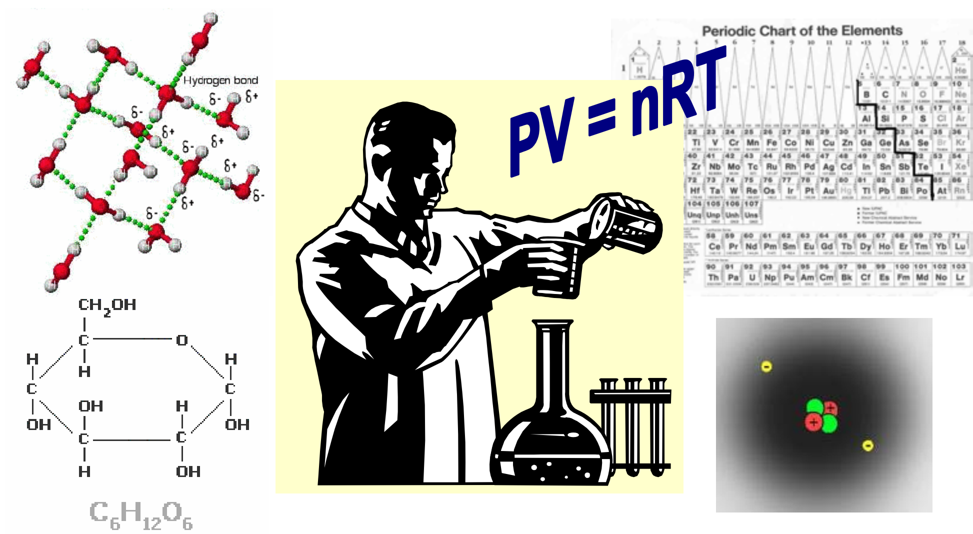
Project EASE

(Effective Alternative Secondary Education)

CHEMISTRY



MODULE 10

What's Inside the Atom?

BUREAU OF SECONDARY EDUCATION
Department of Education
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Module 10
What's Inside the Atom?

What this module is about

Atoms are the basic building blocks of matter. This concept started around 440 B.C. and it changed and evolved throughout the centuries. For example, the ancient Greek philosophers Leucippus and Democritus believed that atoms were solid. But in 1911, Ernest Rutherford proved that the atom was mostly empty space.

In this module, we will present the evolution of the concept of the atom and the modern ideas of atomic structure. We will cover the following lessons:

- **Lesson 1 – Early Ideas about the Atom**
- **Lesson 2 – The Subatomic Particles**
- **Lesson 3 – Radioactivity and the Nuclear Model of the Atom**
- **Lesson 4 – Atomic Spectra and the Atomic Structure**

The topics listed here seemed too "scientific" but the knowledge you will gain from them can be used in different aspects of our life. Ready?

What you are expected to learn

After reading this module, you are expected to have accomplished the following:

1. cite significant changes in the development of the atomic theory;
2. interpret the Law of Conservation of Mass, the Law of Definite Composition, and the Law of Multiple Proportion;
3. explain the statements in Dalton's atomic theory;
4. state the importance of cathode rays and radioactivity in determining the structure of the atom;
5. state the characteristics of subatomic particles;
6. determine the number of protons, electrons, and neutrons of some elements;
7. define isotopes;
8. infer the relationship between atomic mass and relative abundance;
9. compute for the atomic weights of some atoms;
10. describe radioactivity;
11. explain why some radioactive elements are useful and dangerous;

12. state ways of protecting oneself from dangerous radiation;
13. contrast different models of the atom; and
14. discuss the influence of atomic spectra and electron spectra on the modern views of atomic structure.

How to learn from this module

This module is written to meet your special needs. This module allows you to learn at your own pace and space. But for you to gain the most out of this module, we suggest that you do the following:

1. Find a quiet place where you can concentrate on reading this module.
2. Set-up a schedule for reading all the lessons in this module. For example, you may finish up to lesson 2 today, and then, tomorrow, you will tackle lessons three to five. And you will read the next lessons the day after.
3. Conduct the activities described in each lesson. These activities are simple and they can help you understand the concepts presented.
4. Answer the self-tests found at the end of each lesson. These self-tests gauge your understanding of the given lesson. They will tell you whether you have learned or you have not learned enough from the lesson. Do not forget also to answer the pretest and the posttest!

Learning by yourself takes a lot of self-discipline and determination. I'm sure you have these traits in you.

What to do before (Pretest)

Multiple Choice. Choose the letter of the best answer. Write the chosen letter on a separate sheet of paper.

1. What happens to the mass of materials when they undergo a chemical reaction?
   a. Increase
   b. Decrease
   c. Remains the same
   d. Ultimately disappears

2. Which of these was not discovered using the cathode ray tube?
   a. X-rays
   b. Protons
   c. Neutrons
   d. Electrons

3. Which describes the neutron?
    a. It is negatively–charged
    b. It is part of alpha–radiation
    c. It was discovered by Goldstein
    d. It is lightest subatomic particle

4. What is the mass number of an atom of Berkelium that has 97 protons, 97 electrons, and 150 neutrons?
    a. 53
    b. 97
    c. 194
    d. 247

5. Which best describes isotopes?
    a. Same number of neutrons, different number of electrons
    b. Same number of neutrons, different number of protons
    c. Same number of protons, different number of electrons
    d. Same number of protons, different number of neutrons

6. Which of these home appliances uses a cathode ray tube?
    a. Electric fan
    b. Television
    c. Refrigerator
    d. Rice cooker

7. Which can you observe in a radioactive material?
    a. It produces only a little amount of heat.
    b. The atom transmutes into another kind of atom.
    c. The radioactive atom absorbs alpha, beta, and gamma rays.
    d. The atom changes its phase and color as it releases radiation

8. If there were five positive charges (+5) and three negative charges (–3) in a body, what would be the overall charge of the body?
    a. +3
    b. +2
    c. –2
    d. –3

9. What subatomic particles account for the mass of the atom?
    1. electron   2. proton   3. neutron

    a. 1 and 2
    b. 2 and 3
    c. 1 and 3
    d. 2 only

10. Who is regarded as the father of modern atomic theory?
    a. Lavosier
    b. Rutherford
    c. Dalton
    d. Thomson

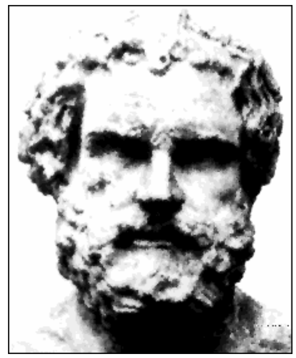
Key to answers on page 27.

Lesson 1. Early Ideas About the Atom

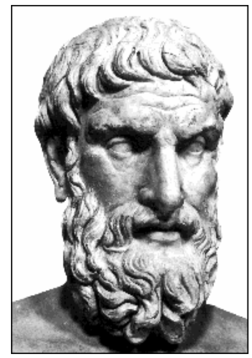
Matter is basically made up of atoms. This theory started more than 2,400 years ago in Ancient Greece. But its rapid development only began about 1,000 years ago, when John Dalton presented his own version of the atomic theory in 1803. In this lesson, we will present the original Greek concept of the atom, and that of Dalton.

The Greek Concept

During the ancient times (around 440 B.C.), many of the "scientists" were philosophers. They did not prove or disprove ideas using experiments. Rather, they used good arguments to show that an idea was true. And so, Leucippus used logical reasoning to support the idea that "***all things are basically made up of atoms***". There were no experiments during his time. Of course, this means that Leucippus did not convince some philosophers. Those who agreed with Leucippus were called "**atomists**". One of the first atomists was Democritus. He was a student of Leucippus. Later on, another scientist-philosopher, Epicurus, improved the "atomos" concept.



