Thermal Physics

- Heat
- Temperature
- Specific Heat Capacity
- Specific Latent Heat

- Key words: heat energy, temperature, specific
- heat capacity

- By the end of this lesson you will be able
- to:
- Describe and explain the terms heat
- energy and temperature.
- State that the same mass of different
- materials needs different quantities of
- heat energy to change their temperature
- by one degree celsius.
- Carry out calculations involving specific
- heat capacity.

Heat and temperature

- Are heat and temperature the same thing? How would you explain to someone else the difference between the two?

- Can you use a thermometer to measure heat?

- What are thermometers used for?

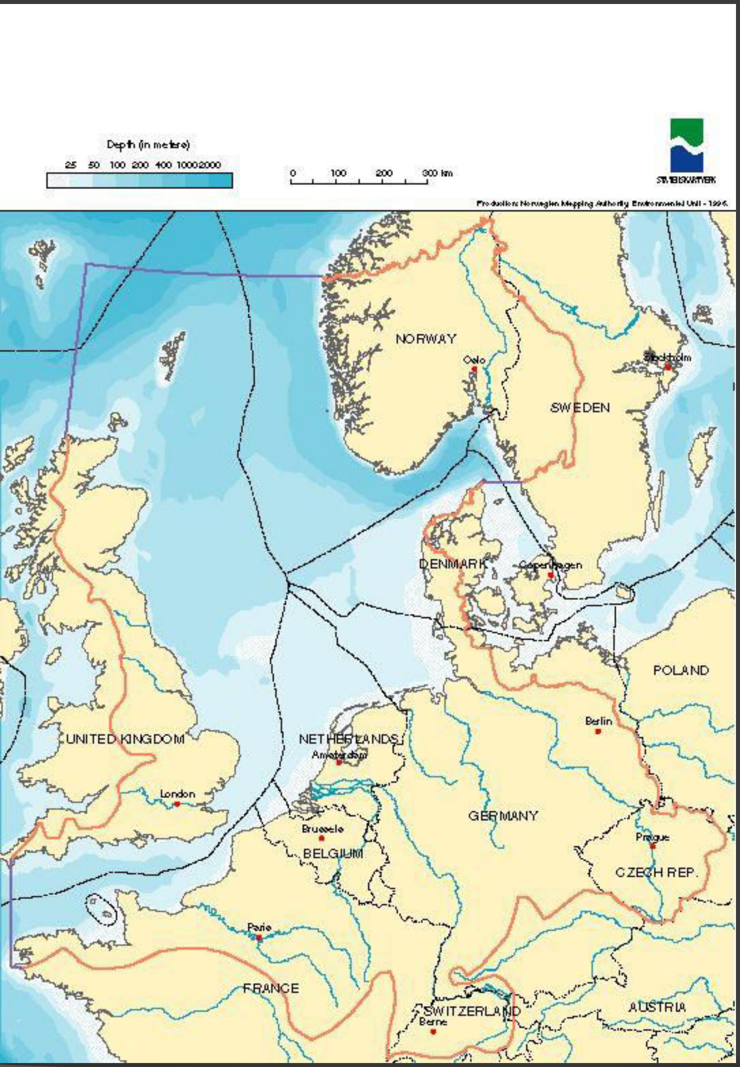
This cup of coffee has been made from freshly boiled water.
Temperature?
Heat?

Both cups of coffee have been made from freshly boiled water (twice as much water has been used)

Heat?

Temperature?

Which is hotter…
and which contains more heat?



Heat

- Heat is a form of energy.
- It is a scalar quantity.
- It is measured in joules (J).

Temperature

- Temperature is an indication of
- how hot or cold an object is.

- It is a scalar quantity.

- It is measured in degrees celsius (°C).

What happens when we heat a substance?

Virtual Int 2 Physics – Mechanics & Heat – Heat - Introduction

When we heat the air in a room, the kinetic energy of the molecules increases. The air molecules move faster.

