States of Matter

SPEAKER NOTES

Put an ice cube on a saucer at the front of the room at the start of the lesson. Ask: what will this look like in 40 minutes, and where will the water have gone by tomorrow? Keep the predictions on the board and return to them at the end.

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By the end of this lesson you can

- Describe particles in solids, liquids and gases
- Explain properties using the particle model
- Name the changes of state
- Tell evaporation from boiling
- Explain gas pressure and diffusion

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By the end of this lesson you can

SPEAKER NOTES

Read the objectives aloud. Ask students to draw three empty boxes labelled solid, liquid and gas; they will fill them with particle drawings during the lesson.

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Everything is made of particles

- Matter is anything that has mass and takes up space
- All matter is made of tiny particles: atoms or molecules
- The particles are always moving
- Attractions between particles pull them together

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Everything is made of particles

SPEAKER NOTES

This is the particle model. It is a model, which means a simplified picture that helps us explain and predict. We draw particles as circles, but real atoms and molecules are far too small to see even with a school microscope.

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Solids

- Fixed shape and fixed volume
- Particles tightly packed, often in a regular pattern
- Particles vibrate about fixed positions
- Cannot flow and are very hard to squash

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Solids

SPEAKER NOTES

Ask students to draw a solid in their first box: circles touching, in neat rows. Ask them to add small zigzag lines to show vibration. Link each property to the picture: no gaps, so it cannot be squashed; fixed positions, so it keeps its shape.

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Liquids

- Fixed volume, but take the shape of their container
- Particles close together with no regular pattern
- Particles move past each other but stay in contact
- Can flow, but are very hard to squash

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Liquids

SPEAKER NOTES

In the second box, students draw particles still touching but jumbled, with arrows showing them sliding past each other. Common error: drawing liquid particles far apart. Remind them that liquids are almost as hard to squash as solids, so the particles must still be close.

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Gases

- No fixed shape or volume: they fill any container
- Particles far apart with no regular pattern
- Particles move quickly and randomly in all directions
- Flow easily and are easy to squash

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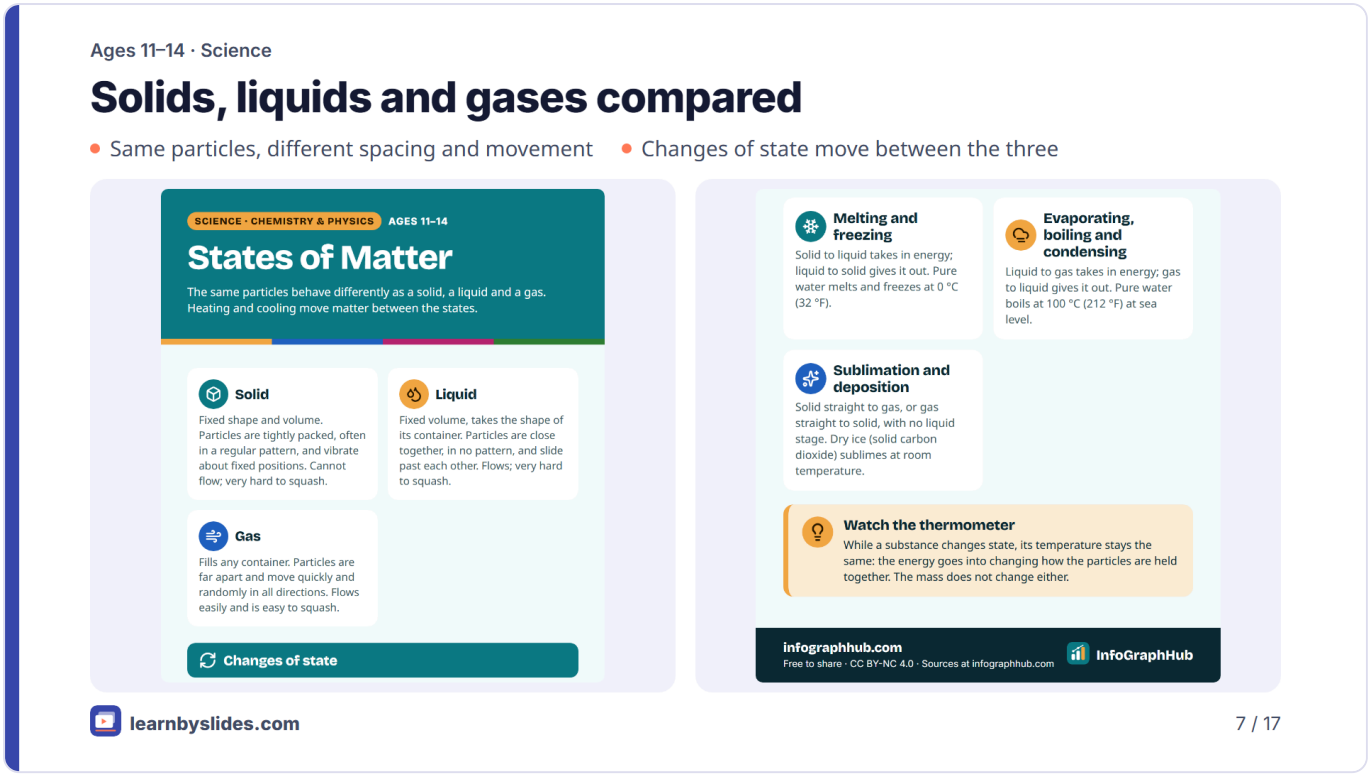
Gases

SPEAKER NOTES

In the third box, students draw a few widely spaced particles with long arrows. The space between gas particles is empty: there is no air between the particles of air. Squeezing a sealed syringe of air works because there is space to push the particles into.



