



Half-Life of Paper, M&M's, Pennies, Puzzle Pieces & Licorice

Grade Level

5-12

Disciplinary Core Ideas (DCI)

3-5ETS1-2, MS-ESS1-4, HS-ESS1-6

Time for Teacher Preparation

40-60 minutes – To gather materials

Activity Time:

40-60 minutes (1 Class Period)

Materials

- Bag of (choose one): M&M's®, pennies, puzzle pieces, or licorice
- Paper – 8.5" x 11"
- Graph Paper
- Zip-Lock Bags
- Pen, Marker, or Pencil
- Rulers
- Student Data Collection Sheets

Safety

- Students should not eat M&M's®, Licorice, Pennies or Puzzle Pieces

Science and Engineering Practices

- Ask questions and define problems
- Use models
- Analyze and interpret data
- Use mathematics and computational thinking
- Construct explanations
- Argue from evidence
- Obtain, evaluate and communicate information

Cross Cutting Concepts

- Patterns
- Cause and Effect
- Scale, Proportion, and Quantity

With the Half-Life Laboratory, students gain a better understanding of radioactive dating and half-lives. Students are able to visualize and model what is meant by the half-life of a reaction. By extension, this experiment is a useful analogy to radioactive decay and carbon dating. Students use M&M's, Licorice, Puzzle Pieces or paper to demonstrate the idea of radioactive decay. This experiment is best used by students working in pairs.

- Systems and System Models
- Energy and Matter: Flows, Cycles, and Conservation

Objectives

Students try to model radioactive decay by using the scientific thought process of creating a hypothesis, then testing it through inference. It is a great introduction to the scientific process of deducing, forming scientific theories, and communicating with peers. It is also useful in the mathematics classroom by the process of graphing the data.

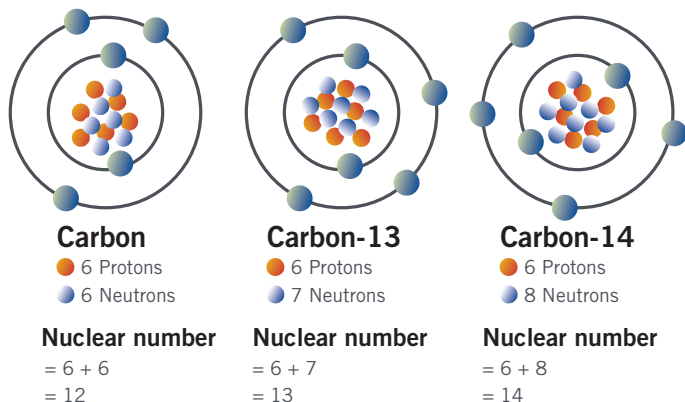
Students should begin to see the pattern that each time they “take a half-life,” about half of the surrogate radioactive material becomes stable. Students then should be able to see the connection between the M&M's, Puzzle Pieces, or Licorice and radioactive elements in archaeological samples. Seeing this connection will help students to understand how scientists can determine the age of a sample by looking at the amount of radioactive material in the sample.

- To define the terms half-life and radioactive decay
- To model the rate of radioactive decay
- To create line graphs from collected data
- To compare data
- To understand how radioactive decay is used to date archaeological artifacts

Background

Half-Life

If two nuclei have different masses, but the same atomic number, those nuclei are considered to be isotopes. Isotopes have the same chemical properties, but different physical properties. An example of isotopes is carbon, which has three main isotopes: carbon-12, carbon-13 and carbon-14. All three isotopes have the same atomic number of 6, but have different numbers of neutrons. Carbon-14 has 2 more neutrons than carbon-12 and 1 more than carbon-13, both of which are stable. Carbon-14 is radioactive and undergoes radioactive decay.



decay at a rate that is characteristic to the isotope. The rate of decay is a fixed rate called a half-life.

The half-life of a radioactive isotope refers to the amount of time required for half of a quantity of a radioactive isotope to decay. Carbon-14 has a half-life of 5,730 years, which means that if you take one gram of carbon-14, half of it will decay in 5,730 years. Different isotopes have different half-lives.

The ratio of the amounts of carbon-12 to carbon-14 in a human is the same as in every other living thing. After death, the carbon-14 decays and is not replaced. The carbon-14 decays, with its half-life of 5,730 years, while the amount of carbon-12 remains constant in the sample. By looking at the ratio of carbon-12 to carbon-14 in the sample and comparing it to the ratio in a living organism, it is possible to determine the age of a formerly living thing. Radiocarbon dates do not tell archaeologists exactly how old an artifact is, but they can date the sample within a few hundred years of the age.

