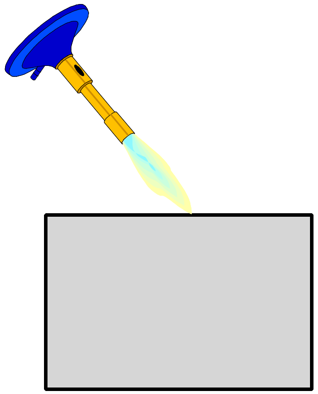
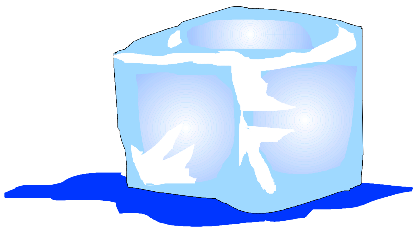
National 5 Physics

"PROPERTIES OF MATTER"



'Specific Heat Capacity'

'Specific Latent Heat'



This section of the "Properties of Matter" unit initially defines the 'temperature' of a substance as 'a measure of the mean (average) kinetic energy of all its particles'. It then defines 'heat' as 'a form of energy that moves from places at higher temperature to places at lower temperature'.

It is explained that 'different materials need different quantities of heat energy to raise the temperature of 1 kg of them by 1 °C'.

The 'specific heat capacity' of a material is defined as 'the quantity of heat energy 1 kg of the material needs to absorb or emit in order to increase or decrease its temperature by 1 °C'.

Problems involving 'heat energy' and the 'mass', 'temperature change' and 'specific heat capacity' of a material using the formula $E_h = c\,m\,\Delta T$ are then introduced.

It is then explained that, 'when a material changes its physical state, its temperature does not change'.

This is followed by the statement that 'different materials need different quantities of heat energy to change the physical state of 1 kg of them'.

The 'specific latent heat' of a material is defined as 'the quantity of heat energy 1 kg of the material needs to absorb or emit in order to completely change its physical state without any change in its temperature'.

The terms 'specific latent heat of fusion' and 'specific latent heat of vaporisation' are introduced.

This is followed by the statement that 'at the appropriate temperatures, the same material requires to absorb different quantities of heat energy to change 1 kg of it from solid to liquid than it does to change 1 kg of it from liquid to vapour (gas)'.

Problems involving 'heat energy' and the 'mass' and 'specific latent heat' of a material using the formula $E_h = m\,l$ are then introduced.

Name: ______________________________

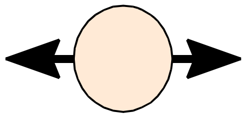
TEMPERATURE

The particles in any substance have **kinetic energy** - they are continuously vibrating and/or move around, depending on the physical state of the substance

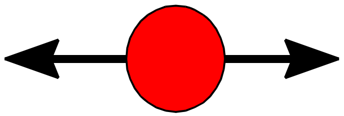
The temperature of a substance is a measure of the mean (average) kinetic energy of all its particles.

THE VIBRATION OF PARTICLES IN SOLIDS, LIQUIDS AND GASES

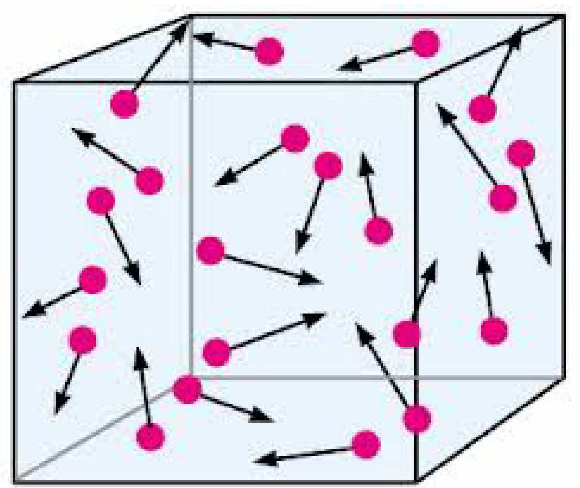
Lower Temperature - Less Particle Vibration. Less kinetic energy.



