



Science in School

The European journal for science teachers

ISSUE 75 – November 2025

Topics Mathematics | Physics



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Teach radioisotopes & decay interdisciplinarily at a low cost

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How to teach radioactive decay and radioisotopes to students who feel that equations are boring? Here are two inexpensive and captivating activities to apply in your classroom!

High-school students might have heard of radiocarbon dating for organic materials, but they might be intimidated by the decay equation as it can feel abstract and dry. While promoting active-participative learning in a 12th grade mathematics-informatics class, I aimed to help students understand the connections between the solutions of the mathematical equations and the behaviours that are observed in the real world. As such, I created a board game with cards to make the connection for given radioisotopes even more obvious. I focused on the probabilistic nature of radioactive decay and on the proportionality between activity and the size of the undecayed population. The students were getting excited not only for working in teams but also because the activity creates just enough of a challenge to spark questions, before imposing answers.

This activity takes between 20 and 35 minutes.

Make sure your students are familiar, at a basic level, with the following concepts, operations, and equations:

- Radioactivity
- Logarithm
- Radioactive decay equation (e.g., mathematical expression, undecayed nuclide population, decay constant, half-life)

If that is not the case, your students may use the [theoretical key points handout](#).

Activity 1: Decay dash – a simple-to-use classroom activity for teaching radioactive decay

This activity simulates radioactive decay using a competitive, teamwork-based classroom game. We have chosen a number of five teams for a variety of radionuclides, but you may adapt the number of teams depending on your classroom's configuration. This is a competition between the teams, so you are able to promote fair play and perseverance among students with the help of science. Obviously, while each team benefits from learning about radioactive decay, the team that first and correctly arranges the snapshot cards from the earliest timepoint to the latest wins!

Materials

- Printed sheets of radionuclide cards

Note: you may choose any radionuclides you like (e.g., Technetium-99m (^{99m}Tc), Cobalt-60 (^{60}Co), Carbon-14 (^{14}C), Caesium-137 (^{137}Cs), Iodine-131 (^{131}I), and Radium-226 (^{226}Ra)). Keep in mind that each team has its own radionuclide; you need to choose five different radionuclides for this activity. You can prepare your own cards or use the [template](#) provided in the supporting material.

^{99m}Tc	^{15}O
$N_0 = 4350 \text{ nuclei}$	$N_0 = 10000 \text{ nuclei}$
$\lambda = 3.2 \times 10^{-5} \text{ s}^{-1}$	$t_{1/2} = 122.2664 \text{ s}$

Example of radionuclide cards

Image courtesy of the author

- Each card should contain the following information:
 - The symbol of the radionuclide, including the mass number and metastability (if applicable)
 - The value N_0 (i.e., the number of undecayed nuclei at the timepoint $t = 0$)
 - The value for the decay constant, λ , or the value for the half-life, $t_{1/2}$ (you may use IAEA's [Live Chart of Nuclides](#) to identify the half-life of your preferred radionuclides)
- Seven 'snapshot' cards for each team, each containing a number of undecayed nuclei at a particular (unknown) timepoint
- Scientific calculator

When you have limited time for the activity or for lower level-classrooms:

Choose a more 'manageable' N_0 value for the calculations, such as $N_0 = 1000$ nuclei. Any value between 1000 and 100000 nuclei is acceptable for the activity's objective. Explicitly give the value for the decay constant. Otherwise, you may give them only the value for $t_{1/2}$. We will elaborate upon this in the 'Procedure' section.

$$N(t) = 2175 \text{ nuclei}$$

$$t =$$

Example of snapshot cards

Image courtesy of the author

Procedure

- Divide the class into five teams, each with its own radionuclide. To make things more exciting, you may let a representative of each team choose a radionuclide randomly.
- For each team, hand out seven 'snapshot' cards.
- If you chose to give only the value for $t_{1/2}$, instruct them to find and write down the value for λ using the radioactive decay equation.
- Instruct your students to calculate the timepoints that correspond to each given number of undecayed radioactive nuclei.
- Encourage your students to 'sort the snapshots out', i.e., to arrange the 'snapshot' cards from the earliest timepoint to the latest. **The cards do not need to be spaced according to the successive time intervals!**
- Ask your students to consider the relationship between the initial population of radionuclides and the number of undecayed nuclei when the values for the time that has passed increase.

