.

1. $^{226}_{88}Ra \rightarrow X + \, ^{4}_{2}He$
2. $^{234}_{91}Pa \rightarrow X + \, ^{0}_{1}e$
3. $^{59}_{26}Fe \rightarrow X + \gamma$
4. $^{234}_{92}U \rightarrow X + \alpha$

Key to answers on page 28

The Half-life

226 *Ra*

Do you have any idea when will half of Radium-226 decay? The time needed for half of the active atoms to decay is known as half life. This means that half-life is the radioactive decay rate. In the case of Radium-226, its half-life is 1620 years. This means that after 1620 years, half of the 5-g sample which is 2.5 grams will decay leaving a 2.5 g active radium-226. Then after another 1620 years, half of the remaining 2.5 grams which is 1.25 grams will decay leaving 1.25 g active radium – 226.

Rates of radioactivity are remarkably constant and are not affected by any external conditions such as changes in pressure and temperature. Uranium-238 for example has a half-life of 4.5 billion years. This is measured using radiation detectors such as a Geiger counter and scintillation counter. A **Geiger counter** detects incoming radiation by its ionizing effect on enclosed gas in a tube. A **scintillation counter**, on the other hand, detects incoming radiation by flashes of light that are produced when charged particles or gamma rays pass through it. The half-life of an isotope is related to its rate of disintegration. Generally, half-life is shorter for more active substances. The half-life can be computed from the rate of disintegration, which can be done in the laboratory.

Geiger Counter   Scintillation Counter

Fig 2.7 Radiation detectors

What you will do

Activity 2.3 Half-Life

Objective:

To develop an understanding of half life of radioactive atoms.

Materials:

100 25-centavo coins, graphing paper

Procedure:

1. Place the 100 25-centavo coins in a shoe box.
2. Pour out the coins on a clean table.
3. Take out the coins that show the head. The coins that showed the head represents the decayed radioactive material.
4. Count how many coins are left after the 1^{st} throw. Record your data on the table provided.

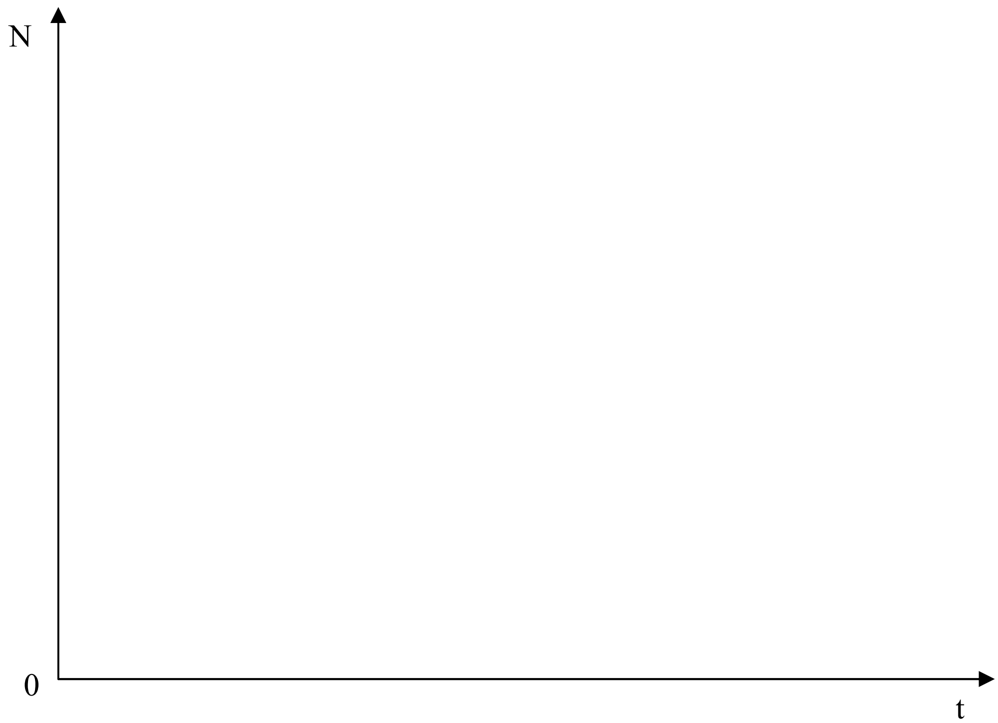
5. Place the remaining coins in the box. Then again pour out the coins on the clean table.
6. Take out the coins that show the head.
7. Count how many coins are left. Record your data on the table provided.
8. Continue doing the activity until only 2 or 3 coins are left.