Higher Temperature - Greater Particle Vibration. Greater kinetic energy.



THE MOVEMENT OF PARTICLES IN A GAS

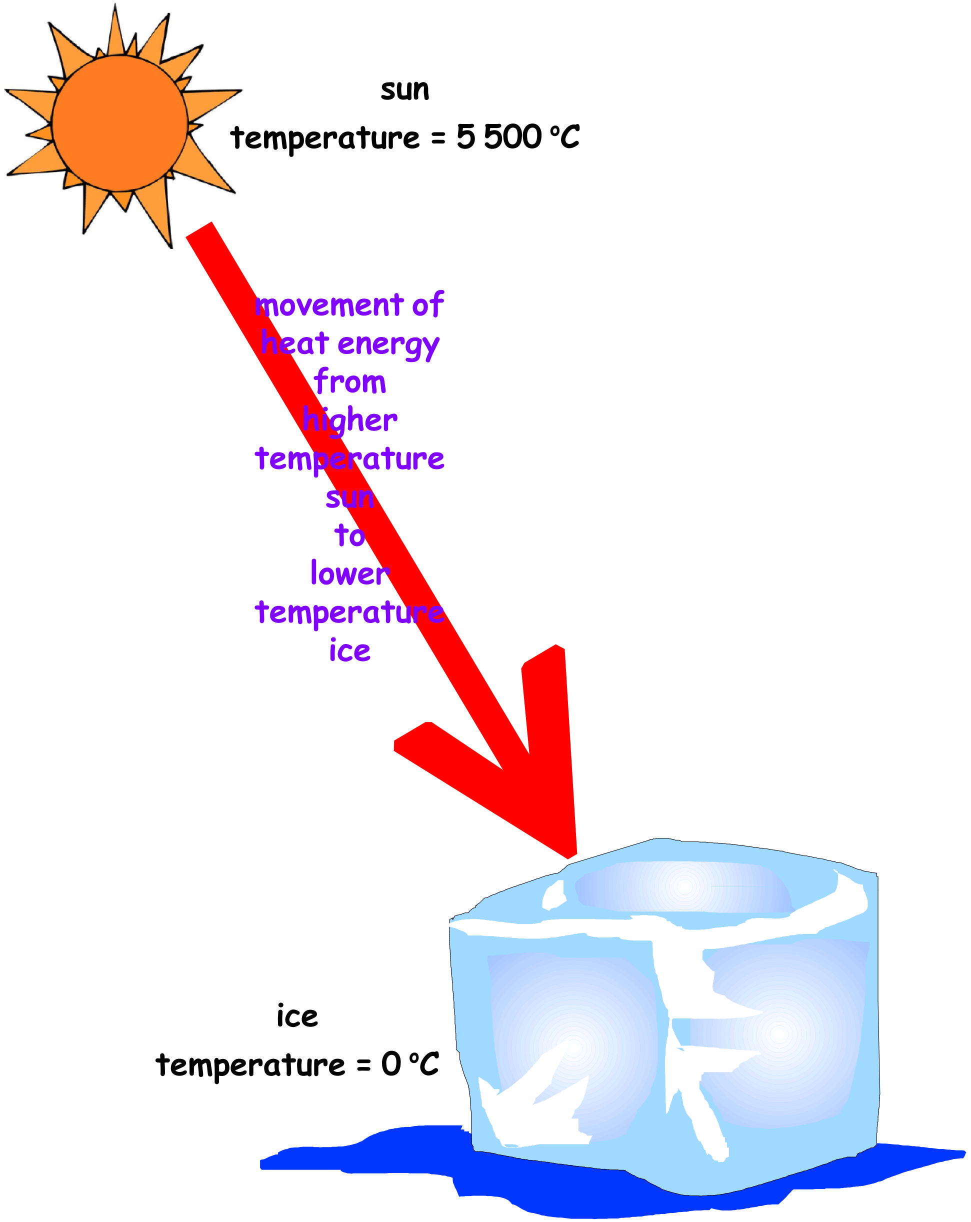


Gas particles move around freely in all directions -the higher the temperature of the gas, the faster the gas particles move. i.e., the greater their kinetic energy.

