**Unstable nucleus**

The nucleus of an atom is made of protons and neutrons.

**A**

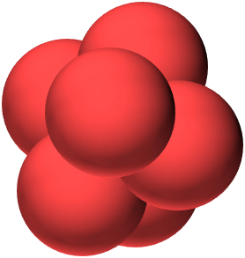
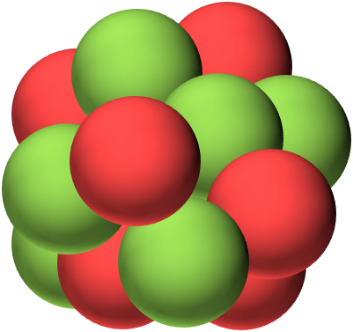
**B**

A nucleus made of

* 6 protons.

A nucleus made of

* 6 protons and
* 6 neutrons.



**a.** Which nucleus is most unstable?

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

|  |  |  |
| --- | --- | --- |
| **A** | Nucleus of just protons. |  |
|  |  |  |
| **B** | Nucleus of protons and neutrons. |  |
|  |  |  |
| **C** | Both are equally unstable. |  |

**b.** What is the best reason for your last answer?

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

|  |  |  |
| --- | --- | --- |
| **A** | Both have the same number of protons. |  |
|  |  |  |
| **B** | Its protons are closer together. |  |
|  |  |  |
| **C** | Its protons are further apart. |  |
|  |  |  |
| **D** | It has neutrons. |  |

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

|  |
| --- |
| **Diagnostic question** |
| **Unstable nucleus** |

**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 the effect of the electrostatic force within an atomic nucleus. |
| Question type: | Two-tier multiple choice |
| Key words: | Radioactive decay, nucleus, proton, neutron, electrostatic force, strong nuclear force |

|  |  |
| --- | --- |
| **P** | **PRIOR UNDERSTANDING**  This diagnostic question probes understanding of ideas that are usually taught at age 11-14, to aid transition from earlier stages of learning. |

**What does the research say?**

Ideas about why some nuclei are stable and others unstable, are useful for explaining, in simple terms, the processes of radioactive decay and why radioactive decay is random. At ages 14-16, students are rarely taught about these ideas or that the causes of alpha, beta and gamma radiation are each different.

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 if students are applying their understanding of electrostatic forces to the protons (and neutrons) that an atomic nucleus is made from.

**Ways to use this question**

Students should complete the questions 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 follow-on question will give you insights into how they are thinking and highlight specific misconceptions that some may hold.

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. A

b. B

**How to respond - what next?**

In an atomic nucleus, a strong nuclear force pulls together protons and neutrons that are in close proximity to each other, irrespective of charge. A repulsive electrostatic force pushes protons apart. The electrostatic force increases as the distance between protons decreases.

In the two nuclei under consideration, the protons in nucleus A are closer together and it is more unstable because the repulsive electrostatic force between its protons is bigger than in B. The attractive strong nuclear force holding each proton to the nucleus is about the same in each case, because each proton has about the same number of immediate neighbours exerting a strong nuclear force on it.

It is relatively common for some students to disregard the electrostatic repulsion between protons in a nucleus. Disregarding the electrostatic repulsion may lead students to deduce that both nuclei are equally stable and choose option A for part b, because that is the only choice that describes a similarity the two nuclei share. Alternatively, they may deduce that nucleus B is more unstable because it is bigger and therefore harder to keep hold of – and choose option D instead.

Options B, D may also be chosen by students who have mixed up the charges on protons and neutrons and consequently think the neutrons repel each other.

A few students may have the right understanding, but confuse ‘unstable’ with ‘stable’ and choose options B, C.

If students have misunderstandings about describing the effect of the electrostatic force within an atomic nucleus, it can help to use the BEST key concept PMA5.1: *Atomic nuclei*, to develop and consolidate understanding of protons and neutrons that make up an atomic nucleus, before introducing ideas of radioactive 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.

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.