The Bodies in Skeleton Lake

Measuring Half-Life and Determining Absolute Age

MATERIALS AND RESOURCES

EACH GROUP

computer with online access

cup, 12-oz plastic

ruler, clear metric

box, pizza style

100 pieces Skittles®

TEACHER

7 beakers, 1000 mL

7 measuring cups, 1/2 cup

2400 pieces beads, pony, green

2400 pieces beads, pony, red

ABOUT THIS LESSON

This lesson is a wonderful introduction to the concept of radiometric dating. The students participate in three hands-on activities, which model both the concept and the real-life practice of absolute dating. The first activity models the exponential decay of a radioactive isotope. In the second activity, the students generate a graph based on known ages of specimens and then use the graph to interpolate the age of skeletons found in a Himalayan lake. Finally, students will use an online simulation to analyze trends in fossils ages among different soil strata.

OBJECTIVES

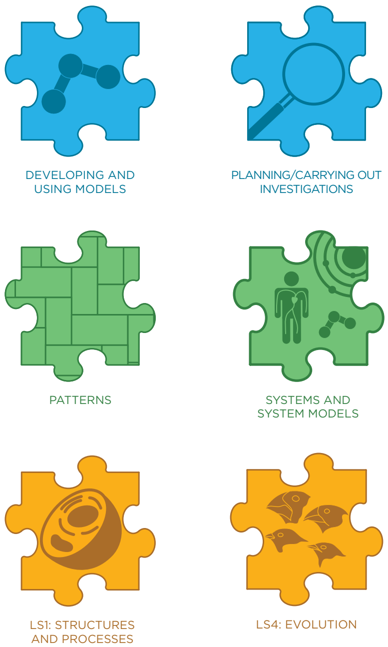
Students will:

- Model the exponential decay of a radioactive isotope
- Use a model to interpolate the age of skeletons found in a Himalayan lake
- Use an online simulation to analyze trends in fossils found in different strata

LEVEL

Biology

NEXT GENERATION SCIENCE STANDARDS



ASSESSMENTS

The following types of formative assessments are embedded in this lesson:

- Assessment of prior knowledge through questioning
- Sharing class data
- As students are making their graphs, check to make sure that they have percent of parent isotope left on the *y*-axis and time on the *x*-axis.
- Ask each group what the line generated in the graph represents.

ACKNOWLEDGEMENTS

Content adapted from a lesson written by Chuck Campbell, an AP Environmental Science and Biology teacher at Russellville High School in Russellville, Arkansas.

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COMMON CORE STATE STANDARDS

(LITERACY) RST.9-10.3

Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.

(LITERACY) RST.9-10.7

Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

(MATH) A-CED.2

Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.

(MATH) A-CED.4

Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. For example, rearrange Ohm's law V = IR to highlight resistance R.

(MATH) N-Q.1

Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

(MATH) S-ID.6A

Represent data on two quantitative variables on a scatter plot, and describe how the variables are related. Fit a function to the data; use functions fitted to data to solve problems in the context of the data. Use given functions or choose a function suggested by the context. Emphasize linear, quadratic, and exponential models.

CONNECTIONS TO AP*

AP BIOLOGY 1

A.4 Biological evolution is supported by scientific evidence from many disciplines, including mathematics.

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TEACHING SUGGESTIONS

Ideally, students should read the Roopkund story before they come to class. However, you might want to set the scene for them before starting. A discussion of half-life and its use (including a review of atomic structure and how it relates to isotopes) is also advisable.

One important concept to ensure that the students understand as they go through the three sections of the lab is that the percents that are used are in comparison to the original amount. For instance, a living organism has a certain amount of several isotopes of carbon. When this organism dies, the original amount of carbon-14 that it has upon death is set at 100%. Then, over time this carbon-14 will decay at a steady rate depending on its half-life. So, after one half-life it will have 50% of the original amount of carbon-14 that it had upon the organism's death.

For Part I of the activity, any box big enough for all 100 candies to be facing label up without touching another candy will suffice. You should lead a short discussion after Part I to ensure that students understand the concepts of half-life and parent to daughter isotope decay. Make sure that the students are giving the box a really good shake every time with the top on.