Democritus



Epicurus

Let us understand the ideas of these atomists by conducting this simple activity:

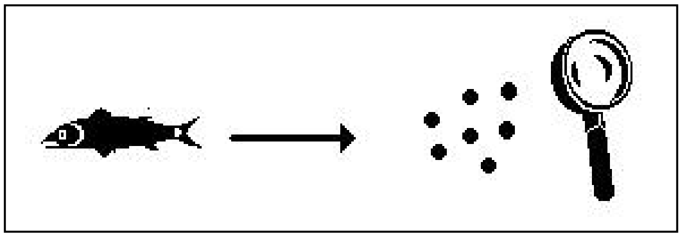
What you will do

Activity 1.1 Cutting Matter

1. Observe the head of a fried fish.
    a. Can you identify the lips? The eyes? The teeth?

2. Using a small knife, chop the head of a fried fish into smaller pieces.
    a. Can you still identify the lips? The eyes? The teeth?
    b. If not, what do you now have?

3. Grind the white eyeball into smaller pieces. Look at the newly formed pieces using a lens.
    a. Are the smaller pieces still similar with the original? Why? Why not?
    b. Can you still cut these pieces into smaller ones?
    c. Is it possible to keep on cutting and dividing these pieces?



The answer of atomists to the question in # 3 c. is obviously “No”. They believe that all matter is made of atoms, which are bits of matter. You can cut and divide matter until you reach a point where the pieces cannot be cut nor divided anymore. This means that atoms cannot be split into smaller bits. According to Democritus,

> *"They have all sorts of shapes and appearances and different sizes.... Some are rough, some hook-shaped, some concave, some convex and some have other innumerable variations."*

Do you agree with them? Now let’s take a look at the Atomic Theory of John Dalton.

Dalton’s Atomic Theory

John Dalton is considered the Father of the Modern Atomic Theory. He was a chemist who studied the works of Lavoisier and Proust. Antoine Lavoisier established the **Law of Conservation of Mass** while Joseph Proust observed the **Law of Definite Proportions**. Using these laws, Dalton formulated his atomic theory. Let us first take a look at these laws.

Law of Conservation of Mass	**Law of Definite Proportions**
“The total mass of materials before a chemical reaction takes place is exactly equal to the total mass of the materials that result after the reaction is completed.”	*“The proportion by mass of the elements in a given compound is always the same.”* It is also known as the “Law of Constant Composition”.

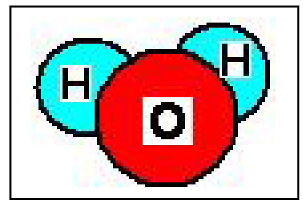
John Dalton believed that these two laws supported the idea of atoms. He formulated an atomic theory that included the observations of Lavoisier and Proust. This atomic theory has these statements:

#1 - **All elements are composed of atoms, which are indivisible and indestructible particles.** For example, an element, like gold, is made up of gold atoms. The atoms of gold cannot be destroyed nor divided to form other atoms. The Law of Conservation of Mass supports this statement.

#2 - **All atoms of the same element are exactly alike.** This means that one atom of the element platinum looks exactly the same as any other atom of platinum. It also means that the mass of one atom of an element is exactly equal to the mass of another atom of the same element.

#3 - **All atoms of different elements are different.** This statement is a follow-up of statement #2. It means that the atoms of the element silver are different from the atoms of the element oxygen. And one important difference among different atoms is their masses. The atoms of an element may have a greater or lesser mass than the atoms of another kind of element. Both statements #2 and #3 agree with the basic assumption of the Law of Definite Proportions: that the mass of atoms does not change.

#4 - **The joining of atoms of two or more elements form compounds**. When an atom of one kind of element is joined with another atom of another kind of element, a compound is formed. Dalton further stated that in any compound, the atoms of the different elements in the compound are joined in a definite whole-number ratio. For example, in the compound water, a particle of water is made up of one atom of oxygen and two atoms of hydrogen. The ratio of oxygen to hydrogen is 1:2.



A water molecule

Some elements also show that they form various ratios. For example, iron can form a compound with oxygen in the ratio of 1:1. This means that for every atom of iron, there is one atom of oxygen. At the same time, iron can form another compound with oxygen in the ratio of 2:3. This means that for every two atoms of iron, there will be three atoms of oxygen. In other words, iron can form two different ratios with oxygen. Other metals like copper and chromium also show this phenomenon. Such phenomenon resulted to the **Law of Multiple Proportions**.

What you will do

Self-Test 1.1

Directions: Answer these questions briefly.

1. Identify the similar ideas between the Greek concept of the atom and the statements in Dalton's atomic theory.

2. Explain the importance of the works of Lavoisier and Proust to the atomic theory of Dalton.

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Key to answers on page 27.

A Scientist Always Asks A Question

Asking questions is a good exercise to sharpen your scientific thinking skills. One good question is: ***Would Dalton have formulated the atomic theory if Lavoisier did not establish the Law of Conservation of Mass?***

Now, it's your turn. Ask a good question now:

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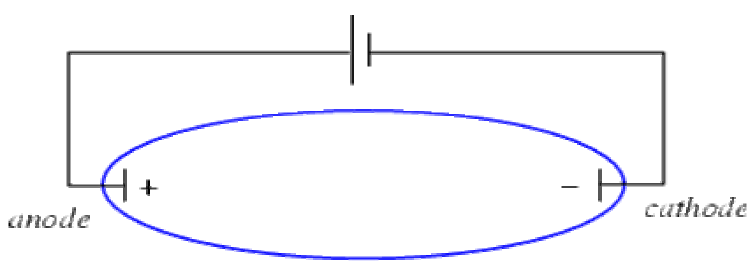
Lesson 2. The Subatomic Particles

What's inside the atom? We already know that an atom is not as solid as a toy marble. In fact, three different subatomic particles inside it have been discovered. "Subatomic" means "inside the atom". These are the protons, the electrons, and the neutrons. But first, we must get acquainted with an instrument that made the discovery of subatomic particles possible: the cathode ray tube.

The Cathode Ray Tube (CRT)

The CRT is a glass tube with two electrodes. One electrode is positive and it is called the **anode**. The other electrode is negative and it is called the **cathode**.



A gas is usually placed inside this tube and electricity is passed through it. As a result, light rays are released from the negative electrode (cathode) and hit the positive electrode (anode). These rays are obviously negatively charged since they come from the cathode and move towards the anode. A scientist named Julius Plucker first identified the cathode rays, and another scientist named Sir William Crookes confirmed this. He invented the Crookes tube, which is actually the prototype of the cathode ray tubes. The cathode ray tube is used in neon signs. Karl Ferdinand Braun further improved the CRT, and his "Braun tube" is the prototype of today's television tubes, radar tubes, and computer monitors. Because of the CRT, Roentgen discovered the **x-rays**. And still because of the CRT, the subatomic particles electrons and protons were discovered.

Subatomic Particles

Here is a table comparing the three subatomic particles.

Table 2.1

Particle	Symbol	Discoverer	Charge	Mass
Electron	e^-	J.J. Thomson, 1897	Negative	9.11×10^{-31} kg
Proton	p^+	E. Goldstein, 1886	Positive	$1.3626231 \times 10^{-27}$ kg
Neutron	n^0	J. Chadwick, 1932	No charge	1.6749×10^{-27} kg

All atoms have a **positive nuclear charge** due to the presence of protons. The number of protons in an atom determines the positive nuclear charge of an atom. Protons also determine the **atomic number** (**Z**) of an element. We can tell how many protons an atom of an element has by knowing its atomic number. For example, the element beryllium (Be) has an atomic number of 4. An atom of beryllium has four protons. The element Krypton (Kr) has an atomic number of 36, and one atom of Krypton has 36 protons.