When we heat snow, the vibration of the molecules increases and it eventually melts.

When we heat water, the molecules vibrate faster.

What happens when we heat a substance?

When we heat a substance it

becomes hotter

or changes state.

How much heat is needed to raise the temperature of an object?

It might depend on…

How much heat is needed to raise the temperature of an object?

As heat energy increases, temperature increases.

E_h T

As mass increases, more heat energy is required to reach the same temperature

It depends on the material!

Each material has its own specific heat capacity (c).

[Virtual Int 2 Physics – Mechanics & Heat – Heat – Specific Heat Capacity]

Specific Heat Capacity

- The specific heat capacity of a
- material is the amount of heat energy
- required to change the temperature of
- 1kg of the substance by 1°C.

$$E_h = cm \quad T$$

Specific Heat Capacity

$$E_h = cmT$$

Heat energy (J)

mass (kg)

Change in temperature (° C)

Specific heat capacity

Units of Specific Heat Capacity

(J)

$$c = \frac{E_h}{m\,T}$$

(kg) (°C)

Specific heat capacity J/kg°C

[Virtual Int 2 Physics – Mechanics & Heat – Heat – Specific Heat Capacity - Example]

Activity 10

- To measure the specific heat capacity of
- different metals.

- Find the power of the immersion heater.
- What will you need to know?
- How can you use the joulemeter and
- stopclock to calculate the power of the
- immersion heater?

Specific Heat Capacity

- Immersion heater
- Energy used (J) [redacted]
- Time (s [redacted]
- Power (W): $P = \frac{E}{t} = \frac{23200}{720} = 32W$

Specific Heat Capacity

- What will you need to know to find the specific heat
- capacity of the metal block?
- Use the apparatus to find the specific heat capacity.
- You must find the mass of the block in kg first.

- Metal:
- Mass (kg):
- Power (W):
- Time taken (s):
- Temperature change (°C):
- Eh (by calculation):

Units of Specific Heat Capacity

Remember $E = Pt$ (J)

