Radioactive Dating

Science Objectives

- Students will discover that radioactive isotopes decay exponentially.
- Students will discover that each radioactive isotope has a specific half-life.
- Students will develop mathematical model for the radioactive decay of C-14 and U-238.
- Students will estimate the age of various objects using radioactive dating with common radioactive isotopes, such as C-14 in dating living organisms and U-238 in dating geological formations and fossils.

Vocabulary

- radioactive decay
- half-life
- exponential
- radioactive isotope
- radioactive dating

About the Lesson

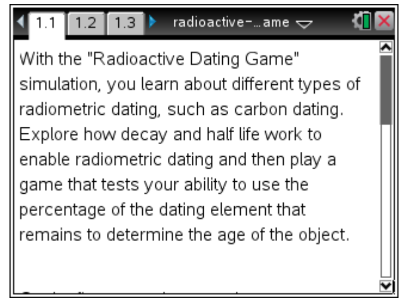
- Students will use the simulation to measure the percent of remaining isotopes for Carbon-14 and Uranium-238 during radioactive decay process. Students will develop mathematical models for the radioactive decay and use these to estimate the age of organic and inorganic materials.

TI-Nspire™ Navigator™

- Send out the *Radioactive Dating Game.tns* file.
- Monitor student progress using Class Capture.
- Use Quick Poll to assess students' understanding.
- Use Live Presenter for students to share their work and present results of explorations.

Activity Materials

- Compatible TI Technologies: TI-Nspire™ CX Handhelds, TI-Nspire™ Apps for iPad®, TI-Nspire™ Software



Tech Tips:

- This activity includes screen captures taken from the TI-Nspire CX handheld. It is also appropriate for use with the TI-Nspire family of products including TI-Nspire software and TI-Nspire App. Slight variations to these directions may be required if using other technologies besides the handheld.
- Watch for additional Tech Tips throughout the activity for the specific technology you are using.
- Access free tutorials at http://education.ti.com/calculators/pd/US/Online-Learning/Tutorials

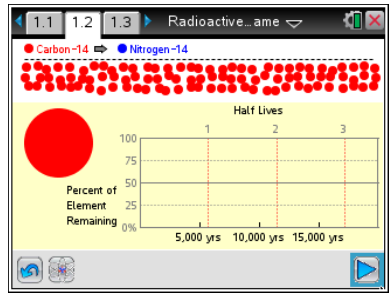
Lesson Files:
Student Activity

- Radioactive_Dating_Student_HS.doc
- Radioactive_Dating_Student_HS.pdf
- Radioactive Dating Game.tns

Discussion Points and Possible Answers

Part 1. Exploring Radioactive Decay

Move to page 1.2.



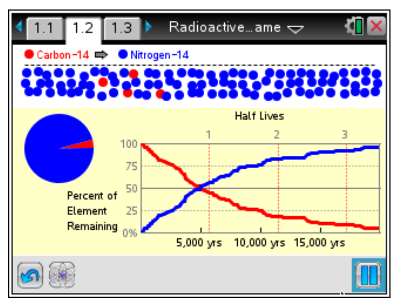
1. In this part of the activity students will observe changes in the remaining percent of an isotope in two radioactive decay processes: $^{14}C \rightarrow {}^{14}N$ and $^{238}U \rightarrow {}^{236}Pb$. Based on simulated experiment, students will measure percent of remaining element after given periods of time. Once on the screen, student can start, pause, and reset the simulation. The percent of element remaining will be shown on a graph as a function of time. Students can also count the number of remaining isotopes on the top of the page.

Q1. What is a half-life of a radioactive element?

Answer: the time it takes for the element to decay to 50% of its initial amount

Q2. What is the half-life of Carbon-14?

Answer: the half-life is about 5700 years



2. Students should select the play button at the bottom of the page and observe the changes in the percent of carbon remaining in the sample. They could use pause button after each half-life to get better estimation by counting the number of remaining carbon isotopes shown on the top of the page. They should repeat experiment at least 3 times and record percent of carbon remaining in the table below.

	Percent of Carbon-14 Remaining			
Half-lives	**Trial 1**	**Trial 2**	**Trial 3**	**Average**
1st	58	50	44	51
2nd	27	21	24	24
3rd	13	9	11	11

Q3. What percent of Carbon-14 is remaining after 1 half-life? Two half-lives? Three half-lives?

Answer: about 50% of initial amount; about 25% of initial amount; about 12.5% of initial amount (students answers will vary slightly)

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Use Quick Poll to collect student responses to questions 3-5. Discuss the reasons for slight differences in student answers, such as probabilistic nature of the half-life. The half-life is the time when the expected value of the number of isotopes that have decayed is equal to half the original number.

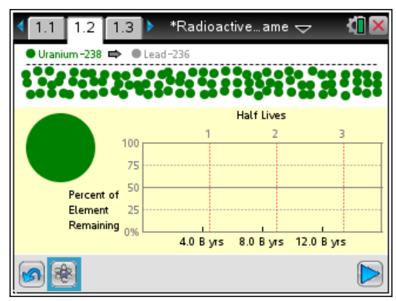
Q4. What do you think the similarities and differences will be in the decay of Uranium-238?

