Internal energy

4.3.2.1 · Particle model of matter · revision notes

Internal energy is the energy stored by the particles that make up a system. You need to define it, explain how heating changes it, and explain why heating either raises the temperature or changes the state. Most questions are 1 to 3 mark definitions and particle explanations, often leading into specific heat capacity or latent heat calculations.

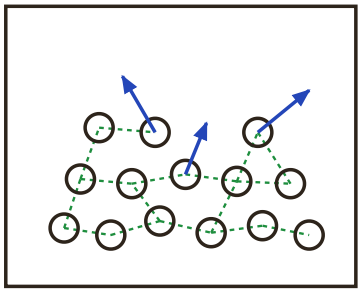
Key facts

- Internal energy = total kinetic energy + potential energy of all the particles in a system
- Potential energy of the particles: due to the forces between them; depends on their separation
- During a change of state: internal energy changes, temperature stays constant
- Kinetic energy of the particles: linked to temperature
- Heating → internal energy increases → temperature rises OR state changes
- Temperature: average kinetic energy of the particles. Internal energy: total energy of all the particles

Notes

What internal energy is

- Energy is stored inside a system by the particles (atoms and molecules) that make it up. This is its **internal energy**.
- Internal energy = the **total kinetic energy and potential energy** of **all** the particles in the system.
- **Kinetic energy**: the particles are always moving (vibrating in a solid, moving around in a liquid or gas). Faster particles have more kinetic energy.
- **Potential energy**: energy stored because of the forces between the particles. It depends on how far apart the particles are. For the same substance, the particles have more potential energy as a liquid than as a solid, and more again as a gas.



kinetic energy:
the particles move

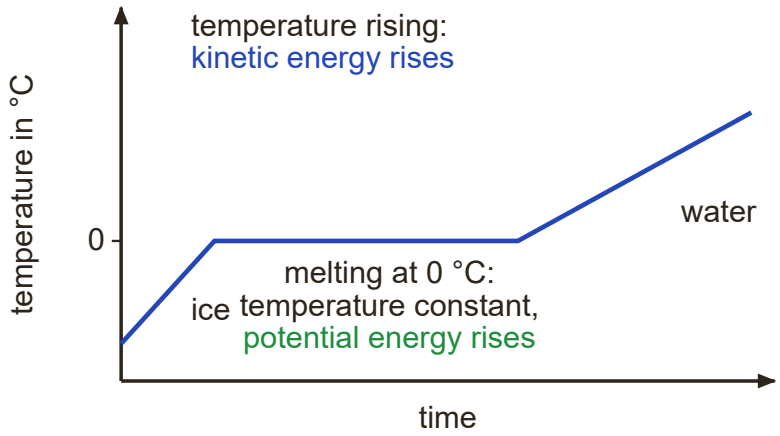
potential energy:
forces between particles
(depends on spacing)

internal energy = total kinetic energy + potential energy of all the particles

Internal energy = kinetic energy + potential energy of all the particles.

Heating a system

- Heating transfers energy to a system. This increases the energy of its particles, so the internal energy of the system increases.
- The energy does one of two things. It **raises the temperature** (the kinetic energy of the particles increases), or it produces a **change of state** (the potential energy of the particles increases as the forces between them are overcome).
- While a substance is changing state, its temperature stays constant even though energy is still being supplied.



Heating raises the internal energy all the time; during melting the temperature stays constant.

- Cooling does the opposite: energy is transferred away from the system, so its internal energy decreases.

Temperature is not the same as internal energy

- **Temperature** is linked to the **average** kinetic energy of the particles.
- Internal energy is the **total** energy of all the particles, so it also depends on how many particles there are (the mass) and on the state.
- Example: a swimming pool at 25 °C has far more internal energy than a cup of tea at 80 °C, because it contains vastly more particles.

