Chemistry – Radioactive Decay

Neatly answer all questions completely for credit. Show all work.

**Teacher Notes**

**Time:** 90 minutes (plus 30 minutes for teacher preparation)

**Overview:**

Radioactive isotopes are unstable. All radioactive matter decays, or breaks down, in a predictable pattern. Radioactive isotopes release radiation as they disintegrate into daughter isotopes.

The rate of decay is a measure of how fast an isotope changes into its daughter isotope. The rate of radioactive decay is conveniently characterized by the isotope’s half-life, the period of time it takes one-half of the original material to decay. Half-lives vary from billions of years to fractions of a second.

**Objectives:**

- **Infer** that the rate of decay can be simulated by a random process.
- **Compare** the numbers of m&ms that are showing heads with the number showing tails.
- **Create** a string plot that represents nuclear decay.
- **Relate** observations to the rate of nuclear decay.
- **Graph** the data.
- **Compare** the results of the two simulation procedures.

**Materials:**

- colored paper or cloth strips, approximately 65 cm × 2.5 cm (2 strips)
- graph paper
- one sheet of stiff poster board, 70 cm × 60 cm
- m&ms or other objects supplied by your teacher (100)
- scissors, tape, meter stick, pencil, and string
- shoe box with lid

**Safety**

While doing this activity, observe the following safety precautions.

- **Always wear safety goggles and a lab apron to protect your eyes and clothing.** If you get a chemical in your eyes, immediately flush the chemical out at the eyewash station while calling to your teacher. Know the locations of the emergency lab shower and the eyewash station and the procedures for using them.

**Lab Preparation:**

For Part A, record your data in the **Data Table**.
Chemistry – Radioactive Decay

Neatly answer all questions completely for credit. Show all work.

PROCEDURE

Part A: Simulating radioactive decay with m&ms

1) Place 100 m&ms into the shoe box so that the head sides are up. The m&ms will represent atoms. Record 100 in the “Unchanged atoms” column and 0 in the “Changed atoms” column.

2) With the lid on the box, shake the box up and down 5 times. We will count each shaking period as being equivalent to 10 s.

3) Open the lid, and remove all of the m&ms that have the tails side up. These m&ms represent the changed atoms.

4) Count the number of m&ms remaining in the box. Record this number in the 10 s row of the “Unchanged atoms” column in the Data Table. Count the number of changed atoms (the m&ms that you removed from the box), and record the number in the 10 s row.

5) Each lab partner should predict how many times steps 2–4 will need to be repeated until only one unchanged atom remains. Record the time that each lab partner predicted. Remember that each shaking period is counted as 10 s, so four shaking periods would be recorded as 40 s.

6) Repeat steps 2–4 by counting and recording each time until only 1 (or 0) m&m with the head side up remains.

Part B: Simulating decay with paper

1) Draw an y-axis and x-axis on the poster board so that they are about 5 cm from the left side and the bottom edge respectively. Label the x-axis as “Time” and the y-axis as “Amount of material.”

2) Along the x-axis, draw marks every 10 cm from the y-axis line. Label the first mark “0” and the next mark “1,” and so on. Each mark represents 1 minute.

3) Place one of the colored strips vertically with its lower edge centered on the 0 mark of the x-axis. Tape the strip in place.

4) Fold the other colored strip in half, and cut it in the middle. Place one-half of the strip so that it is centered on the next mark, and tape the strip in place.

5) Fold the remaining piece of the strip in half, and cut it exactly in the middle.

6) Place one of the pieces so that it is centered on the next mark, and tape the piece in place.

7) Repeat steps 11 and 12, and each time, tape the first piece vertically at the next x-axis mark. Continue until you have at least 8 strips taped along the x-axis.

8) Use the string to join the tops of each strip of paper to make a continuous curve.

Cleanup and Disposal

• “Dispose” of the m&ms and return the box to your teacher. Dispose of the poster board, strips, and string as instructed by your teacher. Clean up your lab station.
Chemistry – Radioactive Decay

Neatly answer all questions completely for credit. Show all work.

Data Table

<table>
<thead>
<tr>
<th>Time (s)</th>
<th>Unchanged atoms</th>
<th>Changed atoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>49</td>
<td>51</td>
</tr>
<tr>
<td>20</td>
<td>23</td>
<td>26</td>
</tr>
<tr>
<td>30</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>40</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>50</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>60</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>70</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>

Analysis

PART A

1) **Predicting Outcomes** How long did it take to have only 1 m&m (0 m&ms) left in the box? How close was your prediction in step 5?

**Answers will vary.**

2) **Analyzing Data** Make a graph of your data on a piece of graph paper. Label the x-axis “Time” and the y-axis “Unchanged atoms.” Plot the number of unchanged atoms versus time. Draw a smooth curve through the data points.

**Plots of data will vary slightly, but the graphs should all display the same trend.**
Chemistry – Radioactive Decay

Neatly answer all questions completely for credit. Show all work.

3) **Analyzing Results** Each trial was comparable to a 10 s period of time. How long did it take for half of your m&ms to be removed from the box? What is the half-life of the process?

10 s; 10 s

4) **Interpreting Graphics** Use your graph to determine the time it takes to have only 25% of the unchanged atoms remaining. In your experiment, how many m&ms remained in the box at that time?

Answers will vary but should be 20 s or 30 s. Answers will vary but should be close to 25 m&ms.

**PART B**

1) **Analyzing Results** How many half lives have passed after 4 minutes?

4 half-lives

2) **Interpreting Graphics** Using the string plot, determine how many minutes it took until only 20% of the original material remained.

