INTRODUCTION

The nuclei of certain atoms are stable and under ordinary circumstances, stable nuclei do not undergo change. The nuclei of other atoms are unstable. These nuclei undergo change spontaneously, that is, without outside help. When unstable nuclei undergo change they give off radiation. Atoms which have unstable nuclei are radioactive and are called radioisotopes or radionuclides.

The change that an unstable nucleus undergoes is called disintegration or decay. When unstable nuclei disintegrate, or decay, certain particles - alpha or beta particles - or bundles of energy called gamma radiation, are emitted.

Atoms and molecules in the path of radiation are ionized, that is, they are stripped of electrons. That means alpha particles, beta particles, gamma radiation and other nuclear emissions have enough energy to remove some electrons from atoms or molecules with which they collide. Positively charged particles and free electrons are left behind after the collisions.

Devices that are used to detect radioactivity are based on the ionizing ability of radiation. One such device is the Geiger-Muller tube which is connected to a counter and is commonly referred to as a nuclear scaler. When a charged particle or gamma radiation enters the Geiger-Muller tube, it ionizes many of the argon gas atoms in the tube. The electrons are attracted to the anode and the argon ions are attracted to the cathode. This produces a surge of current which can be counted by the scaler.

PURPOSE

To investigate the nature of radioactivity and the effect of time, distance, and shielding materials on various radioactive sources using a G.M. tube with counter (generally referred to as a scaler.)

MATERIALS

Geiger-Muller tube (nuclear scaler)
Radioactive sources for alpha particles, beta particles, and gamma radiation
Forceps
Various shielding materials as provided by the instructor
NUCLEAR SPECTROMETRY

PURDUE UNIVERSITY INSTRUMENT VAN PROJECT

SAFETY

Use forceps or tweezers when handling all radioactive material.

Follow the standard safety procedures as explained by your teacher.

PRE-LAB QUESTIONS  none

PROCEDURE

NOTE: WHEN NOT IN USE, ALL RADIOACTIVE SOURCES AND OTHER RADIOACTIVE MATERIAL, SUCH AS LUMINOUS WATCH DIALS, SHOULD BE PLACED AT LEAST 1 METER AWAY FOR THE SCALER WHILE MEASUREMENTS ARE BEING TAKEN.

PART A: BACKGROUND RADIATION

1. Set the voltage dial on the nuclear scaler at 450 volts or at a voltage given to you by your teacher.

2. Turn the scaler on by pressing <<POWER>> button. The instrument does not need to warm-up.

3. Place the empty shield tray in the first shelf slot from the top of the tube.

4. Set the counter interval for 0.5 minutes.
NUCLEAR SPECTROMETRY

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5. Press the <<STOP>> button, then press the <<RESET>> button. At this point, the POWER, STOP and RESET lights should be on, and only zeros will be displayed on the counter.

6. Press the <<COUNT>> button. The scaler will count for the set time interval and stop automatically at the end of the time. At that point the STOP light will come on. Record the final count in your data table.

7. Press the <<RESET>> button.

8. Take 2 more counts for the background reading by pressing the <<COUNT>> button. Press the <<RESET>> button after each count has been recorded.

9. Average the three counts for the background radiation and record your average.

Question A-1. What is being counted?

Question A-2. Where did it come from?

PART B. OBSERVING RANDOMNESS OF DISINTEGRATION

1. Set the counter interval for 0.5 minutes.

2. Using forceps, place the alpha source on the plastic holder and place it on the first shelf position from the top.

3. Press the <<COUNT>> button and record the count when the STOP light comes on.

4. Press the <<RESET>> button.

5. Repeat the count of the alpha source on the first shelf two more times. Record your results.

Question B-1. Compare the three values. Are they exactly the same, very close, or very different?

Question B-2. What do these results indicate about the nature of radioactive decay?

PART C. THE EFFECT OF TIME ON THE AMOUNT OF EXPOSURE TO RADIATION
1. Set the counter interval for 0.5 minutes.