Radioactive materials contain some nuclei that are stable and other nuclei that are unstable. Not all of the atoms of a radioactive isotope (radioisotope) decay at the same time. Rather, the atoms

Finding Half-Life

The basic equation for calculating the amount of radioactive material remaining is: $y = \frac{1}{2^{t_{1/2}}}$

Where,

y = the fraction of the original material remaining

$t_{1/2}$ = the number of half-lives

To find the age of an object using half-life, the following equations are used:

$$t_{\text{age}} = (\text{half-life}) * \log_2 \left(\frac{1}{y} \right) = t_{\text{age}} = \left(\frac{\text{half-life}}{0.693} \right) * \ln(1/y) = t_{\text{age}} = \frac{(-1)}{K} * \ln \left(\frac{n_o}{n_t} \right)$$

Where,

$K = \frac{0.693}{\text{half-life}} = \frac{\ln(2)}{\text{half-life}}$	$y = \text{fraction of original material}$
$\text{and } y = \left(\frac{n_o}{n_t} \right)$	$n_o = \text{amount of parent material left}$
	$n_t = \text{total amount of material} = \text{parent} + \text{daughter}$



Teacher Lesson Plan:

Traditional

Paper

1. Give each student a blank piece of paper. This represents the amount of radioactive material when first formed.
2. Tell the students to take the **Day of the Month** on which they were born and multiply that number by 2,000 (x2000). For example, if you were born on the 23rd day of a month, you would multiply 23 x 2000 and your answer would be 46,000.
3. Have the students calculate their number and fill it into the box labeled **Beginning Amount** in Table 1 of the data collection sheet. This number represents the initial number of Radioactive Atoms in their sheet of paper.
4. Call “Half-Life” at 30 second intervals (until the students have completed their 7th Half-Life). The students will take their number of radioactive atoms and divide by 2 (in half) and write the new number into the box labeled 1st Half-Life.
5. Then, have the students tear the provided sheet of paper in half. They should place the top half of paper onto their desks in front of them. These atoms are now stable and are no longer radioactive.
6. Repeat Steps 1-4 until after the 7th half-life.

M&M's® (or Pennies or Puzzle Pieces)

1. Give each student 10 M&M's® candies of any color and a zip lock bag. All of M&M's® candies are considered radioactive.
2. Have the student put the M&M's® into the zip lock bag and shake the bag. Have the students spill out the candies onto a flat surface.
3. Instruct the students to pick up **ONLY** the candies with the “m” showing - these are still radioactive. The students should count the “m” candies as they return them to the bag.
4. Have the students record the number of candies they returned to the bag under the next Trial.
5. The students should move the candies that are blank on the top to the side – these have now decayed to a stable state.
6. The students should repeat steps 2 through 5 until all the candies have decayed or until they have completed Trial 7.
7. Set up a place on the board where all students or groups can record their data.
8. The students will record the results for 9 other groups in their data tables and total all the Trials for the 100 candies.

Licorice

1. Instruct the students to label the horizontal axis of the graph paper “Time (seconds)” and the vertical axis

“Radioactive Licorice (%)”. Show them how to calibrate the horizontal axes so that one block equals 5 seconds and two blocks equal 10 seconds. Instruct them to mark the horizontal axis at 10-second intervals.

2. Give each student one piece of licorice to place onto the graph paper. Tell them to stretch the full length of the licorice vertically over the time “zero” mark and to make a mark on the paper at the top of the licorice. This mark represents 100% of the radioactive material at time zero.
3. Call out “GO” or “HALF-LIFE” at 10-second intervals for up to 90 seconds. When you say “GO” or “HALF-LIFE,” the students will have ten seconds to remove one-half of their licorice and set it aside. They place the remaining piece of licorice on the 10 seconds line and mark its current height. At 20 seconds, they should again remove half of the licorice and set it aside, then mark the height of the remaining portion on their graphs at the 20 second line. Repeat this process until 90 seconds have gone by.
4. Now, the students should connect all the height marks with a “best fit” line, completing a graph of the “Half-Life of Licorice.”

NOTE: The original strip of licorice represents radioactive material; the portion which is “set aside” during the activity represents the material that has “decayed” and is no longer radioactive.

NGSS Guided Inquiry

Explain about radiation and half-lives of isotopes. Tell students to design their own experiment, using paper, M&M's®, Pennies, other 2 sided material or Licorice as a radioactive material undergoing decay to discover the nature of the half-life of that material.

You might suggest that the students experiment with their graphing results to see if trends begin to form.

