

Structure 1.1.3

Kinetic Energy and Temperature

Temperature as a measure of average particle kinetic energy; Celsius-Kelvin conversions; and how temperature behaves during changes of state.

Level coding used throughout: SL + HL = examinable for everyone. **HL ONLY** = none in Structure 1.1.3 - there is no separate AHL extension for this subtopic.

0 Syllabus map

SL + HL

IB syllabus point	Level	What you must be able to do	Section
Structure 1.1.3	SL + HL	Explain that temperature, T , in kelvin (K), is a measure of the average kinetic energy of particles.	1
Structure 1.1.3	SL + HL	Convert between Celsius and Kelvin values; use K correctly as the SI unit of temperature.	2
Structure 1.1.3	SL + HL	Interpret observable changes in physical properties and temperature during changes of state.	3-5

SYLLABUS LINKS

This point builds directly on Structure 1.1.2 (kinetic molecular theory and states of matter). Later, Reactivity 1.2 explains the energetic direction of phase changes and Reactivity 2.2 develops the distribution of kinetic energies. This booklet does not pre-teach those later topics in unnecessary detail.

1 Temperature and average kinetic energy

SL + HL

Core idea: in the IB particle model, temperature is a measure of the average kinetic energy, E_k , of the particles in a sample. A higher temperature means a higher average particle kinetic energy; a lower temperature means a lower average particle kinetic energy.

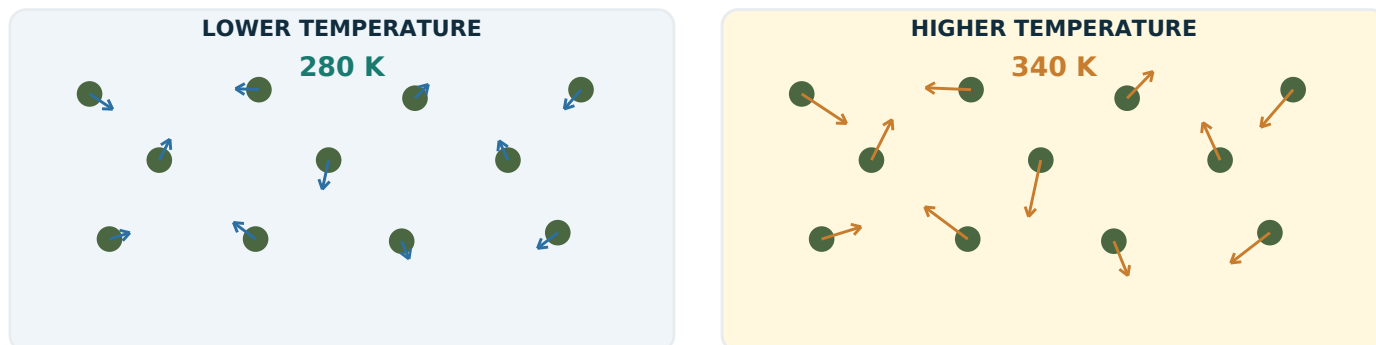
DEFINITION - TEMPERATURE

Temperature, T , is a measure of the average kinetic energy of the particles in a substance. The SI unit is the kelvin, K.

1 Temperature and average kinetic energy

SL + HL

FIGURE 1 • TEMPERATURE AND PARTICLE MOTION



Longer arrows represent greater particle speeds. Individual particles do not all have the same kinetic energy.

Average is the key word. In any real sample, particles do not all move with identical speeds. Some particles have less kinetic energy than the mean and some have more. Temperature summarizes the average behaviour of the enormous number of particles.

COMMON ERROR

Do not write: "at 300 K every particle has the same kinetic energy." That is false. Temperature refers to an average, not a single identical value for every particle.

When a substance is heated without changing state, its temperature usually rises. In the particle model this means the particles gain kinetic energy on average: particles in a gas move faster; particles in a liquid move more rapidly past one another; particles in a solid vibrate more vigorously about their positions.