For Part II of the activity:

- Go ahead and have the class data tables ready on the board when the students come in so that you can roam the room during the first two parts.
- You could use any size scoop you would like as long as you get a standardized sample each time.
- You could use any size "atoms" that you would like as long as your sample size of atoms is large enough to eliminate random error.
- The half-life of the isotope used in this simulation (carbon-14) is 5730 years. You will need to keep a close eye on the students' graphs to make sure they are properly graphing the percentage of parent isotope left (y-axis) and the age of the jar (x-axis).
- Make sure the students use a really good straight edge and a very sharp pencil to do their interpolating (drawing intersection lines on the graph to find where on each axis a particular point corresponds to).
- The actual carbon-dated date of the Roopkund skeletons is 850 A.D. ± 30 years. You will need to keep a close eye on students' graphs to ensure they are properly graphing the percentage of parent isotope left (y-axis) and the age of the jar (x-axis). Values may vary depending on students' graphing skills. Typically, students with good graphing skills should get 763–1013 A.D. as the date (based on doing the lesson in 2013). The better the graphing skills, the closer the student will get to the actual age.
- To make the jars, follow the instructions in Table A. This is based on 400 beads per jar.

TEACHING SUGGESTIONS (CONTINUED)

Table A. Composition of Jars			
Age of Sample	Percent of Parent Isotope Remaining	Number of Beads in Sample	
		Parent	Daughter
Date of death	100%	400	0
5000 years after death	56%	224	176
10,000 years after death	30%	120	280
15,000 years after death	17%	68	332
20,000 years after death	9%	36	364
25,000 years after death	4%	16	384
Roopkund remains	87.5%	350	50

In Part III, make sure to give the students time to just play around in the simulation before doing this part of the lesson. This part could be done at home if the students have internet at home or you can save the simulation onto a flash drive for students who do not. You should prompt the students to look for trends as they are collecting their data.

If your students are having problems understanding the initial concept of radioactive decay you might have them spend more time on the first three tabs in the PhET simulation.

If you need to raise the rigor for students that can be pushed beyond the scope of this lab, have them make their own tables to record their data. You could also scale back some of the procedures and have them design their own experiment to determine the age of the Roopkund remains..

DATA AND OBSERVATIONS

PART I: MODELING EXPONENTIAL DECAY OF SKITTLIUM

Table 1. Skittlium Atomic Decay		
Half-Lives	**Percent Remaining**	**Class Average**
0 (start)	100	100
1	47	50
2	23	25
3	13	12.5
4	7	6.3
5	3	3.1
6	1	1.5
7	1	0.78
8	0	0.39

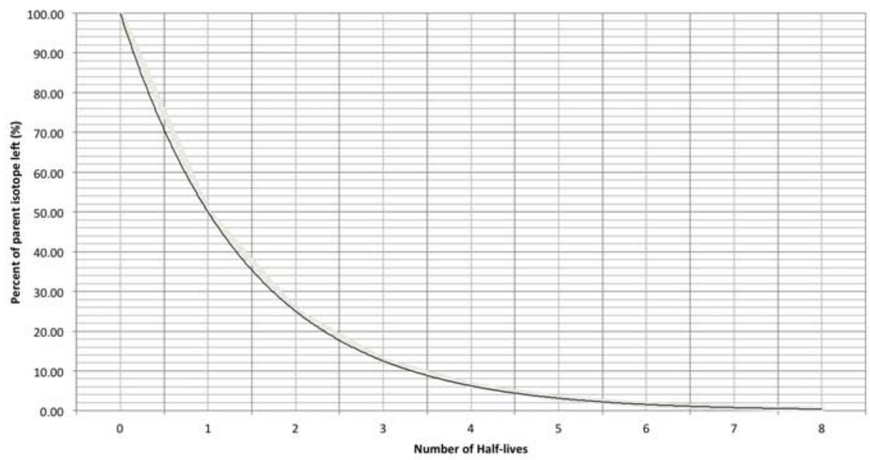

Figure A. Exponential decay of skittlium

DATA AND OBSERVATIONS (CONTINUED)