Answer: The half-life of Uranium-238 will be different. The decay will follow the same pattern over time, e.g about half of element remaining after each half-life.

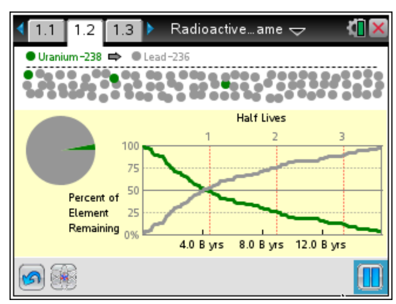
Q5. What is the half-life of Uranium-238?

Answer: about 4.5 billion years

3. In order to explore decay of Uranium-238 student should select in the bottom left corner of the page to switch the element.



4. Students should select the play button at the bottom of the page and observe the changes in the percent of uranium remaining in the sample. They could use the pause button after each half-life to get a better estimation by counting the number of remaining uranium isotopes shown on the top of the page. They should repeat experiment at least 3 times and record percent of uranium remaining in the table below.



	Percent of Uranium-238 Remaining			
Half-lives	**Trial 1**	**Trial 2**	**Trial 3**	**Average**
1st	52	48	46	49
2nd	29	23	24	25
3rd	15	10	14	13

Q6. What percent of Uranium-238 is remaining after 1 half-life? Two half-lives? Three half-lives?

Answer: about 50% of initial amount; about 25% of initial amount; about 12.5% of initial amount (students answers will vary slightly)

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Use Quick Poll to collect student responses to questions 8-10. Discuss differences and similarities in two radioactive decays observed.

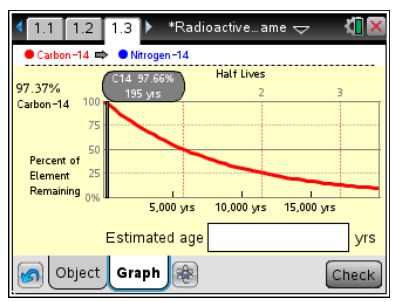
Q7. What function type best describes the radioactive decay curve? Why?

Answer: the exponential function, since amount of remaining isotope is halved after equal interval of time (half-life).

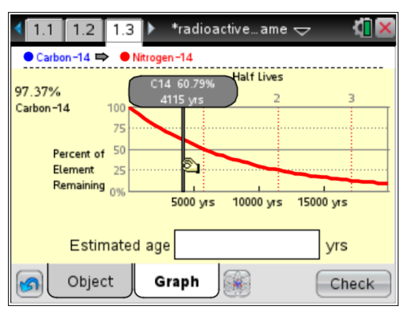
Part 2: Mathematical Model of Radioactive Decay

Move to page 1.3.

5. In this part of the activity students will examine the decay curves of Carbon-14 and Uranium-238 and will develop mathematical model for each curve.



6. Students should grab and drag an examination line to display the time and percent of remaining element for the points on the curve in order to collect necessary information. They should use these data to develop and/or verify the mathematical model for the curve.



Teacher Tip: Students can collect data from the page 1.3 **Graph** tab and use exponential regression in order to find the mathematical model. Alternatively, students can develop mathematical model based on their earlier observation that percent of remaining isotopes is halved after each half-life, creating geometric sequence with ratio ½. Then, they can substitute the data from the simulation to verify their model. At this part of the lesson provide students with actual half-lives of the two isotopes, 5,730 years for C-14 and 4.47 billion years for U-238.

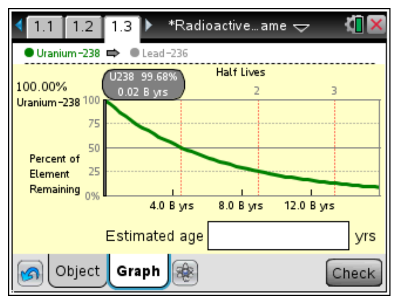
Q8. What is the mathematical model for the exponential decay of Carbon-14? Explain how you developed this model. Verify your model using data collected on page 1.3.

Answer: $\frac{N_C}{100} = \left(\frac{1}{2}\right)^{\frac{t}{5730}}$, so $N_C = 100 \times 2^{-\frac{t}{5730}}$**,** where t is time in years and N_C is percent of remaining carbon. Given point on the curve (8,610 years, 35.29%). Substitute, $t = 8610$, $N_C = 100(2)^{-\frac{8610}{5730}} = 35.2912 \approx 35.29\%$. Students can substitute several points from the curve.

Tech Tip: Students can select [calculator icon] to perform quick calculations.

Tech Tip: Students can select **+ > Calculator** to add a new page to perform calculations.

Q9. What is the mathematical model for the exponential decay of Uranium-238? Verify your model using data on page 1.3.

