# Existence of water in all three states on Earth's surface and the significance of H-bonding.

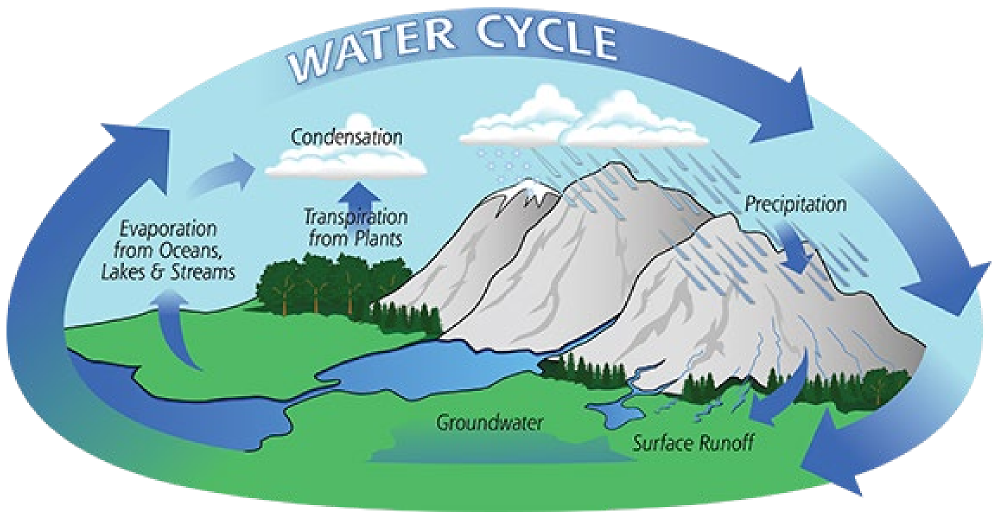


Image from NASA – water cycle

Water is a unique substance as it is the only substance that exists naturally in all three physical states, solid, liquid and gas at surface temperatures and pressures on Earth. Water has relatively high melting and boiling points for such a small molecule. This is a direct consequence of the strong hydrogen bonding between water molecules.

The ability of water to transition easily between all three states under normal Earth conditions drives the water cycle, enabling the continuous movement of water between the oceans, land and atmosphere.

Although water is abundant on Earth's surface, the vast majority is not directly available for human use. A huge percentage, 97%, of the water on the surface is undrinkable and found in the oceans and seas. The remaining is fresh water trapped in the form of ice in glaciers and ice caps, underground and in rivers and lakes. It is the water in rivers and lakes that provides the fresh water resource for life to exist on Earth's surface. This is a very scarce and precious resource as less than 0.1% of total water is usable fresh water.

Hydrogen bonding not only allows water to exist in three states but in doing so enables water to perform three critical functions.

1. Enable the existence of liquid water over a wide temperature range.
2. Enables evaporation and condensation to transfer large amounts of energy (latent heat).
3. As a direct result of point 2 above, supports climate regulation and life.

# Heat Capacity vs Latent Heat (VCE Chemistry - Year 11)

When thermal energy is added to a substance, it can be used in two different ways by the particles of that substance. It can be used to:

- increase temperature (particle kinetic energy increases). This is known as the Specific Heat Capacity of the substance.
- change state (intermolecular forces are overcome)

## 1. Heat Capacity (Specific Heat Capacity)

Specific heat capacity is the amount of energy required to raise the temperature of 1 g of a substance by 1 °C.

- Temperature changes
- No change of state
- Energy increases average kinetic energy of particles
- Units: $J\ g^{-1}\ °C^{-1}$

Formula:
$q = mc\Delta T$, where m is the mass in grams, c is the unique heat capacity of the substance and $\Delta T$ is the change in temperature in $^{0}C$.

## 2. Latent Heat

Latent heat is the energy required to change the state of a substance without changing its temperature.

- Temperature remains constant
- A phase change occurs
- Energy is used to overcome intermolecular forces
- Units: $J\ g^{-1}$

Types:
- Latent heat of fusion (solid ⇌ liquid)
- Latent heat of vaporisation (liquid ⇌ gas)

## Temperature–Phase Change Diagram (Heating Curve)

A temperature–phase change diagram (heating curve) shows how the temperature of a substance changes as energy is added.