EXAM TIP

If a question asks why temperature rises, connect the macroscopic observation to the particle model: energy is transferred to the substance, increasing the average kinetic energy of its particles.

Absolute zero is 0 K, equivalent to -273.15°C . The Kelvin scale begins at absolute zero, which is why Kelvin is the natural SI scale for thermodynamic temperature.

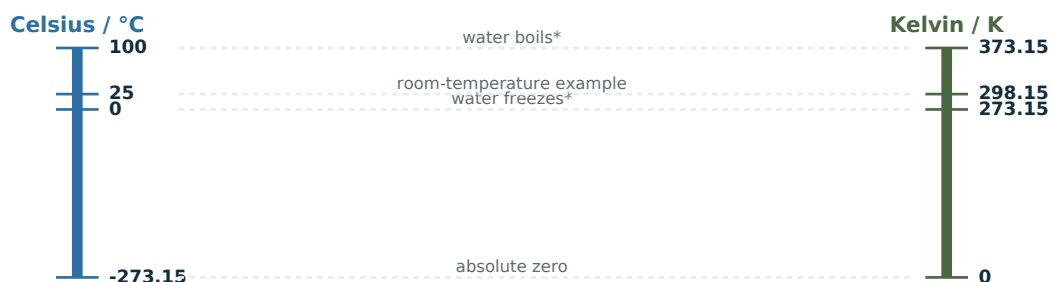
REMEMBER

Kelvin temperatures are written with K, never $^{\circ}\text{K}$. Celsius temperatures use $^{\circ}\text{C}$.

2 Celsius and Kelvin

SL + HL

FIGURE 2 · CELSIUS AND KELVIN SCALES



*At standard atmospheric pressure. The size of one kelvin equals the size of one Celsius degree.

CONVERSION

$T / K = \text{temperature} / ^\circ\text{C} + 273.15$

For the precision normally used in school chemistry, 273 may be used where appropriate unless the question/data require 273.15.

Why the arithmetic is simple: one kelvin is the same size interval as one Celsius degree. The two scales differ only in where zero is placed. Therefore the conversion is an offset, not a multiplication.

Worked example 1 - Celsius to Kelvin

Convert 25.0 °C to kelvin.

$25.0 + 273.15 = 298.15 \text{ K}$ (often reported as 298 K to match the given precision).

Worked example 2 - Kelvin to Celsius

Convert 310 K to degrees Celsius.

$310 - 273.15 = 36.85 \text{ }^\circ\text{C}$, so approximately 37 °C if the Kelvin value is given to the nearest kelvin.

CLASSIC EXAM ERRORS

1. Writing $25 \text{ }^\circ\text{C} = 25 \text{ K}$. 2. Writing “298 °K”. 3. Multiplying by 273.15. 4. Forgetting that a Celsius value may be negative while the corresponding Kelvin temperature remains positive.

Quick sense check

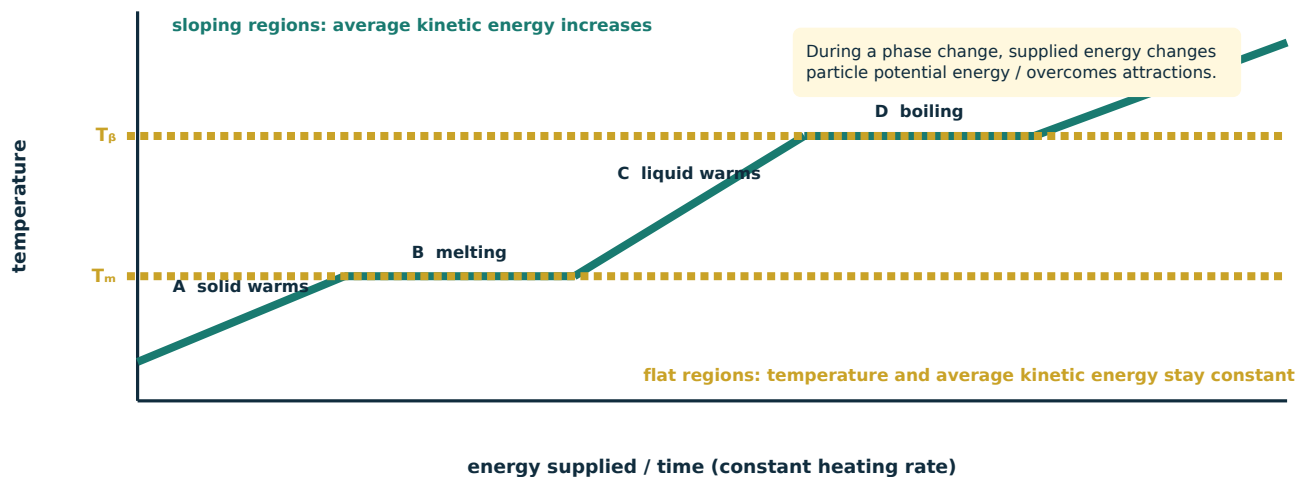
Celsius	Expected Kelvin range
-20 °C	about 253 K
20 °C	about 293 K
100 °C	about 373 K