Student Procedure

Paper

1. Take the **Day of the Month** on which you were born and multiply that number by 2,000 (x2000). For example, if you were born on the 23rd day of a month, you would multiply 23 x 2000 and your answer would be 46,000.
2. Calculate your number and fill it into the box labeled **Beginning Amount** in Table 1. This number represents the initial number of Radioactive Atoms in your sheet of paper.
3. When your teacher calls “Half-Life,” divide your number of radioactive atoms by 2 (in half) and write the new number in the box labeled 1st Half-Life in Table 1.
4. Then, tear the provided sheet of paper in half. Place the top half of paper onto your desk in front of you. These atoms are now stable and are no longer radioactive.
5. Repeat Steps 1-4 until after the 7th half-life.

M&M's® (or pennies or puzzle pieces)

- Put 10 M&M's® candies of any color into a zip lock bag. Each group is starting with 10 M&M's® candies, which is recorded as Trial 0 in the data table. *All of the M&M's® candies are considered to be radioactive at the beginning.*
- Shake the bag and spill out the candies onto a flat surface.
- Pick up **ONLY** the candies with the “m” showing – *these are still radioactive*. Count the “m” candies as you return them to the bag.
- Record the number of candies you returned to the bag under the next Trial.
- Move the candies that are blank on the top to the side – these have now decayed to a stable state.
- Repeat steps 2 through 5 until all the candies have decayed or until you have completed Trial 7.
- Record the results for 9 other groups and total all the Trials for the 100 candies.

Licorice

- Label the horizontal axis of the graph paper “Time (seconds)” and the vertical axis “Radioactive Licorice (%)”. Calibrate the horizontal axes so that one block equals 5 seconds and two blocks equal 10 seconds. Mark the axis at 10-second intervals.
- Start with one piece of licorice to place onto the graph paper. Stretch the full length of the licorice vertically over the time “zero” mark, which is the same as the vertical axis. Make a mark on the graph paper at the top of the licorice. This mark represents 100% of the radioactive material at time zero.
- Your teacher will call out “GO” or “HALF-LIFE” at 10-second intervals up to 90 seconds. When your teacher says “GO” or “HALF-LIFE” you will have ten seconds to remove one-half of your licorice and set it aside. Place the remaining piece of licorice on the 10 seconds line and mark its current height. At 20 seconds, you should again remove half of the licorice and set it aside, then mark the height of the remaining portion on your graph at the 20-second line. Repeat this process until 90 seconds have gone by.
- Now, connect all the height marks with a “best fit” line, completing a graph of the “Half-Life of Licorice.”

NOTE: The original strip of licorice represents radioactive material. The portion which is “set aside” during the activity represents the material that has “decayed” and is no longer radioactive.

Data Collection

Attached Student Data Collection Sheets

Post Discussion/Effective Teaching Strategies

Questions provided on the Student Data Collection Sheets

Questions**Paper**

- Define the term **half-life**.
- What does it mean when we say an atom has “**decayed**”?
- Based on the numbers in **Table 1**, approximately what percentage of the atoms decay in each half-life?
- List two things that stayed the same during this activity and list two things that are different during this activity.
- Do the number of atoms you start with affect the outcome? Explain.
- How do scientists use radioactive decay to date fossils and artifacts?

M&M's® (or Pennies or Puzzle Pieces)

- Define the term **half-life**.
- What does it mean when we say an atom has “**decayed**”?
- Do the number of atoms you start with affect the outcome? Explain.
- Did each group get the same results?
- Did any group still have candies remaining after Trial 7?
- Why do the totals for the 10 groups better show what happens during half-life rather than any other group's results?
- What happens to the total number of candies with each trial (half-life)?
- Plot the total results on a graph with number of candies on the vertical axis and trial number on the horizontal axis. Is the result a straight or a curved line? What does the line indicate about the nature of decay of radionuclides?
- How do scientists use radioactive decay to date fossils and artifacts?

Licorice

- Did the licorice ever completely disappear or just get so small that you couldn't tear it into halves?
- If the entire earth could be divided in half, and then in half again over and over like the piece of licorice for as long as you could, what would be the smallest piece you would end up with?
- If you had started with twice as long a piece of licorice, would it have made any difference in the graph line you would have obtained?

** To try this, move back to a time minus (-) 10 seconds and imagine how tall the licorice would have been then. What really does change when you use more?