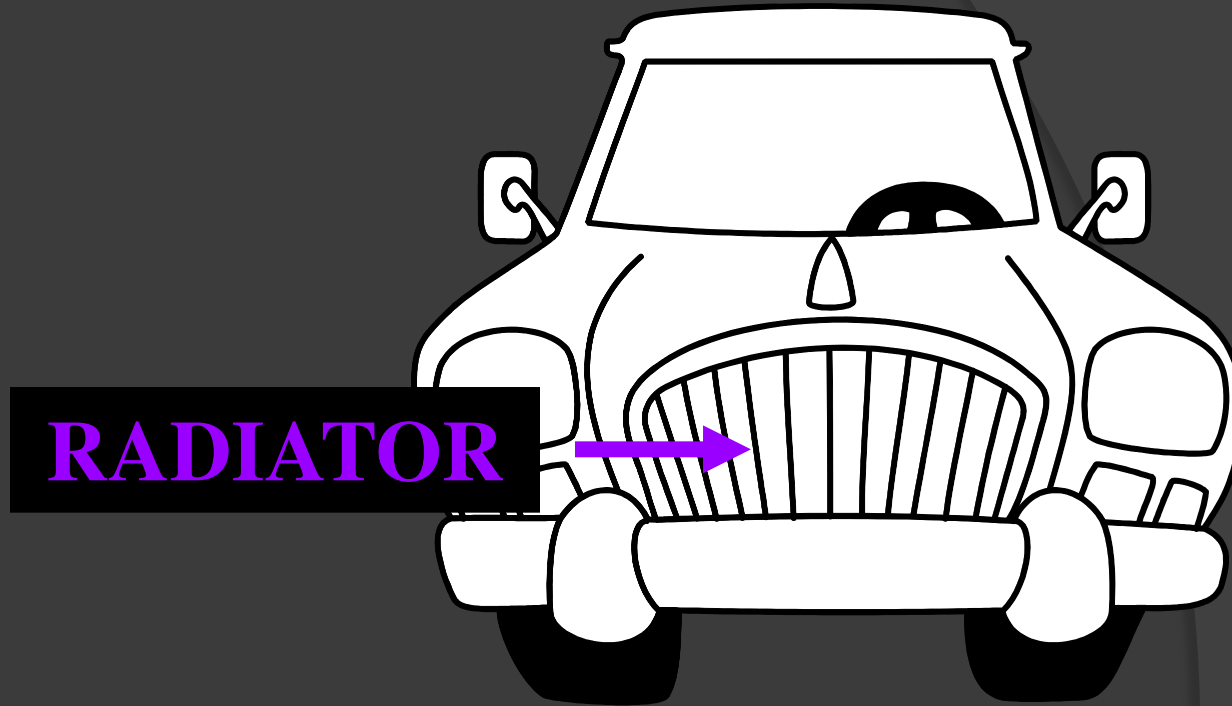
$$c = \frac{E_h}{m\,T}$$

Specific heat capacity J/kg°C

(kg) (°C)

Specific Heat Capacity

- Check your value against the data sheet.
- How does it compare?
- Explain any difference:



Why is water used as the coolant?

Because water has a high specific heat capacity, it can take away a lot of energy without boiling away.

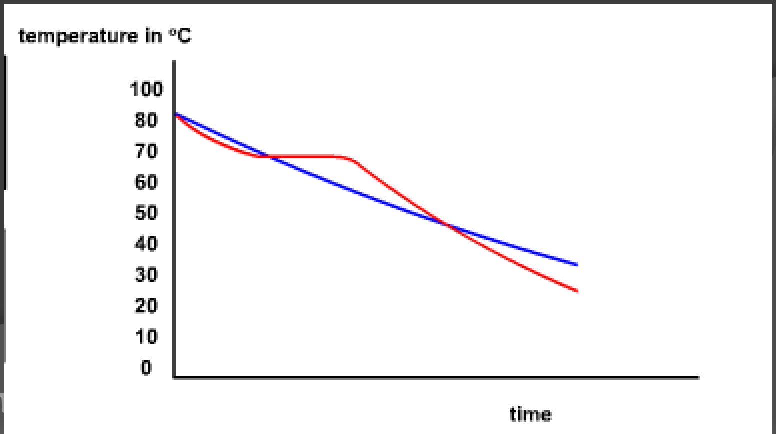
- Key words: heat energy, change of state,
- specific latent heat

- By the end of this lesson you will be able
- to:
- State that heat is gained or lost by a
- substance when its state is changed.
- State that a change of state does not involve
- a change in temperature.
- Carry out calculations involving specific latent
- heat.
- Carry out calculations involving energy, work,
- power and the principle of conservation of
- energy.

Cooling Curves

[Virtual Int 2 Physics – Mechanics & Heat – Heat – Cooling Curves]

- Why does the temperature of the stearic
- acid stop decreasing after a time?
- The acid (red line) is changing from a
- liquid to solid.
- Heat energy is given out, without a change
- in temperature.



What happens when we heat a substance?

When we heat the air in a room, the kinetic energy of the molecules increases. The air molecules move faster.

When we heat water, the molecules vibrate faster.

When we heat snow, the vibration of the molecules increases and it eventually melts.

The temperature does not always rise!

What happens when we heat a substance?

The temperature does not always rise!

Where does the heat energy go?

We must supply energy to change a solid to a liquid or a liquid to a gas.