Temperature is often measured in units of degrees Celsius (°C).

HEAT ENERGY

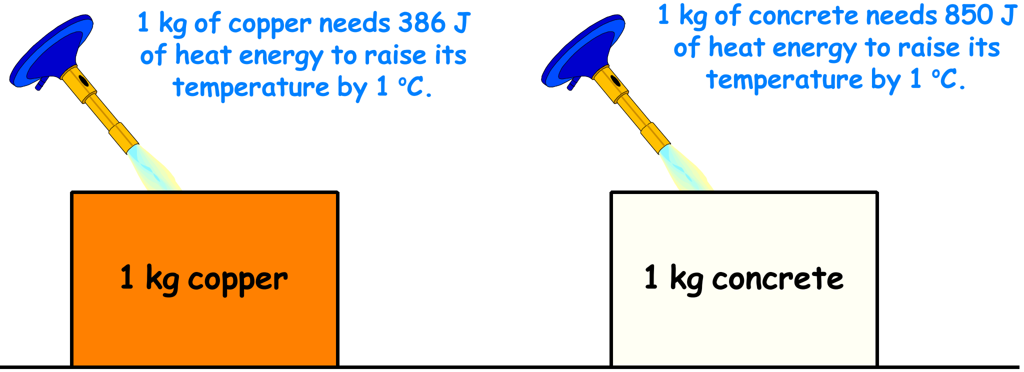
Heat is a form of energy that moves from places at higher temperature to places at lower temperature.



SPECIFIC HEAT CAPACITY

Different materials need different quantities of heat energy to raise the temperature of 1 kg of them by 1 °C.

For example:



The specific heat capacity of a material is the quantity of heat energy 1 kg of the material needs to absorb or emit in order to increase or decrease its temperature by 1 °C.

Each material has a different value of specific heat capacity. Some values are shown in this table:

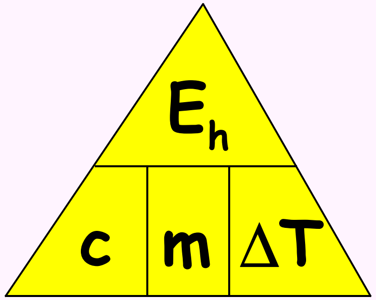
material	specific heat capacity
alcohol	2 350 J kg^{-1} °C^{-1}
aluminium	902 J kg^{-1} °C^{-1}
concrete	850 J kg^{-1} °C^{-1}
copper	386 J kg^{-1} °C^{-1}
glass	500 J kg^{-1} °C^{-1}
water	4 180 J kg^{-1} °C^{-1}

The relationship below applies to any material, so long as it does not melt, freeze, evaporate or condense while heat energy is being absorbed by it or emitted from it:

$$E_h = c\ m\ \Delta T$$

- E_h – heat energy absorbed by [or emitted from] material (J)
- c – specific heat capacity of material (J kg^{-1} °C^{-1})
- m – mass of material (kg)
- ΔT – change in temperature of material (°C)

We assume that during the process of heat absorption, a material does not emit any heat (and that during the process of heat emission, a material does not absorb any heat.)



$E_h = c\,m\,\Delta T$

$c = E_h/(m\,\Delta T)$

$m = E_h/(c\,\Delta T)$

$\Delta T = E_h/(c\,m)$

Worked Examples:

The temperature of a 0..5 kg block of copper **increases** from 20 °C to 25 °C.