How to answer each type of question

Define internal energy

1 to 2 marks | **Grade 4**

1. Say 'the total kinetic energy and potential energy'.
2. Say 'of all the particles (atoms and molecules) in the system'.

Example. What is meant by the internal energy of a system?

Model answer. The total kinetic energy and potential energy (1) of all the particles (atoms and molecules) that make up the system (1).

Describe and explain the effect of heating

2 to 3 marks | Grade 5

1. Say what happens to the internal energy (it increases).
2. Say which energy of the particles changes: kinetic energy if the temperature rises, potential energy if the state changes.
3. Finish with the result: the temperature rises, or the substance changes state.

Example. A pan of water at 20 °C is heated on a hob.
Describe what happens to the internal energy of the water, and explain how this affects the water particles and the temperature.

Model answer. The internal energy of the water increases (1). The water particles gain kinetic energy / move faster on average (1), so the temperature of the water rises (1).

Compare the internal energy of two objects

2 marks | Grade 6

1. Compare the temperatures: the same temperature means the same average kinetic energy per particle.
2. Compare the masses: more mass means more particles, so more total energy.

Example. Beaker A contains 200 g of water at 60 °C. Beaker B contains 800 g of water at 60 °C.
Explain which beaker of water has the greater internal energy.

Model answer. Beaker B (1). The water in both beakers is at the same temperature, but B contains four times as many particles, so the total kinetic and potential energy of all its particles is greater (1).

Explain why the temperature is constant during a change of state

3 marks | Grade 5

1. Say that energy is still being transferred, so the internal energy increases.
2. Say that the energy overcomes the forces between the particles, increasing their potential energy.
3. Say that the kinetic energy of the particles does not change, so the temperature stays the same.

Example. Some ice at 0 °C is heated. The ice melts, but its temperature stays at 0 °C until all the ice has melted.
Explain, in terms of internal energy, why the temperature does not change while the ice is melting.

Model answer. Energy is still being transferred to the ice, so its internal energy increases (1). This energy overcomes the forces between the particles, increasing their potential energy (1). The kinetic energy of the particles does not increase, so the temperature stays the same (1).

Don’t lose marks

- ✕ Defining internal energy as 'heat' or 'the temperature'. It is the total kinetic and potential energy of all the particles.
- ✕ Leaving potential energy (or kinetic energy) out of the definition.

- Saying the temperature rises during melting or boiling. It stays constant while the state changes.
- Saying that a hotter object always has more internal energy. Internal energy also depends on the mass (number of particles) and the state.

More tips

Memory tricks

- Internal energy = kinetic + potential energy of ALL the particles. The words 'total' and 'all' earn the marks.
- Temperature rising → kinetic energy of the particles increasing. State changing → potential energy of the particles increasing.
- Temperature is an average per particle; internal energy is a total for all the particles. A warm swimming pool beats a hot cup of tea.

Exam technique

- Definitions are marked strictly: learn the full wording, including 'of all the particles'.
- In 'explain' questions, go step by step: energy transferred → internal energy increases → which energy of the particles changes → what happens to the temperature or the state.
- When the question says 'in terms of particles', write about the particles (atoms or molecules), not just 'the substance'.

What each grade needs

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

Grade 3 — **State that heating increases the particles' energy**
Heating a system transfers energy to its particles, so the energy they store increases.

Grade 4 — **Define internal energy**
The total kinetic energy and potential energy of all the particles (atoms and molecules) that make up a system.

Grade 5 — **State the two possible effects of heating**
Heating either raises the temperature of the system or produces a change of state.

Grade 5 — **Link temperature to the particles' kinetic energy**
A higher temperature means the particles have a higher average kinetic energy: they move or vibrate faster.

Grade 5 — **Explain energy changes during a change of state**
The energy supplied increases the potential energy of the particles, so internal energy rises but the temperature does not.

Grade 6 — **Explain how temperature differs from internal energy**
A large mass at a low temperature can have more internal energy than a small mass at a high temperature, because it has many more particles.

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