Virtual Int 2 Physics – Mechanics & Heat – Heat – Latent Heat (Fusion)

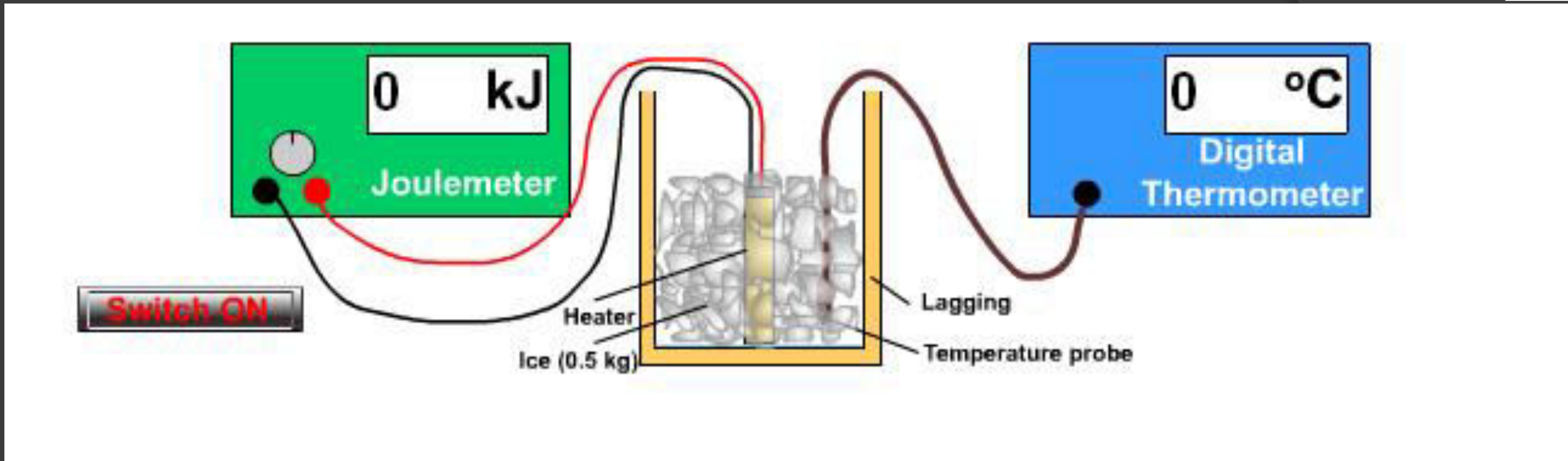
Melting Ice

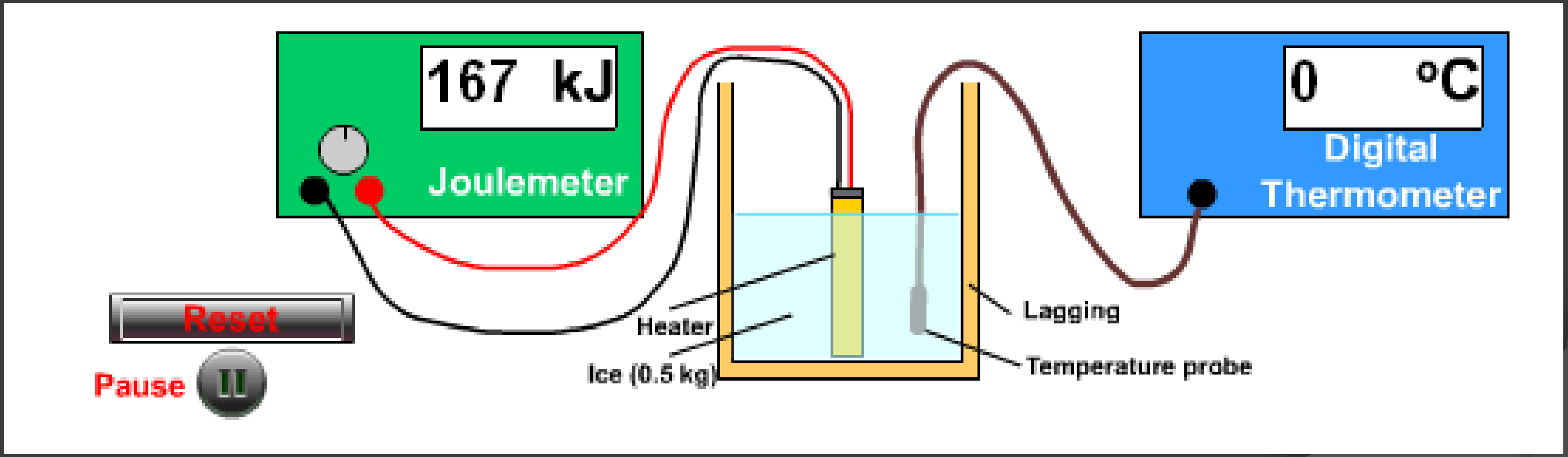
- Virtual Int 2 Physics – Mechanics & Heat – Heat – Latent Heat (Fusion)
- Notice that energy is supplied to the ice but the
- temperature remains at 0 °C.