PART II: AGE DETERMINATION OF THE ROOPKUND SKELETONS

Table 2. Remaining Carbon-14 for Roopkund Skeletons

Group	Date of Death	Years After Death					Roopkund Remains
		5,000	10,000	15,000	20,000	25,000	
1	100	56	30	17	9	4	90
2	100	55	25	18	10	5	89
3	100	57	35	19	11	6	88
4	100	54	32	16	8	3	91
5	100	58	28	15	7	2	92
6	100	56	30	17	9	0	90
7	100	55	31	18	11	8	92
8	100	57	29	19	10	4	95
9	100	50	28	16	7	3	85
10	100	62	32	15	8	5	88
Class Average	100	56	30	17	9	4	90
						Total Age	1160 years

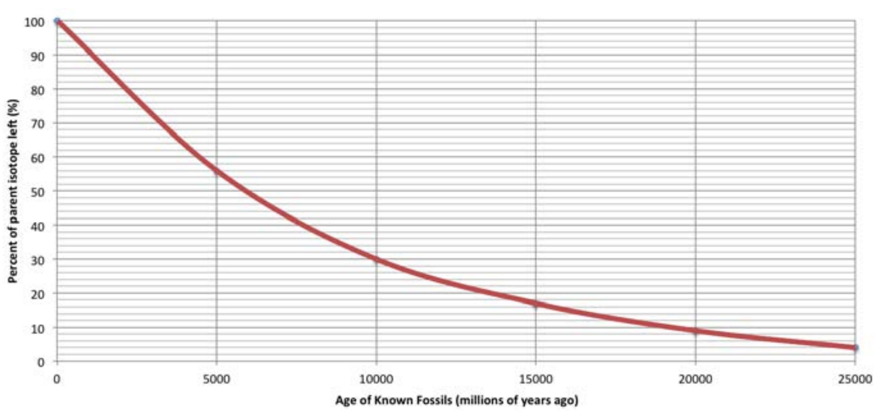

Figure B. Class averages for exponential decay of known fossils

ANSWER KEY

DATA AND OBSERVATIONS (CONTINUED)

PART III: THE RADIOACTIVE DATING GAME (A PhET SIMULATION)

Table 3. Simulated Carbon-14 Dating

Soil Layer	Fossil	Age (Years Ago)
Soil surface	Animal skull	155
	Living tree	0
	Distant living tree	0
	House	74
	Dead tree	236
1st layer down	Bone	1,304
	Wooden cup	1,013
	Human skull	2,187
2nd layer down	Human skull	39,722
	Fish bones	15,925
3rd layer down	Fish fossil 1	27,820,000
	Rock 1	150,150,000
	Dinosaur skull	154,740,000
4th layer down	Rock 2	268,080,000
	Trilobite	309,420,000
5th layer down	Rock 3	444,960,000
	Rock 4	710,300,000
	Rock 5	1,250,000,000

ANSWER KEY

ANALYSIS AND CONCLUSION QUESTIONS

PART I: MODELING EXPONENTIAL DECAY OF SKITTLIUM

1. Using evidence from Graph 1, provide a description of how the amount of parent element is depleted with each passing half-life.

   With every passing half-life, the amount of parent isotope is cut by 50%. For instance, after two half-lives there was only 25% of the original amount left.

2. Is this relationship linear or exponential? Justify your answer using evidence from your graph.

   The relationship is exponential because the amount of isotope decays at a rate proportional to the current value. If it were linear, the rate would be the same no matter what the current value.

   For example, a linear relationship would indicate a loss of 100 atoms per half-life. If you started with 1000 atoms, after one half-life you would have 900, and after two half-lives you would have 800. An exponential relationship indicates that a certain percentage (50%) is lost, so after one half-life you would have 500 and after two half-lives you would only have 250.

3. In your own words, describe what is meant by the term *half-life*.

   Answers may vary. One half-life is the amount of time that it takes for a particular sample to decrease (decay) by one half (50%).

PART II: AGE DETERMINATION OF THE ROOPKUND SKELETONS

1. Determine the age of the Roopkund remains. Justify your answer with evidence from the graph.

   Answers will vary but should be somewhere between 763 to 1013 A.D. Graph 2 show that 90% of carbon-14 left corresponds to 1160 years ago, which would be around 850 A.D.