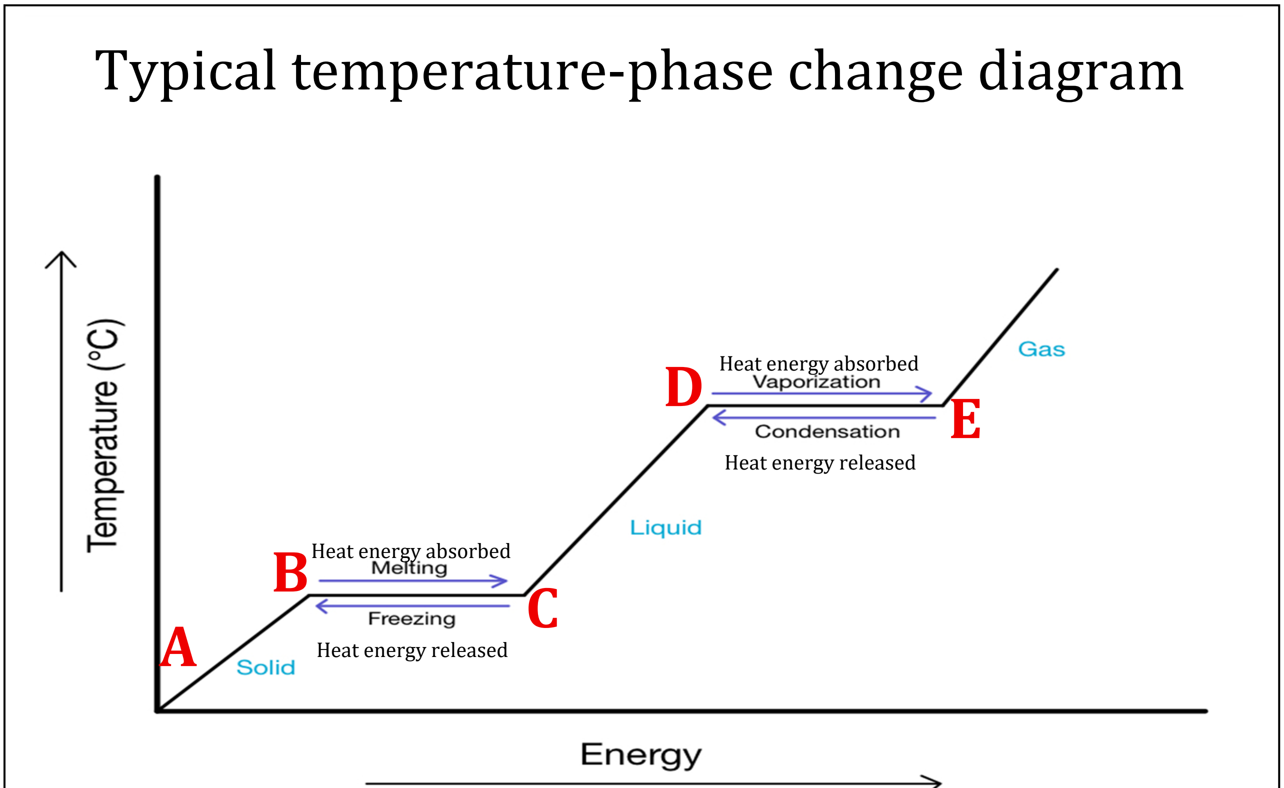


Figure 1 – phase-change diagram

Segment explanations of the phase-change vs temperature diagram in Figure 1

A → B: Solid warming up (heat capacity)

B → C: Melting at constant temperature (latent heat of fusion)

C → D: Liquid warming up (heat capacity)

D → E: Boiling at constant temperature (latent heat of vaporisation)

## In Summary

Heat capacity involves a temperature change with no change of state, while latent heat involves a change of state at constant temperature.

# The chemistry of water’s Climate stabilisation

interesting link – Human impact on the water cycle.

Water cycle

Water plays a critical role in stabilising Earth’s climate due to its high specific heat capacity and high latent heat of vaporisation, both of which arise from strong hydrogen bonding between water molecules. Hydrogen bonds are relatively strong intermolecular forces that must be overcome when water molecules gain energy. As a result, when water absorbs thermal energy, much of this energy is used to weaken hydrogen bonds rather than directly increasing the kinetic energy of the molecules, thus increasing temperature. This means that water can absorb large amounts of energy with only a small increase in temperature.

Because the oceans contain vast quantities of water, they act as a major thermal buffer for the planet. During periods of high solar input, the oceans absorb heat without warming rapidly, preventing extreme increases in atmospheric temperature. Conversely, when surrounding air temperatures decrease, the oceans slowly release stored heat, moderating cooling. This reduces both daily and seasonal temperature variations, particularly in coastal regions.

Water also stabilises climate through its latent heat of vaporisation. When water evaporates from the ocean surface, it absorbs a large amount of energy while remaining at constant temperature. This energy is stored as latent heat in water vapour and transported through the atmosphere. When condensation occurs, hydrogen bonds reform and the stored energy is released, warming the surrounding air. This process redistributes thermal energy globally and drives atmospheric circulation and weather systems.

Together, water's molecular structure and intermolecular forces enable it to store, transport, and release large quantities of thermal energy, making it essential for maintaining relatively stable and life-supporting global climates.

## Short answer questions

1. Using values from item 3, page 4, of the Data Booklet, define and give one example using correct units of the following terms.

- Specific heat capacity.

