Chemistry > Big idea CPS: Particles and structure > Topic CPS1: Substances and mixtures

Key concept (age 11-14)
CPS1.1: Particle model for the solid, liquid and gas states

What's the big idea?

A big idea in chemistry is that all matter is made up of particles called atoms. The structural arrangement and movement of atoms and the forces between them, explain the properties of different materials. A key concept of this big idea is the use of the particle model to explain the properties of substances in the solid, liquid and gas states.

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

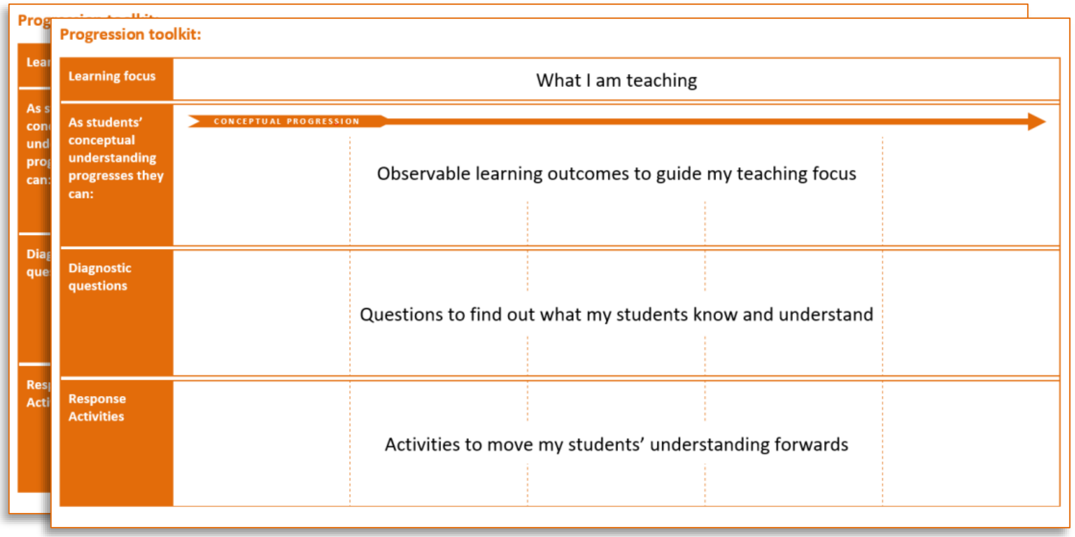
This key concept develops the big idea by using the basic particle model to explain the properties of substances in different states. The model is then extended to consider the forces of attraction between particles, in order to explain differences in the melting and boiling points of different substances.

The conceptual progression starts by checking that students can distinguish the solid and liquid states through observable properties. It then supports the development of understanding of the particle model, in order to enable explanation of properties, including melting points.

The second part of the conceptual progression starts by using understanding of the particle model to develop understanding of the gas state. This enables explanation of the formation of bubbles during boiling.

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: Particle model for the solid and liquid states.

Learning focus	The particle model of matter can explain the properties of substances in the solid and liquid states.				
As students' conceptual understanding progresses they can:	Distinguish substances in the solid and liquid states through observable properties. **P**	Describe substances as being made up of parts that are too small to be seen without magnification.	Describe the arrangement and movement of particles in a substance in the solid and liquid states.	Use the particle model to explain the properties of substances in the solid and liquid states.	Use the particle model to explain why substances have different melting points.
Diagnostic questions		Zooming in	A particle model for the solid and liquid states	Particle explanations	Explaining melting
Response activities			Particle diagram - liquid state		Particle explanations - melting

Key:

P Prior understanding from earlier stages of learning

Progression toolkit: Particle model for gas state.

Learning focus	The particle model can explain the properties of substances in the gas state.				
As students' conceptual understanding progresses they can: (CONCEPTUAL PROGRESSION)	Describe observations of changes of state of water. **P**	Describe how the arrangement and movement of particles alters when a substance changes from the liquid to gas state.	Use the basic particle model to explain the properties of gases.	Use the particle model to explain conservation of mass during changes of state.	Use the basic particle model to explain observations of boiling.
Diagnostic questions		A particle model for the gas state Empty space	Particle explanations - gas state	Predicting mass after changes of state	Bubbles during boiling
Response activities		Water in syringe			Explaining bubbles observed during boiling

Key:

P Prior understanding from earlier stages of learning

What's the science story?