- 167 kJ of energy is required to melt the 0.5 kg of ice
- (to turn the solid to liquid) at 0 °C.

- How much energy would be required to melt 1 kg of ice
- at 0 °C?

- 334 kJ of energy. This is the specific latent heat of
- fusion of water.


0 kJ
Joulemeter
0 °C
Digital
Thermometer
Switch ON
Heater
Ice (0.5 kg)
Lagging
Temperature probe


167 kJ
Joulemeter
0 °C
Digital
Thermometer
Reset
Pause
Heater
Ice (0.5 kg)
Lagging
Temperature probe

Specific Latent Heat of Fusion

- Virtual Int 2 Physics – Mechanics & Heat – Heat – Latent Heat (Fusion)
- When we heat a solid, it will melt and become a liquid.
- At this point, energy is required but the temperature
- does not rise.

- The specific latent heat of fusion of a
- substance is the heat energy required to
- change 1kg of solid at its melting point to
- 1 kg of liquid – without a change in
- temperature.

Specific Latent Heat of Fusion

- The specific latent heat of fusion of a
- substance is the heat energy required to
- change 1kg of solid at its melting point to
- 1kg of liquid – without a change in
- temperature.

$$E_h = ml$$

Heat energy (J)

mass (kg)

Specific latent heat

Units of Specific Latent Heat

(J)

$$l = \frac{E_h}{m}$$

Specific latent heat J/kg

(kg)

