**Predicting radioactivity**

Iodine-131 can be used to treat thyroid cancer.

It decays by beta emission and has a half-life of 8.0 days.

When it is made, the count rate from one capsule is 600 per minute.

After 16 days in storage, the capsule weighs the same.

**1.** What will its count rate be after 16 days?

*Put a tick (✓) in the box next to the best answer.*

|  |  |  |
| --- | --- | --- |
| **A** | 600 per minute. |  |
|  |  |  |
| **B** | 150 per minute. |  |
|  |  |  |
| **C** | 0 per minute. |  |
|  |  |  |
| **D** | Impossible to know. |  |

The count rate from one capsule is measured at 400 per minute.

**2.** How long will it be before the count rate is 50 per minute?

*Put a tick (✓) in the box next to the best answer.*

|  |  |  |
| --- | --- | --- |
| **A** | 24 days. |  |
|  |  |  |
| **B** | 14 days. |  |
|  |  |  |
| **C** | 7 days. |  |
|  |  |  |
| **D** | Impossible to know. |  |

*Physics > Big idea PMA: Matter > Topic PMA5: Nuclear physics > Key concept PMA5.4: Radioactive half-life*

|  |
| --- |
| **Diagnostic question** |
| **Predicting radioactivity** |

**Overview**

|  |  |
| --- | --- |
| Learning focus: | Radioactive half-life is the predicted time it takes for half of a large sample of radioactive nuclei to decay randomly. |
| Observable learning outcome: | Make calculations using values of half-life. |
| Question type: | Simple multiple choice |
| Key words: | Half-life, radioactive atom, radioactive isotope |

**What does the research say?**

Misunderstandings that may stem from a thinking that ‘only clearly determined events can lead to predictable outcomes’ are:

* a radioactive material will be safe and no longer radioactive after one half-life (Lijnse et al., 1990);
* *all* the radioactive atoms will have decayed after one half-life (or after *two* half-lives); and
* half-life is a special time before which, or at which, a particular nucleus decays (Hull and Hopf, 2020).

In each of these examples, students appear to have used the idea that ‘half-life’ is predictable, to develop a misunderstanding that the decay of particular radioactive atoms is also predictable. The last example additionally shows how some students (about a third of a sample of 55 students age 13-14) ascribe the predictive nature of a whole sample to a single radioactive nucleus (Hull and Hopf, 2020). In fact, an individual radioactive nucleus does not have a half-life and its decay is random. Half-life is instead, a *good predictor* of the time it takes for half of a sample of *very many* radioactive nuclei to decay.

Another misunderstanding students have is that atoms disappear during radioactive decay (Prather, 2005). Prather (2005) found that the majority (59%) of (n=258) undergraduate students believed that the mass or volume of a radioactive substance would reduce by half during one half-life. Expressed differently, this means that a radioactive object disappears as it decays. This misunderstanding is likely to stem from the fact that is not clear to a lot of students that radioactive materials contain both stable and unstable atoms.

**Ways to use this question**

Students should complete the question individually. This could be a pencil and paper exercise, or you could use an electronic ‘voting system’ or mini white boards and the PowerPoint presentation.

The answers to the question will show you whether students understood the concept sufficiently well to apply it correctly.

If there is a range of answers, you may choose to respond through structured class discussion. Ask one student to explain why they gave the answer they did; ask another student to explain why they agree with them; ask another to explain why they disagree, and so on. This sort of discussion gives students the opportunity to explore their thinking and for you to really understand their learning needs.

*Differentiation*

You may choose to read the questions to the class, so that everyone can focus on the science. In some situations, it may be more appropriate for a teaching assistant to read for one or two students.

**Expected answers**

1. B 2. A

**How to respond - what next?**

1. There are two half-lives during the 16 days. The original count rate is halved to 300 after 8 days, and halved again to 150 after another 8 days.

A A few students may think wrongly that because it is in storage, the iodine-131 does not decay. Instead, its decay is random and cannot be controlled.

C Some students may think wrongly that half of the iodine decays in one half-life and the other half of it in the second half-life. It is also quite common for some students to have the misunderstanding that a half-life is the time for all of a radioactive isotope to decay.

D A few students may have the misunderstanding that because radioactive decay is random, it is impossible to know for sure how quickly a sample will decay. In reality, because of the very large numbers of radioactive atoms involved, half-life predictions are very accurate.

2. To change from 400 to 50 counts per minute, the count rate needs to halve from 400 to 200, from 200 to 100 and from 100 to 50, which is three half-lives. This takes 3 x 8 = 24 days.

B Students who have the misunderstanding that it takes two half-lives for all of the iodine-131 to decay are likely to chose this option which is just less than two half-lives (1¾ half-lives).

C Students who have the misunderstanding that all of the iodine-131 decays in one half-life are likely to choose this option, which is just less than one half-life (⅞ of a half-life).

D As with question 1, a few students may have the misunderstanding that because radioactive decay is random, it is impossible to know for sure how quickly a sample will decay.

If students have misunderstandings about making calculations using values of half-life, it can help to model what happens to a radioactive material as it decays. Practice calculations can then be used to consolidate understanding.

The following BEST ‘response activity’ could be used in follow-up to this diagnostic question:

* Response activity: Half-life of pizza

**Acknowledgments**

Developed by Peter Fairhurst (UYSEG).

Images: Peter Fairhurst (UYSEG).

**References**

Hull, M. M. and Hopf, M. (2020). Student Understanding of Emergent Aspects of Radioactivity. *International Journal of Physics and Chemistry Education,* 12(2).

Lijnse, P. L., et al. (1990). Pupils' and mass-media ideas about radioactivity. *International Journal of Science Education,* 12.1.

Prather, E. (2005). Students' beliefs about the role of atoms in radioactive decay and half-life. *Journal of Geoscience Education,* 53(4)**,** 345-354.