**Full shells**

When drawing dot and cross diagrams the outer shell of each ion should be full.

A close up of a screen

Description automatically generated

Some students are discussing this full outer shell rule.

Who do you agree with, and why?

**Giles:** The rule works because atoms want a full outer shell.

**Shane:** The rule explains why atoms react.

**Jenny:** The rule helps to work out the formula of some compounds.

**Amanda:** The rule helps to work out the charge of different ions.

|  |  |
| --- | --- |
| Cards for  **Full shells** |  |
| **Shane:** The rule explains why atoms react. | **Giles:** The rule works because atoms want a full outer shell. |
| **Jenny:** The rule helps to work out the formula of compounds. | **Amanda:** The rule helps to work out the charge of different ions. |

|  |  |
| --- | --- |
| Cards for  **Full shells** |  |
| **Shane:** The rule explains why atoms react. | **Giles:** The rule works because atoms want a full outer shell. |
| **Jenny:** The rule helps to work out the formula of compounds. | **Amanda:** The rule helps to work out the charge of different ions. |

*Chemistry > Big idea CPS: Particles and structure > Topic CPS8: Ionic bonding > Key concept CPS8.1: Ionic lattice*

|  |
| --- |
| **Diagnostic question** |
| **Full shells** |

**Overview**

|  |  |
| --- | --- |
| Learning focus: | Ionic bonding occurs through the electrostatic attraction between ions in an ionic lattice. |
| Observable learning outcome: | Recognise the uses and limitations of the idea of full outer shells. |
| Question type: | Talking heads |
| Key words: | ion, atoms |

**What does the research say?**

In an essay Gillespie and Robinson (2007) describe the origins of the octet rule in which shared electrons were said to count towards a total of eight electrons in the valence (outer) shell of atoms in covalently bonded molecules. The rule was consistent with the outer shell of many stable ions containing eight electrons. However this essay describes how the idea was picked up by Langmuir and used in his teaching leading to an over emphasis on the rule which moved from being a simple rule to derive formulae (with exceptions) based on empirical observations to something closer to a fundamental law of nature.

One small research study (Joki and Aksela, 2018) found that whilst students at first had an adequate model of bonding that emphasised electrostatic interactions, by upper secondary level students had developed an equally strong alternative framework of thinking that related to the idea of full outer shells (octet rule).

The paper suggests that this way of thinking is linked to the intuitive idea that “emptiness needs filling”. In contrast the electrostatic framework of thinking is based on the idea that “opposites attract”.

The researchers also explored the challenges of teaching bonding using the electrostatic framework and found that students preferred an explanation where the full outer shell becomes the cause for what happens (chemical reactions). The recommendation is made is to increase students’ metacognitive awareness of different frameworks for thinking and their uses.

The paper mentions a third framework that relates to minimum energy however this is not usually introduced in the school curriculum until later.

**Ways to use this question**

This task is intended for discussion in pairs or small groups. It can be done as a pencil and paper exercise or projected onto a screen.

Students should read the statements and follow the instructions on either the worksheet or the PowerPoint. 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. 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**

Jenny and Amanda correctly describe two ways in which the idea of full outer shells may be used.

**How to respond - what next?**

A student who agrees with Shane is placing more importance in the rule than is justified. The rule may help to work out some chemical formulae or the charge of ions, but it does not provide a scientific explanation as to why atoms react. The full explanation of this may beyond current levels of learning but students could be told that more advanced models are able to explain this.

Agreement with Giles indicates that a student is anthropomorphising atoms. Atoms are not people. They do not have wants or needs.

If students have misunderstandings about the use of language in describing the full outer shell rule, it may help to think about how language helps and hinders understanding. Describing an atom as “wanting” a full outer shell may be a useful memory aid for students to help them get the “right” answer or to draw a dot and cross diagram but it is important that students are made explicitly made aware that clearly atoms do not have wants and needs.

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

* Revision language

**Acknowledgments**

Developed by Helen Harden (UYSEG)

Images: Helen Harden (UYSEG)

**References**

Gillespie, R. J. and Robinson, E. A. (2007). Gilbert N. Lewis and the chemical bond: The electron pair and the octet rule from 1916 to the present day. *Journal of Computational Chemistry,* 28**,** 87-97.

Joki, J. and Aksela, M. (2018). The challenges of learning and teachng chemical bonding at diffeent school levels using electrostatic interactions instead of the octet rule as a teaching model. *Chemical Education Research and Practice,* 19.