Data and Results

Number of throws	Number of decayed coins	Number of coins left
0		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		

Analysis:

1. Using your data what do you notice about the rate at which the coins “decay” as their number decreases?
2. Plot the graph of the number of coins left (N) against the number of throws (t). The number of coins should be along the vertical axis while the number of throws should be on the x-axis.



3. How would you describe the graph?
4. Describe in your own words what half-life is.

Key to answers on page 29

What you will do
Self-Test 2.1

Direction: Answer the following briefly.

1. Identify the daughter nucleus in the decay of $^{234}_{92}U$ by alpha particle emission.
2. Name the element that results from the alpha decay of polonium.
3. If a sample of a radioactive isotope has a half-life of 2 years, how much of the original sample will be left at the end of the 4th year?

Key to answers on page 29

Lesson 3 Nuclear Reaction: A menace?

Take a look at figure 3.1. These are 2 instances of nuclear reactions, one brings about destruction while the other is a constant source of energy of the planet.

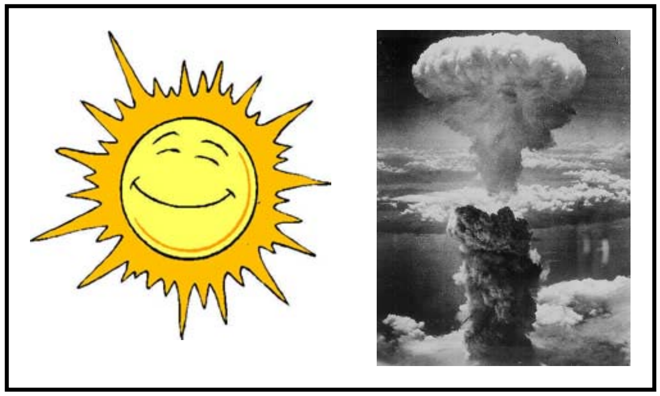


Fig 3.1. Nuclear Reactions

The atomic bomb that hit Hiroshima during World War II was discovered in 1939. It involved the splitting of the atoms, a process known as **nuclear fission**.

Take Note of these!
Nuclear Fission

The nucleus of the atom is held together by a strong nuclear force. When the strong nuclear force is greater than the repulsive electrical force within the nucleus, then the nucleus maintains its shape as shown in figure 3.2. However, if the repulsive electrical force increases and the nuclear force decreases to a critical level, the nucleus elongates. The nucleus further elongates with increasing electrical force until it splits. One way for an atom to split is when it absorbs a neutron.

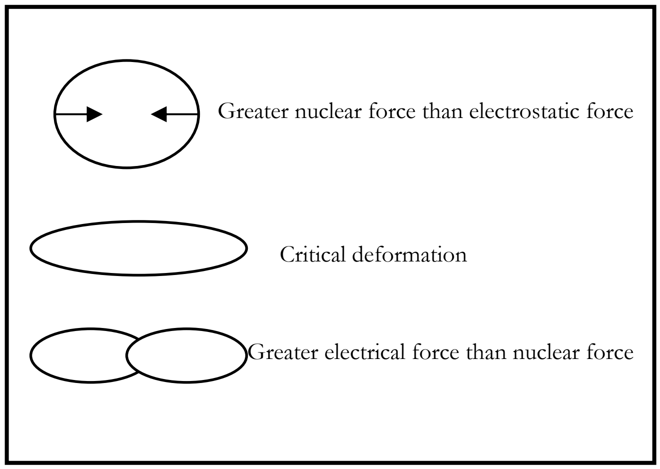


Fig 3.2. Forces within the atomic nucleus

Take a look at figure 3.3. This is what happens when one neutron starts the fission of a uranium atom. It could result to a combination of smaller nuclei emitting two neutrons. These two new neutrons in turn can cause the fissioning of two other atoms which in turn can cause more atomic fissioning. This makes a **chain reaction.** Specifically, fission reaction occurs to the rare isotope of U-235. If a chain reaction occurs in a pure U-235, a great explosion will likely to occur. This makes U-235 a dangerous isotope of Uranium-238. But don't worry, it is very difficult to separate enough U-235 from U-238 for an atomic bomb. In fact, it took the scientists more