The proton is 1,836 times heavier than the electron. When electrons and protons are placed side by side, the proton will be as big as a house, while the electron will only be one of its light switches.

The difference in the number of protons and number of electrons determines the overall charge of the atom. For example, if an atom has 4 protons and 4 electrons, the overall charge of the atom is zero. But if there are 6 protons and 5 electrons, the overall charge of the atom is +1. It is positive because there are more protons than electrons. If there are 12 protons and 14 electrons, the overall charge of the atom is –2. It is negative because there are more electrons than protons.

Together with protons, neutrons make up the **mass number** (**A**) of an atom. For example, the element calcium has a mass number of 40 and an atomic number of 20. This means that the calcium atom has 20 protons. To determine the number of neutrons, use this formula:

$$\begin{array}{ccccc} \text{Mass number} & - & \text{atomic number} & = & \text{number of neutrons} \\ 40 & - & 20 & = & 20 \end{array}$$

The calcium atom also has 20 neutrons.

Now let's try to visualize what the atom looks like.

What you will do
Activity 2.1 Atom Assembly

Let's attempt to assemble the composition of the Boron atom. The atomic number of Boron is 5, the mass number is 11, and the overall charge of the atom is zero. This means that Boron has 5 protons, 5 electrons, and 6 neutrons.

In a plate, place 5 pieces of calamansi fruits. These will be our protons. Then place 6 pieces of lanzones fruits. These will be our neutrons. Then add 5 pieces of rice grains. These will be our electrons.

Now try to assemble the components of a Fluorine atom. Its atomic number is 9, its mass number is 19, and its overall charge is –1.

Describe the contents of your plate.

What you will do
Self-Test 2.1

Directions: Fill up this table. Consult a periodic table to know the symbol of the elements.

Element Name	Element Symbol	Atomic Number, Z	Mass Number, A	Charge of the atom	No. of protons	No. of Electrons	No. of Neutrons
Silicon		14	28	–4			
Silver			108	0	47		
Strontium					38	36	50
Samarium				0		62	88

Key to answers on page 28.

A Scientist Always Asks A Question

Asking questions is a good exercise to sharpen your scientific thinking skills. One good question is: ***Why are there <u>three</u> subatomic particles? Why not two, or four?***

Now, it's your turn. Ask a good question now:

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Atomic Mass and Isotopes

In the periodic table, we find "atomic mass". Is this exactly the same as "mass number"? No, these two terms are not the same due to the existence of **isotopes**. What are isotopes?

What you will do

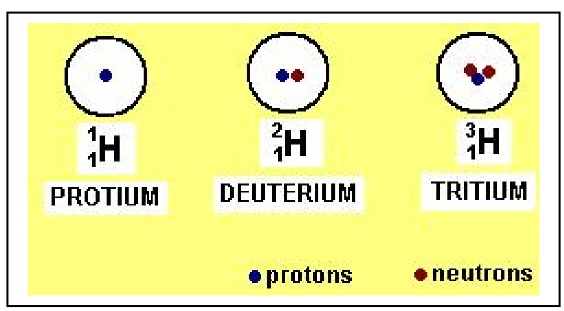
Activity 2.2 The Same But Different

Study two potatoes. These two are the same simply because both are potatoes. But, they are also different. List four things that make one potato different from another.

1. ________________________________
2. ________________________________
3. ________________________________
4. ________________________________

Just like the potatoes, isotopes are atoms of the same element but they have different mass numbers. This means that two atoms can have the same number of protons, but have different numbers of neutrons. For example, the hydrogen element has three different isotopes.

The isotopes of hydrogen are named **protium**, **deuterium**, and **tritium**. All of them have an atomic number of 1. This means that all of them have one proton. But protium has a mass number of 1. It has no neutron. The deuterium has a mass number of 2. It has one neutron. And tritium has a mass number of 3. It has two neutrons.



The existence of isotopes led to the existence of atomic mass. Atomic mass is determined by how much percentage or ***relative abundance*** a certain isotope exists in nature. This can be computed by using this formula:

$$\text{Atomic Mass} = \Sigma \text{ (mass number of one isotope x relative abundance)}$$

The symbol Σ reads "summation". It means that we will **add** the products of the mass number and relative abundance of the isotopes.

For example, nitrogen has two isotopes, ^{14}N and ^{15}N. The ^{14}N or N–14 has a relative abundance of 99.63%, while the ^{15}N or N–15 has a relative abundance of 0.37%. To compute for the atomic mass,

$$\begin{aligned} \text{Atomic mass} &= (0.9963 \times 14) + (0.0037 \times 15) \\ &= 13.9482 + 0.0555 \\ &= 14.0037 \end{aligned}$$

Some Amazing Isotopes

Some isotopes can save lives! Isn't that amazing? Isotopes are used to find out if a person is sick or not. This is called radiation detection. Here are some isotopes and their uses in medicine.

Table 2.2 Isotopes in the world of medicine

Isotope	Uses in Medicine
Iodine – 131	▪ Used to determine the size, shape and activity of the thyroid gland ▪ Treats cancer located in the thyroid gland ▪ Controls a hyperactive thyroid
Cobalt – 57	▪ Determines whether you have enough intake of vitamin B_{12}
Cobalt – 60	▪ Used for radiation therapy treatment of cancer
Gadolinium – 153	▪ Used to determine bone mineralization especially for women who suffer from osteoporosis
Technetium – 99	▪ Used to detect blood flow patterns in the heart ▪ Scans the brain, liver, kidney, and lungs
Carbon –11	▪ With the PET (positron emission tomography) technology, it is used to scan and measure processes that occur in the body
Chromium – 51	▪ Determines the volume of red blood cells and the total volume of blood
Phosphorus – 32	▪ Detects skin cancer or cancer of body tissues that have been exposed to surgery

What you will do
Self-Test 2.2

Directions: Compute for the atomic mass of these isotopes

1. ^{16}O (99.76%), ^{17}O (0.04%), and ^{18}O (0.20%)
2. ^{32}S (95.06%), ^{33}S (0.74%), ^{34}S (4.18%), and ^{36}S (0.02%)
3. ^{35}Cl (75.53%), and ^{37}Cl (24.47%)

Key to answers on page 28.

A Scientist Always Asks A Question

Asking questions is a good exercise to sharpen your scientific thinking skills. One good question is: ***We have three isotopes of hydrogen on planet earth. Will we find a fourth isotope on another planet, like Mars or on a moon, like Titan?***

Now, it's your turn. Ask a good question now:

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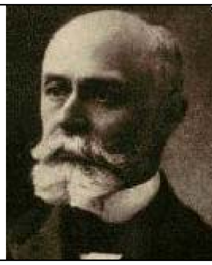
Lesson 3. Radioactivity and the Nuclear Model of the Atom

Some isotopes constantly release their protons, electrons, and neutron. As these subatomic particles are released, tremendous amounts of energy are also emitted. The released particles and the energy that goes with them are called radiation.

