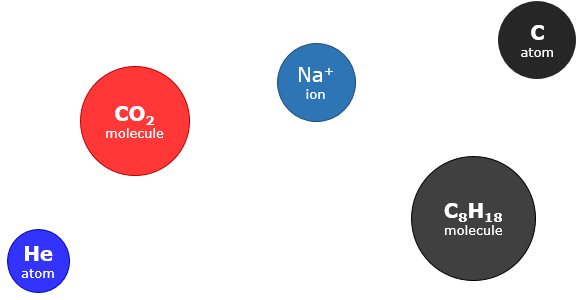
**A particle model for the solid, liquid & gas states**

All substances are made of particles.

A lot of particles are not shaped as a ball, but they are usually drawn as circles on diagrams.

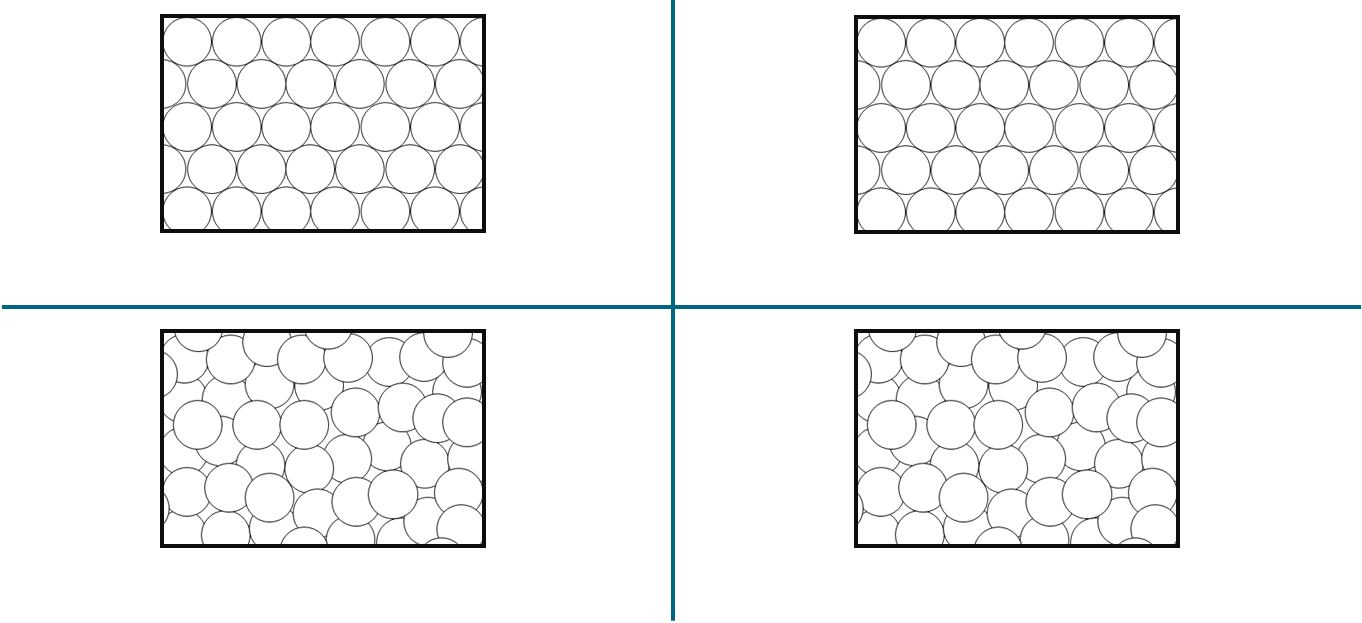
This is just to make the diagrams clearer.



(Particles do not really have different colours either.)

The diagrams in these questions **all** show particles of water.

