

## Nuclear Chemistry

## Introduction

Of the types of radiation produced in nuclear decay reactions, the three most common are **alpha particles** ( $\alpha$ ), **beta-particles** ( $\beta^-$ ), and **gamma rays** ( $\gamma$ ). All of them are considered to be forms of *ionizing radiation*. When ionizing radiation strikes atoms or molecules in their paths they cause electrons to be knocked away, forming ions or free radicals. While this is generally not much of a concern with inanimate materials, these highly reactive species can cause undesirable effects in living tissue.

Because cells in our bodies can be damaged by ionizing radiation, appropriate **shielding** must be used when working with radioactive sources.

**Alpha** ( $\alpha$ ) particles are the heaviest of the forms of radiation and carry the greatest charge, they interact the most strongly with matter and are absorbed within a very short distance. A piece of paper or the outer, dead layer of our skin are sufficient protection against alpha particles. (If inhaled or ingested, however, alpha particles can cause serious damage to internal organs.)

**Beta-** ( $\beta^-$ ) particles, having a smaller mass and charge, are able to penetrate matter to a greater depth, as far as 4-5 mm into body tissue. While beta particles are absorbed before they can reach internal organs, they can be damaging to the skin. Heavy clothing and gloves, or metals such as aluminum, provide adequate protection from beta particles.

We will not work with beta plus emitters or any other forms of radiation either because those isotopes are too short-lived or are not found on earth (e.g. they are only found in stellar extremes).

**Gamma** ( $\gamma$ ) rays, (pure radiation, NOT particles) are the most penetrating of all, passing right through body tissue and metals such as aluminum. They require much more dense materials such as lead or concrete to stop them. Table 1 lists the approximate penetration depths for the types of radiation in various materials.

**Table 1 – Approximate Penetration Depths of Radiation in Various Materials**

	Alpha ( $\alpha$ , ${}^4_2\text{He}$ )	Beta ( $\beta^-$ , ${}^0_{-1}\beta$ )	Gamma ( ${}^0_0\gamma$ )
Body tissue	0.05 mm	5 mm	>50 cm
Aluminum	0 mm	2 mm	30 cm
Lead	0 mm	0.4 mm	30 mm

**Experiment 2 – Types of Radiation (We are not doing experiment 1)****Objective**

In this experiment you will identify the type of radiation produced by various nuclides by examining how much that radiation penetrates shielding materials.

**Procedure**

1. Click experiment 2 from the [www.falconchem.weebly.com](http://www.falconchem.weebly.com) Atomic & Nuclear unit page.
2. Open the **worksheet** for Experiment 2. (You may fill in the data within Excel)
3. Click on the apparatus to start the lab. The experimental setup includes a number of radioactive sources, different types of shielding, and the apparatus to measure the radioactivity. On the right is a Geiger counter that will measure radiation in counts per second. On the left is a holder for the radioactive source, and in the middle is a holder for the shielding material.
4. Click on the drop-down list of radioactive sources and choose a nuclide. Drag the source into the sample holder. Record the name (e.g., iron-59) or the symbol (e.g.,  ${}^{59}\text{Fe}$ ) of the source in the worksheet. (There is information on each nuclide in the box that pops up. After reading it, you can close the box, or it will close on its own when you click on something else.)
5. Click on the Geiger counter switch to turn it on. Record the activity of the sample in counts/sec. (The needle on the gauge may move around a bit. You should try to get an average reading. Note that the scale on the gauge is not linear.)
6. Click the switch again to turn it off.

- Click on the drop-down list of shielding materials and choose one. It will pop up. Drag the shielding object into its holder in the apparatus. The object will turn sideways into the path of the radiation.
- Again click on the Geiger counter switch, and again record the activity in the appropriate column in the worksheet.
- Repeat steps 6 and 7 for the other types of shielding material.
- Repeat steps 3-8 until you have identified the type of radiation given off by several nuclides. Try to find at least one for each type of radiation:  $\alpha$ ,  $\beta$ , and  $\gamma$ .
- SAVE this worksheet either in your student folder OR in a personal drive. You can also email this file to yourself.
- When you have completed the excel sheet, raise your hand and your instructor will confirm your work. Do not proceed until this has happened.

### **Experiment 3 – Shielding**

#### **Objective**

In this experiment you will examine the effectiveness of shielding against the three forms of radiation by three materials: cardboard, aluminum, and lead.

#### **Procedure**

- Click experiment 3 from the [www.falconchem.weebly.com](http://www.falconchem.weebly.com) Atomic & Nuclear unit page.
- Open the worksheet for Experiment 3. (You should fill in the data within Excel)
- Click on the apparatus to start the lab. The apparatus is the same as for experiment 2.
- Click on the drop-down list of radioactive sources and choose radon-222, an  $\alpha$  emitter. Drag the source into the sample holder. (There is information on each nuclide in the box that pops up. After reading it, you can close the box, or it will close on its own when you click on something else.)
- Click on the Geiger counter switch to turn it on. Read the activity from the gauge. (The needle on the gauge may move around a bit. You should try to get an average reading. Note that the scale on the gauge is not linear.) Record the activity of the sample in counts/sec in the worksheet.
- Click the switch again to turn it off.
- Click on the drop-down list of shielding materials and choose a single sheet (1 mm) of one of them. Drag the shielding into its holder in the apparatus.
- Again click on the Geiger counter switch, and again record the activity in the appropriate column in the worksheet.
- Repeat steps 6 and 7 for the other types of shielding material.
- Click on the drop-down list of radioactive sources and choose iron-59, a  $\beta$  emitter. Drag the source into the sample holder and measure its radioactivity.
- Choose one of the shielding materials and measure the radioactivity using 1, 2, 3, and 4 mm thicknesses. Record the activity values in the appropriate cells of the worksheet. Note the graph developing as you enter data.
- Repeat step 10 for the other shielding materials.
- Repeat steps 9-11 for strontium -85, a  $\gamma$  emitter.
- SAVE this worksheet either in your student folder OR in a personal drive. You can also email this file to yourself.
- When you have completed the excel sheet, raise your hand and your instructor will confirm your work. Do not close out the browser until this has happened.