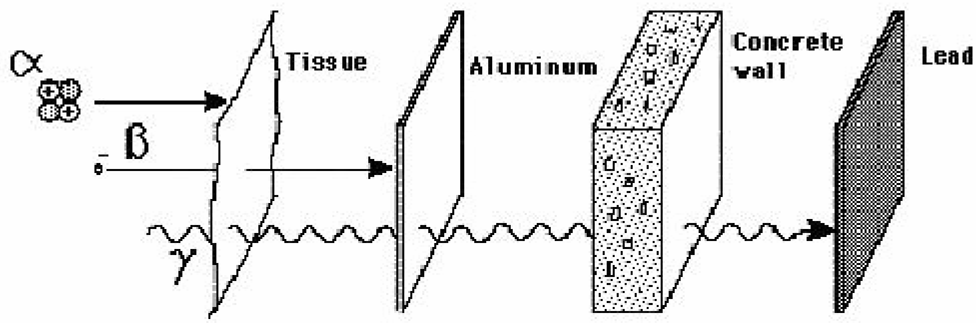
Important historical events

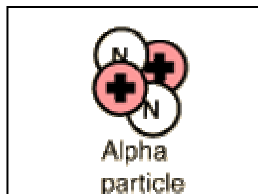
- In November 1895, **Wilhelm Conrad Roentgen discovered the x-rays**.
- **Henri Becquerel discovered radioactivity**. Radioactivity is the spontaneous emission of radiation by some elements. These are called radioactive elements.
- Pierre Curie and Marie Sklodowska Curie also investigated the phenomenon of radioactivity, using uranium ore. As a result, they discovered the elements polonium and radium, which were also radioactive elements.
- Ernest Rutherford, the father of nuclear physics, observed that radioactive elements such us uranium and thorium became different elements. He called this process as **radioactive decay**.

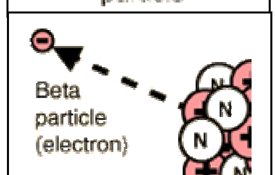
			
Becquerel	Marie Curie	Pierre Curie	Rutherford

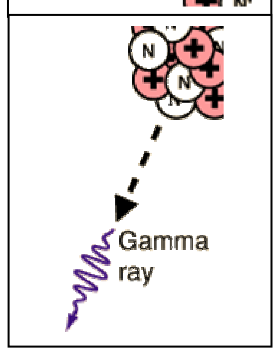
Radioactive Decay

According to Rutherford, there are three types of radiation based on the material that they can pass through. These are **alpha** (symbol is α), **beta** (symbol is β), and **gamma** (symbol is γ). Observe this illustration.









The **alpha radiation** is made of two protons and two neutrons. This means that it is big and positively charged. It cannot pass through tissue. But the alpha radiation is most dangerous especially when taken inside the body. It can damage living cells and body tissues. This is why the alpha radiation is not used in medicine.

The **beta radiation** is made of an electron. It is very small and negatively charged. It can pass through tissue but not through a metal like aluminum. It can also damage body tissues.

The **gamma radiation** is radiant energy coming from the atom. It is a high-energy radiation and has no charge. Because it is neutral, it can pass through paper, metal, and even through thick concrete. Gamma rays are used in medicine. But still it is the most dangerous type of radiation simply because only thick lead can stop it.

Detecting Radiation

Radiation from radioactive elements is dangerous. To avoid overexposure to it, scientists and doctors who work using radioactive elements have ways of detecting radiation.

Photographic Emulsion - This is an old technique that was used by Becquerel. The radiation from elements affect the photographic film in the same way that light can affect the film.

If you have the chance to observe nuclear scientists, you will notice that photographic films or papers are clipped to their laboratory gown. These are called dosimeters. Big changes in the dosimeter mean that too much radiation reached it.

Fluorescent Materials - These materials, when hit by radiation, transform the radiation into light energy that can be seen by the naked eye. One example is the luminous paint used in clocks.

The Cloud Chamber - It is an apparatus developed by T.R. Wilson in 1911. A sample of air is saturated with water vapor, and then, this is cooled and a cloud is formed. When a radioactive material is placed in this chamber, thin lines of fog can be seen to come out of it.

The Geiger Counter - This instrument is made of two parts, a metal guard and a detector. The metal guard is shaped like a tube that is filled with gas. This metal guard has a “window” where radiation can come in and ionize the gas inside. The ionized gas produces a current and this current reaches the detector. Some detectors light up or give flashes of light, while other detectors produce clicking sounds.

Half-Life of Radioisotopes

Radioisotope is a short name for “radiation-active isotopes”. Radioactivity results in the transmutation of a radioisotope into another element. For example, some atoms of uranium transmute and become atoms of element lead. The amount of radioactive material that transmutes into another element can be computed based on its **half-life**.

The half-life is ***the time that it takes one-half of the given starting weight of certain radioactive material to change into another material***. The half-lives of radioactive materials were determined through experiments. Here are the half-lives of some radioisotopes:

Table 3.1 Half-lives of some radioisotopes

Radioactive element	Half-life	Radioactive element	Half-life
Tritium	12.3 years	Uranium – 238	4.5 billion years
Cobalt – 60	5.25 years	Mercury – 190	20 minutes
Carbon – 14	5,730 years	Krypton – 81	13 seconds
Molybdenum – 99	67 hours	Technetium – 99	6 hours

For example, we have 20 grams of mercury–190. Its half-life is 20 minutes. This means that after 20 minutes, half of our radioactive mercury sample was transmuted into other elements. As a result, only 10 grams of mercury–190 are left. Then, after another 20 minutes, half of the 10 grams of mercury–190 were changed, leaving 5 grams of mercury behind.

What you will do
Activity 3.1 Graphing the Radioactive Decay

Your objective in this activity is to create a line graph that will show the radioactive decay of a radioisotope. You will need a pencil and a graphing paper.

1. The horizontal or x-axis will represent the time that passed or elapsed.
2. The vertical or y-axis will represent the amount of radioisotope.
3. Use the data below.

Amount of Tc-99	Hours that passed	Amount of Tc-99	Hours that passed
80 g	0	5	24
40	6	2.5	30
20	12	1.25	36
10	18	0.625	42

4. Describe the graph that you created. What kind of line was formed?
   ____
5. Is it possible to transmute ALL the technetium–99? Why? Why not?
   ____

What you will do
Self-Test 3.1

A. Direction: Each of the items below describes a type of radiation. Write α if it describes an alpha particle, β if it describes a beta particle, or γ if it describes a gamma particle.

_______ 1. It is positively charged.
_______ 2. It has no charge.
_______ 3. The heaviest type of radiation.
_______ 4. The type of radiation that has no mass.
_______ 5. It is composed of electrons.

B. Direction: Answer these problems about half-life. Refer to the Table 2.

1. If we have 100 grams of carbon–14, how long will it take this radioisotope to become 25 grams?

2. A scientist placed 60 grams of Krypton–81 inside a cloud chamber. How much Krypton–81 will be left after 1 minute and 5 seconds?

3. A certain radioisotope originally weighed 200 grams. After 4 hours, only 3.125 grams were left. What was its half-life?

Key to answers on page 28.

The Nuclear Atom

Remember your activity in Lesson 2 when you “assembled an atom”? We couldn’t be sure if we are going to place the “protons” beside the “neutrons” or place an “electron” between the “proton” and a “neutron”. In this lesson, we will have an idea where these subatomic particles are located though not the exact location, but an estimate only.

First, let’s recall a little history. During Democritus’ time, atoms were thought to have different sizes, shapes, and weights. This was changed during Dalton’s time. According to him, atoms are small spheres. Do you think Dalton was right? When J.J. Thomson discovered the electrons, some scientists believed that the atom is like a piece of bread with raisins stuck to its surface. The “piece of bread” is the positively charged body of the atom and the “raisins” are the negatively charged electrons.

And then, Rutherford conducted the alpha–gold foil experiment. The surprising results of this experiment radically changed the way scientists view the atom. To understand one result of the alpha–gold foil experiment, do this activity first.