- Let's go the other direction for a change. Let us suppose the tiny bit of licorice at 90 seconds was your starting place. Then suppose you would double it in size every 10 seconds as you moved left on your graph towards 0 seconds. At 0, of course, you would have reached the size of one piece of licorice. However, what would be the size of the piece of licorice MINUS (-) 40 seconds?
- Using the same method as in questions 4, continue doubling your licorice until you would reach MINUS (-) 100 seconds. How large a piece would you have then?
- Does it really matter how large a sample you start with for this graph? WHY or WHY NOT?
- Describe how the graph would be different if you took another piece of licorice exactly the same size as the first piece but you bit it in half and marked it on the graph every 30 seconds instead of every 10 seconds?

Assessment Ideas

- Question the student about how this experiment is similar to Carbon Dating.

Differentiated Learning/Enrichment

- Have the students calculate the age of objects when given the half-life, original amount, and current amount of that material.

Enrichment Question

- The population of the earth is doubling every 40 years. If the population of the earth is now 7 billion people, how many people will be here when you are 95 years old?

Further Resources

For similar experiments:

<http://www.nuclearconnect.org/in-the-classroom/for-teachers/classroom-activities>

http://www.idahogeology.org/FieldWorkshops/Island_Park_2007b/Cash_Activities/Half-life_activity.pdf

http://hps.org/sciencesupport/documents/half_life.pdf

For more information on Carbon Dating:

<http://www.c14dating.com/>

<http://hyperphysics.phy-astr.gsu.edu/hbase/nuclear/cardat.html>

<http://www.101science.com/Carbon14.htm>

References:

Equations for Half-Life

<http://ipc1.clpccd.cc.ca.us/lpc/hanna/HistoricalGeology/HalfLifeEquations.pdf>

Table on Radiation Measurements

<http://orise.orau.gov/reacts/guide/measure.htm>

Half-Life of Paper

Objectives

- To define the terms half-life and radioactive decay
- To compare data
- To understand how radioactive decay is used to date archaeological artifacts

Procedure

1. Take the **Day of the Month** on which you were born and multiply that number by 2,000 (x2000). For example, if you were born on the 23rd day of a month, you would multiply 23 x 2000 and your answer would be 46,000.
2. Calculate your number and fill it into the box labeled **Beginning Amount** in Table 1. This number represents the initial number of radioactive atoms in your sheet of paper.
3. When your teacher calls “Half-Life,” divide your number of radioactive atoms by 2 (in half) and write the new number in the box labeled 1st Half-Life in Table 1.
4. Then, tear the provided sheet of paper in half. Place the top half of paper onto your desk in front of you. These atoms are now stable and are no longer radioactive.
5. Repeat Steps 1-4 until after the 7th half-life.

Data Collection

Table 1

Beginning Amount	1st Half-Life	2nd Half-Life	3rd Half-Life	4th Half-Life	5th Half-Life	6th Half-Life	7th Half-Life
% Decayed							

Questions

1. Define the term **half-life**.

The time it takes for half of the atoms to decay to a stable state.

2. What does it mean when we say an atom has “**decayed**”?

The atom has fissioned into 2-3 smaller particles, releasing energy in the form of alpha, beta, or gamma rays, and is now at a stable state. When an atom has fully decayed, all the electrons are at the lowest energy shell available, the atom is not releasing alpha, beta or gamma rays.

3. For **Table 1**, at the end of **each** half-life, at approximately what percentage are the atoms decaying?

50%

4. List two things that stayed the same during this activity and list two things that are different during this activity.

The things that stay the same: Total number of atoms, time of half-life

The things that change: number of radioactive atoms, % of radioactive atoms

5. Do the number of atoms you start with affect the outcome? Explain.

No, the half-life defines the ratio and the number of stable atoms. The percent of decrease is the same no matter how many atoms you start with.

6. How do scientists use radioactive decay to date fossils and artifacts?

By looking at the ratio of carbon-12 to carbon-14, they can calculate back to the amount of original carbon-14 using the carbon-14 half-life of 5,730 years.

Enrichment Question

1. The population of the earth is doubling every 40 years. If the population of the earth is now 6 billion people, how many people will be here when you are 95 years old?