3 Heating curves and changes of state

SL + HL

A heating curve plots temperature against time or energy supplied. For a pure substance at constant pressure, a phase change appears as a region where the temperature remains constant while energy continues to be supplied.

FIGURE 3 · GENERIC HEATING CURVE FOR A PURE SUBSTANCE AT CONSTANT PRESSURE



Region	What you observe	Particle interpretation
A, C, E - sloping	Temperature rises within one state.	Average kinetic energy increases.
B - melting plateau	Solid and liquid coexist; temperature remains at the melting temperature.	Energy overcomes some attractions / increases particle potential energy; average kinetic energy remains constant.
D - boiling plateau	Liquid and gas coexist; temperature remains at the boiling temperature.	Energy separates particles further against attractions; average kinetic energy remains constant.

MOST IMPORTANT EXAM SENTENCE

During a change of state, energy can continue to be transferred even though the temperature stays constant. The supplied energy is used to change the arrangement/separation of particles rather than to increase their average kinetic energy.

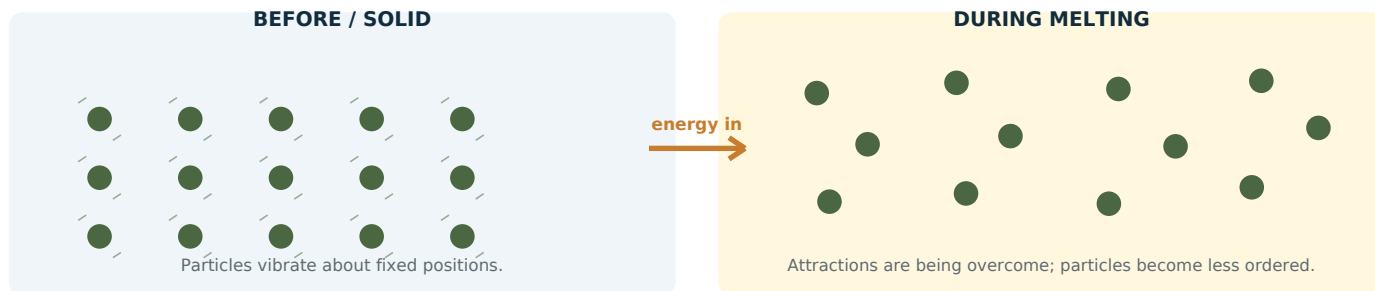
COMMON ERROR

A flat section does not mean "nothing is happening" or "heating has stopped". If energy is still supplied, the phase change is progressing while the average kinetic energy - and therefore the temperature - stays constant.

4 Particle-level interpretation of a phase change

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FIGURE 4 • WHAT THE ENERGY DOES DURING MELTING



The particle model separates two ideas that students often mix up: kinetic energy is associated with particle motion; potential energy is associated with the relative positions and attractions between particles. On a sloping part of a heating curve, the average kinetic energy rises. On a melting or boiling plateau, the temperature is constant while energy changes the particle arrangement.

