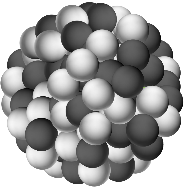
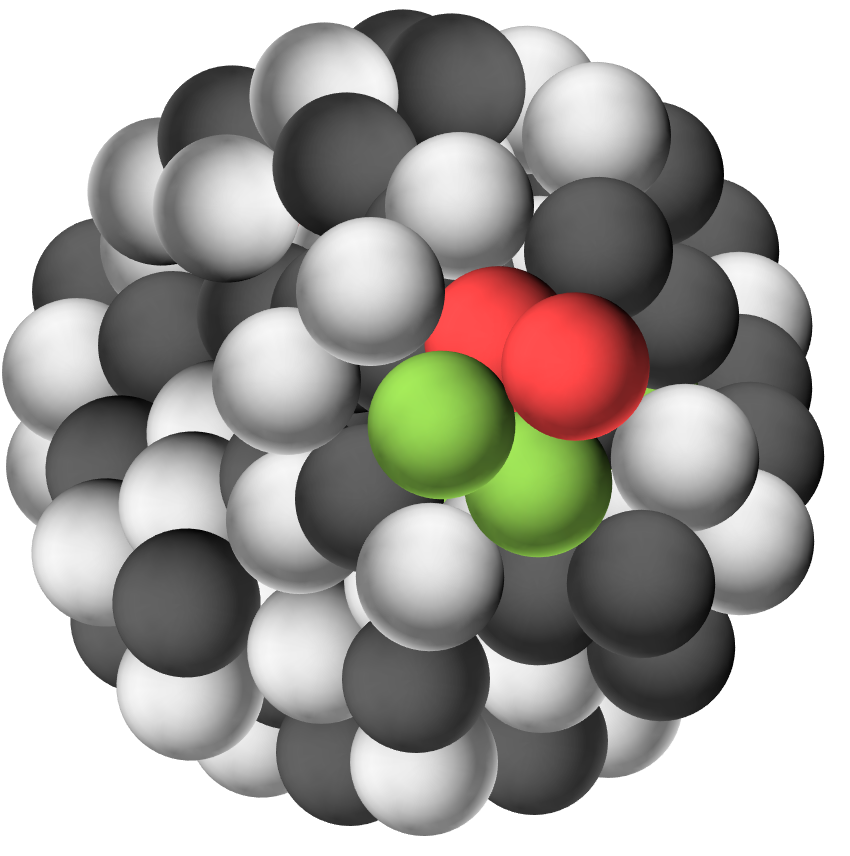
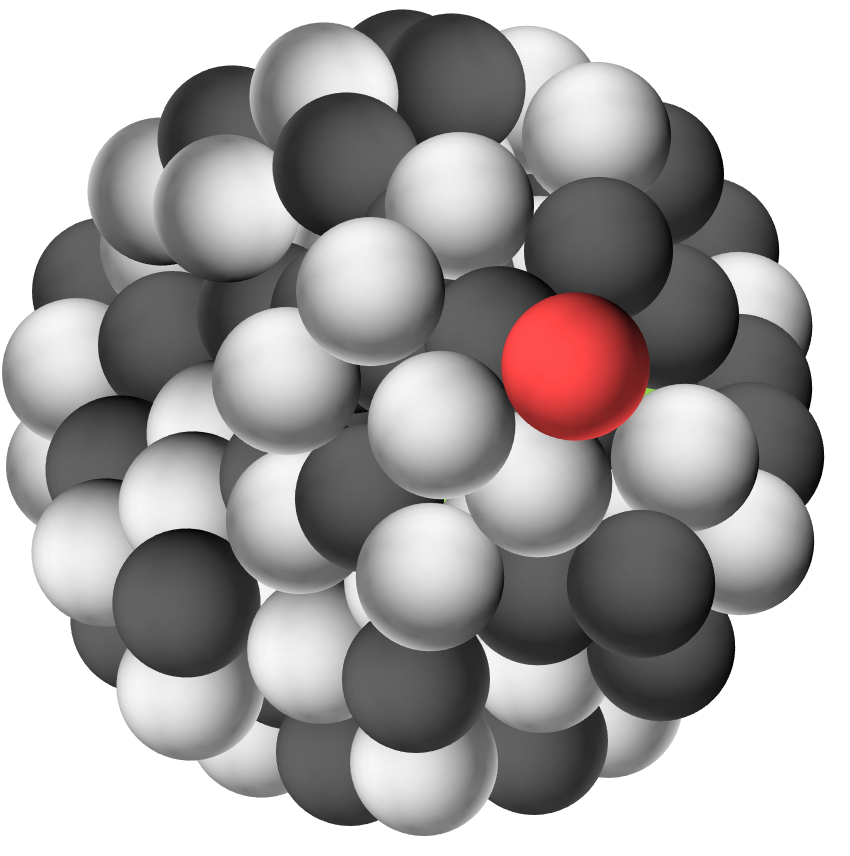
**Why alpha?**



This nucleus is unstable because it is large and has too many protons.