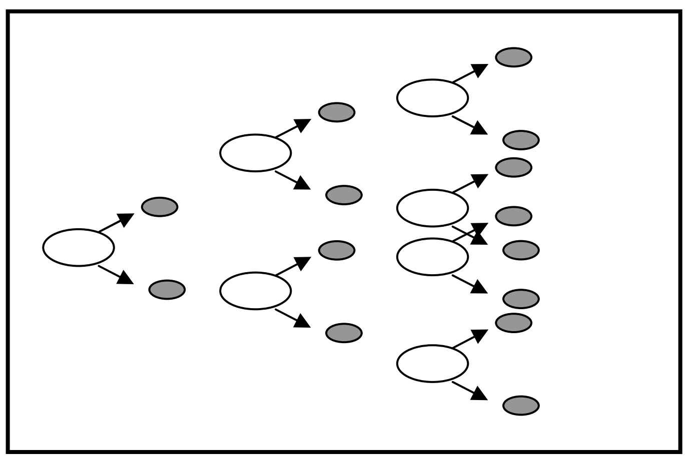


Fig 3.3. Chain reaction

than two years to extract enough U-235 from uranium ore to make one atomic bomb that hit Hiroshima in 1945.

Think about it!

Nuclear Fusion

Take a look at the picture of the sun. What color do you see? Is this the real color of the sun? What about the energy or light it emits? Is it also colored yellow? The sun is really a yellow star. This is because the sun is a middle-aged star. The color of the star tells us its temperature. Yellow stars have surface temperatures of about 6000 ^{o}C. But the inside of the sun is much hotter than the surface.

Astronomers believe that the inside temperature of the sun is over 13 million degrees Celsius (13 000 000 ^{o}C). This very high temperature on the inside makes it possible for the sun to undergo a process called **nuclear reaction**. In a nuclear reaction, the atomic nuclei are changed. Atomic nuclei combine in the sun's interior. This kind of nuclear reaction is called t**hermonuclear fusion.** Since the sun is about 80% hydrogen, 18% helium, and 2% other elements deep inside the sun, the hydrogen nuclei fuse or combine to form a nucleus of helium.

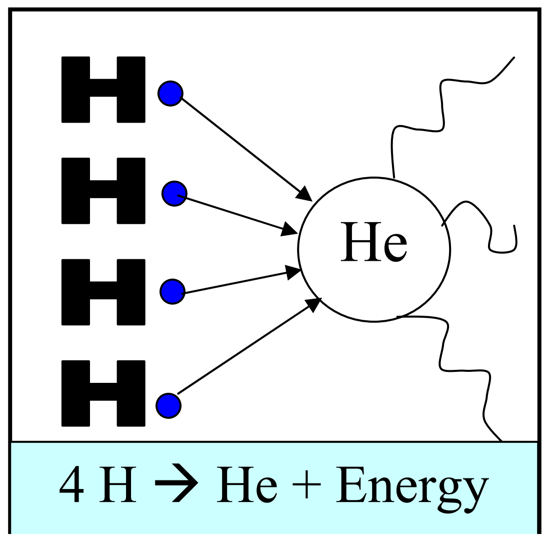


Fig 3.4. Thermonuclear Fusion

In this reaction, four hydrogen nuclei combine to form one helium nucleus. The mass of the helium nucleus is usually much less than the combined mass of the four hydrogen nuclei. This missing mass is a matter that is changed into an amount of energy. This conversion of mass to energy is done using Einstein's principle of matter-energy equivalence. It is usually expressed in his famous equation:

$$E = mc^2$$

where

E = the equivalent energy of a difference in mass
m = difference in mass after a nuclear reaction
c = conversion factor which is also known as the speed of light
= 3×10^8 m/s

This equation means that any change in the mass of a radioactive substance after a nuclear reaction (nuclear fission or nuclear fusion) is converted into a form of energy. In the case of the sun, thermonuclear fusion results to a difference in mass which is detected in the form of electromagnetic waves such as light, UV and microwaves.