Hints for students who get stuck

If they don't understand how to find the expression for the decay constant (λ), ask them where it appears in the decay equation. Is it at an exponent or a base? Then, instruct them to consider the inverse of the exponential function. They should understand that taking the logarithm allows them to derive the quantity at the exponent. This is also the essence of finding the values for specific timepoints t . If needed, insist upon the importance of the negative sign at the exponential and make sure the students include it in their calculations.

Results

Here is a worked example for the following case:

¹⁵ O
$N_0 = 10000$ nuclei
$t_{1/2} = 122.2664$ s

N (t) = 5000 nuclei t =	N (t) = 7400 nuclei t =	N (t) = 2500 nuclei t =	N (t) = 25 nuclei t =
N (t) = 1000 nuclei t =	N (t) = 180 nuclei t =	N (t) = 50 nuclei t =	

Example of cards

Image courtesy of the author

Since we are given the half-life of ¹⁵O, we can find the value of the decay constant:

$$\lambda = \frac{\ln 2}{t_{1/2}} = \frac{\ln 2}{122.2664 \text{ s}} = 5.669 \times 10^{-3} \text{ s}^{-1}$$

We will write this value on the card with the radionuclide, which will be useful for the next calculations.

According to the law of radioactive decay, t is expressed as a function of $\ln(N/N_0)$ in the numerator and λ in the denominator (See the [theoretical key points handout](#) for a step-by-step guide to calculate t). Therefore, we can calculate the necessary values for t .

For example, when $N(t) = 5000$ nuclei:

$$\begin{aligned} t &= -\frac{\ln\left(\frac{5000}{10000}\right)}{5.669 \times 10^{-3} \text{ s}^{-1}} \\ &= -\frac{(-0.69314)}{5.669 \times 10^{-3} \text{ s}^{-1}} \\ &= -(-122.26) \\ t &= 122.26 \text{ s} \end{aligned}$$

122.26 s corresponds to the half-life ($t_{1/2}$) of ¹⁵O.

The same way we find the other values for t :

N (t) = 5000 nuclei t = 122.53 s	N (t) = 7400 nuclei t = 53.11 s	N (t) = 2500 nuclei t = 244.53 s	N (t) = 25 nuclei t = 1056.88 s
N (t) = 1000 nuclei t = 406.17 s	N (t) = 180 nuclei t = 708.65 s	N (t) = 50 nuclei t = 934.61 s	

Example of snapshot cards

Image courtesy of the author

By arranging the snapshot cards in order of increasing time values, we can see that the population of undecayed nuclei decreases exponentially over time:

N (t) = 5000 nuclei t = 122.53 s	N (t) = 7400 nuclei t = 53.11 s	N (t) = 2500 nuclei t = 244.53 s	N (t) = 25 nuclei t = 1056.88 s
N (t) = 1000 nuclei t = 406.17 s	N (t) = 180 nuclei t = 708.65 s	N (t) = 50 nuclei t = 934.61 s	

Example of snapshot cards

Image courtesy of the author

Discussion

In my experience, students have no significant difficulty in realising the pattern: the numbers don't decrease linearly, but exponentially. They begin calculating, estimating, arguing. One of the students suggested plotting the data to verify the curve, which could be done using Microsoft Excel or graph paper. Another student even noticed that the activity mirrored the unpredictability of decay in real systems. Most importantly, they internalized the concept without requiring me to provide incremental values for timepoints or to derive the radioactive decay equation.

