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| **Unit title: Particles** |
| **Synopsis: *In this section put the why, what and how of the topic.*** | **What the research tells us: *In this section put an overview of what the research from Best Evidence tells us.*** |
| The concept of particles and how they interact (physical and chemical properties) explain phenomena on micro and macro scales and is fundamental to students grasping the importance of science to their lives and to enable them to partake in the bigger conversation. For example, it is required to understand the water cycle (physical properties) but, along with content of the elements topic, is essential to understanding the carbon cycle and global warming.Models are a primary aid to scientific thinking (disciplinary content). This topic is a vehicle for exploring the importance of models and how they can support thinking. The model is simple and relatively easy to understand so it is a good vehicle for developing why models are important but also how they can be modified to fit different scenarios (see Elements topic where compounds and chemical changes are introduced).The substantive content is a threshold concept for topics related to physical and chemical processes. The concept is one that is revisited many times and becomes complex; it needs to be built in layers to ensure deep understanding. **AQA:** Relate the features of the particle model to the properties of materials in different states**Know:** Properties of solids, liquids and gases can be described in terms of particles in motion but with differences in the arrangement and movement of these same particles: closely spaced and vibrating (solid), in random motion but in contact (liquid), or in random motion and widely spaced (gas). Observations where substances change temperature or state can be described in terms of particles gaining or losing energy. **Facts:** A substance is a solid below its melting point, a liquid above it, and a gas above its boiling point.**Skill:** None**Apply:** Draw before and after diagrams of particles to explain observations about changes of state, gas pressure and diffusion.Explain the properties of solids, liquids and gases based on the arrangement and movement of their particles. Explain changes in states in terms of changes to the energy of particles. Explain the diffusion of fluids using the particle model. **Extend:** Argue for how to classify substances which behave unusually as solids, liquids or gases. Make predictions about what will happen during unfamiliar physical processes, in terms of particles and their energy.**How are we teaching it (broadly)?**The importance and usefulness of models to scientific thinking is introduced through Democritus’s particle model. His idea, how it supported his thinking and the supporting evidence is explored as students determine whether Democritus behaved scientifically in his proof of concept for matter being composed of indivisible matter. Democritus is also used to show how ‘scientists’ do not work in isolation: Conflict is common in Science and the scientific method often addresses that conflict.More contemporary evidence in support of the application of the particle model is explored (e.g. Dalton). Through this process, the importance of the developing ideas over time and the scientific community are explored; this reinforces messages from the Speed topic. Students apply the model to help them develop an understanding of a range of physical processes. These include changes of state and diffusion. Students apply the model to explain the properties of different materials (including materials that aren’t easily classified as solids, liquids or gases). | * **Many students consider the three states of matter to be three different types of matter. Students do not consider that one substance can exist in different states, rather they allocate a specific state according that observed at room temperature.**

**Several misunderstandings:** * **Spacing between particles – Spacing for the liquid state was shown as in between that of the solid and gas states.**
* **Intrinsic motion of particles – Students showed very little appreciation of the movement of particles.**
* **Ideas of forces of attraction between particles - This was an idea used by very few students.**
* **The ‘space’ between the particles – The idea that there is ‘nothing’ between particles, even in the gas state, caused difficulties for many students.**
* **The nature of the particles – Many students gave macroscopic properties to the particles, seeing them as a fragmentation of the substance as a whole.**
 |
| **Threshold concepts: What concepts do student need to have prior knowledge of?**  | **Which topics develop the concepts from this one?**  |
| **None** | **Revisit as application of forces; in particular fields.****Physical processes and revisited in separation techniques.****Concepts of particles and types of particles are developed in Elements. This topic in itself is a threshold topic for most Chemistry topics. It also features heavily in Biology topics.** |