What you will do

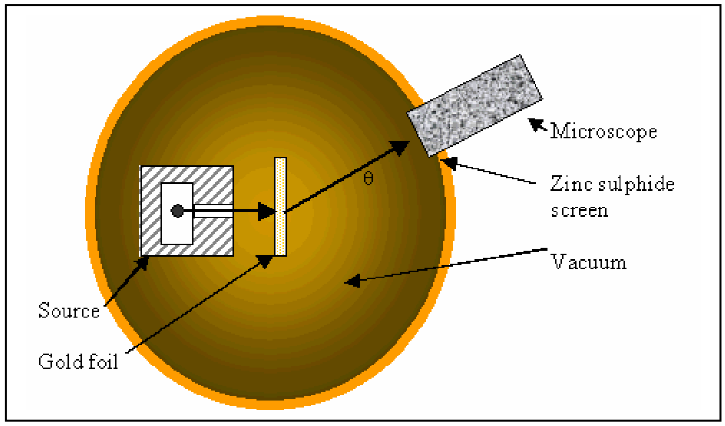
Activity 3.2 Positive and Positive Poles

A magnet has two poles called the North (marked N) and the South (marked S) poles. Let’s assume that the North pole is the “positive” end of the magnet and the South pole is the “negative” end. Place the two positive ends near each other. Observe what happens.

When similar poles of the magnet are placed near each other, the magnets tend to move away from each other. This is because similar poles repel each other. In the same way, like charges also repel each other. Let’s remember this when analyzing the alpha – gold foil experiment.

The Alpha-Gold Foil Experiment

The alpha rays are big positively charged particles that are moving at very fast speeds. If these rays hit an object, there would be much damage. And in the experiment, alpha rays were used to bombard a very thin gold foil. Probably, the plan of Rutherford and his colleagues were to smash the atoms of the gold foil. And so, the set up was like this:



The apparatus was a vacuum to prevent atoms of the air to interfere with the experiment. A microscope was placed slightly behind the gold foil so that the scientists could safely observe what would happen once the alpha rays hit the foil. The microscope couldn't be directly behind the foil because the scientists didn't want the alpha rays or the smashed atoms of gold to come directly straight to them.

From the source, alpha rays were released and they did hit the gold foil at high speeds. But Rutherford and his team of scientists were surprised at the results of the experiments. Their observations from the experiment were:

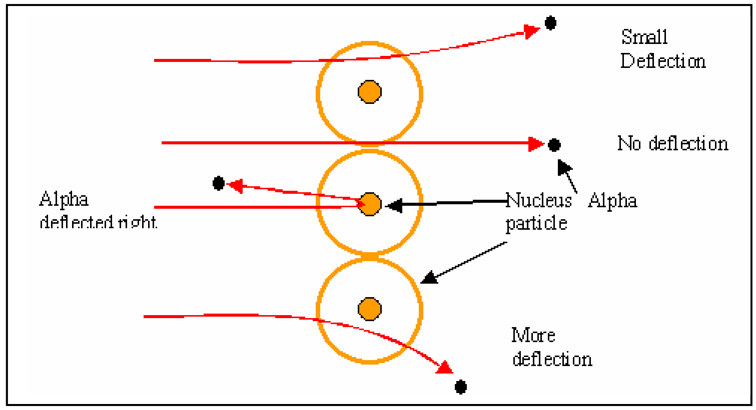
1. Most of the alpha rays just passed through the gold foil.
2. A small portion of the alpha particles was deflected.
3. An even smaller portion of the alpha particles bounced right back.

Table 3.2 shows the conclusions made by Rutherford based from what he observed in the experiment.

Table 3.2 Conclusions from the alpha – gold foil experiment

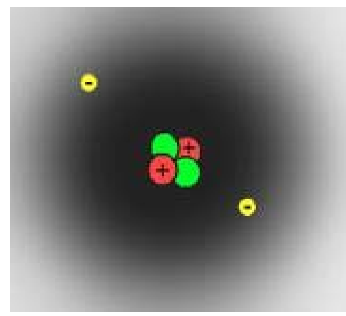
Observations	Conclusions
Most of the alpha rays just passed through the gold foil.	Most of the atom is just empty space. (How else could the alpha particles pass through?)
A small portion of the alpha particles was deflected.	There is a positive charge inside the atom that occupies a very small space. (The small positively charged core inside the atom repelled and deflected the positively charged alpha rays)
An even smaller portion of the alpha particles bounced right back.	The alpha particles that bounced back were traveling directly straight into the positively charged core.

To illustrate what happened, study this diagram. Rutherford called the positively charged core in the atom as the **nucleus** of the atom. And so, another structure of the atom was made.



The Nuclear Model of the Atom

The new model of the structure of the atom is called the nuclear model. This model describes the atom as having a nucleus at its center.



The nucleus of the atom does not have a fixed boundary like the nucleus of a cell. The protons and the neutrons are found together in this nucleus. They are called **nucleons**. An attractive force called the **nuclear force** holds them together.

Rutherford estimated the radius of the nucleus to be 3×10^{-14} m. Researches of scientists in the later years established that the radius of the nucleus is about 1.5×10^{-14} m. Rutherford was almost right.

The electrons in the nuclear model were assumed to just move around the nucleus.

What you will do

Self-Test 3.2

Directions: Draw nuclear models for the atom of the following elements.

Atom of Carbon	Atom of Sodium	Atom of Sulfur	Atom of Neon

Key to answers on page 28.

A Scientist Always Asks a Question

Asking questions is a good exercise to sharpen your scientific thinking skills. One good question is: ***Is it possible to have two nuclei in an atom?***

Now, it's your turn. Ask a good question now:

____

Lesson 4. Atomic Spectra and the Atomic Structure

Up until now, we can think of subatomic particles as small solid spheres. Strangely, a scientist named Louis De Broglie proposed a theory that electrons showed characteristics similar to light. But light is a form of energy. Is this possible? Yes it is. De Broglie's theory was proven by an experiment conducted by Davisson and Germer. In this lesson, we will present some concepts about light and explain how electrons could behave like light.

What you will do

Activity 4.1 Observing Rainbows

To understand more about the nature of light, we will first observe a rainbow. A rainbow usually appears after a rain. What if there is no rain? Don't worry; we can still create a rainbow. All you need is a basin half-filled with water, a mirror, and a plain wall.

Go near the wall and place the basin of water on the ground. Make sure that you do this when the sun is high in the sky. Position the mirror above the water of the basin so that it will catch the rays of the sun and reflect it to the water. A rainbow will appear on the wall.

Observe this rainbow.

1. How are the colors arranged?

   ____

2. Will the arrangement remain the same if you move the mirror upside down? Why? Why not?

   ____

   ____

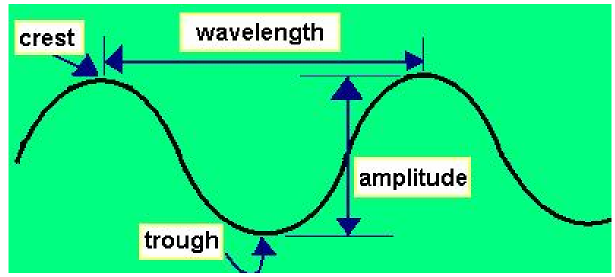
3. Will the arrangement remain the same if you go to another wall? Why?