2. The half-life of ^{14}C is 5730 years. Use evidence from Graph 2 to justify this statement.

   According to Graph 2, 50% of the parent isotope left corresponds to 5730 years.

3. Explain the changes that occur in the atomic structure (numbers of protons, neutrons, and electrons) as carbon-14 decays to nitrogen-14.

   Carbon-14 has 6 protons, 8 neutrons, and 6 electrons. When it decays, it gains a proton and becomes nitrogen-14 (7 protons, 7 neutrons, and 7 electrons).

4. How close was your age approximation of the Roopkund remains? What factors may have contributed to any variation from the actual age? Explain how each would contribute to this variation.

   Answers may vary. The students should be somewhere close to 850 A.D. If they were not, some possible factors would be:

   - Counting error, which would cause the percentages to be incorrect
   - Calculator error, which would cause the percentages to be incorrect
   - Graphing errors, which would cause the interpolation to be incorrect

ANALYSIS AND CONCLUSION QUESTIONS (CONTINUED)

5. 1n 1835, a well-preserved body was found in a peat bog in Jutland, Denmark. She is known as the Haraldskær Woman. Historians and scientists argued over the identity and age of the woman for many years. However, through radiocarbon dating in 1977, her age was determined.

   Using Graph 2, determine what century she lived in if the percent ^{14}C left was 78%. Explain the process by which you determined this answer.

   She lived in the 5th century B.C. According to Graph 2, 78% of the parent isotope left corresponds to about 2500 years ago, and subtraction of this number from the current year is −487 (based on 2013 date).

6. The *thyroid*, an organ located in your neck, produces two main hormones (thyroxine and triiodothyronine), which control the rate of your body's use of energy (metabolism). *Hyperthyroidism* is a disease that involves the thyroid producing too much of both hormones. This could have many debilitating effects on the proper functioning of the body.

   One of the treatments for this disease is using radioactive iodine (^{131}I), which destroys the thyroid. Hormone supplements must be taken for the rest of the patient's life after the elimination of this crucial organ.

   a. Use a periodic table to determine the number of protons, neutrons, and electrons in one atom of the radioactive isotope ^{131}I.

      Iodine-131 has 53 protons, 78 neutrons, and 53 electrons.

   b. The half-life of iodine-131 is eight days. If a patient were given a dose of ^{131}I, predict what percent of the parent isotope would be left after six weeks. Justify your selection of the process that you used.

      There should be between 1.56% and 3.13% left in the body. Six weeks is 42 days and the half-life of ^{131}I is 8 days, so there are 5.25 half-lives in six weeks. This many half-lives corresponds to between 1.56% and 3.13% left.

      100% → 50% → 25% → 12.5% → 6.25% → 3.125% → 1.563%

ANSWER KEY

ANALYSIS AND CONCLUSION QUESTIONS (CONTINUED)

PART III: THE RADIOACTIVE DATING GAME (A PhET SIMULATION)

1. Describe the relationship between the age of the specimen and the depth of the soil. Justify your statement with evidence from your data.

   The deeper down you go, the older the fossils are. The average age of fossils on the soil surface is 155 years. The averages for the other layers are as follows:

   - 1st layer = 1500 years old
   - 2nd layer = 27,823 years old.
   - 3rd layer = 64,481,333 years old
   - 4th layer = 288,750,000 years old
   - 5th layer = 801,753,333 years old

2. Describe the relationship between the complexity of the organism/specimen and the depth of the soil. Justify your statement with evidence from your data.

   As you go deeper into the soil, the fossils are less complex. Toward the top layers, you see human skulls and fish. Toward the bottom, you begin to see less organic material (once living) and mostly rocks.

3. Propose an explanation for your answer to Question 2.

   Over time, organisms have evolved to become more complex than previous ancestors.

4. There were two specimens that still contained 100% of the "original" ^{14}C. Which specimens were they, and how do you explain this percentage?

   The two trees were both still at 100% of the parent isotope left due to fact that they are still alive.