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| **Links to KS3 programme of study:** |
| **Scientific attitudes**Understand that scientific methods and theories develop as earlier explanations are modified to take account of new evidence and ideas, together with the importance of publishing results and peer review**Substantive content****The particulate nature of matter*** the properties of the different states of matter (solid, liquid and gas) in terms of the particle model, including gas pressure
* changes of state in terms of the particle model
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| **Links to KS2 programme of study:** | **Links to KS4 programme of study:** |
| * Compare and group together everyday materials on the basis of their properties, including their hardness, solubility, transparency, conductivity (electrical and thermal), and response to magnets
* Give reasons, based on evidence from comparative and fair tests, for the particular uses of everyday materials, including metals, wood and plastic
* Changes of state – evaporation and condensation
* Separating mixtures – sieving, filtration evaporation
 | Structure, bonding and the properties of matter (Chemistry) * changes of state of matter in terms of particle kinetics

The structure of matter (Physics)* relating models of arrangements and motions of the molecules in solid, liquid and gas phases to their densities
* melting, evaporation, and sublimation as reversible changes
* links between pressure and temperature of a gas at constant volume, related to the motion of its particles (qualitative)
 |
| **Cross-curricular links:** | **Wider development:**  |

**Lesson sequence: Copied from the route through. You might need to make the notes more coherent. Also, check the best evidence files do fit with the lesson.**

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| **Lesson title** | **Best evidence (diagnoastics)** | **Notes** |
| Classifying substances (solids and liquids) according to their properties (KS2 prior learning – if done) | None | If students have encountered this material at KS2, some misconceptions may have already have been introduced. Careful attention will need to given to language used so as not to reinforce misconceptions identified above.  |
| Democritus vs AristotleThe particle model and the arrangement and movement of particles in solids and liquids. | Zooming inA particle model for the solid and liquid states (response activity – Particle Diagram – liquid state) | Use demo of flowing sand to associate particles with property of flowing. A very simple concept of energy (related to movement) and force (attraction) will be used. These will be revisited once Forces and Energy have been taught; at this time, the concept of energy stores will be used.Emphasis needs to be on a range of particle speeds being present; this facilitates learning centred about evaporation in a alter lesson. |
| Explaining properties of solids and liquids using the particle model | Particle explanations  | This is limited to liquids and solids as gases are conceptually problematic for many students. Gases are dealt with separately (along with boiling and evaporation). |
| Changes of state (addressed in KS2 prior learning. However, focus on freezing and melting and what is happening to particle arrangement and movement)Conservation of mass in changes of state | Explaining meltingPredicting mass after changes of state  | In order to avoid several misconceptions, there needs to be a focus on students understanding state through the ambient temperature relative to melting point. The actual melting point will be a reflection of the strength of attraction between adjacent particles (this is the net attraction seen in bonding. This net attraction is the result of attractive forces and repulsion forces). In our simple model of energy, the additional energy enables the particles to overcome attractive forces between specific particles.  |
| Particle model (gases)Changes of state – boiling | A particle model for the gas stateEmpty space | The particle model for gases is introduced here. This should be predicted from other changes of state. |
| Changes of state – evaporation and boiling | Boiling or evaporationDifferent liquids (prior learning)Evaporating temperaturesLocation of evaporation | This lesson explores the differences between evaporation and boiling. To understand evaporation, students do need to understand from earlier work that particles move at different speeds. There are a number of demonstrations used in Best Evidence diagnostics that could be set up in advance. |
| Explaining properties of gases | Particle explanations – gas state | Gases have many associated misconceptions. So, explanations of properties are taught separately. |
| Diffusion | Deodorant | It is important that students understand that there is net movement until equilibrium is reached. Once reached, there is no net movement but particles move in both directions. |

**Lesson sequence and lesson overviews**

**Essential questions:**

* What do scientists think about and why is it important?
* When is simplifying situations in science optional and when is it mandatory? When is it a good idea and when is it a bad idea?
* What are outliers telling us? Error, anomaly or useful information?
* How does what we measure influence how we measure? How does how we measure influence what we measure?
* Does the way we display results affect our interpretation of the results?
* What information does an equation give us?
* How could we increase the efficiency (of a vehicle)?