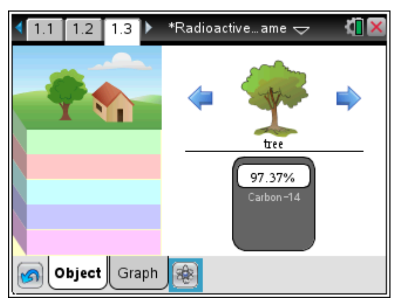


Answer: $N_U = 100 \times 2^{-\frac{t}{4.47}}$**,** where t is time in billion years and N_U is percent of remaining uranium. The formula is similar to the one for the carbon. Select point (3.38 BY, 59.2%).

$N_U = 100(2)^{-\frac{3.38}{4.47}} = 59.2073 \approx 59.2\%$

Part 3: Radioactive Dating

Move to page 1.3 Object tab.



8. Students will select different objects that can be found on the earth's surface and at different geological layers and use radioactive dating to estimate the age of the object. Students should select [atom icon] to switch between carbon dating and uranium dating according to the type of the object.

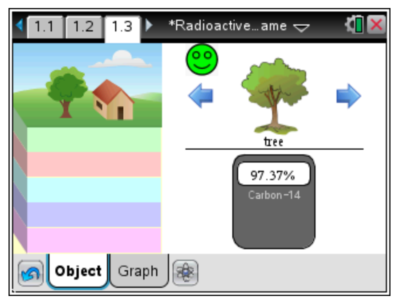
Q10. For what type of objects should you use carbon dating? Why?

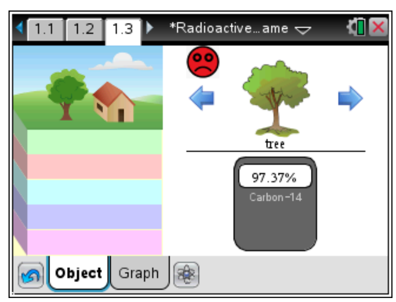
Answer: Carbon dating should be used to determine the age of living materials. Plants and animals naturally incorporate radiocarbon isotope into their tissues. When a creature dies, it ceases to consume more radiocarbon while the C-14 already in its body continues to decay back into nitrogen.

Q11. For what type of objects should you use uranium dating? Why?

Answer: Uranium dating could be used to determine the age of geological formations. The geologist finds minerals that were formed in igneous rock as it cooled. The mineral traps the uranium but not lead as it cools. Once cooled, the uranium slowly turns to lead, but the lead is trapped. The ratio of the uranium to the lead tells how long it has been since the mineral was formed. Uranium dating could also be used to determine the age of pre-historic animals.

9. Students should select the blue arrow on either side of the object to switch the object to date. For each object students should record type of dating used (carbon or uranium) and percent of radioactive element remaining. Students should calculate an estimated age of each object based on their mathematical model of radioactive decay. Students should select the **Graph** tab, enter the age, and then select Check. If the answer is correct, the smiley green face will appear on the page. If the answer is incorrect, the frown red face will appear. The estimated age could be given within about 20% margin error.





Object	Type of Dating	% Element Remaining	Calculated Age (show your calculations)
Tree	Carbon	97.37	$97.37 = 100(2^{-\frac{t}{5730}})$, $t = 220$ years
House	Carbon	99.10	$99.10 = 100(2^{-\frac{t}{5730}})$, $t = 75$ years
Bone	Carbon	83.91	$83.91 = 100(2^{-\frac{t}{5730}})$, $t = 1{,}450$ years

Wooden cup	Carbon	88.23	$88.23 = 100(2^{-\frac{t}{5720}})$, $t = 1{,}035$ years
Human skull	Carbon	76.63	$76.63 = 100(2^{-\frac{t}{5730}})$, $t = 2{,}200$ years
Fish bones	Carbon	14.44	$14.44 = 100(2^{-\frac{t}{5730}})$, $t = 15{,}997$ years
Rock 1	Uranium	97.90	$97.90 = 100(2^{-\frac{t}{4.47}})$, $t = 0.136868$ BY
Dinosaur skull	Uranium	97.63	$97.63 = 100(2^{-\frac{t}{4.47}})$, $t = 0.154678$ BY
Rock 2	Uranium	96.03	$96.03 = 100(2^{-\frac{t}{4.47}})$, $t = 0.26124$ BY
Trilobite	Uranium	95.31	$95.31 = 100(2^{-\frac{t}{4.47}})$, $t = 0.309773$ BY
Rock 3	Uranium	93.28	$93.28 = 100(2^{-\frac{t}{4.47}})$, $t = 0.448611$ BY
Rock 4	Uranium	82.38	$82.38 = 100(2^{-\frac{t}{4.47}})$, $t = 1.24996$ BY

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Use Quick Poll to collect calculated ages of different objects given in the simulation.

Q12. Is there a relationship between the age of the object and the geological layer where it is found? If so, what?

Answer: Student answers will vary. The older objects lay in the layers that were formed earlier, and they are deeper under the surface of the earth.

Wrap Up

When students are finished with the activity, collect students' worksheets.

Assessment

- Formative assessment will consist of questions embedded in the student worksheet. Analyze questions in the student worksheet with the students. Teacher can also collect scores that students earned in the game.
- Summative assessment will consist of questions/problems on the chapter test.