Age of Student	Number of people when student is 95	Age of Student	Number of people when student is 95
10	30.53 billion	15	28 billion
11	30.01 billion	16	27.52 billion
12	29.49 billion	17	27.05 billion
13	28.99 billion	18	26.58 billion
14	28.49 billion		

Half-Life of Paper

Student Data Collection Sheet

Objectives

- To define the terms half-life and radioactive decay
- To compare data
- To understand how radioactive decay is used to date archaeological artifacts

Procedure

1. Take the **Day of the Month** on which you were born and multiply that number by 2,000 ($\times 2000$). For example, if you were born on the 23rd day of a month, you would multiply 23×2000 and your answer would be 46,000.
2. Calculate your number and fill it into the box labeled **Beginning Amount** in Table 1. This number represents the initial number of radioactive atoms in your sheet of paper.
3. When your teacher calls “Half-Life,” divide your number of radioactive atoms by 2 (in half) and write the new number in the box labeled 1st Half-Life in Table 1.
4. Then, tear the provided sheet of paper in half. Place the top half of paper onto your desk in front of you. These atoms are now stable and are no longer radioactive.
5. Repeat Steps 1-4 until after the 7th half-life.

Half-Life – Half-Life of Paper

Student Data Collection Sheet

Name: _____

Date: _____

Data Collection

Table 1

Beginning Amount	1st Half-Life	2nd Half-Life	3rd Half-Life	4th Half-Life	5th Half-Life	6th Half-Life	7th Half-Life
% Decayed							

Half-Life – Half-Life of Paper

Student Data Collection Sheet

Name: _____

Date: _____

Questions

1. Define the term **half-life**.
2. What does it mean when we say an atom has “**decayed**”?
3. For **Table 1**, at the end of **each** half-life, at approximately what percentage are the atoms decaying?
4. List two things that stayed the same during this activity and list two things that are different during this activity.
5. Do the number of atoms you start with affect the outcome? Explain.
6. How do scientists use radioactive decay to date fossils and artifacts?

Enrichment Question

1. The population of the earth is doubling every 40 years. If the population of the earth is now 6 billion people, how many people will be here when you are 95 years old?

Objectives

- To define the terms half-life and radioactive decay
- To observe the exponential nature of radioactive decay
- To create line graphs from collected data
- To compare data
- To understand how radioactive decay is used to date archaeological artifacts

Procedure

1. Put 10 M&M's® candies of any color into a zip lock bag. Each group is starting with 10 M&M's® candies, which is recorded as Trial 0 in the data table. *All of the M&M's® candies are radioactive.*
2. Shake the bag and spill out the candies onto a flat surface.
3. Pick up **ONLY** the candies with the “m” showing - *these are still radioactive*. Count the “m” candies as you return them to the bag.
4. Record the number of candies you returned to the bag under the next Trial.
5. Move the candies that are blank on the top to the side - *these have now decayed to a stable state*.
6. Repeat steps 2 through 5 until all the candies have decayed or until you have completed Trial 7.
7. Record the results for 9 other groups and total all the Trials for the 100 candies.

Toss Results	Trial 0	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Trial 7
Ours	10							
Group 2	10							
Group 3	10							
Group 4	10							
Group 5	10							
Group 6	10							
Group 7	10							
Group 8	10							
Group 9	10							
Group 10	10							
Totals	100							

Questions

1. Define the term **half-life**.

The time it takes for half of the atoms to decay to a stable state.

2. What does it mean when we say an atom has “**decayed**”?

The atom has fissioned into 2-3 smaller particles, generally giving off gamma energy, and is now at a stable state.

3. Do the number of atoms you start with affect the outcome? Explain.

Generally no; however, the larger the number of atoms, the better your data will be. If you start with a very small number of atoms it is difficult to get a good data chart.

4. Did each group get the same results?

No. They should not be the same.

5. Did any group still have candies remaining after Trial 7?

Yes, perhaps. Sometimes it takes more than 7 half-lives for all to decay.

6. Why do the totals for the 10 groups better show what happens during half-life rather than any one group's results?

The higher the total number of atoms, the better the data.

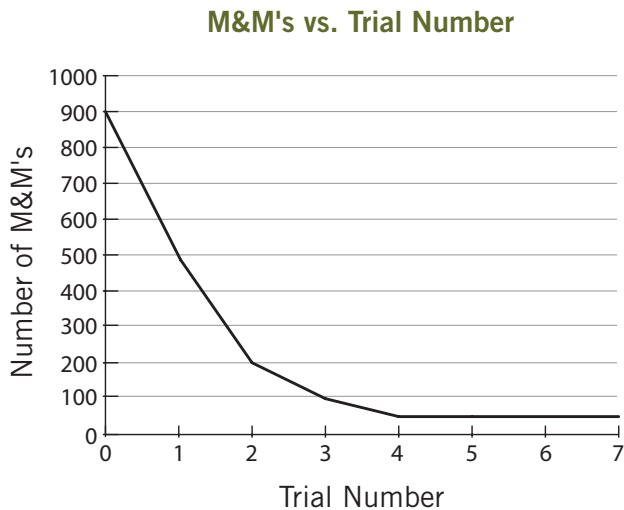
7. What happens to the total number of candies with each trial (half-life)?