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| Lesson | Title and keywords | Objectives | What students are learning | What students are not learning | Suggested activities |
| 1 | **Classifying substances (solids and liquids) according to their properties** What do scientists think about and why is it important?**Key Words: material, particle, mixture, substance, property, density** | **Know the generic properties of solids and liquids.****Able to classify substances as liquids or solids and explain reasoning.** | * Definition of ‘substance’.
* Properties of solids and liquids (liquids: take shape of bottom of container; take up a definite amount of space / cannot be compressed; can be poured. Solids: Definite shape; cannot be compressed.
* Classification using common properties.
* All substances can be solids, liquids or gases depending on the temperature.
 | * Why substances have those properties.
* Particle model.
 | **Connect:** students need to start thinking about the properties of solid and liquids and why we sue them for each function**Modelling:** * Explain to students what is meant by substances
* Students need to understand what is meant by the term properties to ensure they understand how to identify them moving forward
* This is an opportunity to provide students with knowledge about physical and chemical properties
* Use the Syringe model to show the properties of solids and liquids
* Hydraulic brake model

**Introductory task:** Task: Using examples of solids and liquids state the generic properties of both. You must include:* Define a substance
* Define what a property is
* State how the property of each state relates to the function of and uses

Include examples of solids and liquids**Task 1:** Provide students with various solids and liquids / images of solids and liquids and allow them, to describe the properties of liquids and solids. **Task 2:** This task builds upon the previous one. Students now need to relate the properties of solids and liquids to their functions. **Task 3:** Suggest why brake fluid is used in a car braking system. Liquids (flow and not be compressed)**Challenge: Suggest why sand appears to be flowing even though it is a solid**Modelling: You will need to explain the properties of solids and liquids. This can be modelled using the visualiser and the syringes showing states of matter. Applications* Classifying materials that are clearly liquid or solid
* Classifying unusual materials (e.g. blu-tac, sand)
* Relating properties of solids and liquids to use (e.g. iron in bridges; coolants and lubricants in engines; liquid breathing systems <https://www.realclearscience.com/blog/2019/08/15/can_humans_breathe_liquid.html> etc)/

Non-Newtonian fluids in body armour https://www.sciencealert.com/liquid-armour-is-now-a-thing-and-it-stops-bullets-better-than-kevlar |
| Notes including most common misconceptions |
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| Lesson | Title and keywords | Objectives | What students are learning | What students are not learning | Suggested activities |
| 2 | **Democritus vs Aristotle****The particle model and the arrangement and movement of particles in solids and liquids.**What do scientists think about and why is it important?How are models similar or different from the natural world?How should this be modelled? What are the strengths and weaknesses of this model?What are all things made of and how do these things interact? **Key Words: Solid, liquid, gas, states of matter, particles** | **Able to explain the importance of the scientific community in developing scientific ideas.****Understand the importance of models to thinking about scientific ideas and the world around us.****Understand that different models are used in different situations and that models develop over time.** **Understand how the particle model (referencing particle distribution, movement and inter-particle forces) can be used in relation to solids and liquids.** | * Debate / conflict within the scientific community drives change.
* The contribution of Democritus to particle theory and the barriers he had to overcome.
* The similarities and differences between the scientific method and the work of Democritus and Aristotle.
* Models are used to help us think about complex ideas and to explain phenomena.
* All matter is made up of particles (model).
* The Democritus model was simple and did not include particles attracting each other. We now include particles attracting each other.
* The particle model as it relates to solids and liquids. This should include a. Distribution of particles b. movement of particles c. particles having a range of speeds (different amounts of energy) . attraction between particles and how it is different for different substances.
 | * The particle model as it relates to gases (this is taught separately – related to explicitly avoiding misconceptions).
* How the particle model explains the properties of solids, liquids and gasses
* Models are always a true representation of what actually exists.
 | **Connect:** Using the text student can read the text and answer the questions. Link this to the recent pandemic**Modelling:** * Discuss the difference between Aristotle and Democritus’s model of the atom
* Discuss how social status is a highly influential factor when wanting to develop new theories – Link this to the question ‘Does this hold science back sometimes? ‘
* Discuss Aristotle's model and compare this to Democritus’s model.
* Discuss both models and identify similarities and differences
* Discuss how status within society can play a significant part in scientific break throughs

ME Time**Literacy task**: Democritus and his atomic model. Read the text using reading skills and answer the questionTask 1: Describe Aristotle’s & Democritus’s theory of what matter is made up ofTask 2: Compare similarities and differences between the two theoriesTask 3: Suggest why one of them was taken more seriously that the other? How did social status and perception influence this (use the information sheet )Applications* Extent to which Democritus and Aristotle applied scientific methods
* Diagnostic questions from best evidence in order to prepare for the next lesson