2. Using forceps, place the beta source in the plastic holder and place it in the third shelf position from the top.

3. Press the <<COUNT>> button. After the STOP light comes on, record the number of counts on the display.

4. Press the <<RESET>> button.

5. Set the counter interval for 1.0 minutes.

6. Press the <<COUNT>> button. After the STOP light comes on, record the number of counts on the display.

7. Press the <<RESET>> button.

8. Set the counter interval for 2.0 minutes.

9. Press the <<COUNT>> button. After the STOP light comes on, record the number of counts on the display.

10. Press the <<RESET>> button.

Question C-1. From your data, what conclusions can you make concerning time and the amount of exposure to radiation you received?

Question C-2. Predict the approximate number of counts you would measure in 3 minutes.

Question C-3. Approximately how many counts would you observe in 24 hours?

PART D. THE EFFECT OF DISTANCE ON THE AMOUNT OF EXPOSURE TO RADIATION

1. Set the counter interval to 0.5 minutes.

2. Place an empty plastic shield tray in the first shelf position from the top.
3. Using forceps, place the beta source in the plastic holder and place it in the second shelf position from the top.

4. Press the <<COUNT>> button. After the STOP light comes on, record the number of counts on the display.

5. Press the <<RESET>> button.

6. Move the plastic tray containing the beta source to the third shelf position from the top. The empty plastic tray should remain in the first shelf position.

7. Press the <<COUNT>> button. After the STOP light comes on, record the number of counts on the display.

8. Press the <<RESET>> button.

9. Move the plastic tray containing the beta source to the fourth position, then the fifth position and finally the sixth position, counting the radiation at each level.

Question D-1. From your data, why is it preferable to build a nuclear power plant in a sparsely populated area rather than close to a big city?

PART E. THE EFFECT OF SHIELDING ON THE AMOUNT OF EXPOSURE TO RADIATION.

SECTION 1. BETA PARTICLE RADIATION

1. Set the counter interval to 0.5 minutes.

2. Place an empty plastic shield tray in the first shelf position from the top.

3. Using forceps, place the beta source in the plastic holder and place it in the second shelf position from the top.

4. Press the <<COUNT>> button. After the STOP light comes on, record the number of counts on
5. Press the <<RESET>> button.

6. Place a piece of notebook paper on the plastic shield tray in the first shelf position.

7. Press the <<COUNT>> button. After the STOP light comes on, record the number of counts on the display.

8. Press the <<RESET>> button.

9. Replace the notebook paper with another shielding material.

10. Press the <<COUNT>> button. After the STOP light comes on, record the number of counts on the display.

11. Press the <<RESET>> button.

12. Use other shielding materials and take the count as directed by your teacher.

SECTION 2. ALPHA PARTICLE RADIATION

Follow the procedure outlined in Part E, Section 1 but use an alpha source instead of a beta source.

SECTION 3. GAMMA RADIATION

Follow the procedure outlined in Part E, Section 1 but use a gamma source instead of the beta source.

Question E-1. Which source (beta, alpha, or gamma) is most easily shielded?

Question E-2. Which source is the least easily shielded?

Question E-3. Which of the shielding materials was the most effective?
DATA ANALYSIS AND CALCULATIONS

1. Using your textbook as a resource, describe an alpha particle, a beta particle and gamma radiation.

2. Is there a correlation between the mass of the particle radiated and the ease with which it is shielded?

3. Predict the effect on the count for each source if the source had been shielded by two pieces of notebook paper rather than just one.

4. Predict the effect on the count for each source if the source had been shielded by five pieces of notebook paper rather than just one.

5. Graph of distance vs count.
   i. Using your data for PART D, subtract the average background count from the count at each level. This adjusted count is that which is produced by the source.
   ii. Plot a graph of the distance from the source vs. the adjusted count. The distance should go on the horizontal axis and the adjusted count should go on the vertical axis.

6. Describe the relationship between the amount of radiation and the distance from the source.

7. The activity of a radioactive source is 500 counts at a distance of 10 cm. What would be the approximate activity if the source was moved to a distance of 20 cm?

8. How would your exposure to radiation from the sun differ if you were on the planet Mercury or on the planet Pluto?
PART A: BACKGROUND RADIATION

<table>
<thead>
<tr>
<th>Trail Number</th>
<th>Count/ 0.5 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Average Background</td>
<td></td>
</tr>
</tbody>
</table>

Question A-1: What is being counted?

Question A-2: Where did it come from?