Inside a large nucleus, protons and neutrons can form alpha particles.

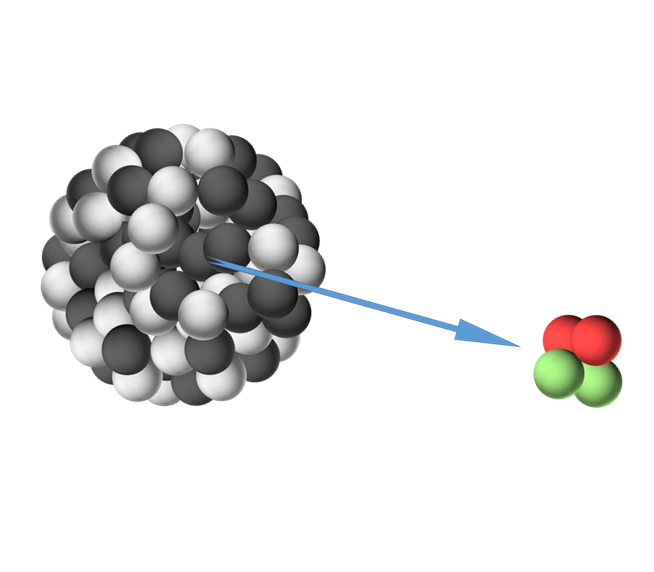
An alpha particle is made of two protons and two neutrons.



A proton in a nucleus

An alpha particle in a nucleus

A large unstable nucleus emits an alpha particle rather than a proton\*.



What explains why an alpha particle is emitted?

*You may put a tick (✓)* ***in more than one box****.*

|  |  |  |
| --- | --- | --- |
| **A** | The protons and neutrons in an alpha particle are held together very strongly. |  |
|  |  |  |
| **B** | An alpha particle has two times the electric charge of a proton. |  |
|  |  |  |
| **C** | An alpha particle has four times the mass of a proton. |  |

*\*Protons can sometimes be emitted, but this is much less common.*

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

|  |
| --- |
| **Diagnostic question** |
| **Why alpha?** |

**Overview**

|  |  |
| --- | --- |
| Learning focus: | Some large nuclei, which are unstable because they contain too many protons, decay spontaneously by alpha radiation because of repulsive forces between protons. |
| Observable learning outcome: | Explain why large nuclei with too many protons emit alpha particles rather than protons. |
| Question type: | Multiple choice |
| Key words: | Radioactive decay, nucleus, proton, neutron, alpha particle, alpha decay, stable, unstable |

|  |  |
| --- | --- |
| **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 about the cause of alpha radiation and why some unstable nuclei emit alpha particles rather than single protons. By thinking about the mechanisms behind alpha 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.

Key to understanding the reasons for alpha decay, is an understanding of the repulsive electrostatic forces between protons in a nucleus. However, amongst students age 13-18, the level of awareness is low that an electrostatic force attracts electrons to a nucleus and causes electrons around a nucleus, or protons within a nucleus, to repel each other (Harrison and Treagust, 1996; Tabor, 2013). In his study, Taber (2013) found that it was more common for students aged 15-18 (N=105) to think instead, that gravity or magnetism attracts electrons towards a nucleus. These findings suggest it is likely that many students think about atomic structure in isolation from their thinking about electrostatic forces and need support to defragment their understanding of each concept.

This diagnostic question checks whether students can apply their understanding of electrostatic repulsion to explain, in simple terms, why an alpha particle is emitted from a large, proton rich, unstable nucleus rather than a proton.

**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**

A and B each contribute to the correct reason.

**How to respond - what next?**

The detailed reason for alpha decay in large, proton rich, unstable nuclei is complex and involves understanding that is beyond what expected at this stage of learning. At this point it is sufficient for students to understand that a combination of two protons and two neutrons (an alpha particle) is very stable and that an alpha particle inside a nucleus experiences about twice the electrostatic repulsion that a single proton does. This leads to an alpha particle (almost always) being emitted before a proton can be.

A Some students are likely to realise from their earlier learning that a small particle with equal numbers of protons and neutrons is stable. Others may deduce this by understanding that the alpha particle in the nucleus is acting as if it is a single particle (which it can be thought of as doing).

B Most students are likely to recognise that twice the electric charge means that the alpha particle experiences about twice the repulsive force of an alpha particle. Some students may consider wrongly that these forces do not work in a nucleus.

C A few students may think that the greater mass of an alpha particle means it can break away more easily. These students may correctly understand that protons and neutrons are moving rapidly (as particles in matter) and assume that the alpha particle has more momentum to break free than a proton. The strong nuclear force however, is too large for this to be possible.

If students have misunderstandings about why large nuclei with too many protons emit alpha particles rather than protons, it can help to review understanding of the electrostatic force between particles in a nucleus.

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

* Response activity: Explaining alpha decay

**Acknowledgments**

Developed by Peter Fairhurst (UYSEG).

Images: Peter Fairhurst (UYSEG).

**References**

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

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