Extent to which the simple Democritus model explains basic properties of materials. This pre-empts the next lesson and helps students realise the importance of particles attracting each other (net attraction) |
| Notes including most common misconceptions |
| * Students must understand the importance of net attraction between particles if they are to understand later concepts. Similar for particles having a range of speeds.
* There is a useful model that uses a bed sheet and plastic balls.
* What the research says:
* Johnson (1998) identifies three misconceptions held by students about the particulate nature of matter:
* Substances are continuous (no recognition of particle ideas)
* Particles are located within a continuous substance (rather than being the substance)
* Particles are the substance (but macroscopic properties are given to the particles)
* These contradict the standard particle model in which the particles are the substance, but the macroscopic properties of the substances arise collectively from the particles.
* 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. This leads to students to have difficulties in explaining observed diffusion of a dye through water or in understanding air pressure.
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| Lesson | Title and keywords | Objectives | What students are learning | What students are not learning | Suggested activities |
| 3 | **Explaining properties of solids and liquids using the particle model**What do scientists think about and why is it important?How are models similar or different from the natural world?How should this be modelled? What are the strengths and weaknesses of this model?What are all things made of and how do these things interact? To what extent does structure explain function and properties? **Key Words: Solid, liquid, gas, states of matter, particles** | Explain the properties of liquids and solids using the particle model. Understand how the behaviour and arrangement of solid spheres in the particle model can cause substances to have a range of properties.. | * How the particle model can be used to explain the properties of solids and liquids.
* A single particle does not have the properties of the substance.
* The arrangement, movement and attraction between particles determine a substances properties.
 | * Explaining properties of gases.
* Detailed concept of forces (this topic is revisited as an application of forces)/
* Detailed concept of energy.
 | **Connect:** Students need to read through the text on the slide and answer the questions. Allow students enough time to really digest the text. Identify the literacy errors and state how to correct them**Modelling:** * Students need to know about particle arrangements
* Use diagrams to help show the particle model
* Use the tray with balls in to show the particle arrangement of solids and liquids
* Use students as a model to act out the behaviour of the particles in solids and liquids
* Talk about the attraction of particles and how this links to the properties

**ME Time****Task 1:** Students need to recall the properties of solids and liquids and then expand their answer to include particle theory. This must include the behaviour of the particles in each state, a diagram and include the attractive forces. **Task 2:** Using their knowledge of the particle arrangements in solids and liquids students need to explain what is happening in the pictures. **Task 3:** Students need to pick a solid or liquid and describe how the properties and particle arrangement allow it to carry out its function.**Challenge: Suggest how non Newtonian fluid works and how this can be linked to body armour**<https://www.youtube.com/watch?v=Fnd-2jetT1w>  |
| Notes including most common misconceptions |  |
| * What the research says:
* Johnson (1998) identifies three alternative models of matter held by students:
* Substances are continuous (with no recognition of particle ideas)
* Particles are located within a continuous substance (rather than being the substance)
* Particles are the substance (but macroscopic properties are given to the particles)
* These contradict the standard particle model in which the particles are the substance but where the macroscopic properties of the substances arise collectively from the particles. The standard particle model can successfully explain some properties of a substance in the solid state.

