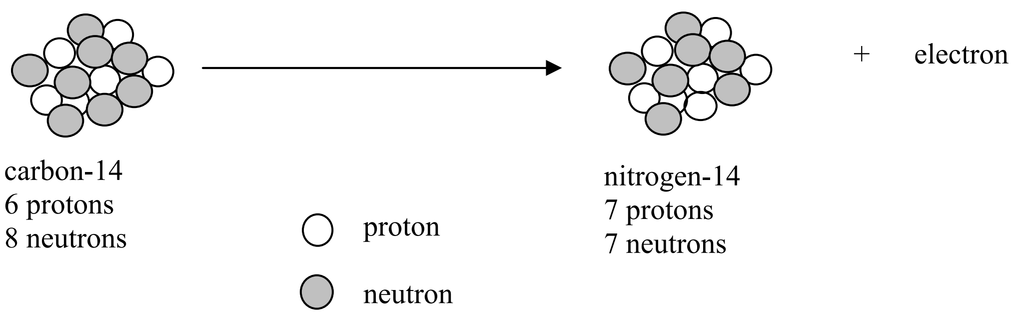
Experiment #6A: Radioactivity

Objectives:
To investigate Strontium-90 as a source of radiation. To determine how the radiation count varies with distance from the source and to compare the absorption qualities of some materials.

Textbook Reference: pp 484-491, 494-505

Introduction:

Some isotopes are not stable. An example is the isotope carbon-14. Carbon-14 spontaneously converts to nitrogen-14 through a process called nuclear decay. The process is shown in the figure below:



In this process one proton has been gained by the nucleus and one neutron has been lost. Since the nucleus now has 7 protons, and not 6, it has become a nitrogen atom. At the same time, an electron has been produced. The electron is a light particle with a negative electrical charge. In the nuclear decay shown above the electron is ejected from the nucleus with high energy and a large velocity. The mass and charge information regarding electrons, protons and neutrons appears below:

Particle	**symbol**	**mass (kg)**	**mass number**	**charge (Coulombs)**	**charge number**
proton	p	1.66×10^{-27}	1	1.6×10^{-19}	+1
neutron	n	1.67×10^{-27}	1	0	0
electron	e^-	9.11×10^{-31}	0	-1.6×10^{-19}	–1

The mass of the electron is much smaller than that of the proton or neutron (about 1/1800 times as much mass). The mass is so much smaller, in fact, that we can assign the value of zero as the mass number of the electron. Also notice that the electrical charge of the electron is equal to that of the proton, except that it's negative. The electron will be important to our discussion of the electronic structure of atoms. But for right now, let's think of the electron as a light and negatively charged particle that can be emitted when the nucleus of an atom undergoes a nuclear decay. There are other types of particles that can be emitted from nuclear processes:

particle	**symbol**	**example**
electron (beta)	${}^{0}_{-1}e$	${}^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}e$
helium nucleus (alpha)	${}^{4}_{2}He$	${}^{238}_{92}U \rightarrow {}^{4}_{2}He + {}^{234}_{90}Th$
gamma	γ	

When the electron is emitted with high energy and velocity it has the ability to penetrate through some materials. But how far the electron can travel through a material depends on the ability of the material to interact with and stop the electron. An important factor in the ability of a particle to pass through without being absorbed is the energy of the particle. In general, a particle with a high energy possesses a greater ability to pass through than a particle with a small amount of energy. Let's consider the particles discussed earlier:

1, Alpha (α) particles, which are helium nuclei, ${}^{4}_{2}He^{2+}$ penetrate matter the least. They consist of two protons and two neutrons.

2. Beta (β) particles are electrons (${}^{0}_{-1}e$) with high energy. Beta particles travel very fast, with speeds that can be near the speed of light. The energy of a particle with mass is equal to its kinetic energy: $\textbf{Kinetic energy} = \frac{1}{2} mv^2$ where m is the mass of the particle and v is its velocity. β particles are about one hundred times more penetrating than α particles. This is because they move at much higher velocities and are not as highly charged (–1 for the electron versus +2 for the helium nucleus).

