*Chemistry > Big idea CPS: Particles and structure > Topic CPS7: Metallic bonding*

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| **Key concept (age 14-16)** |
| **CPS7.1: Metallic structure model** |

**What’s the big idea?**

A big idea in chemistry is that all matter is made up of atoms. The collective, structural arrangement and behaviour of the atoms explains the properties of different substances.

**How does this key concept develop understanding of the big idea?**

This key concept helps to develop the big idea by introducing a model of metallic bonding consisting of a regular arrangement of positive metal ions surrounded by ‘free’ outer electrons.

The conceptual progression starts by checking understanding of the atomic model. It then supports understanding of this model for metallic structure in order to enable understanding of the nature of metallic bonding and the limitations of the model in explaining properties of metals.

**Using the progression toolkit to support student learning**

Use diagnostic questions to identify quickly where your students are in their conceptual progression. Then decide how to best focus and sequence your teaching. Use further diagnostic questions and response activities to move student understanding forwards.

**Progression toolkit: Metallic structure model**

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| **Learning focus** | A model of metallic structure, made up of positive metal ions surrounded by ‘free’ outer electrons, can explain some properties of metals. | | | | |
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| **As students’ conceptual understanding progresses they can:** | **C o n c e p t u a l p r o g r e s s I o n** | | | | |
| Recognise that a diagram of electron arrangement is a model and not a copy of reality. | Describe a model of metallic structure (positive ions and ‘free’ outer electrons). | Critique representations of metallic structure. | Describe metallic bonding as an all-directional electrostatic interaction. | Evaluate the metallic structure model in terms of its ability to explain physical properties of metals. |
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| **Diagnostic questions** | Electron diagram | Metallic structure | Metallic structure diagrams | Chemical bonding | Metal properties |
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| **Response**  **activities** | Electron shells | Atom overlays | Sea of electrons | Metallic bonding diagrams | Explaining metals |

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| Key: | | | |
| **P** | Prior understanding from earlier stages of learning | **B** | Bridge to later stages of learning |

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| **Electron diagram** | **Metallic structure** | **Metallic structure diagrams** | **Chemical bonding** | **Metal properties** |
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| Talking heads | Simple multiple choice | Thinking heads | Talking heads | Confidence grid |
| **Electron shells** | **Atom overlays** | **Sea of electrons** | **Metallic bonding diagrams** | **Explaining metals** |
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| Critiquing language | Clarifying | Critiquing language | Critiquing a representation | Thinking heads |

**What’s the science story?**

A simple model of metallic structure is based up on a regular arrangement of positive metal ions surrounded by ‘free’ outer electrons. In this model, metallic bonding is an all-directional electrostatic force of attraction between the positive ions and negative electrons.

This model can account for simple properties such as why a metal is able to conduct electricity but does not explain why there is variation in the electrical conductivity of different metals. This requires a more sophisticated model.

**Earlier development of understanding (BEST 11-14)**

When applying their understanding to novel situations, students of all ages often revert to earlier misunderstandings. Before moving forward it is worthwhile using diagnostic questions from earlier topics to check that students do not have any persistent misunderstandings that can form barriers to learning. Time spent consolidating the scientific understanding of earlier key concepts before moving forward can accelerate progression later.

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| **Key concept CPS6.1 Atomic Model**  **Learning focus:** The structure of an atom may be represented by an atomic model.  This key concept develops understanding that:   * a model is not an exact representation of reality * a model has an explanatory purpose * multiple models may be used. |

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| **Key concept PEM1.4 Static electricity**  **Learning focus:** Charged objects attract or repel other objects at a distance; they gain charge by the transfer of electrons as the result of rubbing.  This key concept:   * introduces electrostatic forces of attraction and repulsion between like and unlike charges. |

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| **Key concept PEM 1.2 Electric current**  **Learning focus:** Electric current is the flow of electric charge around a circuit that stops or starts flowing everywhere in the circuit at the same time. In a series circuit the current is the same in all places.  This key concept:   * introduces electric current as a flow of electric charge. |

**What does the research say?**

A paper (Cheng and Oon, 2016) quotes (Gilbert, 2004) as describing the learning of school science as the “progressive study of different models of physical phenomena”.

In earlier years, a basic particle model considers metals to be made up of particles, with each metal being made up of one kind of particle (an atom).

At 14-16 students are customarily introduced to the structure of a metal as being made up of a regular arrangement of positive metal ions with ‘free’ outer electrons able to move between them. In this model, metallic bonding is an all-directional electrostatic force of attraction between the positive metal ions and negatively charged electrons. Further on in their chemical education students may be introduced to a more advanced model.

Cheng and Oon (2016) explore the shift in thinking required by students in moving from the simple particle model and a more specific model of metallic structure. This shift is one which, according to the research, students find challenging.

Zohar and Levy (2019) raise another idea involved in reasoning about chemical bonding, the idea that of a balance between the electrostatic forces of attraction and repulsion. In particular, they found that repulsion is not often mentioned, something they suggest leads students into forming a flawed mental model that may be problematic for students who go on to study chemistry at a more advanced level.

De Posada (1999) found that the presentation of metallic bonding can add to student misunderstandings, for example, through the use of metaphor (“sea of electrons”). Some textbooks confusingly mix a particulate idea of electrons in the basic atomic model with the idea of an electron cloud and delocalised electrons in diagrams of metallic structure.

The progression therefore starts by revisiting the atomic model and the idea that a model is not a direct representation of reality. It then checks student understanding of two aspects of a model for metallic bonding (the regular arrangement of positive metal ions and the ‘free’ outer electrons). This leads to consideration of student understanding of metallic bonding in terms of electrostatic forces of attraction and repulsion. Finally, students are asked to consider limitations of this model in terms of explaining properties of metals. This is of particular importance for students progressing to further study of chemistry (and physics) as it prepares them for the idea that the models they study will change as they learn about more advanced ideas.

This key concept introduces a new style of diagnostic question called ‘thinking heads’. The research relating to bonding frequently refers to the idea of a student’s mental model. A paper (Harrison and Treagust, 1996) summarises ideas from the research about the term. ‘Mental models’ are variously described as mental representations generated by an individual during cognitive functioning (Vosniadou, 1994) or intrinsic descriptions of an object or idea that are unique to the learner and arise and evolve through interaction with a target system (Norman, 1983).

This also links with Johnstone’s triangle (Johnstone, 1991) which shows the three ways in which an expert chemist can think about a phenomenon (macroscopically, sub-microscopically and symbolically). Being able to think at the sub-microscopic level is critical for understanding the concepts relating to chemical bonding.

**Guidance notes**

Taber and Coll (2002) suggest a sequence of learning about chemical bonds that could reduce common misconceptions. In particular they suggest that once students have been taught about the molecule concept, they tend to apply this “molecule” schema to all structures. A recommendation is to teach metallic bonding first, and then ionic bonding. Covalently bonded crystals, which in some ways are similar to metallic and ionic structures with a single form of bond holding the entire structure together, are suggested to be taught next. Discrete covalent molecules are considered to be the most complex as they also require an understanding of intermolecular forces. For this reason, it is recommended to leave these until last.

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