Applications* Identify properties of a substance that are required for a use. Explain why those properties exist in terms of particle arrangement, movement and attractive forces.
* Identify a specific role for a substance that is dependent on it being a liquid / solid. Have students explain why the alternative state could not be used. Also, what features of that state are problematic (e.g. substance needs to flow, so particles need to move over each other, so attractive forces cannot be too strong).
* Explain why a substance in a particular state could not be used for a role in terms of properties and reasons a substance has those properties. How would the particle arrangement, movement and attractive forces have to change for it to be useful.
* Explain why liquids remain on globules when in space https://www.youtube.com/watch?v=o8TssbmY-GM
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| Lesson | Title and keywords | Objectives | What students are learning | What students are not learning | Suggested activities |
| 4 | **Changes of state** What do scientists think about and why is it important?How are models similar or different from the natural world?How should this be modelled? What are the strengths and weaknesses of this model?What are all things made of and how do these things interact? **Key Words: Solid, liquid, gas, states of matter, particles, melt, change of state, freeze, melting point, boil, boiling point, evaporate, condense, sublime** | **Define freezing and melting.****Know the relationship that exists between melting point and the strength of inter-particle forces.****Know how the particle model predicts changes to properties on the macro-scale when a substance absorbs or releases energy.****Understand why mass must be conserved during a change of state (in a closed system).** | * The melting point is the temperature that melting / freezing occurs at.
* All substances have a melting point.
* Substances are a solid below their melting point and a liquid or gas above it.
* The melting point is dictated by the magnitude of forces of attraction between particles.
* During melting, energy is absorbed from the surroundings and this affects the movement and arrangement of particles.
* During freezing, energy is absorbed from the surroundings and this affects the movement and arrangement of particles.
* Mass is conserved during changes of state; this is because the total number of particles and their masses have not changed.
 | * Explaining properties of gases.
* Detailed concept of forces (this topic is revisited as an application of forces)/
* Detailed concept of energy.
 | **Connect:** Students need to link their knowledge from previous lessons of the properties of solids and liquids/ particle arrangement to their functions **Modelling:*** Use the tray with balls in to show the particle arrangement of solids and liquids
* Use students as a model to act out the behaviour of the particles in solids and liquids
* Talk about the attraction of particles and how this links to the properties
* Discuss how temperature determines the state of a substance
* Use the tray and ball models to show the changes of state or use the blanket and ball model to show this. Make sure you talk about limitations of the model

**ME TIME****Task 1:** Name and define the changes of state of state in your own words. Include a diagram showing the state change and two examples of each state change.**Task 2:** Model using balls (buy) and allow student to evaluate the modelused**Challenge:** Explain what would happen if the specifically choose material wasn’t used when building the international space station**Modelling:**  |
| Notes including most common misconceptions |
| * Research by Johnson and Papageorgiou (2010) recommends that the particle model is used to explain why substances melt at different temperatures. These differences arise from differences between the forces of attraction between particles. The state of a substance results from how these forces of attraction compare with the energy of the movement of the particles (which depends upon the temperature). When a substance melts the particles have sufficient energy to overcome these forces and move, whilst still staying close together.
* A review of research by Hadenfeldt, Liu and Neumann (2014) organised student understanding of conservation of matter into different levels. At the most basic level students believe that a substance can disappear when it changes state. It is suggested that conservation of matter is beyond their everyday experience and therefore students have little exposure to the concept. An understanding of the particle model allows students to have a higher level of understanding as they realise that the number of particles stays the same during a change of state, so a substance cannot simply disappear. The next stage is to link this with the idea that mass too will remain unchanged.

