

Essential Question

How do particles differ in solids, liquids, and gases?

Three Phases of Matter

What changes from phase to phase is how close the particles are, how they are arranged, and how they move.

Two Types of Solids

- **Crystalline solids:** particles in a regular, repeating pattern (e.g., NaCl, diamond, ice)
- **Amorphous solids:** particles with no regular pattern (e.g., glass, plastic)

In both types the particles are touching and locked in place.

Solids: Particle Motion

- Particles vibrate in place.
- No overall translation: particles do not move past each other.
- Structure depends on interparticle forces and how well particles pack.

Because the particles stay in fixed positions, a solid has a definite shape and a definite volume.

Liquids

- Particles are in close contact.
- Particles are always moving and colliding.
- IMFs (like H-bonding) and temperature affect how particles move and arrange.

Liquid particles are still touching, so a liquid has a definite volume. They can slide past each other, though, so a liquid flows and takes the shape of its container.

Gases

- Particles are far apart.
- Constant, random motion.
- Minimal forces between particles.
- No definite shape or volume.

With almost nothing holding them together, gas particles spread out to fill whatever container they are in. Most of a gas sample is empty space.

Gases: Spacing and Collisions

- Spacing and collisions depend on T, P, and V.
- Smaller V $\rightarrow$ particles closer $\rightarrow$ more collisions.
- Higher T $\rightarrow$ faster particles $\rightarrow$ more collisions.

Same particles, less room: squeezing a gas into a smaller volume packs the particles closer together, so they collide with each other and with the walls more often.

Molar Volume

- **Solid $\approx$ Liquid:** particles are in close contact in both phases, so the molar volumes are similar.
- **Gas $\gg$ Liquid:** gas particles are far apart, so the same number of particles takes up far more space.

Molar volume is the volume taken up by one mole of a substance.

Molar Volume

Phase	Molar volume
Ice (0 °C)	19.6 mL/mol
Liquid water (25 °C)	18.0 mL/mol
Steam (100 °C)	~30,600 mL/mol

Summary

	Solid	Liquid	Gas
Spacing	Touching	Touching	Far apart
Motion	Vibrate in place	Slide past each other	Fast, random
Shape	Definite	Takes container's	Takes container's
Volume	Definite	Definite	Fills container

Drawing Particle Diagrams

- Use the same number of particles in each phase.
- Solids and liquids: particles touching.
- Phase changes break IMFs, not covalent bonds.

When water boils, the H₂O molecules move apart from each other, but each molecule stays whole.

Example: Particle Diagrams of Water

Try it first!

Draw a particle diagram of $\text{H}_2\text{O}(\text{s})$, $\text{H}_2\text{O}(\text{l})$, and $\text{H}_2\text{O}(\text{g})$. Use 10 molecules in each box.

Example: Choosing a Particle Diagram

Try it first!

Which diagram best represents $\text{Br}_2(\text{l})$ at $25\text{ }^{\circ}\text{C}$?

Diagram: Four boxes labeled A to D. A: paired atoms in neat rows at the bottom. B: paired atoms close together but disordered in the lower part of the box. C: a few paired atoms spread far apart. D: single unpaired atoms touching but jumbled at the bottom.

Example: Explaining Molar Volume

Try it first!

Steam has a molar volume about 1,700 times larger than liquid water. Explain this difference at the particle level.

	Molar volume
H ₂ O(l) at 25 °C	18.0 mL/mol
H ₂ O(g) at 100 °C	~30,600 mL/mol

Big Ideas

- Solids and liquids: particles touching.
- Solids vibrate in place; liquids slide past each other.
- Gases: far apart, fast, random motion.
- Phase changes break IMFs, not covalent bonds.