It should be about half of what you started with for each trial.

Questions

8. Plot the total results on a graph with number of candies on the vertical axis and trial number on the horizontal axis. Is the result a straight or a curved line? What does the line indicate about the nature of decay of radionuclides?

The first 3 to 4 half-lives are where the majority of radioactive decay occurs.



9. How do scientists use radioactive decay to date fossils and artifacts?

By looking at the ratio of carbon-12 to carbon-14, they can calculate back to the amount of original carbon-14 using the half-life of carbon-14 = 5,730 years.

Enrichment Question

1. The population of the earth is doubling every 40 years. If the population of the earth is now 6 billion people, how many people will be here when you are 95 years old?

Age of Student	Number of people when student is 95	Age of Student	Number of people when student is 95
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11	30.01 billion	16	27.52 billion
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13	28.99 billion	18	26.58 billion
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Half-Life of M&M's[®]

Student Data Collection Sheet

Objectives

- To define the terms half-life and radioactive decay
- To observe the exponential nature of radioactive decay
- To create line graphs from collected data
- To compare data
- To understand how radioactive decay is used to date archaeological artifacts

Procedure

1. Put 10 M&M's[®] candies of any color into a zip lock bag. Each group is starting with 10 M&M's[®] candies, which is recorded as Trial 0 in the data table. *All of the M&M's[®] candies are radioactive.*
2. Shake the bag and spill out the candies onto a flat surface.
3. Pick up **ONLY** the candies with the “m” showing - *these are still radioactive*. Count the “m” candies as you return them to the bag.
4. Record the number of candies you returned to the bag under the next Trial.
5. Move the candies that are blank on the top to the side - *these have now decayed to a stable state*.
6. Repeat steps 2 through 5 until all the candies have decayed or until you have completed Trial 7.
7. Record the results for 9 other groups and total all the Trials for the 100 candies.

Toss Results	Trial 0	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Trial 7
Ours	10							
Group 2	10							
Group 3	10							
Group 4	10							
Group 5	10							
Group 6	10							
Group 7	10							
Group 8	10							
Group 9	10							
Group 10	10							
Totals	100							

Half-Life – Half-Life of M&M's®

Student Data Collection Sheet

Name: _____

Date: _____

Questions

1. Define the term **half-life**.
2. What does it mean when we say an atom has “**decayed**”?
3. Do the number of atoms you start with affect the outcome? Explain.
4. Did each group get the same results?
5. Did any group still have candies remaining after Trial 7?
6. Why do the totals for the 10 groups better show what happens during half-life rather than any one group's results?
7. What happens to the total number of candies with each trial (half-life)?

Half-Life – Half-Life of M&M's®

Student Data Collection Sheet

Name: _____

Date: _____

Questions

- Plot the total results on a graph with number of candies on the vertical axis and trial number on the horizontal axis. Is the result a straight or a curved line? What does the line indicate about the nature of decay of radionuclides?

- How do scientists use radioactive decay to date fossils and artifacts?

Enrichment Question

- The population of the earth is doubling every 40 years. If the population of the earth is now 6 billion people, how many people will be here when you are 95 years old?

Objectives

- To define the terms half-life and radioactive decay
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- To understand how radioactive decay is used to date archaeological artifacts

Procedure

1. Label the horizontal axis of the graph paper “Time (seconds)” and the vertical axis “Radioactive Licorice (%)”. Calibrate the horizontal axes so that one block equals 5 seconds and two blocks equal 10 seconds. Mark the axis at 10-second intervals.
2. Start with one piece of licorice to place onto the graph paper. Stretch the full length of the licorice vertically over the time “zero” mark, which is the same as the vertical axis. Make a mark on the graph paper at the top of the licorice. This mark represents 100% of the radioactive material at time zero.
3. Your teacher will call out “GO” or “HALF-LIFE” at 10-second intervals up to 90 seconds. When your teacher says “GO” or “HALF-LIFE,” you will have ten seconds to remove one-half of your licorice and set it aside. Place the remaining piece of licorice on the 10 seconds line and mark its current height. At 20 seconds, you should again remove half of the licorice and set it aside, then mark the height of the remaining portion on your graph at the 20-second line. Repeat this process until 90 seconds have gone by.
4. Now, connect all the height marks with a “best fit” line, completing a graph of the “Half-Life of Licorice.”