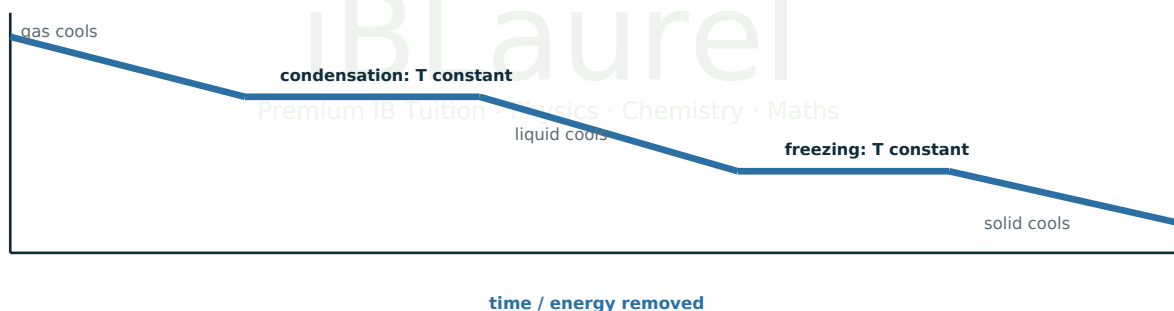
EXAM LANGUAGE

For melting or boiling, an excellent answer includes both points: (1) temperature/average kinetic energy remains constant; (2) energy is used to overcome interparticle attractions / increase separation and potential energy.

5 Cooling curves and observable changes

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FIGURE 5 • COOLING CURVE: THE SAME LOGIC IN REVERSE



On cooling, the pattern is reversed. Temperature falls while a single phase cools. During condensation or freezing, the temperature remains constant for a pure substance at constant pressure while the phase change occurs.

Change	Macroscopic observation	Particle-level description
Melting	solid → liquid; fixed shape is lost; material can flow	particles become less ordered and can move past one another
Boiling	liquid → gas; gas occupies available space	particles become much more separated and move freely
Condensation	gas → liquid	particles become closer together; attractions become more influential
Freezing	liquid → solid; fixed shape develops	particles become ordered and vibrate about fixed positions

6 Exam toolkit and worked applications

SL + HL

How to answer a graph question

- First decide whether the graph is on a sloping region or a plateau.
- Sloping region: temperature changes, so average kinetic energy changes.
- Plateau: a phase change is occurring; temperature and average kinetic energy remain constant while energy changes particle arrangement/separation.
- If asked for the state, remember that two phases coexist during the plateau.

Worked example 3 - interpreting a plateau

A pure substance is heated at constant pressure. Its temperature remains at 64 °C for four minutes even though the heater remains switched on. Explain this observation. [2]

Model answer: The substance is undergoing a change of state at 64 °C, so its temperature and average kinetic energy remain constant. The energy supplied is used to overcome interparticle attractions / change particle separation rather than increase average kinetic energy. [1 + 1]

Worked example 4 - comparing two temperatures

Sample X is at 285 K and the same substance is later at 315 K. State what has changed at particle level. [1]

Answer: The particles have a greater average kinetic energy at 315 K. Do not claim that every particle moves faster than every particle in the cooler sample.

Worked example 5 - negative Celsius temperature

Convert -40.0 °C to K.

$-40.0 + 273.15 = 233.15$ K. Notice that a negative Celsius temperature is still well above 0 K.

WHAT IB IS LIKELY TO TEST

Short questions commonly target: correct Kelvin notation, Celsius/Kelvin conversion, the word average, identification of a phase-change plateau, and an explanation of why temperature remains constant while energy transfer continues.

FORWARD LINK - DO NOT OVERLEARN HERE

Later in Reactivity 2.2, IB Chemistry uses a graphical distribution of particle kinetic energies. For Structure 1.1.3, you only need the qualitative idea that particles have a range of kinetic energies and temperature reflects the average.