**1.** Which is the best diagram to show the particles in ice?



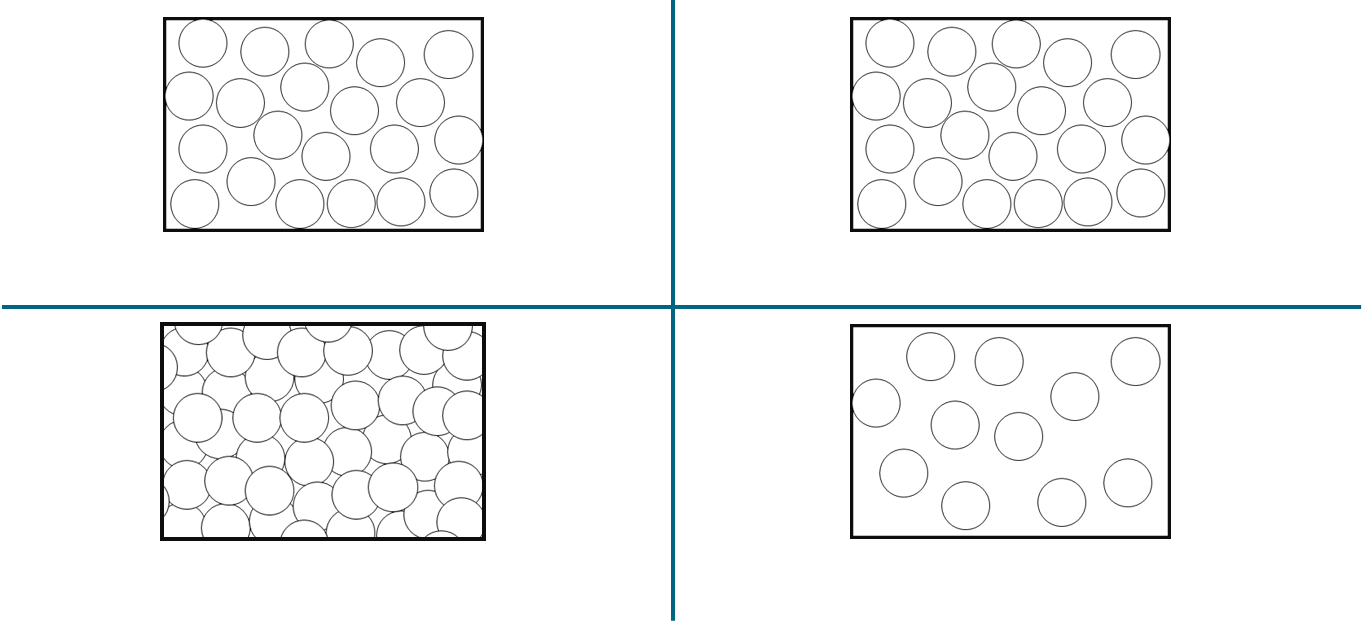
**A** Particles not moving.

**B** Particles vibrating on the spot.

**C** Particles moving freely.

**D**  Particles not moving.

**2.** Which is the best diagram to show the particles in **water**?



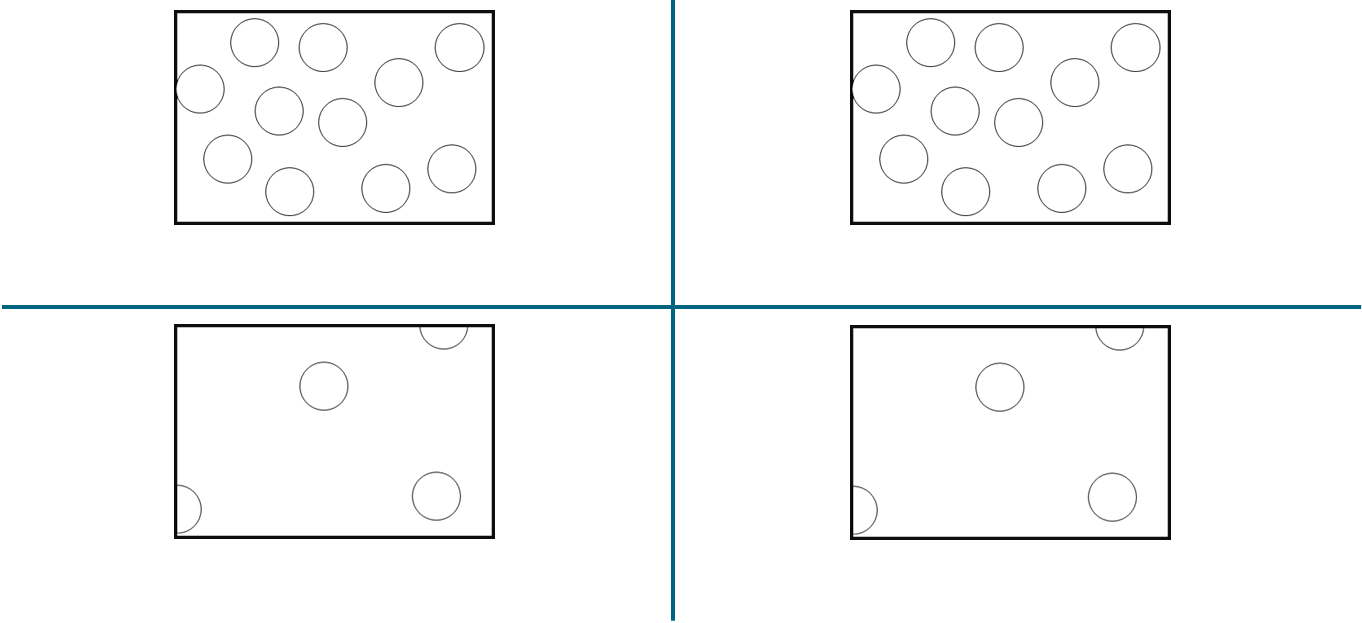
**A** Particles vibrating on the spot.