5. How far down into the soil did you go until you needed to switch isotopes? Explain why you needed to switch isotopes.

   From the third layer down, you are not able to use ^{14}C anymore. The amount of ^{14}C is so small that it cannot be measured.

6. Exit the simulation and re-enter. Click on the dead tree and determine the age again. Did you get the same answer? Repeat this several more times. How does the age vary over several attempts? What does this tell you about the accuracy of radioactive dating?

   Answers will vary. Over several tries, the age varied by three years. Radioactive dating can get very close to the actual age but cannot tell you the exact age.

   For instance, the Roopkund remains were actually dated at 850 A.D. ± 30 years.

The Bodies in Skeleton Lake

Measuring Half-Life and Determining Absolute Age

NATIONAL MATH + SCIENCE INITIATIVE

MATERIALS

computer with online access

cup, 12-oz plastic

ruler, clear metric

box, pizza style

100 pieces Skittles®

In 1942, in the state of Uttarakhand in India high in the Himalayan Mountains, a forest ranger came upon a ghastly site. While walking past Roopkund, a glacial lake tucked away inside a mountain pass, he discovered hundreds of skeletons. It was a mystery for many years why there were so many bodies inside and surrounding the lake. During the winter months the lake is frozen; however, in the summer when the lake melts you can still find traces of bones and skulls of both humans and horses.

In total, scientists and archeologists believe that there are around 500 human skeletons in and around the lake, but it is thought that almost 600 perished here around the same time. It is thought the people were traveling on a pilgrimage to honor the Goddess Nanda Devi when they were struck by a vicious hailstorm. With no possible shelter in sight, the hail rained down on the helpless victims and is thought to have been around 7 cm in diameter (just a bit smaller than a baseball). Many of the pilgrims' skulls were found with huge holes. The pilgrims included men, women, and children.

Scientists were curious about what the age of these skeletons actually were. In the 1960s they used carbon-dating techniques to ascertain that the skeletons were most likely from somewhere between the 12th and 15th centuries. However in 2004, scientists at the Oxford University Radiocarbon Accelerator Unit in Oxford, England, using more sophisticated and advanced equipment, were able to determine the age of the skeletons more accurately. In this lesson, you will determine approximate age of these skeletons using your understanding of radiometric dating.

Radiometric dating is used to determine the approximate age of materials, both organic and nonorganic, dating back hundreds, even billions of years ago. The idea is that certain radioactive isotopes that are present in matter decay at a fixed exponential rate. Carbon-12 is the most abundant form of carbon on the planet. However, carbon-14, a radioactive isotope of carbon, is made in the atmosphere when cosmic rays bombard atmospheric nitrogen causing a nuclear reaction that turns nitrogen atoms into radioactive carbon-14.

PRODUCTION OF CARBON-14

$$\text{neutron} + {}^{14}_{7}\text{N} \rightarrow {}^{14}_{6}\text{C} + \text{proton} \qquad \text{(Eq. 1)}$$

Producers fix carbon dioxide from the atmosphere and use it to make organic materials through photosynthesis. Therefore, they will take in a certain percentage of radioactive carbon (^{14}C) during this process. When consumers feed on these producers they assimilate this carbon into their bodies. When the consumer dies, the available carbon-14 (parent element) will decay over time at a fixed exponential rate into nitrogen-14 (daughter element).

DECAY OF CARBON-14

$${}^{14}_{6}\text{C} \rightarrow {}^{14}_{7}\text{N} + e^{-}\ \text{(electron)} \qquad \text{(Eq. 2)}$$

When half of the ^{14}C isotopes have decayed in this manner, it is called a **half-life**. The half-life for ^{14}C is 5730 years. After two half-lives, you would expect 25% of the radioactive isotopes to still remain (11,460 years).

Radiometric dating is an example of *absolute dating*, which gives a close approximation of the age of a particular sample. On the other hand, *relative dating* is a type of dating that geologists use to determine if a particular specimen is younger or older than another specimen.

PURPOSE

In this lab activity, you will simulate a model of exponential decay of an isotope. You will then measure percentages of decayed isotopes over known periods of time and use a student-generated graph of these data to determine the half-life. This graph will then be used to determine the age of the Roopkund skeletons. Finally, you will participate in a radioactive dating simulation in which you will review what you have learned in Part I and Part II, and use this knowledge to analyze fossils among different strata.