7 Practice questions - Part A: multiple choice

SL + HL

Choose the best answer. Each question is worth [1].

- Which statement best describes temperature in the IB particle model?
A. The total kinetic energy of all particles
B. The kinetic energy of the fastest particle
C. A measure of the average kinetic energy of particles
D. The potential energy stored between particles
- Which temperature is equal to 25 °C?
A. 248 K B. 273 K C. 298 K D. 325 K
- Which unit notation is correct for thermodynamic temperature?
A. °K B. K C. K° D. kelvin degrees
- A pure solid is heated at constant pressure. During melting, which statement is correct?
A. Temperature rises and average kinetic energy rises
B. Temperature stays constant and average kinetic energy stays constant
C. Temperature stays constant because no energy is transferred
D. Average kinetic energy falls while temperature rises
- A sample is warmed from 290 K to 320 K without a change of state. Which statement is correct?
A. Average particle kinetic energy increases
B. Average particle kinetic energy decreases
C. Particle potential energy must become zero
D. Every particle has exactly the same kinetic energy at 320 K
- Which Celsius temperature is closest to 250 K?
A. -23 °C B. 23 °C C. 77 °C D. 523 °C

8 Practice questions - Part B: structured

24 marks

7. Convert the following temperatures, showing your working:
(a) 18.0 °C to K. [1]
(b) 355 K to °C. [1]
(c) State one notation rule that distinguishes the Kelvin scale from the Celsius scale. [1]
8. A student says: "At 300 K all particles in a sample have the same kinetic energy." Explain why this statement is incorrect, and state what temperature actually represents. [3]
9. A pure substance is heated at constant pressure. A section of its heating curve is horizontal even though energy continues to be supplied.
(a) State what is happening to the state of the substance. [1]
(b) State what happens to the average kinetic energy of the particles. [1]
(c) Explain where the supplied energy goes. [2]

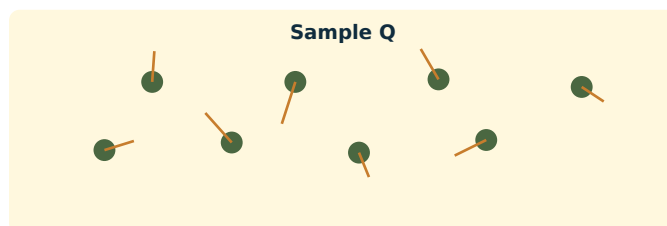
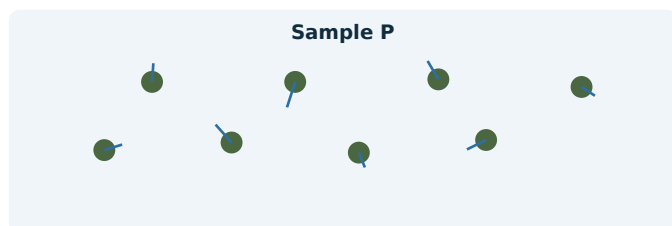
8 Practice questions - Part B continued**24 marks total**

10. A student heats a substance and records the following data.

Time / min	0	2	4	6	8	10	12
Temperature / °C	-12	-4	0	0	0	18	41

- (a) Identify the temperature at which a change of state is occurring. [1]
 (b) Identify the most likely change of state if the sample starts as a solid and is continuously heated. [1]
 (c) Explain why the temperature is unchanged from 4 to 8 minutes. [1]

11. The diagrams below represent the same substance in the same physical state. Arrow length represents particle speed.



- (a) Deduce which sample has the higher temperature. [1]
 (b) Justify your answer using kinetic energy. [1]
 (c) Explain why the arrows within one sample are not all identical in length. [1]

12. A beaker contains a pure liquid at its boiling temperature. The heater supplies energy for a further three minutes while liquid remains present.