Applications* Identifying a state of substance from its melting point and the ambient temperature.
* Using melting point information and ambient temperatures on different planets to identify materials to use on explorer vehicles to use on other planets (e.g. for structural materials, hydraulic fluids etc). Where large changes in surface temperature are experienced (e.g. on Mercury) identify change sof state that might occur and how this might affect the usefulness of the vehicle.
* Similar for the International Space Station (121 Celsius in the Sun and -157 Celsius in the shade) <https://www.forbes.com/sites/quora/2018/10/24/how-difficult-is-it-to-keep-the-space-station-warm/?sh=2ce98f014af7>
* Similar for exploring the depths of the ocean especially as they approach thermal vents https://www.nhm.ac.uk/discover/survival-at-hydrothermal-vents.html
* Explaining the changes of state that would occur in the above situations if the wrong material were chosen.
* Describing changes of state occurring in this car being engulfed by lava: <https://www.youtube.com/watch?v=wiRdr5LzbwY>
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| Lesson | Title and keywords | Objectives | What students are learning | What students are not learning | Suggested activities |
| 5 | **Particle model (gases)****Changes of state – boiling and condensation**What do scientists think about and why is it important?How are models similar or different from the natural world?How should this be modelled? What are the strengths and weaknesses of this model?What are all things made of and how do these things interact? **Key Words: particles, change of state, boil, boiling point, evaporate, condense,**  | **Define boiling and condensing.****Describe what you would see if a substance is boiling.****Describe the particle model for gases.****Know the relationship that exists between boiling point and the strength of inter-particle forces.****Know how the particle model predicts changes to properties on the macro-scale when a substance absorbs or releases energy.****Understand why mass must be conserved during a change of state (in a closed system).** | * The particles in gases collide infrequently.
* The speed (energy) of particles in a gas varies (this is important for explaining evaporation)
* The size and mass of particles in a gas is exactly the same as in the liquid / solid states of that substance. Only the arrangement and movement is different.
* The particles are so far apart that the attractive forces between particles are weak (this concept is addressed in Fields)
* The boiling point is the specific temperature at which a substance boils / condenses.
* Substances are gases at temperatures above the boiling point and liquids / solids below the boiling point.
 | * Detailed concept of forces (this topic is revisited as an application of forces)/
* Detailed concept of energy.
* Evaporation (addressed in the next lesson); this is a complex change of state and students need to grasp the details of the particle model and boiling before addressing it.
 | **Connect::** Students need to make a comparison between the particle arrangement in solids/liquids with the particle arrangement in a gas. (They will not have looked at this on detail)**Modelling:*** Students need to look at images of particle arrangement in gasses and compare this to particle arrangement in liquids and solids
* Use the tray with balls in to show the particle arrangement of solids and liquids
* Use the tray and ball or use the blanket and ball model to show boiling and condensing. Make sure you talk about limitations of the model
* Use experiments to show the conservation of mass when boiling and condensing

**Me Time:****Task 1:** Describe the particle arrangement of gasses, include the forces of attraction between the particles and a diagram**Task2:** Practical showing change of state - boil the water and allow the condense through a condensing tube**Task 3**: Using scientific knowledge from the lesson explain what has happened in the practical**Challenge:** Suggest what causes a condensation to from on a bathroom mirror when having a hot shower. Would this change if the mirror was heated / non heatedModelling: Allow students to boil water so they can see the change of state that is happening. Collect the steam in a distillation set up as you can then include conservation of mass. Check the mass before and after.  |
| Notes including most common misconceptions |
|  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.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. This particle model 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.Research by Johnson (1998) shows that the empty space between particles is problematic for many students. Often it is labelled as ‘air’. However, it is not clear what students consider air to be. A later study by Johnson and Papageorgiou (2010) also indicates that many students have very limited understanding of what a substance in the gas state actually is or that it is in fact a substance at all.Applications• Identifying a state of substance from its melting point, boiling point and the ambient temperature. • Describing the states present when a liquid boils in terms of particle arrangements, movements and attractive forces.• Explaining what happens to liquids as they approach Deep Sea Black / White Smokers in terms of particles.• Condensation on mirrors in bathrooms. Heated mirror vs unheated mirror |

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| Lesson | Title and keywords | Objectives | What students are learning | What students are not learning | Suggested activities |
| 6 | **Changes of state – evaporation and boiling**What do scientists think about and why is it important?How are models similar or different from the natural world?How should this be modelled? What are the strengths and weaknesses of this model?What are all things made of and how do these things interact? **Key Words: particles, change of state, boil, boiling point, evaporate, condense,** | Define evaporation and boiling.Understand the differences between boiling and evaporation. Able to identify boiling and evaporation in different scenarios and justify their answer.Able to explain why evaporation can occur at all temperatures. | * Boiling and condensation occur at a specific temperature called the boiling point.
* Boiling occurs at every point in a liquid.
* Evaporation occurs at all temperatures, including when the temperature of the liquid is below the ambient temperature.
* Evaporation only occurs at the surface of a liquid.
* Evaporation occurs because some particles have more energy than others at all temperatures.
* Those particles with most energy can leave the surface of the liquid (change of state from liquid to gas).
 | * Detailed concept of forces (this topic is revisited as an application of forces)/
* Detailed concept of energy.
* Sublimation.
 | **Connect::** Students need to use the new KS3 books to find textbook definitions of specific words.**Modelling:*** Model evaporation using salt water and a watch glass, students will see that the water evaporates and the salt is left
* This is an opportunity for student to use their knowledge and understanding to apply this to the practical
* Use the image to show how evaporation only happens at the surface of the material

