Changes of state and specific latent heat

6.3.2.3 · Physics · revision notes

Latent heat is the energy needed to change the state of a substance without changing its temperature. You need to define specific latent heat, use E = m L (on the equation sheet), tell latent heat of fusion from latent heat of vaporisation, and interpret heating and cooling graphs. Harder questions combine E = m L with ΔE = m c Δθ or with power and time.

Key facts

- E = m L (on the equation sheet); E in J, m in kg, L in J/kg
- Fusion: solid ↔ liquid. Vaporisation: liquid ↔ vapour (gas)
- Heating graph: sloping part = temperature changing; flat part = state changing
- Specific heat capacity → temperature change. Specific latent heat → change of state
- Specific latent heat: energy to change the state of 1 kg with no change in temperature
- During a change of state: internal energy changes, temperature does not
- Freezing and condensing release energy; E = m L gives how much
- Experiment: L = E ÷ m, E from a joulemeter or E = P t, m = mass that changed state

Notes

Latent heat

- The energy needed for a substance to change state is called **latent heat**.
- During a change of state, the energy supplied changes the internal energy (the potential energy of the particles) but **not the temperature**.
- When a substance freezes or condenses, the same amount of energy per kilogram as was needed to melt or boil it is transferred to the surroundings, again at constant temperature.

Specific latent heat

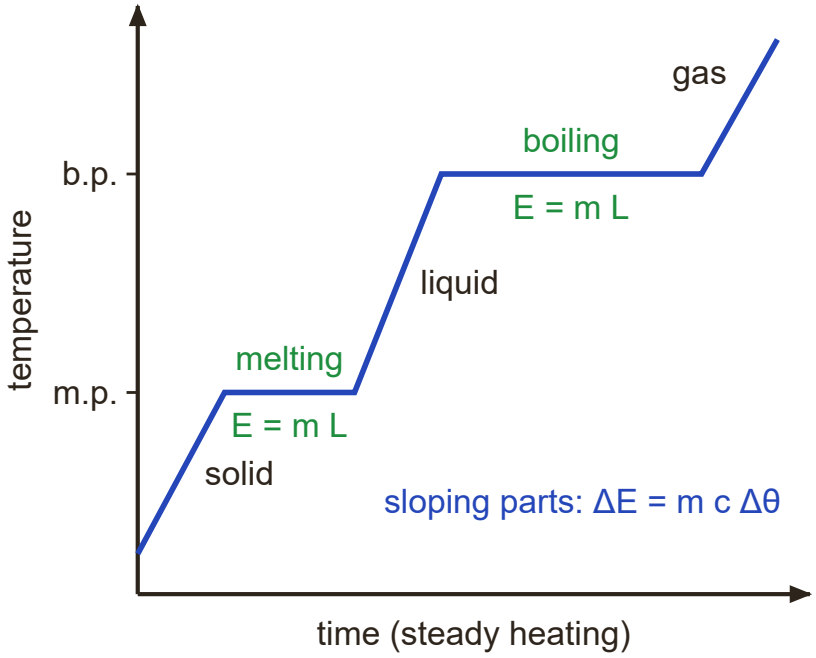
- The **specific latent heat** (L) of a substance is the amount of energy needed to change the state of **1 kg** of it with **no change in temperature**.
- thermal energy for a change of state = mass × specific latent heat: **E = m L** (on the equation sheet). E in J, m in kg, L in J/kg.
- **Specific latent heat of fusion**: for a change between solid and liquid (melting, or freezing).
- **Specific latent heat of vaporisation**: for a change between liquid and vapour (boiling, or condensing).
- For water, the specific latent heat of vaporisation is several times bigger than that of fusion: to form a gas, the forces between the particles must be overcome so they can move far apart. Grade 7+ only

Measuring specific latent heat

- Fusion of water: put crushed ice at 0 °C in a funnel with an immersion heater and a joulemeter; collect the melted water in a beaker below.
- A second funnel of ice with no heater, left for the same time, shows how much the room melts: subtract this mass.
- Vaporisation: heat water in a beaker on a balance with an immersion heater. Once it boils, record the mass lost and the energy supplied.
- E from the joulemeter (or E = P t); L = E ÷ m, with m in kg.
- The value is usually too high: some energy is transferred to the surroundings. Insulating the container reduces this.