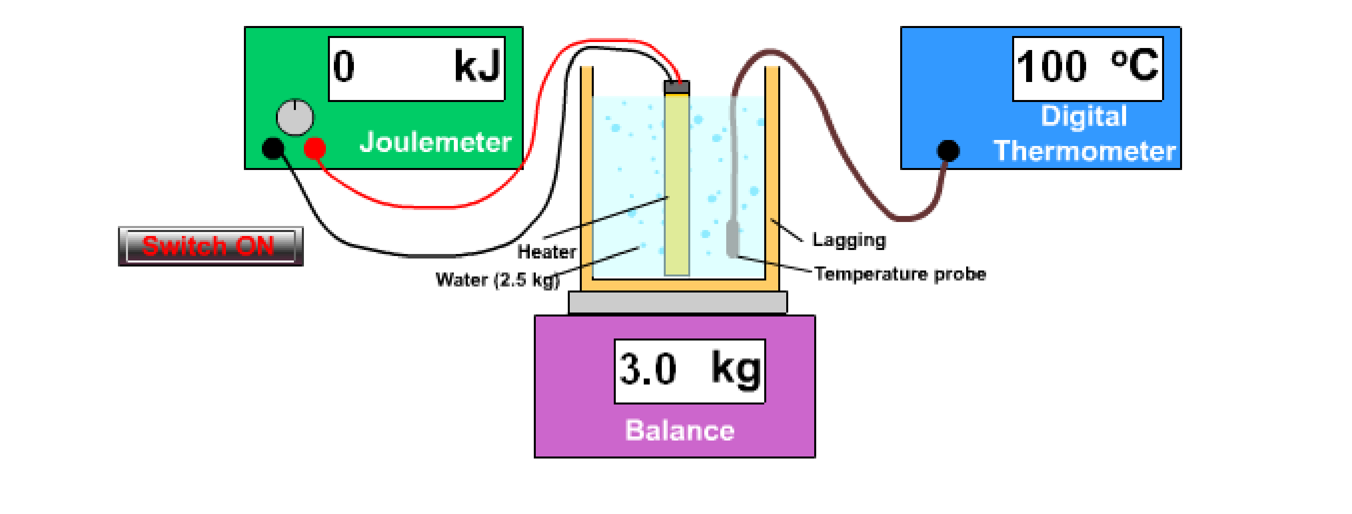
Boiling Water

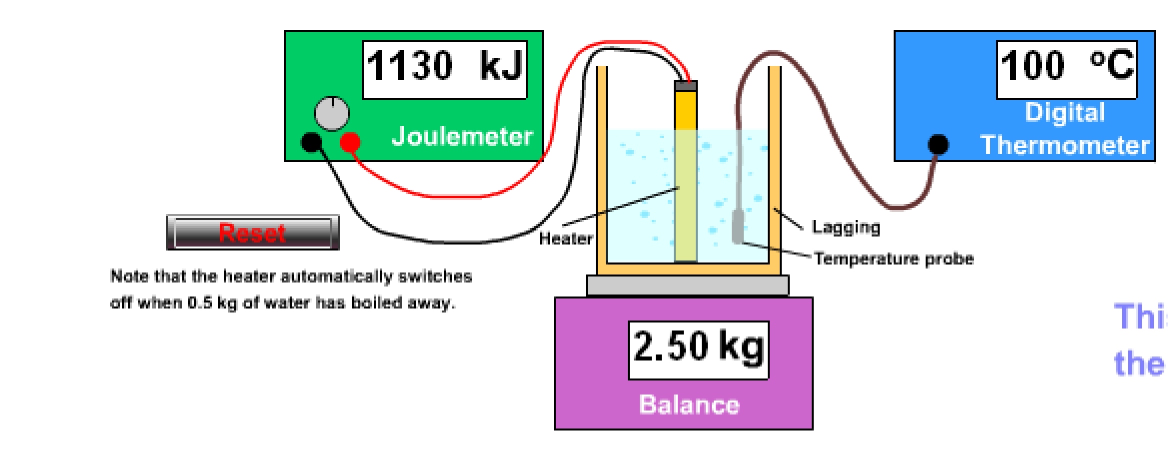
- Virtual Int 2 Physics – Mechanics & Heat – Heat – Latent Heat (Vaporisation)
- Notice that energy is supplied to the water but the
- temperature remains at 100 °C.

- 1130 kJ of energy is required to evaporate 0.5 kg of
- liquid (to turn 0.5 kg to gas) at 100 °C.

- How much energy would be required to evaporate 1 kg of
- water at 100 °C?

- 2260 kJ of energy. This is the specific latent heat of
- vaporisation of water.





Note the heat required to boil away 0.5 kg of water.

Notice that the temperature remains at 100 °C

This is the latent heat required to change the state of 0.5 kg from water to steam.

Specific Latent Heat of Vaporisation

- Virtual Int 2 Physics – Mechanics & Heat – Heat – Latent Heat (Vaporisation)
- When we heat a liquid, it will evaporate and become a
- gas. At this point, energy is required but the
- temperature does not rise.

- The specific latent heat of vaporisation
- of a substance is the heat energy
- required to change 1kg of liquid at its
- boiling point to 1kg ofvapour (gas) –
- without a change in temperature.