   ____

   ____

The Electromagnetic Spectrum

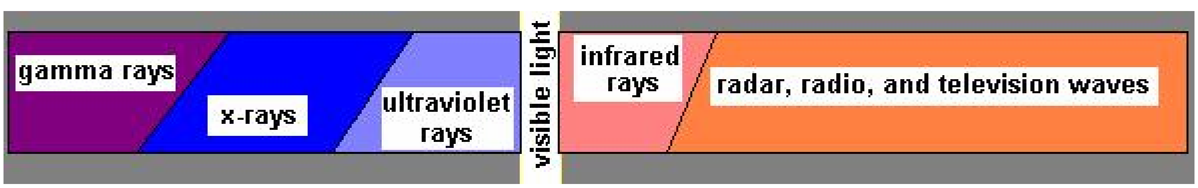
The rainbow showed that the colors of light are arranged in a specific way. To understand why, we must think of light as a moving wave. A wave has five known properties. These are **crest**, **trough**, **wavelength**, **amplitude**, and **frequency**.



The crest is the highest point of a wave while the trough (pronounced as "truf") is the lowest point. The distance between two crests (or two troughs) is the wavelength. If a horizontal line is drawn from the crest and another from the trough, the distance between these two lines is the amplitude. Now let's imagine this wave to move to the right. At a certain point, crests after crests are going to pass through. The number of crests (or troughs) that will pass through our imaginary point within a period of time is the frequency.

The colors of the rainbow have different wavelengths. Red has the longest wavelength and violet has the shortest. A wave also has a specific amount of energy. Light waves with longer wavelengths have lesser energy than light waves with shorter wavelengths. In the colors of the rainbow, red has the least energy while violet has the greatest energy.

The colors of the rainbow are just a small part of the electromagnetic spectrum. Study this diagram.

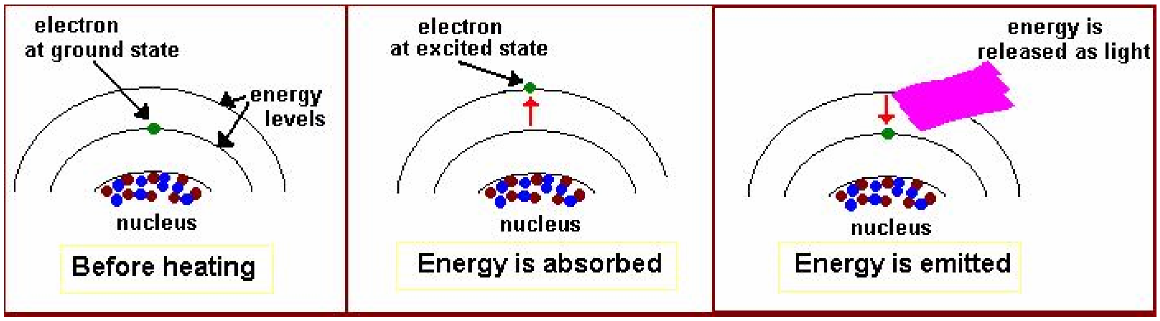


Beyond the color red is the infrared or heat radiation. The waves of infrared have longer wavelengths and lesser energy. Beyond the color red is the ultraviolet radiation. The waves of UV rays have shorter wavelengths and greater energy. The large amount of energy that the UV rays have can harm body tissues.

Bohr's Ideas and Energy Levels

Some elements emit certain light energy when they are heated. For example, the element lithium, when heated produces a particular red color; cesium, when heated, produces a blue color; barium produces a green color; and potassium produces a violet color. This phenomenon led Niels Bohr to the idea that the electrons in an atom are found in certain distances from the nucleus. These "distances" are related to the energy that an electron has, and these are called **energy levels**.

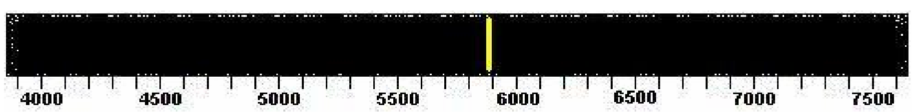
If the atom is not yet heated, the electron stays at its usual ***ground state***. Then, when the atom is heated, the electron absorbs energy. Since it now has more energy, it jumps to a higher energy level. This electron is now at its ***excited state***. Of course, this excited state is unusual and not stable. And so, the electron must go back to its original energy level. To do so, the electron must release its extra energy. The released energy is in the form of light. We see it as the element's color when it is heated.



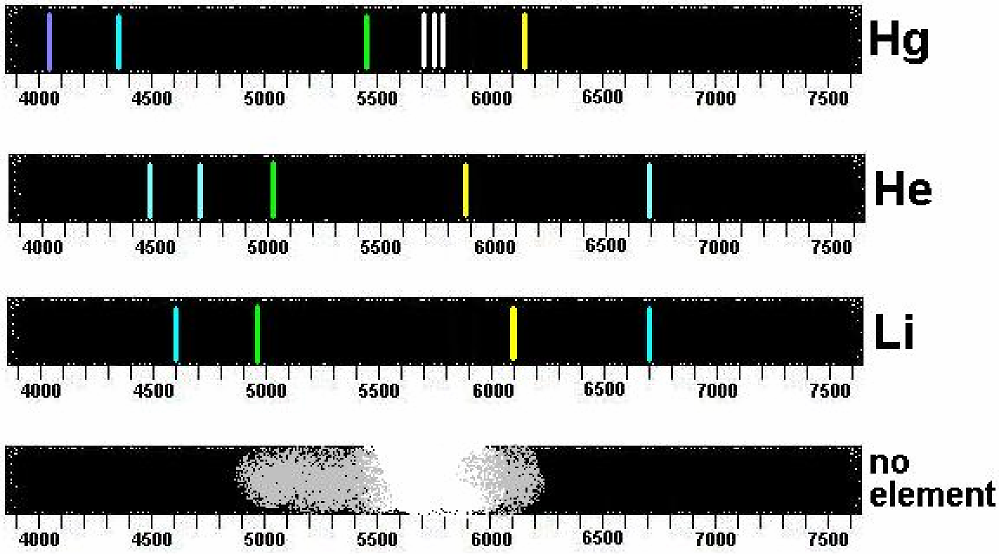
But not all light released by the atom can be seen by our eyes. To see all the light energy released by atoms, an instrument called spectroscope is used.

Emission and Absorption Spectra

The light released by an element that is heated is called its ***emission spectrum***. This is the light detected by a simple spectroscope. At the same time, an element is also capable of absorbing energy. An "absorption spectroscope" is an instrument that detects the ability of an atom's electrons to absorb a certain amount of energy. This absorbed energy is called the **absorption spectrum**. Instead of colors that appear, this instrument shows lines instead. When you pursue a science course in college, you will learn more details about how a spectroscope works. But right now, let us see what an absorption spectrum looks like.



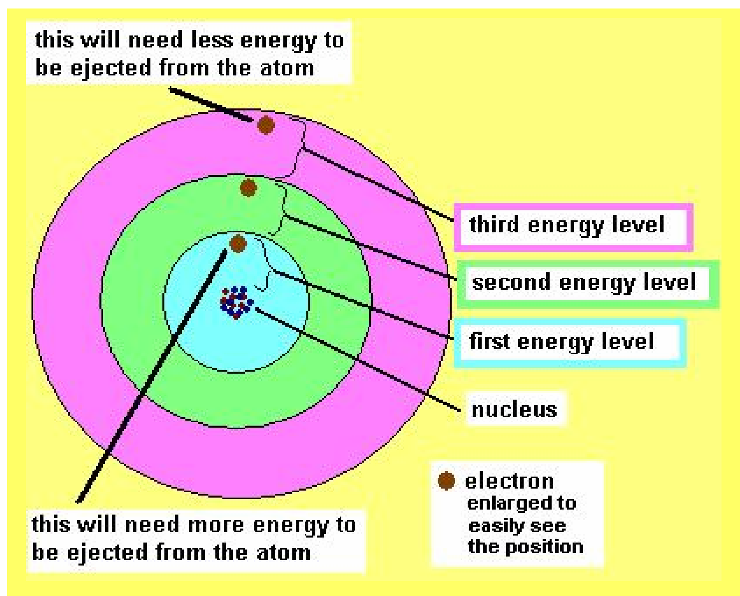
This is an **absorption spectrum**, which is also called a line spectrum. The numbers are the wavelengths of light in Angstrom units. One Angstrom is equal to 1 x 10^{-10} meters. Study some spectra below.