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______________________________________________________________________________2 marks

- Latent heat of vaporisation.of water at 100$^{o}$C

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2. Using water as an example, explain why temperature does not change as water changes from ice to liquid.

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3. Given the latent heat of fusion of ice is 344 kJ/kg and the specific heat of ice is 2.1 kJ/kg, calculate the energy, in kJ, needed to liquefy 100 grams of ice at -25 $^{o}$C, assuming no evaporation of the sample takes place.

*3 marks*

4. Using item 3, page 4, of the Data Booklet, calculate the energy, in kJ, required to heat 50.0 g of water from 20.0 °C to 30.0 °C. *3 marks*

5. 1200 Joules of heat energy increases the temperature of an unknown mass of water by 50.0 $^{o}$C Given that no water is lost through evaporation calculate the mass of the water in grams. *2 marks*

6. Calculate the amount of energy required to vaporise 100 gram of water at 10$^{o}$C.

*4 marks*

7. Why does water require more energy to raise its temperature compared with other molecules of similar size?

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8. Why does temperature remain constant during boiling?

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_____________________________________________________________________ *2 marks*

9. Using item 3 of the Data Booklet, calculate the final temperature of 10.0 grams of water at 25 $^{o}$C if 0.400 kJ of energy was delivered through an electric current. Assume no energy loss to the environment. *3 marks*

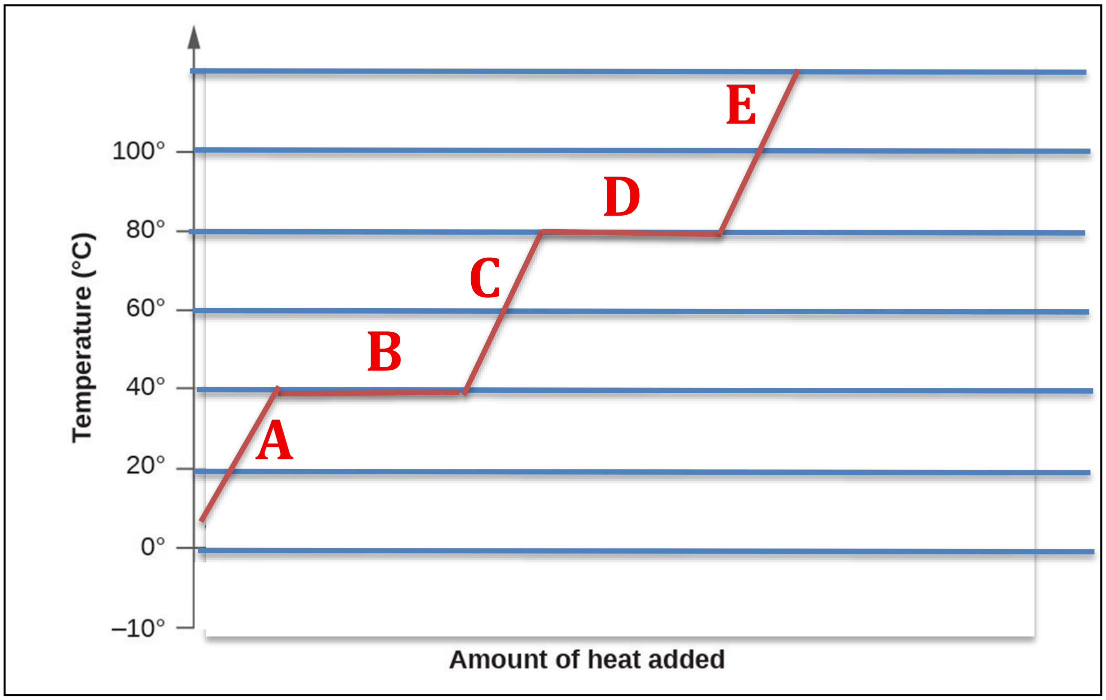


Figure 2 – Phase-change diagram of an unknown substance.

10. Identify which parts of the phase-change curve, figure 2, can apply to the formula Energy = $mc\Delta T$? Explain your answer.

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11. Identify which parts of the phase change curve in figure 2, apply to the formula Energy = mass X Latent heat.

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12. Using your knowledge of chemistry, explain why Melbourne, a coastal city, has a more moderate climate with smaller temperature variations than the climate of Alice Springs?

Average Daily Temperature Variation (°C)

| Month | Melbourne | Alice Springs |
|---|---|---|
| January | 11.6 °C | 18.5 °C |
| February | 11.3 °C | 18.0 °C |
| March | 10.6 °C | 16.8 °C |
| April | 9.5 °C | 13.9 °C |

Figure 3 – Ayers Rock near Alice Springs

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*4 marks*

13. Water has an unusually high specific heat capacity and latent heat of vaporisation for a molecule of its size. Explain how these properties arise and how they support the survival of aquatic life.

*4 marks*