Answers will vary but should be approximately 2.3 min.

**Conclusions**

1) **Inferring Conclusions** If you started with a paper strip that was twice as long, would the half-life change?

The half-life will be the same.

2) **Inferring Conclusions** Is there a relationship between the graph from Part A and the string plot from Part B?

Both curves have the same shape. In both cases, half of the original objects or half of the length disappears in each trial.
Chemistry – Radioactive Decay

Neatly answer all questions completely for credit. Show all work.

Simulation of Nuclear Decay Using M&ms and Paper

Radioactive isotopes are unstable. All radioactive matter decays, or breaks down, in a predictable pattern. Radioactive isotopes release radiation as they disintegrate into daughter isotopes.

The rate of decay is a measure of how fast an isotope changes into its daughter isotope. The rate of radioactive decay is conveniently characterized by the isotope’s half-life, the period of time it takes one-half of the original material to decay. Half-lives vary from billions of years to fractions of a second.

Objectives:

• Infer that the rate of decay can be simulated by a random process.
• Compare the numbers of m&ms that are showing heads with the number showing tails.
• Create a string plot that represents nuclear decay.
• Relate observations to the rate of nuclear decay.
• Graph the data.
• Compare the results of the two simulation procedures.

Materials:

• colored paper or cloth strips, approximately 65 cm × 2.5 cm (2 strips)
• graph paper
• one sheet of stiff poster board, 70 cm × 60 cm
• m&ms or other objects supplied by your teacher (100)
• scissors, tape, meter stick, pencil, and string
• shoe box with lid

Safety

While doing this activity, observe the following safety precautions.

• Always wear safety goggles and a lab apron to protect your eyes and clothing. If you get a chemical in your eyes, immediately flush the chemical out at the eyewash station while calling to your teacher. Know the locations of the emergency lab shower and the eyewash station and the procedures for using them.

Lab Preparation:

For Part A, record your data in the Data Table.
Chemistry – Radioactive Decay

Neatly answer all questions completely for credit. Show all work.

PROCEDURE

Part A: Simulating radioactive decay with m&ms

1) Place 100 m&ms into the shoe box so that the head sides are up. The m&ms will represent atoms. Record 100 in the “Unchanged atoms” column and 0 in the “Changed atoms” column.

2) With the lid on the box, shake the box up and down 5 times. We will count each shaking period as being equivalent to 10 s.

3) Open the lid, and remove all of the m&ms that have the tails side up. These m&ms represent the changed atoms.

4) Count the number of m&ms remaining in the box. Record this number in the 10 s row of the “Unchanged atoms” column in the Data Table. Count the number of changed atoms (the m&ms that you removed from the box), and record the number in the 10 s row.

5) Each lab partner should predict how many times steps 2–4 will need to be repeated until only one unchanged atom remains. Record the time that each lab partner predicted. Remember that each shaking period is counted as 10 s, so four shaking periods would be recorded as 40 s.

6) Repeat steps 2–4 by counting and recording each time until only 1 (or 0) m&m with the head side up remains.

Part B: Simulating decay with paper

1) Draw an y-axis and x-axis on the poster board so that they are about 5 cm from the left side and the bottom edge respectively. Label the x-axis as “Time” and the y-axis as “Amount of material.”

2) Along the x-axis, draw marks every 10 cm from the y-axis line. Label the first mark “0” and the next mark “1,” and so on. Each mark represents 1 minute.

3) Place one of the colored strips vertically with its lower edge centered on the 0 mark of the x-axis. Tape the strip in place.

4) Fold the other colored strip in half, and cut it in the middle. Place one-half of the strip so that it is centered on the next mark, and tape the strip in place.

5) Fold the remaining piece of the strip in half, and cut it exactly in the middle.

6) Place one of the pieces so that it is centered on the next mark, and tape the piece in place.

7) Repeat steps 11 and 12, and each time, tape the first piece vertically at the next x-axis mark. Continue until you have at least 8 strips taped along the x-axis.

8) Use the string to join the tops of each strip of paper to make a continuous curve.

Cleanup and Disposal

• “Dispose” of the m&ms and return the box to your teacher. Dispose of the poster board, strips, and string as instructed by your teacher. Clean up your lab station.
Chemistry – Radioactive Decay

Neatly answer all questions completely for credit. Show all work.

Data Table

<table>
<thead>
<tr>
<th>Time (s)</th>
<th>Unchanged atoms</th>
<th>Changed atoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>70</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Analysis

PART A

1) Predicting Outcomes How long did it take to have only 1 m&m (0 m&ms) left in the box? How close was your prediction in step 5?

2) Analyzing Data Make a graph of your data on a piece of graph paper. Label the x-axis “Time” and the y-axis “Unchanged atoms.” Plot the number of unchanged atoms versus time. Draw a smooth curve through the data points.
Chemistry – Radioactive Decay

Neatly answer all questions completely for credit. Show all work.

3) **Analyzing Results** Each trial was comparable to a 10 s period of time. How long did it take for half of your m&ms to be removed from the box? What is the half-life of the process?

4) **Interpreting Graphics** Use your graph to determine the time it takes to have only 25% of the unchanged atoms remaining. In your experiment, how many m&ms remained in the box at that time?

**PART B**

1) **Analyzing Results** How many half lives have passed after 4 minutes?

2) **Interpreting Graphics** Using the string plot, determine how many minutes it took until only 20% of the original material remained.

**Conclusions**

1) **Inferring Conclusions** If you started with a paper strip that was twice as long, would the half-life change?

2) **Inferring Conclusions** Is there a relationship between the graph from Part A and the string plot from Part B?