**Me Time****Task 1**: Using the KS3 Activate book one (page 86) ask students to write 5 key facts about evaporation and boiling (mid-way through the lessons) **Task 2:** **Practical Salt water – water bath watch glass.** Using their knowledge from the lesson scientifically explains what is happening with the experiment**Task 3**: ‘Only particles with the most energy will evaporate’ Students need to explain this sentence **Challenge:** Looking at the photos of the same volume of water but in different shape glasses suggest why evaporation has taken place at different rates (I need to physically do this to take photos)**Modelling:** You can use the tray of balls to model changes of state from liquid to gas. Use salt water in a watch glass to show the water has evaporated and left the salt behind |
| Notes including most common misconceptions |
| * Research by Coştu and Ayas (2005) found that some students associated evaporation only with water and not other liquids. This may be due to limitations in their experience with other liquids as reported by Kind (2004).
* As part of their research Coştu and Ayas (2005) presented situations to students through a series of short experiments. They then used questioning to discover more about students’ understanding.
* One question used was “Does evaporation take place on the surface of the alcohol or in all parts of it? Why?”
* A few students correctly explained that particles left from the surface of the liquid. All those that were identified to hold a “specific misconception” were found to think that evaporation occurs in all parts of a liquid.
* Research (Coştu and Ayas, 2005) found that some students thought that heating was necessary for evaporation to take place. The process of evaporation was therefore linked to a temperature difference between the liquid and the surroundings. According to these students, if the temperature of the surroundings was higher than the temperature of the liquid then evaporation would take place, but otherwise it would not.

Applications* Comparison of evaporation and boiling.
* Explaining what happens to liquids in different scenarios. E.g. Tall glass of water left for a few hours doesn’t evaporate noticeably. If it is spilt, it evaporates quickly. Identify process and explain why it disappeared quickly in the second case.
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| Lesson | Title and keywords | Objectives | What students are learning | What students are not learning | Suggested activities |
| 7 | **Explaining properties of gases**What do scientists think about and why is it important?How are models similar or different from the natural world?How should this be modelled? What are the strengths and weaknesses of this model?What are all things made of and how do these things interact? To what extent does structure explain function and properties? **Key Words: Gas pressure, particles, collisions** | Able to use the particle model of gases to explain the properties of gases.Able to identify the state of a substance form the ambient temperature and the melting and boiling points of a substance. | * Gases fill the container (usually, as density relative to the density of air affects this) because the particles tend to spread out.
* Gases can be poured because the particles move independently of each other (attractive forces are weak).
* Gases can be compressed because the amount of space between particles can be reduced.
 |  | **Connect:** Students need to read through the text on the slide and answer the questions. Allow students enough time to really digest the text. Identify the literacy errors and state how to correct them**Modelling:*** Use the tray with balls in to show the particle arrangement in gasses
* Use students as a model to act out the behaviour of the particles in gasses
* Talk about the attraction of particles and how this links to the properties
* Compare to solids and liquids regarding forces of attraction between particles
* Get a jar of carbon dioxide and show its presence by putting a lit splint in there, then pour this into another jar and do the same. Student will not see the gas flows but when you put the splint in there it will go out thus showing the presence of carbon dioxide.

**Me Time****Task 1:** State the properties of gasses, include particle behaviour, forces of attraction. Use the carbon dioxide demonstration to support your answer. Include a diagram.**Task 2:** Students need to explain how the properties of a gas relate to the uses**Task 3:** Suggest why gas couldn’t be used in a car braking system. Explain in terms of particles. Secondly explain what has happen to the images of gas cylinders. **Challenge:** suggest what would happen if gasses stayed in the same place. Get a jar of carbon dioxide and show its presence by putting a lit splint in there, then pour this into another jar and do the same. Student will not see the gas flow but when you put the splint in there it will go out thus showing the presence of carbon dioxide. |
| Notes including most common misconceptions |
| Johnson (1998) identifies three alternative models of matter held by students:1. Substances are continuous (with no recognition of particle ideas)
2. Particles are located within a continuous substance (rather than being the substance)
3. Particles are the substance (but macroscopic properties are given to the particles)