Each element has its own unit line spectrum. As technology improved, it is now possible to see the spectrum of electrons! The technology is called **photoelectron spectroscopy**.

Electron Spectra

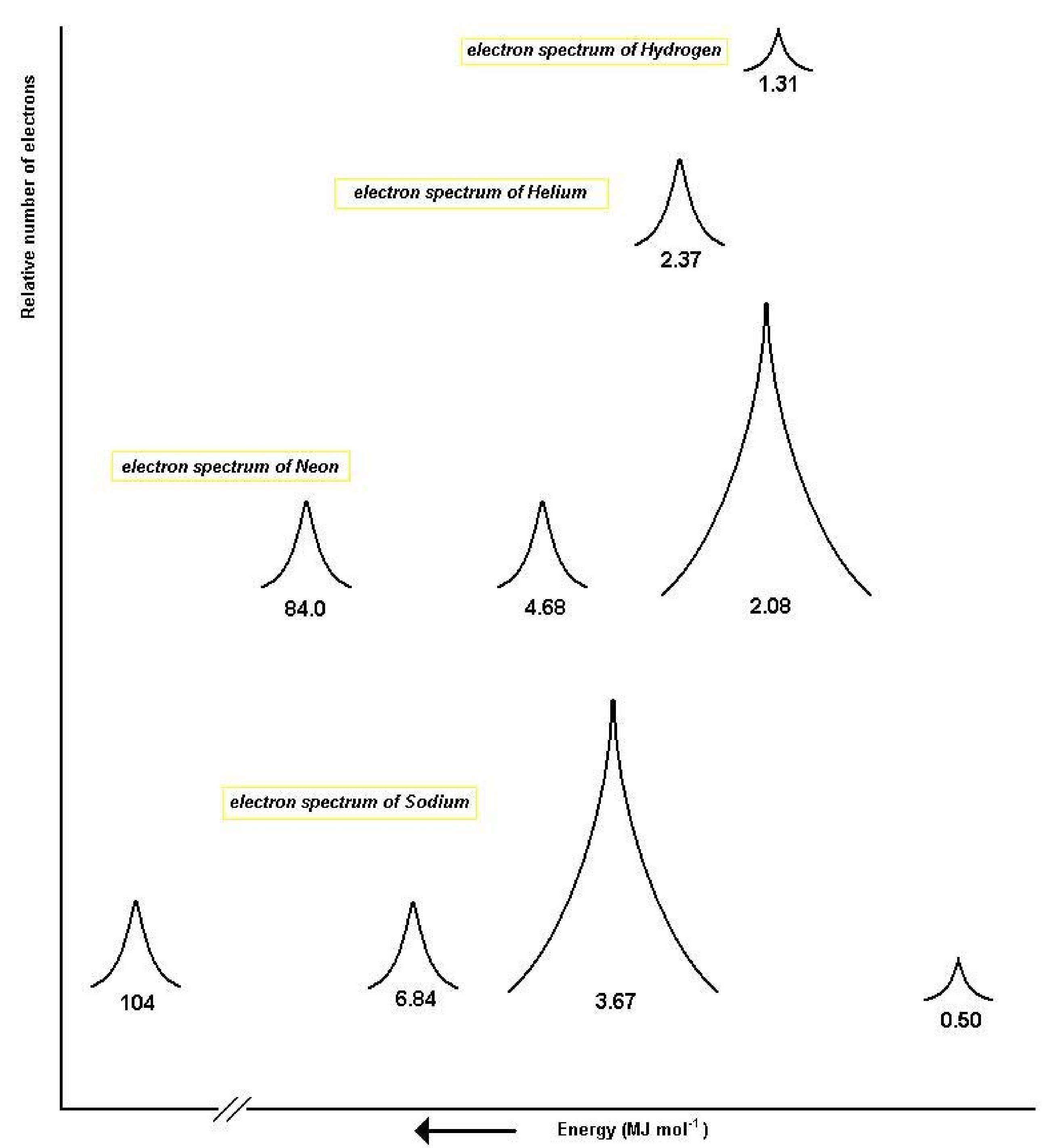
In photoelectron spectroscopy, the atom of an element in its gaseous state is hit by radiation. The radiation has enough energy to remove an electron from any energy level. Of course, when the electrons are nearer to the nucleus, it will take a greater amount of energy to eject them. If the electrons are farther from the nucleus, a lesser amount of energy is needed to eject the electron.



The energies of the ejected electrons are measured by the photoelectron spectrometer. A ***photoelectron spectrum*** is produced. Refer to the spectra in the next page as you continue reading so that we will have a clearer image of electrons in their energy levels.

Hydrogen has one electron and this is why we have only one "peak" in its spectrum. Helium has two electrons, but its spectrum shows only one peak. This peak is higher than that of hydrogen. This means that there are two electrons having the same energy. It also means that helium's two electrons are found on the same energy level, the first energy level.

Neon has three peaks. The first two peaks are as high as the peak of helium. This means that each of the first two peaks of Neon has two electrons.



The first peak needed about 84.0 MJ/mol of energy, while the second peak needed about 4.68 MJ/mol of energy. This means that the two electrons in the first peak are found in one energy level, and the two electrons in the second peak are found in another energy level. The electrons in the first peak are nearer to the nucleus since it needed greater energy. The third peak of neon is about three times higher than the first two. This means that this peak represents six electrons of neon. Notice the amount of energy it needed. The six electrons only needed 2.08 MJ/mol of energy. This is very near the amount of energy needed in the second peak (4.68 MJ/mol). This means that the electrons in the second peak and in the third peak are found in the same energy level. But why are there two peaks in that energy level? The only reason is that this energy level has sublevels of energy. We can conclude that Neon has two energy levels. The first energy level contains two electrons, and the second energy level contains a total of eight electrons. There are also two sublevels in the second energy level. Two electrons are found in the first sublevel, and the six electrons are found in the second sublevel.

Based on the spectrum, sodium has three energy levels. The first energy level has two electrons needing energy equal to 104 MJ/mol. The second energy level has sublevels again. The first sublevel has two electrons needing energy equal to 6.84 MJ/mol, and the second sublevel has six electrons needing energy equal to 3.67 MJ/mol. The third energy level has one electron only. Notice how small the peak is. It also needed the least amount of energy, only 0.50 MJ/mol. This means that this sole electron is found in the outermost energy level, the farthest from the nucleus.

What you will do

Self-Test 4.1

Directions: **True or False**. Write **T** if the statement is true, and **F** if it is false.

___________ 1. The highest point in a wave is called the frequency.
___________ 2. The green color has a longer wavelength than the blue color.
___________ 3. The ultraviolet rays have more energy than x-rays.
___________ 4. Three electrons can occupy each orbital.
___________ 5. The f-orbital has more orientations than the p-orbital.
___________ 6. An energy level can have two or more sublevels.
___________ 7. An electron at its excited state has less energy than when it is at the ground state.
___________ 8. Radiation can eject electrons from its energy level.
___________ 9. Two elements can have the same absorption spectra.
___________ 10. Two electrons can have the same amount of energy.