**B** Particles moving freely.

**C** Particles moving freely.

**D**  Particles moving freely.

**3.** Which is the best diagram to show the particles in **steam**?



**A** Particles not moving.

**B** Particles moving freely.

**C** Particles not moving.

**D**  Particles moving freely.

*Physics > Big idea PMA: Matter > Topic PMA3: Energy of moving particles > Key concept PMA3.3: Specific latent heat*

|  |
| --- |
| **Diagnostic question** |
| **A particle model for the solid, liquid & gas states** |

**Overview**

|  |  |
| --- | --- |
| 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. |
| Observable learning outcome: | Describe the arrangement and movement of particles in a substance in the solid, liquid and gas states. |
| Question type: | Simple multiple choice |
| Key words: | Particle, vibration, solid state, liquid state, gas state |

|  |  |
| --- | --- |
| **P** | **PRIOR UNDERSTANDING**  This diagnostic question probes understanding of ideas that are usually taught at age 11-14, to aid transition from earlier stages of learning. |

**What does the research say?**

Johnson and Papageorgiou (2010) suggest that the use of a ‘solids, liquids and gases’ framework for teaching may give rise to students misunderstanding the states of matter by inferring that solids, liquids and gases are three different types of matter. ‘Gases’ at room temperature are in fact substances where the forces of attraction between particles are very weak and therefore these forces are overcome, even at room temperature.

It should be noted that use of the term ‘attraction’ is inconsistent with later understanding of a chemical bond as a balance between attraction and repulsion. For this reason, Johnson suggests that alternative terminology, such as ‘ability to hold’ may be preferable.

Research by Johnson (1998) shows that students’ particle diagrams often show the spacing for particles in a liquid as being in between the spacing for the solid state and the gas state.

It has also shown that students have very little appreciation of the idea of the intrinsic motion of particles.

Research has found that students often have a very weak understanding of what ‘a gas’ actually is. Evidence suggests that students may benefit from extrapolating the particle model to predict the arrangement and movement of particles that form a substance in the gas state. The particle model in question 3 may then help students to think of ‘a gas’ as being a substance thereby improving their conceptual understanding of ‘a gas’. Linking the model to the arrangement and movement of particles forming a substance in the liquid states may also help students understand changes of state.

**Ways to use this question**

Students should complete the question 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.

The answers to the question will show you whether students understood the concept sufficiently well to apply it correctly.

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**

1. B

2. C

3. D

**How to respond - what next?**

Question 1 addresses the intrinsic motion of particles that make up a substance in the solid state. The idea of intrinsic motion for the solid state is the most difficult for students to understand. If students think macroscopically about the particles it is difficult to see why they would be vibrating. For those thinking of particles being embedded ‘in the solid’, the particles certainly wouldn’t be moving.

Question 2 addresses the spacing and motion of particles. Options B, C and D are correct for the motion but in B and D the particles are too far apart. Options A and B are the most likely wrong choices as they both depict a transition from the particle arrangement in the solid state. (Option B has sometimes been used wrongly in textbooks.)

The idea of intrinsic motion is easier for the liquid state than the solid state probably because bulk movement within the liquid state is familiar to students. If students imagine a sample of water that is not flowing, some who are thinking macroscopically may choose option A.

Question 3 addresses intrinsic motion and spacing for the gas state. Options B and D are correct for the motion, but in B the particles are too close together (although one could argue about the pressure – the question does not imply other than ‘normal’ pressure). However, some of these students may be thinking of particles being embedded in the continuous substance where the ‘gas’ would allow the unimpeded motion (unlike ‘swimming in ‘a liquid’ or being stuck ‘in a solid’). Few are likely to choose A or C.

If students have misunderstandings about describing the arrangement and movement of particles in a substance in the solid, liquid and gas states, it can help to discuss and make clear the links between the particle model and observations that can be made about substances that are in their solid, liquid or gas state. Careful questioning should elicit, for example, the understanding that particles in a solid vibrate: they cannot be moving around as the solid does not flow, but we know they vibrate because they sometimes vibrate so much that they can damage skin and cause a burn when one is touched. Similarly, examining diagrams of substances in their liquid or gas states, students should be able to predict approximately how much each can be squashed as particles are pushed into the gaps between them. The correct diagrams can be confirmed by using a syringe, to compress air by a large amount, but water not at all.

For some students, resources in the following BEST ‘11-14 Key concept’ could be used to challenge misunderstandings and to consolidate understanding of the particle model in follow up to this diagnostic question:

* Chemistry key concept - CPS1.1 Particle model for the solid, liquid and gas states.

**Acknowledgments**

Developed by Peter Fairhurst (UYSEG), based on the BEST diagnostic questions: *CPS1.1 A particle model for the solid and liquid states* and *CPS1.1 A particle model for the gas state* that were developed by Helen Harden (UYSEG). Helen Harden in turn developed these questions from ones selected from a collection of ASK items devised for research by Philip Johnson and teacher support material developed for York Science by Andrew Hunt.

Images: Peter Fairhurst (UYSEG).

**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.* 42(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.