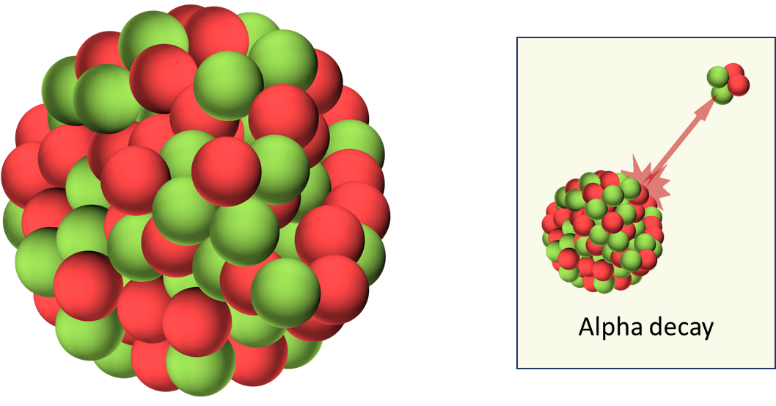
**Alpha decay story**

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

An unstable nucleus like this can emit an alpha particle.



Describe alpha decay.

Pick ***one*** statement in each row to explain how.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 1 | A large nucleus is unstable if it has too many protons. | | | |
| 2 | In the nucleus, the electrostatic force pushes protons apart. | | In the nucleus, the strong nuclear force pushes protons apart. | |
| 3 | If the force is big enough, an alpha particle is emitted from the nucleus. | | | |
| 4 | An alpha particle is made of two protons. | | An alpha particle is made of two protons and two neutrons. | |
| 5 | It is emitted at a speed of about  15 000 000 m/s. | | It is emitted at a speed of about  10 cm/s. | |
| 6 | The nucleus is destroyed. | | The nucleus is pushed back the other way. | |
| 7 | The atom is now a different element. | The atom does not exist anymore. | | The atom is the same element & more stable. |

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

|  |
| --- |
| **Diagnostic question** |
| **Alpha decay story** |

**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: | Describe what happens to an atom and its nucleus during an alpha decay. |
| Question type: | Explanation story |
| Key words: | Radioactive decay, nucleus, proton, neutron, alpha particle, alpha decay, unstable |

**What does the research say?**

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.

During alpha decay, the nucleus of the radioactive atom loses two protons and two neutrons and therefore becomes an atom of a different element. The valence electrons around the nucleus will be affected indirectly because after radioactive decay the proton number of the atom is changed. However, the actual process of radioactive decay involves just the nucleus; and all alpha particles originate from a nucleus and account for a very small fraction of its mass.

This does not appear to be understood by the majority of students. In a study in the USA, Prather (2005) found that just 26% of high school students (n=19) and 33% of first year undergraduate students, who were non-science majors studying physics (n=258), thought that radioactive decay involved just the nucleus of an atom.

Prather (2005) also 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.

**Ways to use this question**

This task is intended for discussion in pairs or small groups. It is best done as a pencil and paper exercise.

Students should read the statements and follow the instructions on the worksheet. Listening in to the conversations of each group will often give you insights into how your students are thinking. Each member of a group should be able to report back to the class.

Feedback from each group can be used, with careful teacher questioning, to bring out a clear description or explanation of the science.

*Differentiation*

The quality of the discussions can be improved with a careful selection of groups; or by allocating specific roles to students in each group. For example, you may choose to select a student with strong prior knowledge as the scribe, and forbid them from contributing any of their own answers. They may question the others and only write down what they have been told. This strategy encourages contributions from more members of each group.

NB in any class, small group discussions typically improve over time and a persistence with this strategy is often very successful in the medium to long term.

**Expected answers**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 1 | A large nucleus is unstable if it has too many protons. | | | |
| 2 | In the nucleus, the electrostatic force pushes protons apart. | | In the nucleus, the strong nuclear force pushes protons apart. | |
| 3 | If the force is big enough, an alpha particle is emitted from the nucleus. | | | |
| 4 | An alpha particle is made of two protons. | | An alpha particle is made of two protons and two neutrons. | |
| 5 | It is emitted at a speed of about  15 000 000 m/s. | | It is emitted at a speed of about  10 cm/s. | |
| 6 | The nucleus is destroyed. | | The nucleus is pushed back the other way. | |
| 7 | The atom is now a different element. | The atom does not exist anymore. | | The atom is the same element & more stable. |

**How to respond - what next?**

2. It is common for students to ignore electrostatic repulsion between protons in a nucleus and the second statement may be chosen by these students to explain what is happening.

4. An alpha particle cannot comprise of just two protons as they repel each other and neutrons are needed to hold them together more strongly. Having two protons and two neutrons enables the particles to have a particularly strong attraction, as they are, on average, closer together than other arrangements, which results in a bigger strong nuclear force between them.

5. 10 cm is the range of alpha particles in air, rather than the ‘speed’ at which they are emitted.

6. It is common for students to think that a radioactive nucleus disappears or is destroyed after radioactive decay. This may be because the word ‘decay’ is associated with ‘wearing away’ in other contexts.

7. Some students may misunderstand radioactive decay in terms of an unstable atom becoming a more stable version of the same atom. In alpha decay an atom of a different element is formed that has two fewer protons than the original atom.

If students have misunderstandings about describing what happens to an atom and its nucleus during an alpha decay, it can help to review students’ understanding of atomic structure and isotopes, perhaps using the BEST key concept: PMA5.1 Atomic nuclei.

Giving students the opportunity to draw a cartoon strip to describe the process of alpha decay, or to model it with modelling clay, can help to develop and consolidate understanding.

The following BEST ‘response activity’ could also 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**

Harrison, A. G. and Treagust, D. F. (1996). Secondary students' mental models of atoms and moelcules: Implications for teaching chemistry. *Science Education,* 80(5)**,** 509-534.

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

Tabor, K. S. (2013). Upper secondary students' understanding of the basic physical interactions in analogous atomic and solar system models. *Research in Science Education,* 43**,** 1377-1406.