Solids, liquids and gases compared

SPEAKER NOTES

Use the poster to check students' three drawings. Ask them to correct any box that does not match. Point out that the particles themselves are the same in all three states: only their spacing, arrangement and movement change.

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What decides the state?

- Attractions between particles pull them together
- Movement energy lets particles break away
- Strong attractions, little energy: solid
- More energy than the attractions can hold: gas

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What decides the state?

SPEAKER NOTES

Use a tug-of-war image: attractions pull particles together while movement energy pulls them apart. Heating gives particles more movement energy, so a solid can become a liquid and then a gas. Cooling does the opposite.

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Changes of state

- Melting: solid to liquid; freezing: liquid to solid
- Evaporating or boiling: liquid to gas
- Condensing: gas to liquid
- Sublimation: solid straight to gas, as with dry ice
- Deposition: gas straight to solid

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Changes of state

SPEAKER NOTES

Draw a triangle on the board with solid, liquid and gas at the corners and add an arrow for each change. Dry ice is solid carbon dioxide; at room temperature and normal pressure it turns straight into a gas. Changes of state are physical changes: the substance is still the same substance, and its mass does not change.

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Energy in, energy out

- Melting, boiling and sublimation take in energy
- Freezing, condensing and deposition give out energy
- During a change of state, the temperature stays the same
- The energy goes into changing how particles are held together

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Energy in, energy out

SPEAKER NOTES

Sketch a heating curve: temperature rises, then a flat section while the solid melts, then rises again, then another flat section while the liquid boils. Students are often surprised that a pan of boiling water stays at the same temperature however hard you heat it.

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Water's fixed points

0 °C · 100 °C

pure water freezes at 0 °C (32 °F) and boils at 100 °C (212 °F) at sea level

- Lower air pressure means a lower boiling point
- In Leadville, Colorado (US), water boils at about 90 °C

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Water's fixed points

SPEAKER NOTES

Leadville is a mountain town in the Rocky Mountains where the air pressure is about 68 kPa, roughly two-thirds of the 101.3 kPa at sea level, so water boils at around 90 °C (194 °F). The boiling point is the temperature at which the liquid's vapour pressure equals the pressure of the air above it.

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Evaporation vs boiling

Evaporation

- Happens at any temperature
- Only at the surface of the liquid
- Only the fastest particles escape
- Slow and quiet, like a puddle drying

Boiling

- Happens only at the boiling point
- Throughout the whole liquid
- Particles across the liquid escape
- Fast, with bubbles of vapour

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Evaporation vs boiling

SPEAKER NOTES

Ask students where the puddle goes on a sunny day without ever reaching 100 °C. Only the fastest-moving particles at the surface have enough energy to break away, so evaporation is slow but happens at any temperature. Warmer liquids evaporate faster because more particles have enough energy.

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Gas pressure and diffusion

- Gas particles hit the walls of their container
- These collisions push on the walls: that is gas pressure
- Heating makes particles faster, so they hit harder and more often
- Diffusion: particles spread from where there are many to where there are few

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Gas pressure and diffusion

SPEAKER NOTES

Demonstrate diffusion by spraying air freshener or opening a bottle of perfume at the front and asking students to raise a hand when they smell it. Gases diffuse quickly because their particles move fast and there is lots of space between them. Ask why a sealed bag of crisps swells on a warm day.

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Example

Example: a kettle and a cold window

1. Water is heated in a kettle until it boils
2. Water particles leave the liquid as an invisible gas
3. The gas reaches a cold window and loses energy
4. It condenses back into liquid droplets on the glass

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Example: a kettle and a cold window

SPEAKER NOTES

Ask students to name each change of state and say whether energy is taken in or given out at each step. Then ask them to draw particle diagrams for the water in the kettle, in the air and on the window. Kettles get hot: keep any real demonstration at a safe distance.

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Common mix-ups

- Particles do not melt, expand or change size
- Only the spacing and movement of particles change
- There is empty space, not air, between gas particles
- Mass stays the same when a substance changes state

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Common mix-ups

SPEAKER NOTES

Ask students to vote true or false before revealing each bullet. A sealed bag of ice that melts has exactly the same mass afterwards; you can show this on a balance. When something expands on heating, it is because the particles move more and spread out, not because each particle grows.

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Quick check

Why can a gas be squashed into a smaller volume but a liquid cannot?

- **A** Gas particles are smaller
- **B** Gas particles are far apart with space between them
- **C** Liquid particles do not move
- **D** Gases have no mass

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Quick check

SPEAKER NOTES

Answer: gas particles are far apart. Liquid particles are already touching, so there is almost no space to push them into. Use wrong answers to revisit the common mix-ups slide.

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Key takeaways

- All matter is made of moving particles
- Solids vibrate in place; liquids slide past; gases move freely
- Changes of state take in or give out energy
- Temperature stays constant during a change of state
- Gas pressure comes from particles hitting surfaces

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Key takeaways

SPEAKER NOTES

Look at the ice cube from the start of the lesson and ask students to explain what has happened using particles. Then move to the five-question quiz on the page. Homework idea: draw a labelled heating curve for water from −10 °C to 110 °C.

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