What you will do

Activity 3.1 Reminiscing Nuclear Energy

Look for articles or pictures of the Bataan Nuclear Power Plant. Identify what nuclear reaction is used to acquire energy. What are the possible advantages and disadvantages of its construction and operation in the Philippines (Cite at least 2 advantages and 2 disadvantages).

Key to answers on page 29

What you will do

Self-Test 3.1

Direction: Answer the following very logically.

1. What happens when U-238 absorbs a neutron?
2. What becomes of the loss in mass of nucleons when heavy atoms split?
3. What becomes of the loss in mass of nucleons when light atoms fuse to become heavier ones?
4. Why are fusion reactors not yet a present day reality like fission reactors?

Key to answers on page 29

Lesson 4 Applications and Implications

Did you know that most radiation that we encounter originate in nature? It is in the ground where you stand on, in the bricks and in the building. Even air is slightly radioactive. This natural background radiation is believed to be present before we even know about it. It is believed to be existing before the human race existed.

How much radiation do you receive when you undergo chest x-ray? Is this amount of radiation harmful to the tissue?

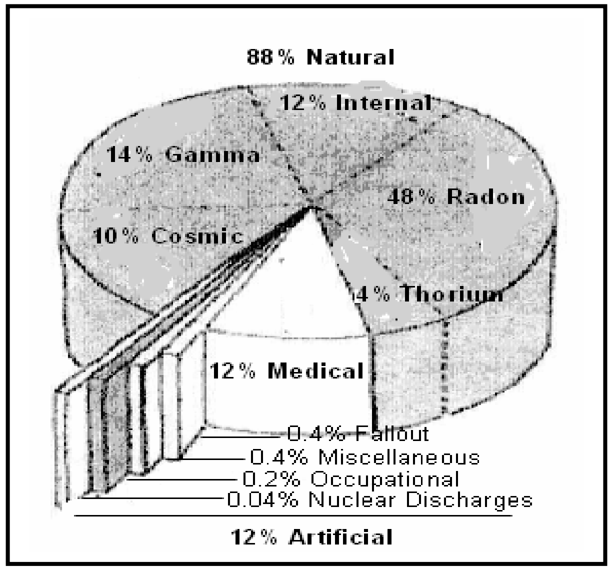


Fig 4.1. Background radiation

Read this!

The amount of ionizing radiation or '**dose**' received by a person is measured in terms of the energy absorbed in the body tissue and is expressed in **gray**. One gray (Gy) is one joule deposited per kilogram of mass. Equal exposure to different types of radiation expressed as gray does not necessarily mean the same biological effects. For example, one gray of alpha radiation will have greater effect than one gray of beta radiation. The unit known as **sievert (Sv)** is used to express the radiation effect as **effective dose**. Accordingly, 2-10 sievert doses are believed to cause severe radiation sickness and can be fatal.

Fig 4.2 Chest X-ray

Table 4.1. Effective dose in Sv and their corresponding biological effects.

Effective dose	Biological Effect
1 Sv	Threshold for causing immediate radiation sickness
100 mSv and above	The probability of cancer increases with dose
20 mSv/yr	Estimated effective dose of people who work in mines and hospitals
2 mSv/year	Typical background radiation from natural sources. This is close to the minimum dose received by all humans anywhere on Earth.

What you will do

Activity 4.1 Computing my effective dose

We live in a radioactive world. By filling out this form, you will get an idea of the amount of radiation you are exposed to every year. The average Filipino is exposed to between 100 and 300 units each year.

	YOUR ANNUAL TOTAL
Cosmic radiation that reaches earth:	44
Because cosmic radiation is modified by the atmosphere add 1 for every 100 feet above sea level	______
If your house is brick or concrete add 45 stone add 50 wood add 35	______
Ground radiation	15
Water, food, air radiation	25
Nuclear weapons testing fallout	4
If you have had a chest x-ray this year add 9 for each one:	______
If you've had intestinal x-ray add 210	______
For each 1500 miles you've flown in an airplane during the year add 1:	______

If you live within 5 miles from a nuclear plant add 0: ______

If you sleep with your spouse add 0.1: ______

TOTAL ______________

*Note: The unit in this computation is mSv. Check out table 4.1 if your annual dose is within the optimum range.

