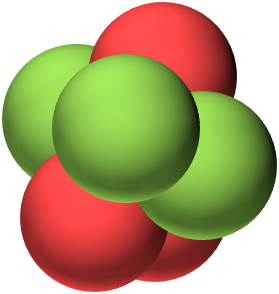
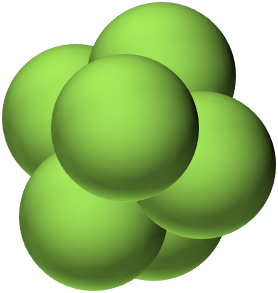
**Differently unstable**

The nucleus of an atom is made of protons and/or 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 neutrons. |  |
|  |  |  |
| **B** | Nucleus of protons and neutrons. |  |
|  |  |  |
| **C** | Each is as unstable as the other. |  |

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

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

|  |  |  |
| --- | --- | --- |
| **A** | Neutrons do not repel each other. |  |
|  |  |  |
| **B** | Protons repel each other. |  |
|  |  |  |
| **C** | The strong nuclear force is the same in each. |  |
|  |  |  |
| **D** | Neutrons are unstable away from protons. |  |

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

|  |
| --- |
| **Diagnostic question** |
| **Differently unstable** |

**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: | Restate, in own words, the reasons why a nucleus cannot be made of just neutrons. |
| Question type: | Two-tier multiple choice |
| Key words: | Radioactive decay, nucleus, proton, neutron, electrostatic force, strong nuclear force |

**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.

When discussing radioactive decay, it is important to make a clear distinction between a radioactive particle and radiation. These two terms are commonly mixed up and this can lead to the forming of misunderstanding (Plotz, 2017). A radioactive atom is unstable and may undergo radioactive decay, and emit radiation. Beta particles are a type of radiation. They are not radioactive because they are stable particles and do not undergo radioactive decay; they are dangerous because they are moving at a very high speed.

This diagnostic question checks students understanding of protons and neutrons in a nucleus and whether they know that neutrons are unstable away from the close proximity of protons.

**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. D

**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. When a neutron is not in very close proximity to a proton it is likely to decay into a proton with the emission of a very high-speed electron, called a beta particle. On its own, there is about a fifty-fifty chance that a neutron will decay at some time during the next ten minutes.

In nucleus A, there are no protons so some of the neutrons are likely to decay quickly with the emission of beta particles. Nucleus B is a stable nucleus because it has protons in close proximity to its neutrons and the strong nuclear force is stronger than the electrostatic force between its protons.

All the statements in *part b* are correct.

Options A and B both explain why nucleus B is more unstable because of differences between the electrostatic forces in each nucleus. These students are applying their understanding of electrostatic forces and are ignoring other understanding they should have. They are not applying the understanding that (small) stable nuclei contain roughly equal numbers of protons and neutrons. Neither are they applying the understanding that a nucleus of neutrons alone would not be able to attract electrons in order to form an atom.

Option C may be chosen by a few students if they think wrongly that there are no repulsive forces between protons in a nucleus, which is quite common.

Although the correct answer may not be familiar to students, it can be arrived at logically by applying understanding of protons and neutrons, which should enable them to disregard options A, B and C, but not D.

If students have misunderstandings about describing the reasons why a nucleus cannot be made of just neutrons, it can help to review what they already know about the structure of nuclei of common atoms. Careful questioning should elicit understanding that options A, B and C, in *part b*, do not explain why the nuclei of atoms found in nature all have protons, and that option D is the most likely reason why neutrons are not found separately under normal conditions.

(N.B. An exception is neutron stars, which are formed of neutrons that are made stable by immense gravitational forces).

**Acknowledgments**

Developed by Peter Fairhurst (UYSEG).

Images: Peter Fairhurst (UYSEG).

**References**

Plotz, T. (2017). Students' conceptions of radiation and what to do about them. *Physics Education,* 52(1)**,** 014004.