**Neutron rich**

Carbon-12 is a stable isotope of carbon.

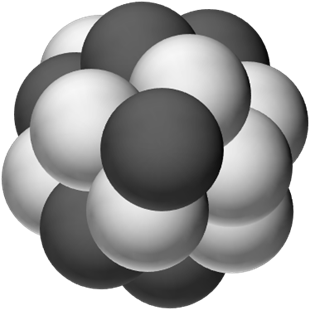
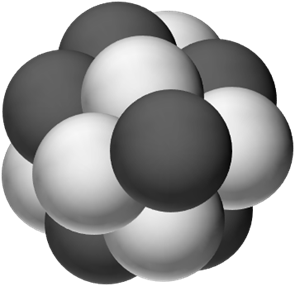
Carbon-14 is radioactive isotope and can decay by emitting a beta-particle.

A carbon-12 nucleus

* *6 protons*
* *6 neutrons*

A carbon-14 nucleus

* *6 protons*
* *8 neutrons*



Carbon-12 is not radioactive and carbon-14 is radioactive.

What is different about carbon-14 that makes it radioactive?

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

|  |  |  |
| --- | --- | --- |
| **A** | Its neutrons can move far enough away from a proton to decay. |  |
|  |  |  |
| **B** | Its neutrons are less stable because they are further from protons. |  |
|  |  |  |
| **C** | It has more neutrons, so it is more likely that one will decay. |  |

*Physics > Big idea PMA: Matter > Topic PMA5: Nuclear physics > Key concept PMA5.2: Radioactive decay*

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| --- |
| **Diagnostic question** |
| **Neutron rich** |

**Overview**

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| --- | --- |
| Learning focus: | Some nuclei, which are unstable because they have too many neutrons, decay spontaneously by beta radiation because neutrons are unstable away from the close proximity of protons. |
| Observable learning outcome: | Explain why the chances of beta decay increase with the proportion of neutrons to protons in a nucleus. |
| Question type: | Simple multiple choice |
| Key words: | Radioactive, isotope, nucleus, proton, neutron, neutron-rich, beta particle, beta decay |

|  |  |
| --- | --- |
| **B** | **BRIDGING**  This diagnostic question probes understanding of ideas that are usually taught at age 16-19, to build a bridge to later stages of learning. |

**What does the research say?**

At ages 14-16, students are rarely taught that the causes of alpha, beta and gamma radiation are each different. By thinking about the mechanisms behind beta decay students can develop of a useful mental model that can help challenge misunderstandings about radioactive decay and clarify gaps in understanding that could otherwise lead to some confusion or uncertainty.

Prather (2005) found that, even after tuition, 59% of the undergraduates believed that the mass or volume of a radioactive substance reduced by half after one half-life, when half the substance had decayed. This outcome is suggestive that the language used to describe what is happening: ‘half of it has decayed’ and ‘half-life’ is taken literally by students; which in turn suggests that many students do not have a clear mental model of radioactive decay that they can draw on.

This diagnostic question checks whether students can apply their understanding of what makes neutrons more unstable, to explain why neutron rich isotopes can often decay by beta emission.

**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 answer**

B

**How to respond - what next?**

On their own, neutrons are unstable and after ten minutes about half of the neutrons in a sample will have decayed. The close proximity of protons makes neutrons stable; and the closer the proximity, the greater the stability.

A Some students may think that there is a fixed distance, between a proton and a neutron, after which the neutron decays. This ignores the random nature of radioactive decay, and increasing the distance instead increases the *probability* of a decay.

C If this were the correct reason, then it would be expected that carbon-14 is about 20% more radioactive than carbon-12, because it has 20% more neutrons. Instead, carbon-14 is radioactive and carbon-12 is stable. Additionally, oxygen-16, which has the same number of neutrons as carbon-14, is stable.

If students have misunderstandings about explaining why the chances of beta decay increase with the proportion of neutrons to protons in a nucleus, it can help to consider what is happening in terms of a model, and then to give students the opportunity to work in pairs or in small groups to explain why some nuclei are more likely to undergo beta decay than others.

A useful model to consider is perhaps that of some students who are more likely to misbehave, the further they are from a teacher. Being further from a teacher does not mean they *will* misbehave, although they are perhaps *more likely* to misbehave. This analogy can be extended to consider classrooms with different numbers of teachers (protons) and students (neutrons).

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

* Response activity: The chances of beta.

**Acknowledgments**

Developed by Peter Fairhurst (UYSEG).

Images: Peter Fairhurst (UYSEG).

**Reference**

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