Key to answers on page 29

Although radiation is a menace at high levels, radiation in correct doses has many uses. Medical and dental x-rays discern hidden problems. Radiation is used to diagnose ailments. Cancer patients are treated with radiation.

Aside from its medical applications, radiation can also be used as a technique by archeologist to establish the dates of wooden artifacts and skeleton. This process is known as carbon dating. The dating of older, but non-living things like the planet earth is done using uranium dating technique. Further, nuclear reactions can produce large amounts of energy that could sustain life on earth for a long time. We all benefit from a multitude of products and services made possible by the careful and responsible use of radiation

Fig 4.3. Applications of Radiation

What you will do

Self-Test 4.1

Direction: Answer the following very briefly.

1. Cite at least 3 applications of radiation.
2. What is the probable reason why some people think of radiation as a menace?
3. Differentiate carbon-dating and uranium-dating.

Key to answers on page 30

Let's summarize

1. Radioactivity is the process of atomic transformation.
2. Radiation is an energy released in the form of high speed particles or electromagnetic waves during a nuclear reaction.
3. Henry Becquerel discovered that uranium is radioactive. Marie and Pierre Curie discovered the element radium.
4. The isotope of an element has the same number of protons as the element but has different number of neutrons.
5. Ionizing radiation has enough energy to separate molecules or remove electrons from an atom while non-ionizing radiation does not have enough energy to remove electrons from an atom.
6. Radioactive atoms decay and emit three distinct types of rays: alpha particle in an alpha decay, beta particle in a beta decay, and gamma ray in a gamma decay.
7. Transmutation is the changing of one element to another by emission of an alpha particle or a beta particle.
8. Half-life is the time needed for half of the active atoms to decay.
9. Geiger counter is a radiation detector that detects incoming radiation by its ionizing effect on enclosed gas in a tube. Scintillation counter is a radiation detector that detects incoming radiation by flashes of light that are produced when charged particles or gamma rays pass through it.
10. There are two types of nuclear reactions: nuclear fusion and nuclear fission. Nuclear fission is the splitting of atom that releases tremendous amount of energy while nuclear fusion involves combining the nuclei of atom to produce large amounts of energy.
11. Radiation can be a menace through the production of atomic bombs. However, radiation is of great help to humans especially in the field of medicine and archeology, and as an energy source.

Posttest

Direction: Choose the letter of the best answer. Write your answer on a separate sheet of paper

1. The energy released in the form of high speed particles or electromagnetic waves during a nuclear reaction is known as ____________.
    a. chemical energy
    b. electrical energy
    c. stored energy
    d. radiation

2. The physicist and the specialist in the field of fluorescence who discovered that the element uranium is radioactive is ______________.
    a. Marie Currie
    b. William Roentgen
    c. Ernest Rutherford
    d. Henri Becquerel

3. Which of the following compose the nucleons?
    a. electrons, protons and neutrons.
    b. electrons and protons
    c. neutrons and electrons
    d. protons and neutrons

4. What do you call the force that maintains the electrons in their orbitals?
    a. nucleonic force
    b. gravitational force
    c. electrostatic force
    d. strong nuclear force

5. Helium is 4x as massive as hydrogen. Compared to the size of hydrogen, helium is ___________.
    a. smaller
    b. of the same size
    c. twice as large
    d. four times as large

6. Which among the ionizing radiation can penetrate the least into a material?
    a. an x-ray
    b. a beta particle
    c. a gamma ray
    d. an alpha particle

7. The reasons alpha rays are easy to stop is that they _____________.
   a. are relatively big
   b. slow down easily
   c. are doubly changed
   d. All of the above.