PART B: RANDOMNESS OF DISINTEGRATION

<table>
<thead>
<tr>
<th>Trail Number</th>
<th>Count/ 0.5 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

Question B-1. Compare the three values. Are they exactly the same, very close, or very different?

Question B-2. What do these results indicate about the nature of radioactive decay?
PART C: THE EFFECT OF TIME ON THE AMOUNT OF EXPOSURE TO RADIATION

<table>
<thead>
<tr>
<th>Time Interval</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5 min</td>
<td></td>
</tr>
<tr>
<td>1.0 min</td>
<td></td>
</tr>
<tr>
<td>2.0 min</td>
<td></td>
</tr>
</tbody>
</table>

Question C-1. From your data, what conclusions can you make concerning time and the amount of exposure to radiation you received?

Question C-2. Predict the approximate number of counts you would measure in 3 minutes.

Question C-3. Approximately how many counts would you observe in 24 hours?
PART D. THE EFFECT OF DISTANCE ON THE AMOUNT OF EXPOSURE TO RADIATION

<table>
<thead>
<tr>
<th>Shelf Position</th>
<th>Distance From Source</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>2nd From Top</td>
<td>2 cm</td>
<td></td>
</tr>
<tr>
<td>3rd From Top</td>
<td>3 cm</td>
<td></td>
</tr>
<tr>
<td>4th From Top</td>
<td>4 cm</td>
<td></td>
</tr>
<tr>
<td>5th From Top</td>
<td>5 cm</td>
<td></td>
</tr>
<tr>
<td>Bottom</td>
<td>6 cm</td>
<td></td>
</tr>
</tbody>
</table>

Question D-1. From your data, why is it preferable to build a nuclear power plant in a sparsely populated area rather than close to a big city?

PART E. THE EFFECT OF SHIELDING ON THE AMOUNT OF EXPOSURE TO RADIATION

<table>
<thead>
<tr>
<th>Shielding Material</th>
<th>Beta Count</th>
<th>Alpha Count</th>
<th>Gamma Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>notebook paper</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Question E-1. Which source (beta, alpha, or gamma) is most easily shielded?
Question E-2. Which source is the least easily shielded?

Question E-3. Which of the shielding materials was the most effective?

Question E-4. Which of the shielding materials was the least effective?

DATA ANALYSIS AND CALCULATIONS

1. Using your textbook as a resource, describe an alpha particle, a beta particle and gamma radiation.

2. Is there a correlation between the mass of the particle radiated and the ease with which it is shielded?

3. Predict the effect on the count for each source if the source had been shielded by two pieces of notebook paper rather than just one.

4. Predict the effect on the count for each source if the source had been shielded by five pieces of
5. Graph of distance vs count.

   i. Using your data for PART D, subtract the average background count from the count at each level. This adjusted count is that which is produced by the source.

   ii. Plot a graph of the distance from the source vs. the adjusted count. The distance should go on the horizontal axis and the adjusted count should go on the vertical axis.

6. Describe the relationship between the amount of radiation and the distance from the source.

7. The activity of a radioactive source is 500 counts at a distance of 10 cm. What would be the approximate activity if the source was moved to a distance of 20 cm?

8. How would your exposure to radiation from the sun differ if you were on the planet Mercury or on the planet Pluto?
CLASSROOM USAGE

This is considered a discovery lab. It may be appropriate for physical science as well as practical and college prep chemistry classes.

CURRICULUM INTEGRATION

Nuclear Energy - this may be done anytime while studying the unit.

PREPARATION

Shielding materials have to be provided. Some things which can be used are plastic wrap, aluminum foil, a piece of fabric, lead foil, window glass, wood (tongue depressors), tissue, and cotton.

GETTING READY

It is important to familiarize yourself with the set-up and operation of the nuclear scaler. Our scalers work at the 450 volt setting, but it would be best to verify that this is a good operating voltage.

You will probably want the students to work in pairs.

TIME

This experiment will probably require two lab periods.

SAFETY AND DISPOSAL
The radioactive sources will not provide any unusual hazard for the students. They should handle the samples with forceps. If there is a concern about having touched a sample, washing the hands will be sufficient.

VARIATIONS

This lab may be expanded, cut back, or rearranged to fit your schedule. You may want the students to bring in some different materials. Some students may want to change the time intervals.