These contradict the standard particle model in which the particles are the substance but where the macroscopic properties of the substances arise collectively from the particles. The standard particle model can successfully explain some properties of a substance in the gas state.Applications* Storage of large volumes of gas in cylinders as gases can be compressed. E.g. compressed gas for scuba divers; compressed air used to fill ballast tanks of submarines so they can surface.
* Consequences of gases not filling a space (some parts of a room wouldn’t contain air).
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| Lesson | Title and keywords | Objectives | What students are learning | What students are not learning | Suggested activities |
| 8 | **Diffusion**What do scientists think about and why is it important?What are all things made of and how do these things interact? **Key Words: diffusion, particles, concentration, high, low** | **Explain the process of diffusion.** **Understand that diffusion is a dynamic process even when equilibrium is reached.** **Explain the link between diffusion and the fact that gases fill a container.** | * Particles in a fluid have a net movement from a region of high concentration to an area of low concentration.
* Particles continue to move after equilibrium is reached; however, the net movement is zero.
* Diffusion occurs because of the natural and random movement of particles in fluids.
* Diffusion occurs in gases and liquids.
 | * Osmosis and active transport.
* Factors affecting the rate of diffusion are not requited yet.
 | **Connect:** Students need to use the image to explain what is happening. Students need to identify the ‘small circles’ as particles. This builds on knowledge from previous learning. They should be able to observe that the particles are spreading out**Modelling:** * Use students to model diffusion and Brownian motion
* Experiment showing diffusion of gases in a tube (concentrated hydrochloric acid and ammonia)
* Acids to model diffusion tube & You can show diffusion in gases by filling a gas jar with natural gas. Show it combusts. Refill it. Then put an inverted gas jar on top of it and remove the lids. The natural gas will spread evenly between the gas jars. This can be shown by setting light to both
* Opportunity for a class practical using agear plate and universal indicator, add acid into the middle to show it diffusing

**Me Time****Task 1:** Students need to put a tea bag in hot water and record the observations scientifically. From this student can use their knowledge form the lesson to explain **Task 2**: Students need to define equilibrium and describe how this applies to the diffusion**Task 3**: Think about these examples of diffusion. Suggest which will reach equilibrium first and why? 1. Placing a spoonful of coffee in 50cm3 of hot water
2. Placing a spoonful of coffee in 50cm3 of cold water

**Challenge:** Explain why we had to use facemask in the classroom during covid and why did windows need to be opened to allow ventilation |
| Notes including most common misconceptions |
| * Misconceptions include:
* Various researchers (Odom, 1995; Tomažič and Vidic, 2012; Stains and Sevian, 2015; Oztas and Oztas, 2016) have used diagnostic questions to reveal common misunderstandings about diffusion in school children that can persist in students up to university level, including that:
* molecules in an area of high concentration want to spread out, or move to seek out an area with more room;
* molecules move only in one direction, from an area of higher concentration to an area of lower concentration (a failure to understand the random movement of particles versus the concept of net movement);
* movement of particles stops after the concentration gradient between two areas has been equalised by diffusion (possibly because students interpret “no net movement” to mean “no movement of particles”);
* diffusion of a substance through a solvent requires a chemical reaction, or occurs because the substance splits up into smaller bits that mix with the solvent.
* Some students believe that diffusion requires an external force or mechanical event (rather than resulting from the intrinsic movement of particles), a misunderstanding that may be linked to students’ everyday experiences of stirring and dissolving, such as stirring sugar into tea (Çalýk, Ayas and Ebenezer, 2005; Stains and Sevian, 2015).
* Students can struggle to understand and explain diffusion because of the apparent disconnect between what happens at the macroscopic level and what happens at the particle level – e.g. molecules collide and move in random directions and do not stop, but there is net movement from high concentration to low concentration until equilibrium is reached (AlHarbi et al., 2015; Stains and Sevian, 2015).
* It has also shown that students have very little appreciation of the idea of the intrinsic motion of particles. This leads to students to have difficulties in explaining observed diffusion of a dye through water or in understanding air pressure.

Applications* Relating diffusion to diffusion of substances from a tea bag (plus other examples).
* If diffusion didn’t happen, oxygen partial pressures around students would decrease and carbon dioxide concentrations would increase
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