Calculate the quantity of heat energy the copper must **absorb** to cause this

For copper, c = 386 J kg^{-1} °C^{-1}

ΔT = 25 - 20 = 5 °C increase

$E_h = c\ m\ \Delta T$

$= 386 \times 0.5 \times 5$

= <u>965 J</u>

The temperature of a 1.5 kg block of glass **decreases** from 30 °C to 22 °C.

Calculate the quantity of heat energy the glass must **emit** to cause this temperature **decrease**.

For glass, c = 500 J kg^{-1} °C^{-1}

ΔT = 30 - 22 = 8 °C decrease

$E_h = c\ m\ \Delta T$

$= 500 \times 1.5 \times 8$

= <u>6 000 J</u>

Using the values for specific heat capacity given in the table on page 3 of this booklet to perform the following calculations:

1) The temperature of 0.15 kg of alcohol <u>increases</u> from 18 °C to 22 °C.

Calculate the quantity of heat energy the alcohol must have absorbed to cause this temperature increase.

2) The temperature of 0.25 kg of aluminium <u>increases</u> from 2 °C to 10 °C.

Calculate the quantity of heat energy the aluminium must have absorbed to cause this temperature increase.

3) The temperature of 50 kg of concrete <u>increases</u> from -5 °C to 15 °C.

Calculate the quantity of heat energy the concrete must have absorbed to cause this temperature increase.

4) The temperature of 65 kg of copper <u>increases</u> from -2 °C to 25 °C.

Calculate the quantity of heat energy the copper must have absorbed to cause this temperature increase.

5) The temperature of 0.03 kg of glass <u>decreases</u> from 15 °C to 8 °C.

Calculate the quantity of heat energy the glass must have emitted to cause this temperature decrease.

6) The temperature of 0.95 kg of water <u>decreases</u> from 80 °C to 25 °C.

Calculate the quantity of heat energy the water must have emitted to cause this temperature decrease.

7) The temperature of 1.2 kg of alcohol <u>decreases</u> from 62 °C to -1 °C.

Calculate the quantity of heat energy the alcohol must have emitted to cause this temperature decrease.

8) The temperature of 90 kg of aluminium <u>decreases</u> from 6 °C to -8 °C.

Calculate the quantity of heat energy the aluminium must have emitted to cause this temperature decrease.

9) 0.50 kg of a liquid absorbs 31 350 J of heat energy when its temperature increases from 0 °C to 15 °C.

Calculate the specific heat capacity of the liquid.

10) 3 150 J of heat energy is emitted by 1.8 kg of a solid as its temperature decreases from 2 °C to -1.5 °C.

Calculate the specific heat capacity of the solid.

11) The temperature of 2.2 kg of a liquid increases from 5 °C to 15 °C as it absorbs 46 530 J of heat energy.

Calculate the specific heat capacity of the liquid.

12) When a concrete slab emits 318 750 J of heat energy, its temperature falls from 25 °C to -5 °C.

Calculate the mass of the concrete slab.

13) The temperature of a copper block increases from 20 °C to 64 °C as it absorbs 25 476 J of heat energy.

Calculate the mass of the copper block.

14) A glass ornament's temperature falls from 22.2 °C to 17.8 °C as 2 310 J of heat energy is emitted from it.

Calculate the mass of the glass ornament.

15) The temperature of 0.45 kg of water increases as it absorbs 13 167 J of heat energy.

Calculate the increase in temperature of the water.

16) 0.95 kg of alcohol emits 80 370 J of heat energy while its temperature decreases.

Calculate the decrease in temperature of the alcohol.

