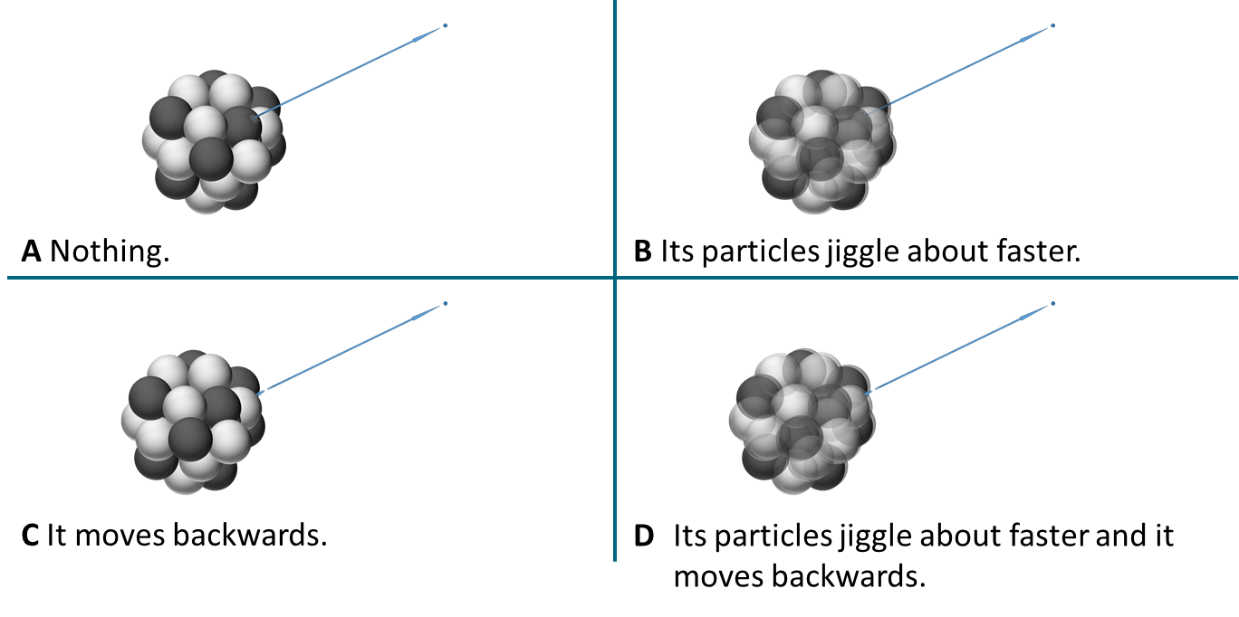
**After beta**

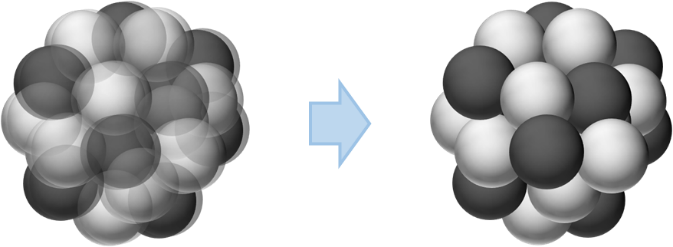
In this unstable nucleus a neutron decays into a proton.

This causes a beta particle to be created, which is emitted from the nucleus.

**1.** What happens to the nucleus *after* the beta particle is emitted?

****

**2.** How does an excited nucleus reduce the energy it has?



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

|  |  |  |
| --- | --- | --- |
| **A** | Friction between protons and neutrons slows them down. |  |
|  |  |  |
| **B** | It warms the air by friction. |  |
|  |  |  |
| **C** | It emits light. |  |
|  |  |  |
| **D** | It emits gamma radiation. |  |

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

|  |
| --- |
| **Diagnostic question** |
| **After beta** |

**Overview**

|  |  |
| --- | --- |
| 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 a nucleus usually emits gamma radiation after a beta decay. |
| Question type: | Simple multiple choice |
| Key words: | Radioactive decay, nucleus, proton, neutron, beta particle, beta decay, unstable, excited |

**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 gamma decay, this diagnostic question is designed to support the development of a useful mental model that can help challenge students’ 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 momentum and the transfer of energy to describe what happens to the nucleus of an atom following beta decay.

**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. D

2. D

**How to respond - what next?**

A beta particle has a tiny fraction of the mass of the nucleus it is emitted from, but it is typically emitted at speeds approaching the speed of light. It has enough momentum to cause the nucleus to recoil and to disrupt its protons and neutrons and leave them jiggling about more quickly than they were. If the amount of energy the nucleus has because of its excited state is sufficiently large, the nucleus can emit gamma radiation (a gamma photon) to transfer its extra energy away.

(N.B. For clarity, this question treats the nucleus as being static when the beta particle is emitted, and also ignores the role of anti-neutrinos in beta decay, which is typically introduced to physics students at a later stage of their learning).

1. To explain a correct answer to this question, students understanding of the mass and speed of a beta particle need to be combined to produce a momentum that can be sufficient to affect a nucleus.

A A few students may consider the beta particle (electron) too small to affect the nucleus ‘in a noticeable way’.

B A model that many students may consider is that of a person throwing a small ball. This will make the person move about and wobble a bit if they throw the ball with a lot of force – but they do not move backwards, because of friction between the person and the floor.

C This option may be chosen by students who consider protons and neutrons to be fixed in place, or that the nucleus is a single solid object like a ball.

2. A Some students are likely to think that friction between the protons and neutrons will slow them down and cause them to become hotter. But this would not transfer energy away from the nucleus and another mechanism is necessary.

B It is common for younger students to think that the space between the electrons in an atom is filled with air, or some other substance. A few students may still apply this misunderstanding and think that the nucleus can transfer energy by rubbing against this.

C A few students, perhaps from watching films, may think that radioactive substances glow, or give off light and chose option C.

If students have misunderstandings about explaining why a nucleus often emits gamma radiation after a beta decay, it can help to provide students with the opportunity to work in pairs or small groups to explain in their own words why gamma radiation usually follows a beta decay. This can develop and consolidate understanding through structured discussion and feedback.

A useful model for them to consider is perhaps that of a person sat on a wheelie chair who throws a ball away at a very, very fast speed.

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

* Response activity: Beta decay story.

**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.