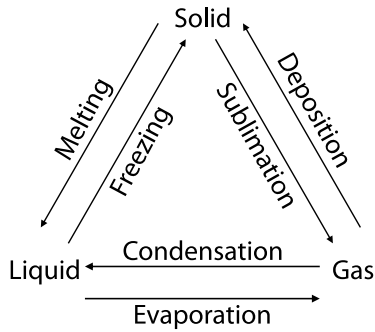
31 Latent Heat



The three most commonly encountered states of matter are solids, liquids and gases.

When a substance changes state, it does not change temperature but thermal energy is still transferred.

The energy needed to change the state of a substance is called latent heat.

Specific latent heat of fusion, L, is the energy transferred from 1 kg of a substance changing from liquid to solid at a constant pressure. [unit: J/kg]

Specific latent heat of vaporisation is the energy transferred to 1 kg of a substance changing from liquid to gas at a constant pressure.

Equation:

thermal energy transferred for a change of state $=$ mass $\times$ specific latent heat

$$Q = mL$$

	Latent heat of fusion	Latent heat of vaporisation
Melting	Energy gained by substance	—
Freezing	Energy lost to surroundings	—
Evaporating	—	Energy gained by substance
Condensing	—	Energy lost to surroundings

Example – The specific latent heat of fusion of ice is 3.36×10^5 J/kg. How much thermal energy is transferred to melt 2.00 kg of ice?
$Q = mL = 2.00 \times 336\,000 = 672\,000$ J $= 672$ kJ

31.1 Work out the missing measurements from the following table.

Q	m	L
8.38 MJ	(a)	838 000 J/kg
251 kJ	0.75 kg	(b)
(c)	100 g	449 000 J/kg
740 mJ	10.0 mg	(d)
1.09 MJ	(e)	199 000 J/kg

31.2 A student measures 250 g of water and pours it into a beaker. They boil the water over a Bunsen burner for five minutes, then measure the mass of the water again; this time it is 200 g. The specific latent heat of vaporisation of water is 2 260 kJ/kg. How much energy has been transferred in evaporating the water?

31.3 Pure water boils at 100 °C, has a specific latent heat of vaporisation of 2 260 kJ/kg and a specific heat capacity of 4 200 J/(kg K).

(a) How much energy is required to boil away 2.0 kg of water if it is already at 100 °C?

(b) How much energy is required if the water started at 40 °C? *[Hint: you need to use the heat capacity of water to work out the energy needed to raise the temperature of the water – see section 30 on page 91.]*

31.4 1 000 kg of steam is condensed back to water in the condenser of a power station each hour. The specific latent heat of vaporisation of water is 2 260 kJ/kg. Calculate the energy output to the environment this causes each second.

31.5 A typical fluid used in a fridge has a latent heat of vaporisation of 200 kJ/kg. The fluid needs to remove 30 J from the fridge each second, and it does this by boiling alone. Calculate the minimum mass of fluid which must flow through the fridge each second.

31.6 How much energy would be required to enable 5.0×10^{-3} kg of ethanol to evaporate? The specific latent heat of vaporisation of ethanol is 840 kJ/kg.

31.7 A sample of solid ethanoic acid is at its melting point of $17.0\ ^\circ$C. It has a specific latent heat of fusion of $192\,000$ J/kg. How much ethanoic acid can be melted with 864 kJ of thermal energy?

31.8 Liquid nitrogen boils at $-196\ ^\circ$C. 40.0 kg of liquid nitrogen in a dewar flask completely evaporates when 7.96 MJ of thermal energy is transferred. What is its latent heat of vaporisation?

31.9 A 1000 W heater is placed in an insulated beaker containing 750 g of water at $100\ ^\circ$C. The water vapour is allowed to escape. Assume that there is no loss to the surroundings via conduction, convection or radiation. The specific latent heat of vaporisation of water is $2\,260$ kJ/kg.

(a) How much water is left after 5.0 minutes?

(b) How long will it take for half of the water to have evaporated?