Key to answers on page 29.

A Scientist Always Asks A Question

Asking questions is a good exercise to sharpen your scientific thinking skills. One good question is: ***What would have happened if photoelectron spectroscopy was never invented?***

Now, it's your turn. Ask a good question now:

Let's Summarize

In this module, you have learned the following important concepts:

1. According to the modern atomic theory, all elements are composed of atoms. Compounds are formed when two or more atoms of different elements join together.
2. The Law of Conservation of Mass states that the total mass of the reactants before a chemical reaction takes place is exactly equal to the total mass of the products of the reaction.
3. The Law of Definite Proportions states that the proportion by mass of the elements in a given compound is always the same.
4. Cathode rays and radioactivity helped in determining the structure of the atom.
5. The subatomic particles are electrons, protons, and neutrons. Electrons are negatively charged; protons are positively charged; and neutrons have no electrical charge.
6. The positive nuclear energy of an atom is due to the presence of protons. Protons also determine the atomic number of an element.
7. The difference in the number of protons and number of electrons determines the overall charge of the atom.
8. Protons and neutrons make up the mass number of an atom.
9. Isotopes are atoms with the same atomic number but different mass numbers.
10. The atomic mass of an element is determined by the isotopes' relative abundance in nature and the mass numbers of each isotope.
11. Many isotopes are used to diagnose and/or treat diseases.
12. Radioactivity is the spontaneous emission of radiation by a material.
13. There are three types of radiation based on the material that they can pass through. These are alpha (symbol is α), beta (symbol is β), and gamma (symbol is γ).
14. Radiation from radioactive elements is dangerous. Radiation can be detected by using dosimeters, fluorescent materials, cloud chambers, and Geiger counters.
15. The half-life is the time that it takes one-half of the given starting weight of certain radioactive material to change into another material.

16. The alpha-gold foil experiment led to the development of the nuclear model of the atom. The atom has a small nucleus that contains the protons and the neutrons. Most of the atom is empty space. The electrons are moving around the nucleus.
17. A wave has five properties: crest, trough, wavelength, amplitude, and frequency.
18. When heated, the electrons of an atom absorb energy and jump from one energy level to a higher energy level, transforming from the ground state into the excited state.
19. The light released by an element that is heated is called its emission spectrum. This light is the one that is detected by a simple spectroscope.
20. Absorption spectroscopy detects the ability of an atom's electrons to absorb a certain amount of energy called the absorption spectrum.

Posttest

Multiple Choice. Choose the letter of the best answer. Write the chosen letter on a separate sheet of paper.

1. The element X in a compound was involved in a chemical reaction. After the reaction was completed, which of these would likely happen to the mass of element X?
    a. It will increase
    b. It will disappear
    c. It will be doubled
    d. It will remain the same

2. All these were discovered because of the cathode ray, except
    a. X-rays
    b. Protons
    c. Neutrons
    d. Electrons

3. Which statement describes the neutron?
    a. It is positively-charged.
    b. It is part of a gamma radiation.
    c. It was discovered by Rutherford.
    d. It is the heaviest subatomic particle.

4. What is the mass number of an atom of the artificial element Promethium that has 61 protons, 61 electrons, and 84 neutrons?
    a. 23
    b. 122
    c. 145
    d. 206

5. Which best describes isotopes?
    c. Same number of neutrons, different number of electrons
    d. Same number of neutrons, different number of protons
    e. Same number of protons, different number of electrons
    f. Same number of protons, different number of neutrons

6. Which of these technologies uses a cathode ray tube?
   a. Cellular phone
   b. Computer monitor
   c. Microwave oven
   d. Air-conditioning unit

7. Which does **NOT** happen to a radioactive material?
   a. It produces a tremendous amount of heat.
   b. The atom transmutes into another kind of atom.
   c. The radioactive atom absorbs alpha, beta, and gamma rays.
   d. It emits high–energy waves that can pass through thick concrete.

8. If there were six positive charges (+6) and three negative charges (–3) in a body, what would be the overall charge of the body?
   a. +3
   b. +2
   c. –2
   d. –3

9. How do we call the protons and neutrons that are found together in the nucleus?
   a. Nuclei
   b. Nucleons
   c. Mass Number
   d. Atomic Mass

10. He is one of the first atomist who believed that all things are made up of atoms.
    a. Dalton
    b. Democritus
    c. Goldstein
    d. Rutherford

Key to answers on page 29.

Key to Answers

Pretest

1. c
2. c
3. b
4. d
5. d
6. b
7. b
8. b
9. b
10. c

Lesson 1

Self-Test 1.1

1. Similar ideas include: 1) matter is composed of atoms; 2) indestructibility and invisibility of the atom; and 3) atoms of different elements have different weights or masses

2. Lavoisier's Law of Conservation of Mass, and Proust's Law of Definite Proportion has the same assumptions about the atom as in the Atomic Theory of Dalton. These assumptions include: 1) Atoms cannot be destroyed; and 2) Atoms have constant mass.

Lesson 2

Self-Test 2.1

Element Name	Element Symbol	Atomic Number, Z	Mass Number, A	Charge of the atom	No. of protons	No. of Electrons	No. of Neutrons
Silicon	Si	14	28	– 4	14	18	14
Silver	Ag	47	108	0	47	47	61
Strontium	Sr	38	88	+2	38	36	50
Samarium	Sm	62	150	0	62	62	88

Self-Test 2.2

1. 15.9994 a. m. u
2. 32.064 a. m. u
3. 35.453 a. m. u

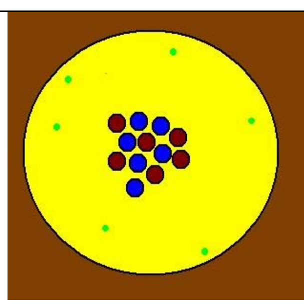
Lesson 3

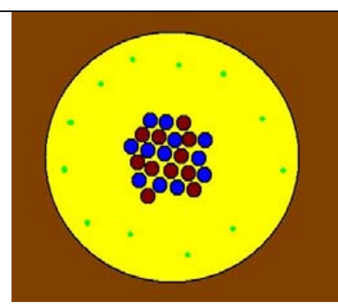
Self-Test 3.1

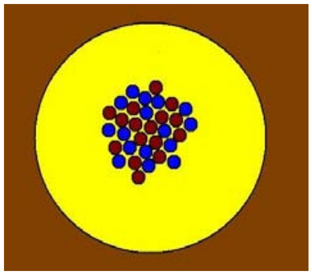
A.
1. α
2. γ
3. α
4. γ
5. β

B.
1. 11, 460 years
2. 1.875 grams
3. 40 minutes

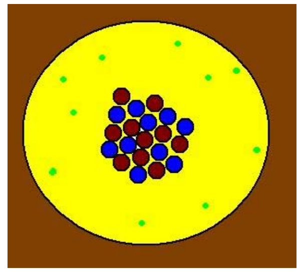
Self-Test 3.2


Atom of Carbon


Atom of Sodium



Atom of Sulfur



Atom of Neon

Lesson 4

Self-Test 4.1

1. F	6. T
2. T	7. F
3. F	8. T
4. F	9. F
5. T	10. T

Posttest

1. d	6. c
2. c	7. c
3. d	8. a
4. c	9. b
5. d	10. b

References

Hill, J. & Kolb D. (1995). *Chemistry for changing times*. (7th ed.) NJ: Simon & Schuster (Asia) Pte.Ltd.