Specific Latent Heat of Vaporisation

The specific latent heat of vaporisation of a substance is the heat energy required to change 1kg of liquid at its boiling point to 1kg of gas – without a change in temperature.

$$E_h = ml$$

Heat energy (J)

mass turned into vapour (kg)

Specific latent heat

Units of Specific Latent Heat

(J)

$$l = \frac{E_h}{m}$$

Remember m is the mass turned into vapour.

Specific latent heat J/kg

(kg)

Example

Calculate the heat required to

a) change 2.0 kg of ice at 0 °C to water at 0 °C

b) change 0.60 kg of water at 100 °C to steam at 100 °C.

a) $E_h = ml$ where l is the specific latent heat of fusion of water

List all the values and their units: m = 2.0 kg l = 3.34×10^5 J/kg

$$E_h = 2 \times 3.34 \times 10^5$$
$$= 668000$$
$$= 670 \text{ kJ}$$
$$= 6.7 \times 10^5 \text{ J} \quad \text{(To 2 significant figures)}$$

b) $E_h = ml$ where l is the specific latent heat of vaporisation of water

List all the values and their units: m = 0.60 kg l = 22.6×10^5 J/kg

$$E_h = 0.60 \times 22.6 \times 10^5$$
$$= 1356000$$
$$= 1.4 \text{ MJ}$$

Notice that the specific latent heat of vaporisation is larger than the specific latent heat of fusion.

[redacted]

Heat - Summary

Temperature is a measure of the ____ or coldness of an object.

Different materials need different quantities of heat to change their ____ by one degree celsius.

Specific heat capacity is the ____ required to raise the temperature of 1 kg of the material by one °C

The unit of ____ heat capacity is J/kg °C.

The specific latent heat of fusion is the heat required to change 1 kg of the material from a ____ to a liquid at the ____ point.

Heat is needed to change a liquid into a ____ .

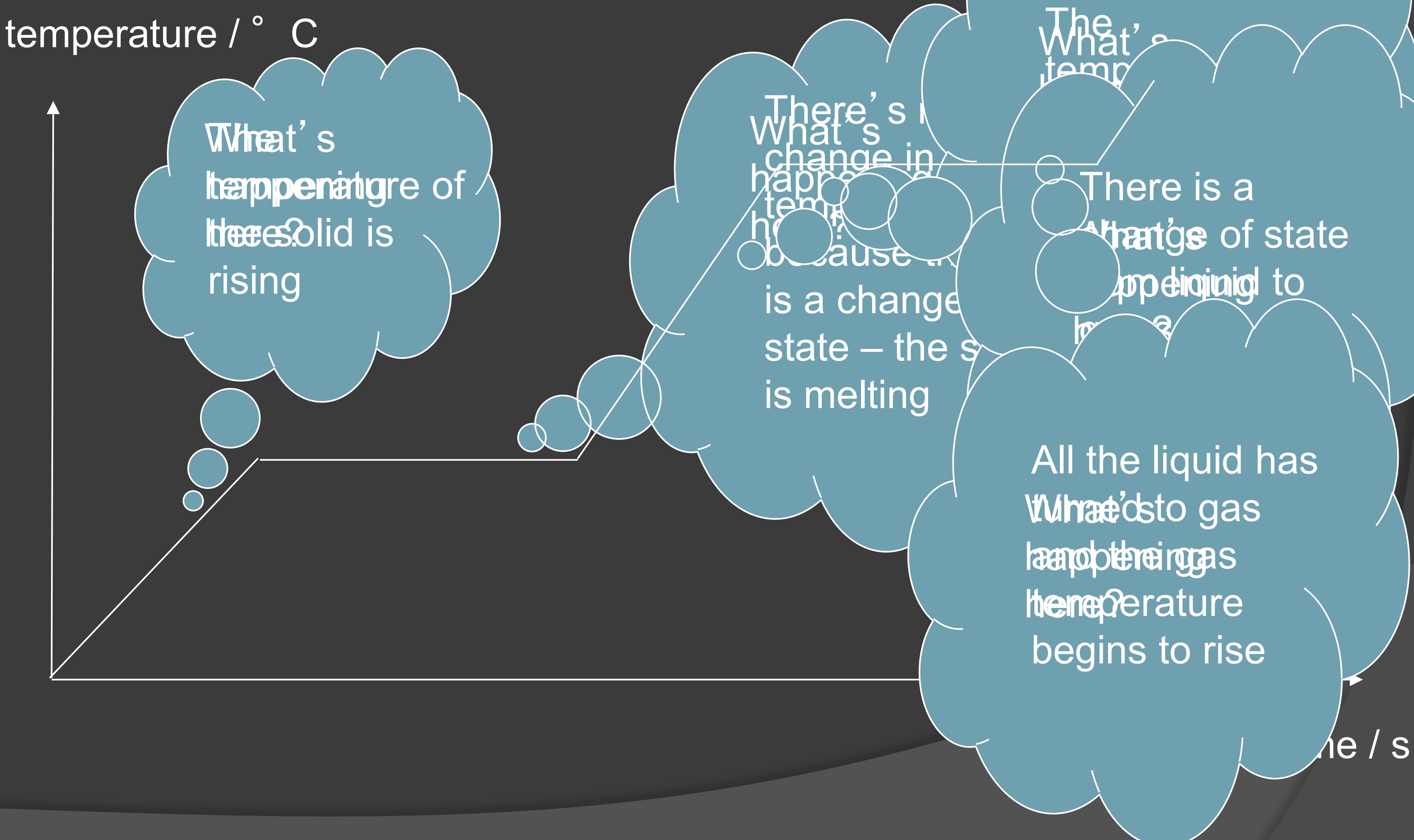
When a volatile liquid (such as perfume) evaporates from the skin, the heat needed is taken from the skin which then feels ____.