NOTE: The original strip of licorice represents radioactive material; the portion which is “set aside” during the activity represents the material that has “decayed” and is no longer radioactive.

Half-Life of Licorice

Questions

1. Did the licorice ever completely disappear or just get so small that you couldn't tear it into halves?

Got too small.

2. If the entire earth could be divided in half, and then in half again over and over like the piece of licorice for as long as you could, what would be the smallest piece you would end up with?

Answers will vary. A grain of sand. An atom.

3. If you had started with twice as long a piece of licorice, would it have made any difference in the graph line you would have obtained?

** To try this, move back to a time minus (-) 10 seconds and imagine how tall the licorice would have been then. What really does change when you use more?*

It would have been taller at the beginning, but still ends up very small in just a few half-lives.

4. Let's go the other direction for a change. Let us suppose the tiny bit of licorice at 90 seconds was your starting place. Then suppose you would double it in size every 10 seconds as you moved left on your graph towards 0 seconds. At 0, of course, you would have reached the size of one piece of licorice. However, what would be the size of the piece of licorice MINUS (-) 40 seconds?

The piece of licorice would be 16 times larger than the original piece.

5. Using the same method as in question 4, continue doubling your licorice until you would reach MINUS (-) 100 seconds. How large a piece would you have then?

The piece of licorice would be 1024 times larger than the original piece at 0 seconds.

6. Does it really matter how large a sample you start with for this graph? WHY or WHY NOT?

No, there would be more decays that occur, but the number of half-lives would remain the same.

Questions

7. Describe how the graph would be different if you took another piece of licorice exactly the same size as the first piece but you bit it in half and marked it on the graph every 30 seconds instead of every 10 seconds?

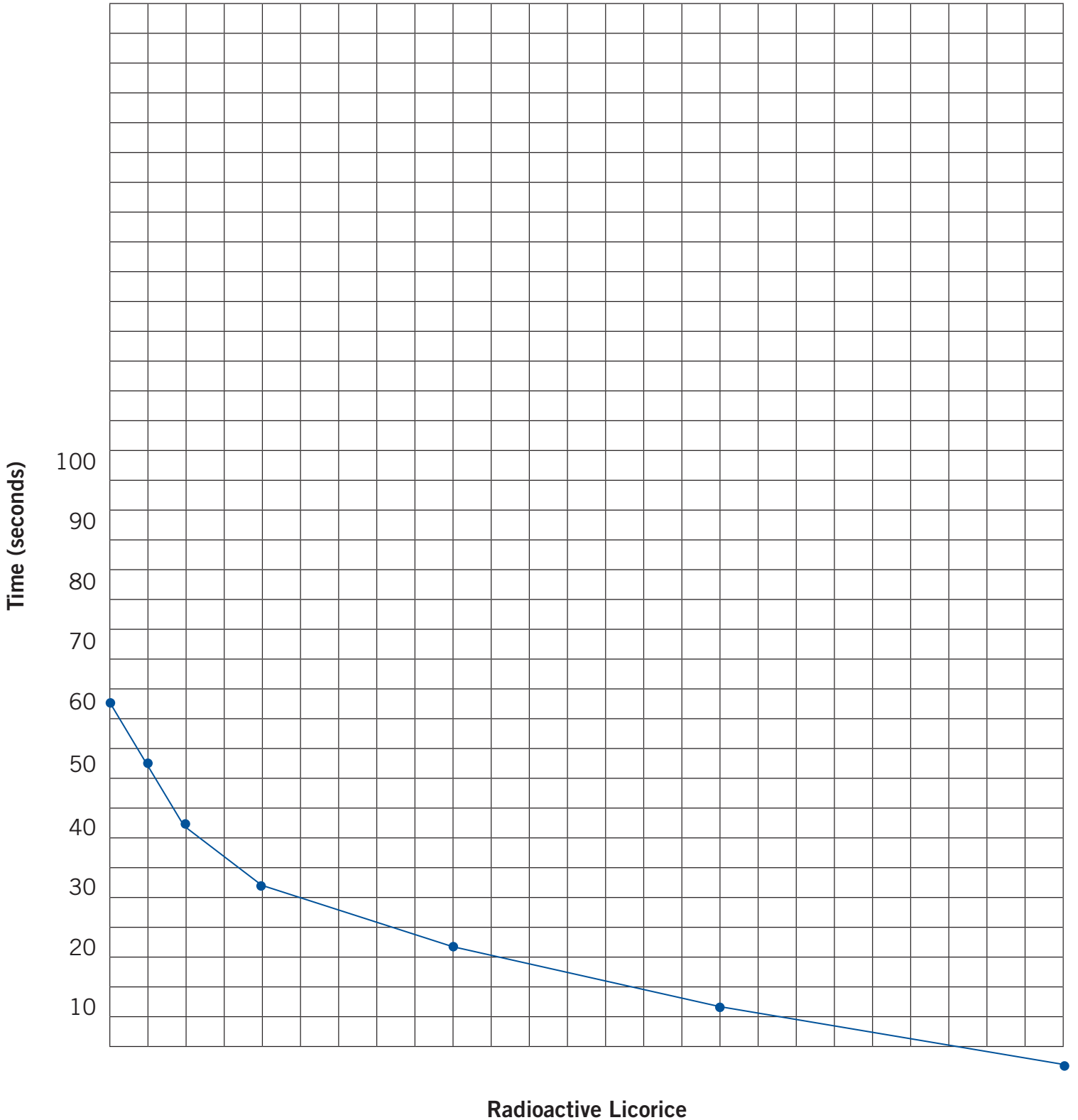
It would take three times as long to completely decay.