Heating and cooling graphs

- A heating graph (temperature against time) for a solid heated steadily has sloping parts and flat parts.
- **Sloping parts**: the temperature of one state is rising (energy calculations use ΔE = m c Δθ).
- **Flat parts**: a change of state at constant temperature, at the melting point (first flat part) or the boiling point (second flat part). Energy calculations use E = m L.



Flat parts: changes of state (E = m L). Sloping parts: temperature change (ΔE = m c Δθ).

- With steady heating, a longer flat part means more energy was needed. For water, the boiling section is much longer than the melting section.
- A cooling graph works the same way in reverse: its flat parts show condensing or freezing, where energy is released while the temperature stays constant.
- Keep the two ideas separate: specific heat capacity is for a temperature change without a change of state; specific latent heat is for a change of state without a temperature change.

How to answer each type of question

Calculate the energy for a change of state

2 marks **Grade 5**

1. Check the question is about a change of state with no temperature change, then choose E = m L.
2. Choose the right L: fusion for melting or freezing, vaporisation for boiling or condensing.
3. Make sure the mass is in kg, substitute and give the unit (J).

Example. Calculate the energy needed to melt 0.25 kg of ice at 0 °C.
specific latent heat of fusion of ice = 334 000 J/kg

Model answer.

E = 0.25 × 334 000 (1)

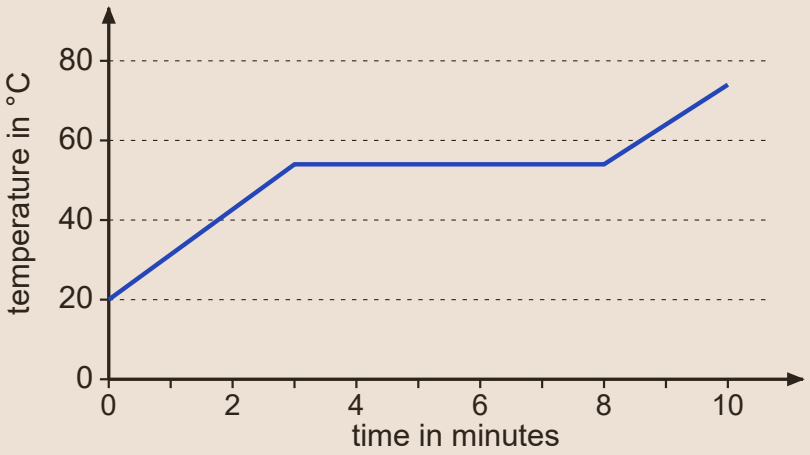
E = 83 500 J (1)

Interpret a heating or cooling graph

2 to 4 marks | **Grade 6**

1. Find the flat sections: these are the changes of state. Read off their temperature (the melting or boiling point).
2. Sloping sections show one state warming up or cooling down.
3. Explain a flat section with internal energy: the energy changes the potential energy of the particles, not their kinetic energy, so the temperature stays constant.

Example. A student heats a solid substance at a steady rate and plots a graph of temperature against time. The temperature rises from 20 °C to 54 °C in the first 3 minutes, stays at 54 °C from 3 minutes to 8 minutes, then rises again.



(a) State the melting point of the substance. (1 mark)

(b) Explain why the temperature stays constant between 3 and 8 minutes, even though the substance is still being heated. (2 marks)

Model answer.

(a) 54 °C (1)

(b) The substance is melting (changing state) (1). The energy supplied increases the internal energy by increasing the potential energy of the particles, not their kinetic energy, so the temperature does not change (1).

Multi-step: change of state plus temperature change

4 to 5 marks | Grade 7

1. Split the process into stages: each change of state and each temperature change.
2. Use $E = m L$ for each change of state and $\Delta E = m c \Delta\theta$ for each temperature change.
3. Add the energies for all the stages and give the unit.