8. Large nuclei, like radium are radioactive because ____________.
   a. they have too much mass
   b. there are too many protons
   c. there are too many isolated neutrons
   d. they can hold extra particles, like beta rays

9. When Uranium (90 protons) ejects a beta particle, how many protons does the remaining nucleus have?
   a. 92 protons
   b. 91 protons
   c. 90 protons
   d. 89 protons

10. What happens to the atomic number of an element which emits 1 alpha particle and 1 beta particle?
    a. increases by 1
    b. stays the same
    c. decreases by 2
    d. decreases by 1

11. What happens to the atomic number of an element which emits 1 alpha particle?
    a. increases by 1
    b. stays the same
    c. decreases by 2
    d. decreases by 1

12. A sample of a certain radioactive material has a half-life of 1.5 year. How much of this radioactive material will be left at the end of 3 years?
    a. one sixteenth
    b. one eighth
    c. one quarter
    d. one half

13. The half-life of most radioactive isotopes is about _________.
    a. 5700 years
    b. a few years
    c. a few seconds
    d. half lives range from very short to very long

14. The half life of a certain isotope is 2 days. At the end of 2 days, how much of the isotope remains?
    a. one half
    b. one quarter
    c. one eighth
    d. none of it

15. Which of the following nuclear reactions is responsible for the release of energy by the sun?
    a. Nuclear Fission
    b. Thermonuclear Fusion
    c. None of the above
    d. Needs more information to say

16. When an element splits, the process would yield ___________.
    a. a net release of energy
    b. a net absorption of energy
    c. neither absorption nor release
    d. Not enough information to say

17. Which shape uses the smallest amount of material when creating a critical mass?
    a. cube
    b. cone
    c. sphere
    d. elongated box

18. If gold were used as nuclear fuel, it would be best ____________.
    a. fused
    b. split
    c. either fused or split
    d. neither fused nor split

19. An experimenter finds that 50% of a sample of U-238 has decayed. Since U-238 has a half-life of 4.5 billion years, the sample's age is about __________.
    a. 0.60 billion years
    b. 1.12 billion years
    c. 2.25 billion years
    d. 4.50 billion years

20. The reason carbon-dating works is that ______________.
    a. plants and animals are such strong emitters of carbon-14
    b. after a plant or animal dies, it stops taking in fresh carbon-14
    c. there is so much non-radioactive carbon dioxide in the air
    d. when a plant of an animal dies, it stops producing oxygen

Key to answers on page 30

Key to Answers

Pretest

1. A
2. A
3. D
4. C
5. D
6. B
7. D
8. C
9. C
10. A
11. B
12. B
13. D
14. B
15. A
16. A
17. D
18. B
19. C
20. A

Lesson 1

Activity 1.1

										[1]U		
							[1]P	I	E	R	R	E
		[2]R								A		
		A		[3]P				[2]H	E	N	R	I
[3]R	A	D	I	O	A	C	T	I	V	I	T	Y
		I		L						U		
		U		A						M		
		M		N								
				D								

