*Physics > Big idea PMA: Matter > Topic PMA3: Energy of moving particles*

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| **Key concept (age 14-16)** |
| **PMA3.3: Specific latent heat** |

**What’s the big idea?**

A big idea in physics is matter. Matter is a more formal word for ‘stuff’. Anything that can be stored in a container, or weighed, is matter. Scientific ideas can help to explain why a given material behaves as it does, and may help scientists to develop new materials with specific properties.

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

This key concept helps to develop the big idea by developing a physical understanding of why the temperature of a substance does not change during a change of state, in order for students to understand calculations of specific latent heat.

The conceptual progression starts by checking understanding of the particle model of matter. It then supports the development of understanding and interpreting the physical changes shown on heating curves, and then on cooling curves, in order to enable understanding of specific latent heat.

**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: Specific latent heat**

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| **Learning focus** | Specific latent heat (of a particular change of state) is the amount of energy needed to change the state of 1 kg of a substance without changing its temperature. | | | | |
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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** | | | | |
| Describe the arrangement and movement of particles in a substance in the solid, liquid and gas states.  **P** | Use the particle model to describe what happens to a substance when it changes state.    **P** | Make and understand calculations using the equation E = m x L | Interpret a heating curve and explain physical changes to a substance that is heated from the solid state to the liquid state, or from the liquid state to the gas state. | Interpret a cooling curve and explain physical changes to a substance that is cooled from the gas state to the liquid state, or from the liquid state to the solid state. |
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| **Diagnostic questions** | A particle model for the solid, liquid and gas states | Cheese on toast | Hidden energy | Boiling point | Freezing point |
| Boiling water |
| Melting point |
| The state of water |
|  |  |  |  |  |  |
| **Response**  **activities** |  | The state we’re in |  | Faster melting |  |

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| Key: | | | |
| **P** | Prior understanding from earlier stages of learning |  |  |

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| **A particle model for the S, L & G states** | **Cheese on toast** | **Boiling water** | **The state of water** | **Hidden energy** |
|  |  |  |  |  |
| Simple multiple choice | Simple multiple choice | Simple multiple choice | Simple multiple choice | Confidence grid |
| **Boiling point** | **Melting point** | **Freezing point** | **The state we’re in** | **Faster melting** |
|  |  |  |  |  |
| Two-tier multiple choice | Confidence grid | Simple multiple choice | Critiquing a representation | Predict, explain; observe, explain  PEOE |

**What’s the science story?**

Heating a system will change the energy stored within the system and raise its temperature or produce changes of state.

Specific latent heat of fusion is the amount of energy required to melt one kilogram of a material whilst it is at its melting point. Specific latent heat of vaporisation is the amount of energy required to vaporise one kilogram of a material whilst it is at its boiling point.

The amount of energy required to melt or vaporise a material is calculated by multiplying the specific latent heat of the material by its mass.

**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 to check that students do not have any persistent blocks on their learning. Time spent consolidating the scientific understanding of earlier concepts before moving forward can accelerate progression later.

**Key concept:** CPS1.1 Particle model for the solid, liquid and gas states

Learning focus: the particle model of matter can explain the properties of substances in the solid, liquid and gas states.

This key concept:

* Introduces the particle model of matter.
* Develops an understanding of how the particle model can explain the properties of a substance in the solid, liquid and gas states.
* Uses the understanding of the arrangement and movement of particles to explain changes of state.

**What does the research say?**

It is quite possible to introduce specific latent heat in terms of energy transfers without mentioning the particle model of matter, but it can be helpful to students to make some links between the two sets of ideas (Millar, 2011). This is because the particle model can be used to explain the *mechanism* of how energy is transferred during a change of state when there is no corresponding change of temperature.

In a very large study of students in the United States, called Project 2061, the American Association for the Advancement of Science (AAAS) found that students age 14-18 held the following misunderstandings about particles during a change of state:

* The identity of the molecules of a substance changes during a phase change. (14% held this misunderstanding)
* Molecules change weight/mass during a phase change. (14%)
* Molecules change size during a phase change. (9%)
* Matter is destroyed during boiling. (7%)
* Matter is destroyed during melting. (10%)
* The molecules of a substance break down into individual atoms when the substance boils. For example, molecules of water become atoms of hydrogen and oxygen when water boils. (34%)

In order to understand the mechanisms that explain specific latent heat, students need a clear understanding of the motion and arrangement of the particles of a substance in each of its solid, liquid and gas states and to understand that particles in each state are otherwise identical. The BEST chemistry key concept CPS1.1 *Particle model for the solid, liquid and gas states* can be used to review and develop students’ understanding of these ideas.

Heating a substance without a change of state increases the motion of particles and the temperature of the substance. When melting or vaporising a substance, its particles are moved apart against their electrostatic attraction, a very small amount for melting and rather more for vaporisation (Millar, 2011). As particles move apart against the attractive force that holds them together, their movement slows and prevents the temperature of the substance from rising until the change of state is complete.

In a large study of Turkish students (n=656), Adadan and Yavuzkaya (2018) found that 20% of those age 13-16 thought that heating always increases the temperature of a substance, even as it is boiling. This misunderstanding can be challenged effectively by direct measurement if students complete practical work to measure temperatures of a substance over the time that it changes state (Adadan and Yavuzkaya, 2018; Bauer and Chan, 2019). Temperature can be observed clearly to reach a constant value as water boils. A heating curve that shows a similar plateau when a substance melts can be produced by heating salol in a boiling tube in a water bath. A heating curve is easier to explain than a cooling curve and easier for most students to understand (Millar, 2011).

Adadan and Yavuzkaya (2018) found that 29% of 15- to 16-year-olds in their study thought that ice was always 0oC, and 32% that water cannot be 0oC. These students appear to be relying on recall of factual knowledge rather than on clear understanding. In other studies, students believed that the temperature of ice cubes existing in a warm room must be above 0°C, and that water cannot exist at 0°C even if ice cubes remain in a puddle of water (Chu et al., 2012; Kacovsky, 2015).

Cooling a substance without a change of state reduces the motion of particles and the temperature of the substance. As a substance changes state from a gas to a liquid, or from a liquid to a solid, the particles are pulled together by their electrostatic attraction. The attractive force accelerates particles as they move closer together and the particles’ increased movement prevents the temperature of the substance from falling until the change of state is complete.

**Guidance notes**

Specific latent heat is a deceptively difficult idea to teach well. Using and applying the equation is relatively easy for many students, but the explanation of why temperature remains constant during a change of state is challenging. The understanding of specific latent heat builds both on a good knowledge of the particulate model of matter, and also on a good understanding of how a force changes the speed of an object. In particular an explanation of specific latent heat requires a clear understanding that the temperature of a substance increases when its particles move more quickly and reduces when they move less quickly.

At age 14-16 it will suffice for students to say that when a substance is at its melting or boiling point, instead of increasing temperature energy from heating moves particles apart against an attractive electrostatic force. When a substance is cooling (transferring energy to its surroundings) at its melting or boiling point electrostatic forces do work on particles to pull them together, which stops the average speed of particles from reducing and the temperature from falling.

**References**

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