3. Gamma (γ) particles are a form of electromagnetic energy (light) of high frequency and short wavelength. γ rays have the most penetrating power of all three particles discussed (about a thousand times that of α particles).

Detection of Radioactivity

Radioactivity may be detected using a device called a Geiger tube. A Geiger tube is a gas-filled cylinder that contains a wire running down its center to which a positive voltage is applied. When an alpha, beta, or gamma particle enters the tube it often collides with a gas particle in the tube. This results in ionization of the gas. The gas particle loses one or more electrons during the collision. These electrons are ejected at high speed and collide with other atoms, resulting in the emission of other electrons. These ejected electrons are attracted to the wire because of the applied positive voltage. When the electrons collide with the wire they flow through an electrical circuit attached to the wire and a pulse of current is detected. This pulse is displayed as a count. The number of counts displayed by the detector depends on how many particles entered the detector and is called intensity. The intensity is often expressed in units of counts per minute (cpm) or counts per second (cps).

Background radiation

When a Geiger counter is used, there will often be some small intensity recorded, even if there is no obvious radioactive source near the detector. This small intensity is called background radiation and is caused by particles emitted from radioactive materials found on earth and from materials outside the earth (cosmic rays). When a radioactive source is measured it is necessary to subtract the background count.

Procedure

Equipment and Supplies: A Geiger tube and counter, planchet holder, a planchet of the strontium-90 (${}^{90}_{38}Sr$), a set of absorbers. The counter records the counts and time thus allowing you to calculate the counts per minute (cpm). The absorber set contains absorbers of polyethylene, paper, aluminum, and lead of varying thickness.

Determining the Background Radiation Count

1. The background count is produced from cosmic rays and objects around us. While measuring the background, all planchets that are not being measured should be kept at least 6 ft from any Geiger tube in the class.
2. Switch on the counter. It may initially display random numbers.
3. Place the shelf of the planchet holder in the bottom notch.
4. Press the RESET button to set the display to zero.
5. Set TIME to 60 sec. Press COUNT to measure the background for one minute. Record the counts below.

Background Radiation: _____________

Class Average: ______________

Determining the Effect of Distance

Starting with the lowest shelf as number 1, measure the distance from the shelf to the top to the nearest 0.1 cm. Measure the distance of each shelf. Place a planchet of Strontium-90, a beta emitter, on the shelf. Set the timer for 1 minute count intervals. Count at each shelf and record your data in Table 1.

Table 1. Effect of Distance on Intensity of Radiation

Shelf Level	Distance (cm)	Intensity (CPM)
1		
2		
3		
4		
5		

Determining the Effect of Different Absorbers

1. Keep the shelf at level 4 for this part of the experiment. Place a planchet of Strontium-90, symbol side facing the Geiger tube on the shelf of the planchet holder. Obtain a count and record the value in Table 2. Then subtract the average background counts per minute to determine the amount of radioactivity from the Strontium-90.

2. Select a nonmetal absorber to place between the radioactive source and the detector. Do this by placing the absorber directly over the planchet. All runs will be performed at the same distance so you can compare the effect of using different absorbers. Make one measurement of 60 seconds. Record the result in Table 2. Then subtract the average background counts per minute.

3. Repeat step 2 using aluminum and then lead as absorbers.

Effect of absorbers

Table 2. Effect of Different Absorbers

	air	nonmetal	aluminum	lead
CPM				
CPM – Class Average Background				

Answer the following questions.

1) Which of the absorbers is the best? Which is the least absorbent?

2) How does the count vary with distance?

3) The half-life of a radioactive substance is the time required for the number of radionuclides to reach half of its value. The half-life of iodine-131 is 8 days. If 100 mg of this radioisotope is present at a given time, how much will remain 16 days later?

4) Complete the following nuclear equation:

$^{199}_{78}Pt \rightarrow\ ^{199}_{79}Au + \_\_\_\_\_$

What kind of subatomic particle was emitted?