Example. Calculate the energy needed to turn 0.50 kg of ice at 0 °C into water at 20 °C.
specific latent heat of fusion of ice = 334 000 J/kg
specific heat capacity of water = 4200 J/kg °C

Model answer.

Melting: $E = 0.50 \times 334\,000 = 167\,000$ J (1)
Warming: $\Delta E = 0.50 \times 4200 \times 20$ (1) $= 42\,000$ J (1)
Total $= 167\,000 + 42\,000 = 209\,000$ J (1)

Find specific latent heat from experimental data

3 to 4 marks | Grade 5

1. Find the energy supplied with $E = P t$ (power in W, time in s).
2. Find the mass that changed state (e.g. the mass of water boiled away) in kg.
3. Calculate $L = E \div m$ and give the unit J/kg.

Example. A student keeps a kettle with a power of 2.4 kW boiling with its lid open. In 120 s, the mass of water in the kettle decreases by 0.125 kg.
(a) Calculate the specific latent heat of vaporisation of water given by these results. Give your answer to 2 significant figures. (3 marks)
(b) The true value is lower than the student's value. Suggest why. (1 mark)

Model answer.

(a) $E = 2400 \times 120 = 288\,000$ J (1)
$L = 288\,000 \div 0.125$ (1)
$L = 2\,304\,000 = 2.3 \times 10^6$ J/kg (to 2 s.f.) (1)
(b) Some of the energy from the kettle was transferred to the surroundings instead of boiling the water, so less than 288 000 J was used to boil the 0.125 kg (1).

Don’t lose marks

- Using the wrong specific latent heat: fusion when the question is about boiling, or the reverse.
- Putting a temperature change into $E = m L$. The temperature does not change during a change of state.
- Saying the energy supplied during melting is 'lost' or 'does nothing'. It increases the internal energy (the potential energy of the particles).
- In multi-step questions, missing out a stage or leaving the mass in grams.
- Writing the unit of specific latent heat as J/kg °C. It is J/kg.

More tips

Memory tricks

- On a heating graph: Level line → Latent heat ($E = m\,L$); Climbing line → c ($\Delta E = m\,c\,\Delta\theta$).
- Fusion sounds like 'fuse' (melt together): solid ↔ liquid. Vaporisation contains 'vapour': liquid ↔ gas.
- There is no $\Delta\theta$ in $E = m\,L$. If the temperature doesn't change, you can't be using c.
- Sense check for water: boiling away 1 kg (about 2.26 million J) takes far more energy than heating 1 kg from 0 °C to 100 °C (420 000 J).

Exam technique

- Before calculating, decide: does the temperature change (use c) or does the state change (use L)? Some questions need both.
- Set out multi-step answers stage by stage with a label (melting, warming, boiling) so each stage can earn its marks.
- When explaining a flat section, use the words 'internal energy' and 'potential energy of the particles', and say the temperature does not change.
- Read graph values carefully from the axes; a melting or boiling point is the temperature of a flat section.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 4 — **Know temperature stays constant during state changes**
While a substance melts, boils, freezes or condenses, its temperature does not change.

Grade 5 — **Define specific latent heat**
The amount of energy needed to change the state of 1 kg of a substance with no change in temperature.

Grade 5 — **Use $E = m\,L$**
Calculate the energy for a change of state with E in J, m in kg and L in J/kg.

Grade 5 — **Find changes of state on heating graphs**
Flat sections show a change of state at the melting or boiling point; sloping sections show a temperature change.

Grade 5 — **Find specific latent heat from experimental data**
Use $E = P\,t$ for the energy supplied and the mass that changed state, then $L = E \div m$.

Grade 6 — **Distinguish latent heat of fusion and vaporisation**
Fusion: changing between solid and liquid. Vaporisation: changing between liquid and vapour (gas).

Grade 6 — **Tell specific heat capacity from specific latent heat**
Specific heat capacity is for a temperature change with no change of state; specific latent heat is for a change of state with no temperature change.

Grade 7 — **Do multi-step heating and melting calculations**
Work out each stage separately with $\Delta E = m\,c\,\Delta\theta$ or $E = m\,L$, then add the energies.

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