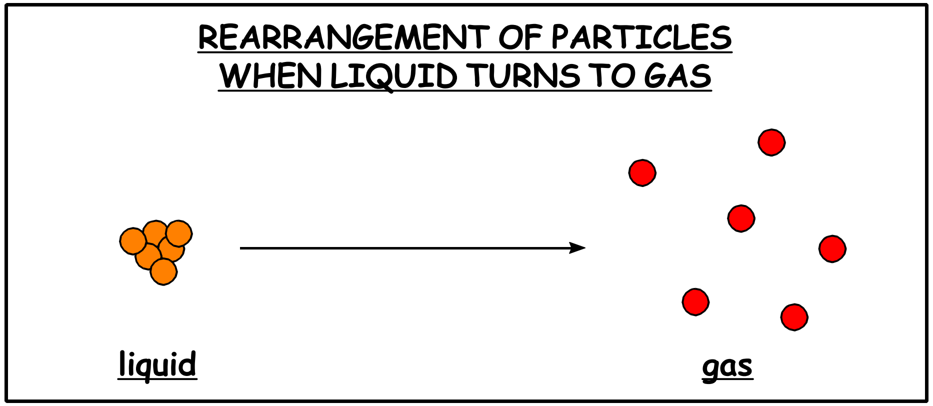
17) The temperature of an aluminium metal sheet of mass 19 kg increases as it absorbs 77 121 J of heat energy.

Calculate the temperature increase of the aluminium metal sheet.

SPECIFIC LATENT HEAT

When a material melts, freezes, evaporates or condenses, we say it is changing its physical state.

When melting, freezing, evaporating or condensing takes place, the temperature of the material does not change - instead, any energy absorbed or emitted by the material causes a rearrangement of the particles in the material.
For example:



For a substance to melt or evaporate, it must absorb heat energy.

For a substance to freeze or condense, it must emit heat energy.

In these circumstances, any heat energy absorbed or emitted is known as **latent heat**.

Different materials need different quantities of heat energy to change the physical state of 1 kg of them.

The specific latent heat of a material is the quantity of heat energy 1 kg of the material needs to absorb or emit in order to completely change its physical state without any change in its temperature.

If a material is changing its physical state from solid to liquid (or vice versa), the term **specific latent heat of fusion** is used.

If a material is changing its physical state from liquid to vapour [gas] (or vice versa), the term **specific latent heat of vaporisation** is used.

At the appropriate temperatures, the same material requires to absorb different quantities of heat energy to change 1 kg of it from solid to liquid than it does to change 1 kg of it from liquid to vapour (gas).

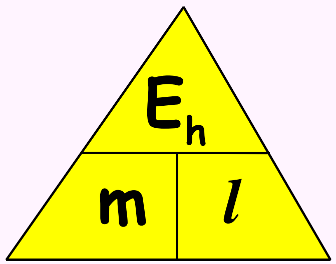
This is illustrated by comparing **specific latent heat** values. For example:

- specific latent heat of fusion of water = 3.34×10^5 J kg^{-1}.
- specific latent heat of vaporisation of water = 22.6×10^5 J kg^{-1}.

The relationship below applies to any material that is changing its physical state without any change in its temperature:

$$E_h = m\,l$$

- E_h — heat energy absorbed by [or emitted from] material (J)
- m — mass of material (kg)
- l — specific latent heat of fusion [or vaporisation] of material (J kg^{-1})



$E_h = m\,l$

$m = E_h / l$

$l = E_h / m$

18) A lead fishing weight of mass 0.015 kg has reached its melting point temperature.

Calculate the quantity of heat energy the lead fishing weight must absorb in order to change its physical state completely from solid to liquid.

[specific latent heat of fusion of lead = 0.25×10^{5} J kg^{-1}]

19) A copper block of mass 0.85 kg is at its melting point temperature.

Calculate the quantity of heat energy the copper block must absorb in order to change its physical state completely from solid to liquid.

[specific latent heat of fusion of copper = 2.05×10^{5} J kg^{-1}]

20) A sample of liquid water, mass 1.2 kg, has reached its freezing point temperature.

Calculate the quantity of heat energy the water sample must emit in order to change its physical state completely from liquid to solid ice.