All matter is made up of particles. The arrangement and movement of these particles is described by the particle model. This model can be used to explain observed changes of state. In order to account for differences between the melting and boiling point of substances, the particle model must be extended to include forces of attraction between particles.

What does the research say?

In their paper on rethinking the introduction of particle theory Johnson and Papageorgiou (2010) consider the implications of the common practice of introducing the particle model through a 'solids, liquids and gases' framework and propose instead a framework based on the concept of a 'substance' (see key concept CSU1.1: Substance). In particular, their proposed framework includes the idea that a substance can exist in different states and that the state at room temperature is dependent upon the substance's melting and boiling point.

It is suggested that the common framework of 'solids, liquids and gases' may give rise to misunderstandings including that these states form three distinct types of matter. Any thinking about forces of attraction between particles can be attributed *to* the state, rather than being predictive *of* the state. For this reason, this key concept forms part of a topic that also includes the key concept of substance.

In his paper on the progression in children's understanding of basic particle theory Johnson (1998) summarises findings from previous research. A significant number of children's responses were expressed only in macroscopic terms. Those who did talk about particles had several misunderstandings:

i) Spacing between particles – Spacing for the liquid state was shown as in between that of the solid and gas states.
ii) Intrinsic motion of particles – Students showed very little appreciation of the movement of particles.
iii) Ideas of forces of attraction between particles - This was an idea used by very few students.
iv) The 'space' between the particles – The idea that there is 'nothing' between particles, even in the gas state, caused difficulties for many students.
v) The nature of the particles – Many students gave macroscopic properties to the particles, seeing them as a fragmentation of the substance as a whole.

The first misunderstanding could be reinforced by some textbook diagrams where the spacing is shown incorrectly.

Four possible models were used during the research to identify and categorise students' ways of thinking:

Model X: Continuous substance - Nothing resembling particles was drawn.

Model A: Particles in the continuous substance - Particles were drawn but the substance was also said to be between the particles.

Model B: Particles are the substance but have macroscopic character - Particles were drawn with nothing in between but the particles were given similar properties to the bulk substance as if they are small bits of it.

Model C: Particles are the substance and the properties of each state are a result of the particles collectively - The particles were drawn and together described as forming the substance. Properties were attributed to the collective properties of the particles.

Views on whether students need to pass through a necessary set of ideas, in order to fully understand the particle model or whether these should be regarded as specific alternative conceptions were not conclusive.

The progression toolkit for this key concept uses diagnostic questions to find out what model students hold, in order to inform subsequent teaching.

By the end of the progression, students are challenged to explain melting point. This requires understanding of the existence of forces of attraction between particles, something research showed was lacking in many students.

Research shows that students often have a very vague understanding of the gas state, and often may perceive a 'gas' as something other than an actual substance. Johnson (2012) therefore suggests advantages of introducing the particle model for the solid and liquid states first and then using these to introduce the gas state. This can help reduce misunderstandings about the spacing of particles (with nothing in between) as well as their movement. For this reason, this key concept is split into two progression toolkits.

Guidance notes

The language used when teaching about the particle model should be carefully considered in terms of how it either reinforces or fails to challenge students' different models of thinking. For example, a phrase such as 'particles in a solid' could reinforce the idea that the particles are embedded within a continuous substance. The idea that particles are minute fragments of the bulk substance could inadvertently be introduced by initial teaching of particles as 'the smallest part a substance can be broken down into'. An alternative phrase, such as 'particles make up a substance', needs to emphasise that the particles collectively form the substance.

References

Johnson, P. (1998). Progression in children's understanding of a 'basic' particle theory: A longitudinal study. International Journal of Science Education. 20 (4) 393-412

Johnson, P. and Papageorgiou, G. (2010). Rethinking the introduction of particle theory: a substance-based framework. Journal of research in science teaching. 47 (2) 130-150

Johnson, P. (2012). Introducing particle theory. In Taber, K. (ed.) *ASE Science Practice: Teaching Secondary Chemistry.* New edition ed. London: Hodder Education.