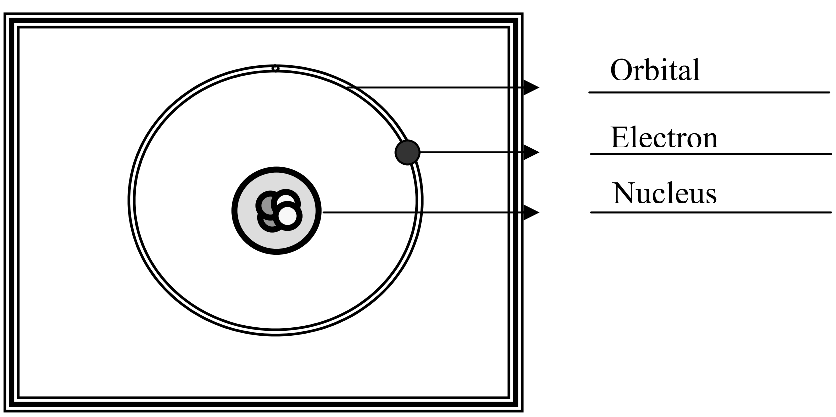


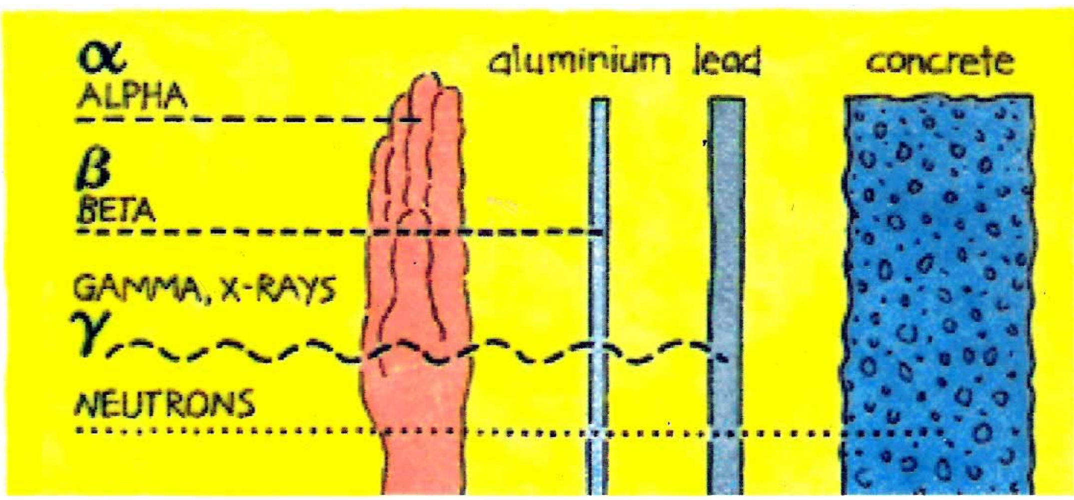
Fig 1.2. The Atom

Self-Test 1.1

1. The discovery of Radium.
2. Antoinne Henri Becquerel
3. Protons and neutrons
4. The number of electrons is equal to the number of protons in an electrically neutral atom.
5. Isotopes of a given element have the same number of protons or atomic number but have different number of neutrons.

Lesson 2

Activity 2.1



Activity 2.2.

1. $^{222}_{86}Rn$

2. $^{234}_{92}U$

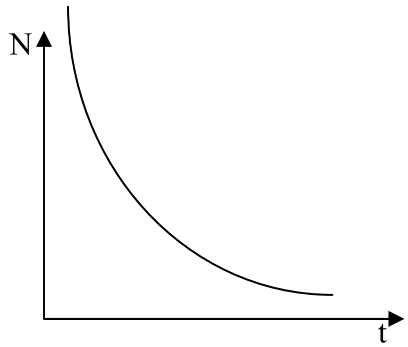
3. $^{59}_{26}Fe$

4. $^{230}_{90}Th$

Activity 2.3.

Analysis

1. As the number of coins decreases, the rate at which the coins "decay" also decreases. This is because as the atoms are disintegrating all the time, there will be fewer and fewer atoms left which still have to disintegrate.

2. 

3. The graph shows a decreasing N as t increases.
4. Half life is the time it takes for the amount of radioactive substance to be reduced to half its original value.

Self-Test 2.1.

1. ${}^{234}_{92}U \rightarrow {}^{230}_{90}Th + {}^{4}_{2}He$
   (daughter)
2. ${}^{209}_{84}Po \rightarrow {}^{204}_{82}Pb + {}^{4}_{2}He$
   Lead (Pb) is the element that results from alpha decay of polonium

3. One-fourth

Lesson 3

Activity 3.1

1. Nuclear Fission is used as a process of acquiring energy in Bataan Nuclear Power plant.
2. Advantages:
   a. New source of energy
   b. Additional employment or jobs
   Disadvantages:
   c. Radiation pollution
   d. Cycle disruption

Self-Test 3.1

1. U-238 will emit a beta particle and becomes neptunium.
2. Loss in mass is radiated as energy.
3. Loss in mass is radiated as energy.
4. Sustained fusion reaction is not yet possible on earth.

Lesson 4

Activity 4.1 – Answers may vary

Self-Test 4.1

1. Applications
    a. Cancer treatment
    b. Carbon-dating
    c. Source of energy
2. Disadvantages
    a. Construction of destructive atomic bombs
    b. Excessive radiation use brings about cancer
    c. Radiation pollution
3. Carbon-dating is a technique used in dating dead living organisms while uranium-dating is a technique used in dating older nonliving things.

Post Test

1. D
2. D
3. D
4. C
5. D
6. D
7. D
8. D
9. B
10. D
11. C
12. C
13. D
14. A
15. B
16. A
17. C
18. C
19. D
20. B

-End of Module-

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