There are 8 blanks in this summary.

Fill in the blanks in lower case (CAPS LOCK OFF)

You have correctly completed - 0

- A solid is continuously heated until it
- eventually reaches the gas stat



Evaporation

- How does sweating
- keep us cool?

Cooling by melting

The i
energ
takes
from
beer,
cool.

Principle of Conservation of Energy

- Energy cannot be created or destroyed –
- simply transferred from one form to
- another.

Doing work to lift an object

When work is done to lift an object – the object gains potential energy.

Energy is neither created nor destroyed, simply transformed from one form into another.

Potential to Kinetic Energy

At the top of the rollercoaster, the cart has potential energy. This is converted to kinetic energy.

Energy is neither created nor destroyed, simply transformed from one form to another.

In reality, some energy is "lost" due to friction – this means it is converted to a form which isn't useful (heat).

Kinetic Energy to ?

What energy transformation takes place the bring a moving car to a halt?

How can the force required to do this be calculated?

Conservation of Energy

- The principle of conservation of energy
- also applies when we use electrical energy
- to heat substances.

Example

- Calculate the time taken for a 500 W
- heater to melt 2 kg of ice at 0 °C.

- Think – we are talking about change of
- state without a change of temperature
- therefore latent heat.

- What do I know?

- Latent heat of fusion of ice $l = 3.34 \times 10^5$ J/kg
- $P = 500$ W
- $m = 2$kg
- $t = ?$

- Energy required to melt the ice = ?
- Time taken to melt the ice = ?

- What do I know?
- Latent heat of fusion of ice l = 3.34×10^5 J/kg
- P = 500 W
- m = 2kg
- t = ?

$$E_h = ml$$

$$E_h = 2 x 3.34 x 10^5$$

$$E_h = 6.68 x 10^5 J$$

$$t = \frac{E}{P}$$

Conservation of energy tells us that the energy required to melt the ice must be the electrical energy provided by the heater.

$$t = \frac{6.68 x 10^5}{500}$$

$$t = 1336 s$$