Extension activity: Speaking mathematically about radioactive decay

These questions are meant to evaluate how well the students understand the quantitative aspects of radioactive decay.

- If we double the time, does this halve the population of undecayed nuclei? What if we multiply the time by an integer n ? Does this make the population n times smaller?
- Which part of the decay equation 'shows' us the exponential decrease? Can you give other examples of similar equations in physics?
- Would it make sense for the undecayed population to (also) be expressed as a decimal for certain values of timepoints? Why or why not? (Hint: this helps explain the probabilistic nature of radioactive decay.)
- Does the population of the undecayed nuclide ever become exactly zero? If yes, when? If not, why?

Activity 2: Investigating how radionuclides shape science and society

This activity takes the form of an inquiry-based group project. Students are invited to work as scientific consultants, using data and background knowledge to analyse how certain properties of radionuclides (half-life, decay constant, energy

levels) are applied in real-life scenarios. While this activity typically takes longer than Activity 1 (35–50 min), bear in mind that it may be useful even in classes where mathematics is not taught intensively. As such, it strengthens interdisciplinary understanding by solving realistic problems that require both scientific reasoning and communication.

Materials

- Different worksheets for each team describing a case study scenario. This activity provides three different scenarios:
 - [Worksheet A - Archaeology](#)
 - [Worksheet B - Medical physics](#)
 - [Worksheet C - Recent history](#)
- Access to the internet (for further research)
- Whiteboards or flipchart papers for group presentations

Procedure

1. Divide the class into three teams.
2. Give each team one of the worksheets (you can use the worksheets provided or create ones on your own).
3. Instruct each team to use the indicated sources or other forms of verified information to find their solutions to the tasks.
4. Have each team present their conclusions to the class in a five-minute pitch. Encourage your students to provide concrete feedback.

Discussion

The students enthusiastically engaged with this real-world challenge. Many were surprised to learn how radioactive decay is applied in medicine and archaeology beyond the usual nuclear physics topics. The team working on radiocarbon dating discussed how the half-life of carbon-14 makes it ideal for ancient samples, not recent ones. And the medical group realized that the short half-life of technetium-99m limits radiation exposure while allowing effective imaging. Several groups raised insightful questions about public perceptions of radiation, which sparked valuable classroom discussions about radiophobia and responsible science communication. Students appreciated having the opportunity to reason and explain rather than just calculate. «

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Resources

- Read about the [\$^{14}\text{C}\$ decay](#).
- Check the [Live Chart of Nuclides](#).
- Learn about [Technetium-99m](#) and its value for [medical imaging](#) procedures.
- Read about how archaeological plant remains can help us learn about [ancient environmental changes](#).
- Check out this explanation of the '[old wood effect](#)'.
- Read a short introduction to [Radium-226](#).
- Find out who the '[Radium Girls](#)' were, then watch the [trailer](#) for the film based on their story.
- Explore how we safely store highly radioactive waste by building a hands-on model: Lopez-Fernandez M (2025) [Discover bentonites, the heroes of radioactive waste repositories](#). *Science in School* **72**.
- Study nuclear decay and ionizing radiation safely in the physics classroom: Meier A (2025) [Exploring radioactivity safely with potassium carbonate](#). *Science in School* **74**.
- Discover how quantitatively measure radon levels around you: Budinich M, Vascotto M (2010) [The 'Radon school survey': measuring radioactivity at home](#). *Science in School* **14**: 54–57.
- Learn about the history of the periodic table: Demoncheaux E (2010) [The periodic table: its story and significance by Eric R Scerri](#). *Science in School* **23**: 57–60.
- Discover the properties of the elements of the periodic table: Cheng MHK (2019) [Quiz: elemental pursuit](#). *Science in School* **47**: 38–40.
- Explore the hidden contributions of women to our knowledge of chemical elements and the collaborative nature of scientific discovery: Lykknes A, Van Tiggelen B (2019) [In their element: women of the periodic table](#). *Science in School* **47**: 8–13.

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