**RADIOACTIVITY**

(Revised:6-16-11)

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

250 mL Beaker

Ring Stand

3-Prong Clamp

**For the extra extensions of the lab:**

•Empty paint can

•pH probes

•Soil, rock, sand, etc.

•Plastic jewelry baggies

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.

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. CAN WE DETECT RADIATION IN CELL PHONES?

1. Set the counter interval to 0.5 minutes.

2. Place a cell phone in the tube.

3. Run three different tests to test for ionizing radiation from your cell phone. First with the phone

simply on, then with the phone receiving a text, and lastly with the phone receiving a call.

Question D-1. What are current forms of ionizing radiation that we receive in our lives? How do

we protect ourselves against them?

Question D-2. From your data, what conclusions can you make concerning the amount of ionizing

radiation that the cell phone put out?

Question D-3. What do, or should, phone manufacturers take into account when designing these

cell phones in terms of limiting the amount of ionizing radiation?

PART E. 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 E-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 F. 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

the display.

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

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

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

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

PART G. SHIELDING NUCLEAR WASTE

1. After fuel is spent inside of a nuclear reactor it must be stored temporarily. This is done by

placing the spent fuel in pools of water.

2. We will test how deep the pools need to be to safely protect against ionizing radiation from spent

fuel.

3. Attach the Geiger-Muller tube to a ring stand with a 3-prong clamp. It must be just tall enough

to be able to house the 250 mL beaker.

4. Place the gamma source directly underneath the G-M tube. Take 3 counts with a time interval of

30 seconds.

5. Next place the 250 mL beaker over the gamma source. Again, take 3 counts.

6. Then add 1 cm. of water to the beaker. Take 3 counts.

7. Continue adding 1 cm. of water and taking 3 counts up to 8 cm. of water.

Question G-1. Make a graph of distance of shielding versus counts per half-minute.

Question G-2. Draw a best-fit line. The minimum depth that the fuel is placed at is 8 ft.

(they are placed much deeper than this though). Using your data, at a depth

of 8 ft. how much (in a percent) would the water reduce the original activity

of the fuel?

**EXTENSION ON THIS ASPECT AND IDEAS:**

1. This lab is very long. Could be done as a regular chemistry class doing parts A-F. Then part G (with all of its extensions coming after) can be done in another class at a department’s discretion (I will be using that part in my environmental science class for instance).
2. Students could also test the water in and of itself after prolonged exposure to radiation samples. This leads to the connection of what happened at Fukushima and how there were worries about the water supply being contaminated.
3. Students could also check to see if ionizing-radiation leads to a pH change in the water. Thus providing a wonderful opportunity to see just how the ecology changes as a result.
4. Could also use things other than water. Ideas thrown out were soil, rock, sand.
5. Also spoke about using a paint can and how well it shields. Students could then design their own nuclear containment container and run with it. Explain their reasoning, have a competition with the entire class, etc.
6. After data is collected talk about local nuclear power plants (Illinois), where the New Madrid fault line is located, its activity in the past. Students could provide a report on possibility for H2O contamination due to nuclear power, earthquakes, accidents, etc.
7. Based on results, would you live next to a power plant, what should we do as a country regarding the expansion of nuclear power, etc.

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?

NAME \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

CLASS PERIOD \_\_\_\_\_\_\_\_\_\_

**RADIOACTIVITY DATA SHEET**

PART A: BACKGROUND RADIATION

|  |  |
| --- | --- |
| Trail Number | Count/ 0.5 min |
| 1 |  |
| 2 |  |
| 3 |  |
| Average Background |  |

Question A-1: What is being counted?

Question A-2: Where did it come from?

PART B: RANDOMNESS OF DISINTEGRATION

|  |  |
| --- | --- |
| Trail Number | Count/ 0.5 min |
| 1 |  |
| 2 |  |
| 3 |  |

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

|  |  |
| --- | --- |
| Time Interval | Count |
| 0.5 min |  |
| 1.0 min |  |
| 2.0 min |  |

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: CAN WE DETECT RADIATION IN CELL PHONES?

|  |  |
| --- | --- |
| Phone Scenario | Count |
| Turned On |  |
| Receiving a Text |  |
| Receiving a Call |  |

Question D-1. What are current forms of ionizing radiation that we receive in our lives? How do

we protect ourselves against them?

Question D-2. From your data, what conclusions can you make concerning the amount of ionizing

radiation that the cell phone put out?

Question D-3. What do, or should, phone manufacturers take into account when designing these

cell phones in terms of limiting the amount of ionizing radiation?

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

|  |  |  |
| --- | --- | --- |
| Shelf Position | Distance From Source | Count |
| 2nd From Top | 2 cm |  |
| 3rd From Top | 3 cm |  |
| 4th From Top | 4 cm |  |
| 5th From Top | 5 cm |  |
| Bottom | 6 cm |  |

Question E-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 F. THE EFFECT OF SHIELDING ON THE AMOUNT OF EXPOSURE TO RADIATION

|  |  |  |  |
| --- | --- | --- | --- |
| Shielding Material | Beta Count | Alpha Count | Gamma Count |
| notebook paper |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |

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

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

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

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

PART G: THE EFFECT OF DEPTH ON THE AMOUNT OF EXPOSURE TO RADIATION

|  |  |
| --- | --- |
| DEPTH | Count |
| 0 cm of H2O |  |
| 1 cm of H2O |  |
| 2 cm of H2O |  |
| 3 cm of H2O |  |
| 4 cm of H2O |  |
| 5 cm of H2O |  |
| 6 cm of H2O |  |
| 7 cm of H2O |  |
| 8 cm of H2O |  |

Question G-1. Make a graph of distance of shielding versus counts per half-minute.

Question G-2. Draw a best-fit line. The minimum depth that the fuel is placed at is 8 ft.

(they are placed much deeper than this though). Using your data, at a depth

of 8 ft. how much (in a percent) would the water reduce the original activity

of the fuel?

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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.

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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?

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**TEACHERS' GUIDE**

**RADIOACTIVITY**

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.