[specific latent heat of fusion of water = 3.34×10^{5} J kg^{-1}]

21) A 500 kg volume of molten (liquid) aluminium is at the temperature where it can solidify.

Calculate the quantity of heat energy the aluminium must emit in order to change its physical state completely from liquid to solid.

[specific latent heat of fusion of aluminium = 3.95×10^{5} J kg^{-1}]

22) A sample of liquid turpentine, mass 1.4 kg, has reached its boiling point temperature.

Calculate the quantity of heat energy the liquid turpentine sample must absorb in order to change its physical state completely from liquid to vapour (gas).

[specific latent heat of vaporisation of turpentine = 2.90×10^{5} J kg^{-1}]

23) A sample of liquid alcohol of mass 0.92 kg has reached its boiling point temperature.

Calculate the quantity of heat energy the liquid alcohol sample must absorb in order to change its physical state completely from liquid to vapour (gas).

[specific latent heat of vaporisation of alcohol = 11.2×10^{5} J kg^{-1}]

24) A 0.36 kg sample of water vapour (steam) has reached its condensing point temperature.

Calculate the quantity of heat energy the water vapour sample must emit in order to change its physical state completely from vapour (gas) to liquid water.

[specific latent heat of vaporisation of water = 22.6×10^{5} J kg^{-1}]

25) 1.75 kg of glycerol vapour has reached its condensing point temperature.

Calculate the quantity of heat energy the glycerol vapour must emit in order to change its physical state completely from vapour (gas) to liquid.

[specific latent heat of vaporisation of glycerol = 8.30×10^{5} J kg^{-1}]

26) A lead pendulum bob has reached its melting point temperature.

In order to change its physical state completely from solid to liquid, the lead must absorb 8 000 J of heat energy.

Calculate the mass of the lead pendulum bob..

[specific latent heat of fusion of lead = 0.25×10^5 J kg^{-1}]

28) A sample of liquid alcohol has reached its freezing point temperature.

In order to change its physical state completely from liquid to solid, the alcohol must emit 173 250 J of heat energy.

Calculate the mass of the alcohol sample.

[specific latent heat of fusion of alcohol = 0.99×10^5 J kg^{-1}]

27) A copper casting is at its melting point temperature.

In order to change its physical state completely from solid to liquid, the copper must absorb 86 100 J of heat energy.

Calculate the mass of the copper casting.

[specific latent heat of fusion of copper = 2.05×10^5 J kg^{-1}]

29) A liquid water sample is at its freezing point temperature.

In order to change its physical state completely from liquid to solid ice, the water must emit 718 100 J of heat energy.

Calculate the mass of the water sample.

[specific latent heat of fusion of water = 3.34×10^5 J kg^{-1}]

30) A sample of liquid glycerol, mass 0.65 kg, has reached its boiling point temperature.

In order to change its physical state completely from liquid to vapour (gas), the glycerol must absorb 539 500 J of heat energy.

Calculate the specific latent heat of vaporisation of glycerol.

32) A 1.15 kg sample of alcohol vapour has reached its condensing point temperature.

In order to change its physical state completely from vapour (gas) to liquid, the alcohol must emit 1 288 000 J of heat energy.

Calculate the specific latent heat of vaporisation of alcohol.

31) A sample of liquid turpentine of mass 0.95 kg is at its boiling point temperature.

In order to change its physical state completely from liquid to vapour (gas), the turpentine must absorb 275 500 J of heat energy.

Calculate the specific latent heat of vaporisation of turpentine.