PROCEDURE

PART I: MODELING EXPONENTIAL DECAY OF SKITTLIUM

Your teacher will have 100 atoms of skittlium and one box available for each group.

1. Arrange each candy so that the "S" is facing upward. This indicates that it is still the radioactive form of the isotope.
2. Now pick up the box and shake it several times. Put the box down and open the lid. This simulates one half-life.

   Take out all of the isotopes of skittlium that have decomposed into their "daughter" elements (the ones with the "S" face down) and record the percent of skittlium remaining inside the box (amount of skittlium isotopes left inside the box/100) in Table 1.
3. Close the lid and shake the box again, simulating another half-life. Open the lid and take out the isotopes that have decomposed. Record the percent of skittlium atoms remaining in the box in Table 1.
4. Continue repeating Step 3 until all skittlium atoms have decayed into their daughter element.
5. Write your group's answers up on the board. Record the class data in Table 3 and calculate the averages.
6. Construct a graph (Graph 1) of the class averages from Table 1. The percent of parent element should be on the y-axis and the age of the sample should be on the x-axis.

PROCEDURE (CONTINUED)

PART II: AGE DETERMINATION OF THE ROOPKUND SKELETONS

The beads in the jars represent atoms. The green beads represent the parent element (carbon-14) and the red beads represent the daughter element (nitrogen-14).

1. From the "Date of Death" jar, use the small cup that is provided to remove a measured amount of beads. This ensures that a random sampling is taken. Calculate the percent of carbon-14 in the sample and record it in Table 2.
2. From the jar that is 5000 years after death, use the small cup to remove a measured amount of beads. Calculate the percent of carbon-14 in the sample and record this value in Table 2.
3. Repeat Step 2 for each of the remaining jars:
   a. 10,000 years after death
   b. 15,000 years after death
   c. 20,000 years after death
   d. 25,000 years after death
4. Write your group's answers on the board. Record the class data in Table 2 and calculate the averages.
5. Construct a graph (Graph 2) of the averages from Table 2. The percent of parent element should be on the *y*-axis and the age of the sample should be on the *x*-axis.
6. Obtain a measured sample of the Roopkund remains jar. Calculate the percent of carbon-14 left in the sample and record this value in Table 2.
7. Use Graph 2 to find the age of the remains. Record your answer in Table 2.

PROCEDURE (CONTINUED)

PART III: THE RADIOACTIVE DATING GAME (A PhET SIMULATION)

1. Go to http://phet.colorado.edu/en/simulation/radioactive-dating-game.
2. Click on "Run Now" to launch the simulation.
3. There are four tabs in the simulation. Take some time to play around and familiarize yourself with the content contained in the first three tabs. Do not worry about messing anything up, as you can always click on the "Reset" button.

   Once you feel comfortable with these simulations, click on the final tab ("The Dating Game").
4. Click and hold the radioactive probe and place it on the cow skull. Notice that it shows the percentage of ^{14}C still left in the sample.
5. Use the green slider to find the position on the graph that corresponds to that percentage. Input the approximate age of the skull and click "Enter" or "Check Estimate." You should get a green "smiley face" if you correctly determined the approximate age.

   Record this value in Table 3. Check with your teacher to see how close you came to the real age of the remains.
6. Use this same technique to determine the approximate age of the other 17 specimens and record their ages in Table 3. You may have to switch radioactive isotopes to accurately determine the age of some of the older specimens.

