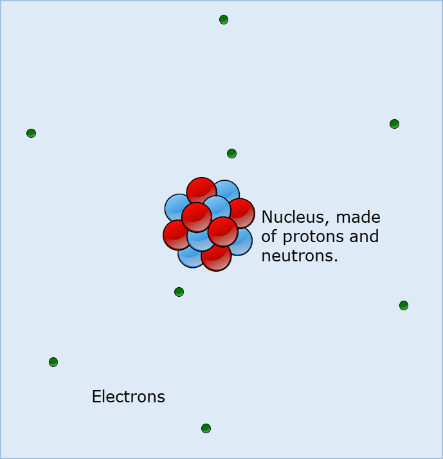
**Protons and neutrons**

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



Model of an atom.

Protons have a positive charge.

Neutrons have no charge.

A proton and a neutron both have about the same mass.

(A neutron has a tiny bit more.)

A proton has about 2000 times more mass than an electron.

What are the forces in an atom?

For each statement, tick (✓) **one** column to show what you think*.*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | | I am **sure** this is right | I think this is right | I think this is wrong | I am **sure** this is wrong |
| **A** | Protons repel each other with an electrostatic force. |  |  |  |  |
| **B** | Electrons in an atom repel each other. |  |  |  |  |
| **C** | Protons attract electrons with an electrostatic force. |  |  |  |  |
| **D** | Neutrons and protons attract each other with an electrostatic force. |  |  |  |  |
| **E** | Neutrons and protons attract each other with a force that is not electrostatic. |  |  |  |  |

*Physics > Big idea PMA: Matter > Topic PMA5: Nuclear physics > Key concept PMA5.1: Atomic nuclei*

|  |
| --- |
| **Diagnostic question** |
| **Protons and neutrons** |

**Overview**

|  |  |
| --- | --- |
| Learning focus: | There is a fixed number of positively charged protons in the nucleus of each atom of an element, but the number of neutrons can vary to make isotopes that are either stable or unstable. |
| Observable learning outcome: | Describe the properties of protons and neutrons in a nucleus. |
| Question type: | Confidence grid |
| Key words: | Atom, nucleus, electron, proton, neutron, positive charge, negative charge, attract, repel |

**What does the research say?**

The way in which a few students conflate the nucleus of an atom to the nucleus of a cell illustrates how sometimes students can make wrong connections between different pieces of information. Using metaphors to develop understanding of atomic structure can be very helpful, but as Harrison and Treagust (1996) found, can also lead to confusion: electron shells can misconstrued as protective enclosures around atoms; and electron clouds as loose structures in which electrons are embedded.

Metaphors or analogies used to explain atomic structure need to be made explicit in teaching; and characteristics of models used should be overtly connected to students’ understanding of the real-world atom (Harrison and Treagust, 1996; Tabor, 2013; Zarkadis et al., 2017).

The level of awareness is low amongst students, 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.

To develop a deeper understanding of the structure of nuclei, Brock, Manning and Walsh (2021) suggest starting by reinforcing understanding of the structure and scale of an atom by modelling Rutherford’s scattering experiment. Their next step is to introduce the proton and neutron.

**Ways to use this question**

Students should complete the confidence grid 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.

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**

Statements A, B, C and E are right; and statement D is wrong.

**How to respond - what next?**

The rule for electrostatic forces is that like charges repel and opposite charges attract. This means that electrons repel each other as they each have a negative charge. This helps to explain why they are spaced out around the nucleus of an atom, and also why they are attracted to the nucleus.

Electrostatic repulsion also means that protons in the nucleus repel each other. The fact that they are held together in the nucleus means there must be a different kind of force of attraction between neutrons and protons. (This is called the strong nuclear force, and is usually taught to students aged 16-18.)

There is no electrostatic attraction between protons and neutrons because there is no charge on a neutron.

A, B Many students fail to recognise that protons in nucleus, or electrons around an atom, must repel each other with an electrostatic force. Their thinking is fragmented and they are not applying the general rule for charges in this particular situation.

C In a similar way, many students fail to recognise that electrons are attracted to the protons in a nucleus by electrostatic attraction. The most common misunderstandings are that gravity or magnetism attracts electrons to a nucleus.

D Some students may think that protons and neutrons attract with an electrostatic force because they have seen charged rods attracting pieces of tissue paper that have ‘no charge’.

A neutron is different to an object that has ‘no charge’. This is because an object with ‘no charge’ contains equal numbers of positive and negative charges (protons and electrons) that *can* interact with each other through the electrostatic force.

It is likely that some students think that protons and neutrons attract with an electrostatic force because they think that neutrons have a negative electric charge.

E The correct understanding that protons repel each other and are not attracted to neutrons by the electrostatic force, may lead to students to form misunderstandings about what force holds a nucleus together, unless the scientific understanding is made clear.

To complete the explanation, a force of attraction is needed, which is one that students are unlikely to have come across before, called the strong nuclear force. If this is not introduced (briefly), students’ misunderstandings that either gravity or magnetism is involved may be reinforced.

If students have misunderstandings about the properties of protons and neutrons in a nucleus, the stories of how each part of an atom was discovered can be used to clarify the nature of each particle:

* electrons were discovered in cathode rays in 1897;
* atoms were found to have positively charged nuclei containing protons in 1909 (Rutherford’s scattering experiment);
* the mass of most nuclei was found to be about twice the mass of the protons they contained, so a new particle was searched for and in 1932 the neutron was discovered (using a version of Rutherford’s scattering experiment).

To construct and consolidate a clearer understanding of protons and neutrons, students could work in pairs or small groups and use the statements in the question to, in their own words, describe the structure of a nucleus and explain why the protons in it do not fly apart.

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

* Response activity: Holding it together

**Acknowledgments**

Developed by Peter Fairhurst (UYSEG).

Images: Peter Fairhurst (UYSEG); atomic nucleus by Clker-Free-Vector-Images from Pixabay.

**References**

Brock, R., Manning, A. and Walsh, K. (2021). Atomic physics. In de Winter, J. & Hardman, M. (eds.) *Teaching Secondary Physics.* 3rd ed. London: Hodder Education.

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.

Zarkadis, N., Papageorgiou, G. and Stamovlasis, D. (2017). Studying the consistency between and within student mental models of atomic structure. *Chemistry Education Research and Practice,* 18**,** 893-902.