- (a) Predict what happens to the temperature during these three minutes. [1]
 (b) State what happens to the average kinetic energy of the particles. [1]
 (c) Explain, at particle level, how the supplied energy causes vaporization. [2]

13. A gas is cooled at constant pressure until it condenses and then the liquid cools further.

- (a) Sketch or describe the expected temperature-time pattern, including the condensation stage. [2]
 (b) State what happens to the average kinetic energy of the particles during condensation. [1]
 (c) State one observable physical change as condensation occurs. [1]

9 Answers & Mark-Scheme Notes**Part A + B****Part A - multiple choice**

1. C - Temperature is a measure of average particle kinetic energy.
2. C - $25 + 273.15 = 298.15$ K, so 298 K.
3. B - The kelvin symbol is K with no degree sign.
4. B - During melting of a pure substance at constant pressure, temperature and average kinetic energy remain constant while energy drives the phase change.
5. A - A higher Kelvin temperature corresponds to greater average particle kinetic energy.
6. A - $250 - 273.15 = -23.15$ °C.

Part B - structured

7. [3]
 - (a) $18.0 + 273.15 = 291.15$ K, normally 291 K to matching precision. [1]
 - (b) $355 - 273.15 = 81.85$ °C, approximately 82 °C. [1]
 - (c) Kelvin uses K without a degree sign; Celsius uses °C. [1]
8. [3]
 - Particles in a sample have a range of kinetic energies / speeds. [1]
 - Therefore they do not all have identical kinetic energy at a given instant. [1]
 - Temperature is a measure of the average kinetic energy of the particles. [1]

Marker note: "temperature is the kinetic energy" is too imprecise unless average is included.
9. [4]
 - (a) A change of state is occurring; for a heating curve this could be melting or boiling depending on the plateau. [1]
 - (b) The average kinetic energy remains constant. [1]
 - (c) Energy is used to overcome interparticle attractions / increase particle separation [1] and therefore changes particle potential energy/arrangement rather than increasing average kinetic energy. [1]
10. [3]
 - (a) 0 °C. [1]
 - (b) Melting (solid → liquid). [1]
 - (c) The supplied energy is being used for the phase change, so temperature / average kinetic energy remains constant. [1]

WHY SOME ANSWERS LOSE MARKS

A response such as "the particles stop moving during melting" is incorrect. Particle motion continues; what remains constant is the average kinetic energy, not motion itself.

9 Answers & Mark-Scheme Notes continued

Part B

11. [3]

(a) Sample Q. [1]

(b) Its particles have the greater average speed / average kinetic energy, represented by the longer arrows overall. [1]

(c) Particles in a sample have a range of speeds and kinetic energies; temperature refers to the average. [1]

12. [4]

(a) The temperature remains constant at the boiling temperature while liquid and gas coexist. [1]

(b) The average kinetic energy remains constant. [1]

(c) The supplied energy is used to overcome attractive forces between particles [1], allowing particles to become much more separated / enter the gas phase. [1]

13. [4]

(a) Temperature falls as the gas cools, then shows a horizontal plateau during condensation, then falls again once the sample is fully liquid. [2]

(b) The average kinetic energy remains constant during condensation. [1]

(c) Accept: formation of liquid droplets / gas becomes a liquid / the material occupies a definite volume rather than filling the container. [1]

FINAL 30-SECOND CHECKLIST

Before the exam, make sure you can say all five without hesitation:

1. Temperature measures average particle kinetic energy.

2. $K = ^\circ C + 273.15$ (and $^\circ C = K - 273.15$).3. Kelvin uses K, not $^\circ K$.

4. On a heating/cooling slope, average kinetic energy changes.

5. On a phase-change plateau, temperature and average kinetic energy stay constant while energy changes particle arrangement/separation.

Syllabus alignment and source note

Prepared for IB Diploma Chemistry, syllabus first taught 2023 / first assessment 2025. Alignment checked against the International Baccalaureate Chemistry guide, Structure 1.1.3, and the current IB Chemistry subject information. This independent iBLaurel resource is not endorsed by the International Baccalaureate.

End of Structure 1.1.3 - Kinetic Energy and Temperature

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