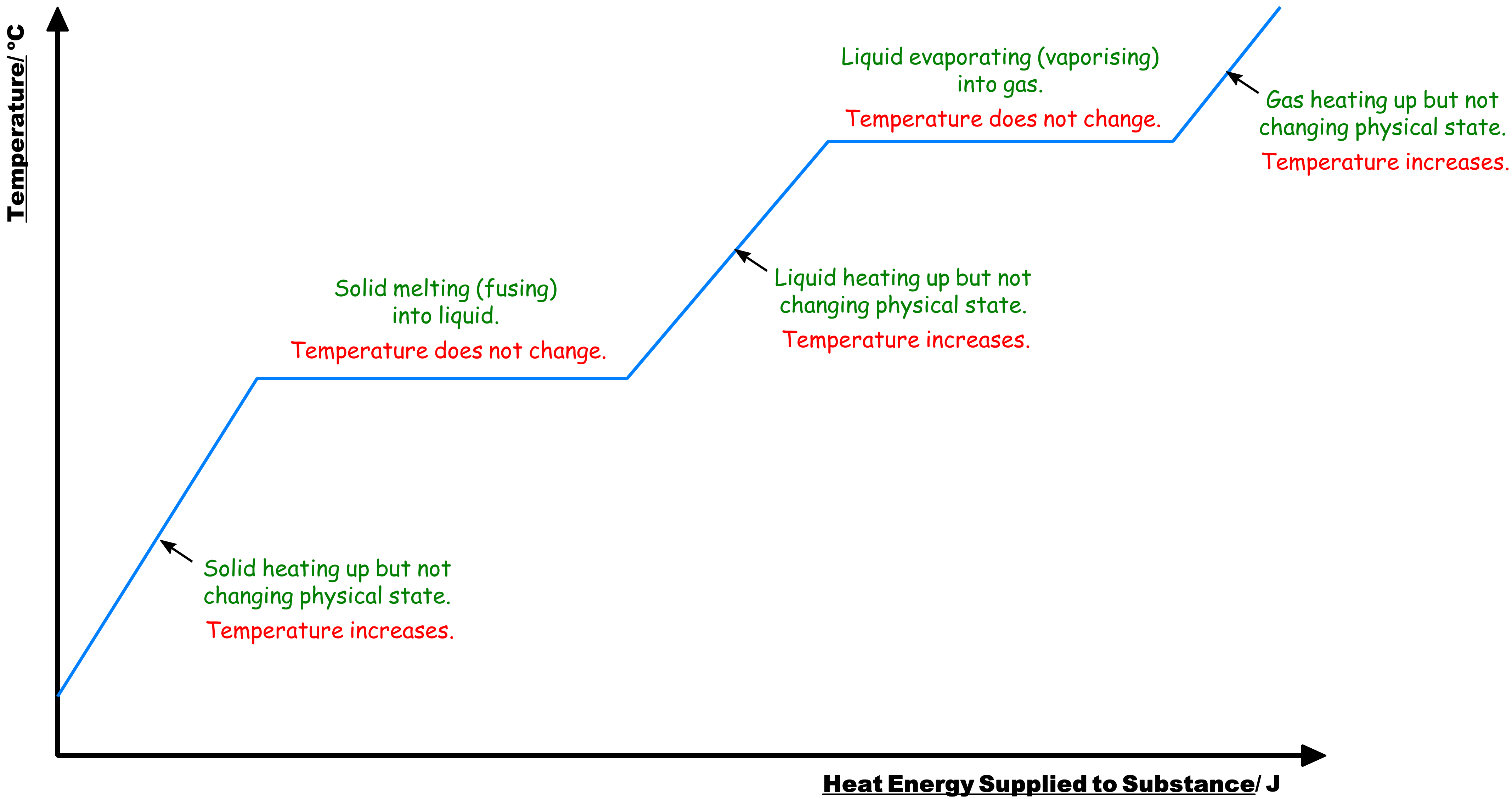
33) 4.25 kg of water vapour is at its condensing point temperature.

In order to change its physical state completely from vapour (gas) to liquid water, the water must emit 9 605 000 J of heat energy.

Calculate the specific latent heat of vaporisation of water.

Temperature-Heat Energy Graph

This is a typical graph showing how the **temperature** of a **solid substance** changes as **heat energy** is supplied to it:



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