DATA AND OBSERVATIONS

PART I: MODELING EXPONENTIAL DECAY OF SKITTLIUM

Table 1. Skittlium Atomic Decay

Half-Lives	Percent Remaining	Class Average
0 (start)		
1		
2		
3		
4		
5		
6		
7		
8		

DATA AND OBSERVATIONS (CONTINUED)

Graph 1: Exponential Decay of Skittlium

DATA AND OBSERVATIONS (CONTINUED)

PART II: AGE DETERMINATION OF THE ROOPKUND SKELETONS

Table 2. Remaining Carbon-14 for Roopkund Skeletons

Group	Date of Death	Years After Death					Roopkund Remains
		5,000	10,000	15,000	20,000	25,000	
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
Class Average							
						Total Age	

DATA AND OBSERVATIONS (CONTINUED)

Graph 2: Averages of Class Data

DATA AND OBSERVATIONS (CONTINUED)

PART III: THE RADIOACTIVE DATING GAME (A PhET SIMULATION)

Table 3. Simulated Carbon-14 Dating

Soil Layer	Fossil	Age (Years Ago)
Soil surface	Animal skull	
	Living tree	
	Distant living tree	
	House	
	Dead tree	
1st layer down	Bone	
	Wooden cup	
	Human skull	
2nd layer down	Human skull	
	Fish bones	
3rd layer down	Fish fossil 1	
	Rock 1	
	Dinosaur skull	
4th layer down	Rock 2	
	Trilobite	
5th layer down	Rock 3	
	Rock 4	
	Rock 5	

ANALYSIS AND CONCLUSION QUESTIONS

PART I: MODELING EXPONENTIAL DECAY OF SKITTLIUM

1. Using evidence from Graph 1, provide a description of how the amount of parent element is depleted with each passing half-life.

2. Is this relationship linear or exponential? Justify your answer using evidence from your graph.

3. In your own words, describe what is meant by the term *half-life*.

ANALYSIS AND CONCLUSION QUESTIONS (CONTINUED)

PART II: AGE DETERMINATION OF THE ROOPKUND SKELETONS

1. Determine the age of the Roopkund remains. Justify your answer with evidence from the graph.

2. The half-life of ^{14}C is 5730 years. Use evidence from Graph 2 to justify this statement.

3. Explain the changes that occur in the atomic structure (numbers of protons, neutrons, and electrons) as carbon-14 decays to nitrogen-14.

4. How close was your age approximation of the Roopkund remains? What factors may have contributed to any variation from the actual age? Explain how each would contribute to this variation.

ANALYSIS AND CONCLUSION QUESTIONS (CONTINUED)

5. 1n 1835, a well-preserved body was found in a peat bog in Jutland, Denmark. She is known as the Haraldskær Woman. Historians and scientists argued over the identity and age of the woman for many years. However, through radiocarbon dating in 1977, her age was determined.

   Using Graph 2, determine what century she lived in if the percent ^{14}C left was 78%. Explain the process by which you determined this answer.

6. The *thyroid*, an organ located in your neck, produces two main hormones (thyroxine and triiodothyronine), which control the rate of your body's use of energy (metabolism). *Hyperthyroidism* is a disease that involves the thyroid producing too much of both hormones. This could have many debilitating effects on the proper functioning of the body.

   One of the treatments for this disease is using radioactive iodine (^{131}I), which destroys the thyroid. Hormone supplements must be taken for the rest of the patient's life after the elimination of this crucial organ.

   a. Use a periodic table to determine the number of protons, neutrons, and electrons in one atom of the radioactive isotope ^{131}I.

   b. The half-life of iodine-131 is eight days. If a patient were given a dose of ^{131}I, predict what percent of the parent isotope would be left after six weeks. Justify your selection of the process that you used.

ANALYSIS AND CONCLUSION QUESTIONS (CONTINUED)

PART III: THE RADIOACTIVE DATING GAME (A PhET SIMULATION)

1. Describe the relationship between the age of the specimen and the depth of the soil. Justify your statement with evidence from your data.

2. Describe the relationship between the complexity of the organism/specimen and the depth of the soil. Justify your statement with evidence from your data.

3. Propose an explanation for your answer to Question 2.

4. There were two specimens that still contained 100% of the "original" ^{14}C. Which specimens were they, and how do you explain this percentage?

ANALYSIS AND CONCLUSION QUESTIONS (CONTINUED)

5. How far down into the soil did you go until you needed to switch isotopes? Explain why you needed to switch isotopes.

6. Exit the simulation and re-enter. Click on the dead tree and determine the age again. Did you get the same answer? Repeat this several more times. How does the age vary over several attempts? What does this tell you about the accuracy of radioactive dating?