Enrichment Question

1. The population of the earth is doubling every 40 years. If the population of the earth is now 6 billion people, how many people will be here when you are 95 years old?

Age of Student	Number of people when student is 95	Age of Student	Number of people when student is 95
10	30.53 billion	15	28 billion
11	30.01 billion	16	27.52 billion
12	29.49 billion	17	27.05 billion
13	28.99 billion	18	26.58 billion
14	28.49 billion		

Half-Life of Licorice



Half-Life of Licorice

Name: _____

Date: _____

Student Data Collection Sheet

Objectives

- To define the terms half-life and radioactive decay
- To observe the exponential nature of radioactive decay
- To create line graphs from collected data
- To compare data
- To understand how radioactive decay is used to date archaeological artifacts

Procedure

1. Label the horizontal axis of the graph paper “Time (seconds)” and the vertical axis “Radioactive Licorice (%)”. Calibrate the horizontal axes so that one block equals 5 seconds and two blocks equal 10 seconds. Mark the axis at 10-second intervals.
2. Start with one piece of licorice to place onto the graph paper. Stretch the full length of the licorice vertically over the time “zero” mark, which is the same as the vertical axis. Make a mark on the graph paper at the top of the licorice. This mark represents 100% of the radioactive material at time zero.
3. Your teacher will call out “GO” or “HALF-LIFE” at 10-second intervals up to 90 seconds. When your teacher says “GO” or “HALF-LIFE,” you will have ten seconds to remove one-half of your licorice and set it aside. Place the remaining piece of licorice on the 10 seconds line and mark its current height. At 20 seconds, you should again remove half of the licorice and set it aside, then mark the height of the remaining portion on your graph at the 20-second line. Repeat this process until 90 seconds have gone by.
4. Now, connect all the height marks with a “best fit” line, completing a graph of the “Half-Life of Licorice.”

NOTE: The original strip of licorice represents radioactive material; the portion which is “set aside” during the activity represents the material that has “decayed” and is no longer radioactive.

Half-Life – Half-Life of Licorice

Student Data Collection Sheet

Name: _____

Date: _____

Questions

1. Did the licorice ever completely disappear or just get so small that you couldn't tear it into halves?
2. If the entire earth could be divided in half, and then in half again over and over like the piece of licorice for as long as you could, what would be the smallest piece you would end up with?
3. If you had started with twice as long a piece of licorice, would it have made any difference in the graph line you would have obtained?
** To try this, move back to a time minus (-) 10 seconds and imagine how tall the licorice would have been then. What really does change when you use more?*
4. Let's go the other direction for a change. Let us suppose the tiny bit of licorice at 90 seconds was your starting place. Then suppose you would double it in size every 10 seconds as you moved left on your graph towards 0 seconds. At 0, of course, you would have reached the size of one piece of licorice. However, what would be the size of the piece of licorice MINUS (-) 40 seconds?
5. Using the same method as in question 4, continue doubling your licorice until you would reach MINUS (-) 100 seconds. How large a piece would you have then?
6. Does it really matter how large a sample you start with for this graph? WHY or WHY NOT?

Half-Life – Half-Life of Licorice

Student Data Collection Sheet

Name: _____

Date: _____

Questions

7. Describe how the graph would be different if you took another piece of licorice exactly the same size as the first piece but you bit it in half and marked it on the graph every 30 seconds instead of every 10 seconds?

Enrichment Question

1. The population of the earth is doubling every 40 years. If the population of the earth is now 6 billion people, how many people will be here when you are 95 years old?

