THERMAL PHYSICS

Thermal Properties of Matter

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Specific Heat Capacity

We know that temperature is a measure of the average KE per particle in a substance. However not all substances will behave in the same way when heated.

The specific heat capacity of a material is the amount of energy (in Joules) needed to increase the temperature of one kilogram of mass of the material by one Kelvin.

$$\Delta Q = mc\,\Delta T$$

ΔQ = Amount of heat energy (J)
ΔT = Change in temp (K)
m = mass (kg)
c = specific heat capacity($Jkg^{-1}K^{-1}$)

Experimental determination of s.h.c.

See sheet.

Note: To minimise error…

1. Low mass thermometer and heater
2. Insulation
3. Wait for max temp after turning off
4. Stir liquids

Also… Consider s.h.c. of calorimeter (beaker / container)

Q. Explain the following in terms of particles… (you may wish to remind yourself of the definition of absolute temperature)…

a. To raise the temperature of 1 kg of lead by one Kelvin requires 130J, whereas for 1 kg of copper 390J are needed.

b. To raise the temperature of one mole of lead or one mole of copper by one Kelvin requires about the same amount of energy.

Heat Capacity

Whereas ‘specific’ heat capacity is ‘per kg’ of a material, heat capacity (or thermal capacity) is the energy required to raise a certain objects temperature by one Kelvin, irrespective of its mass.

Heat capacity = mass x specific heat capacity

$$C = mc$$

So…

$$\boxed{\Delta Q = C\Delta T}$$

m = mass (kg)
C = heat capacity (JK^{-1})
c = specific heat capacity($Jkg^{-1}K^{-1}$)
ΔT = Change in temp (K)
ΔQ = Amount of heat energy (J)

E.g.

What is the heat capacity (thermal capacity) of 5kg of sand?

How much heat is required to raise the temperature of the sand by 7.5°C (c_{sand} = 835 $Jkg^{-1}K^{-1}$)?

A.

$$C = mc = 5 \times 835 = \underline{4175\ JK^{-1}}$$

$$\Delta Q = C\Delta T = 4175 \times 7.5 = \underline{31312\ J}$$

Note: A glass beaker containing water has a heat capacity that is equal to that of the water plus that of the glass. So for such an object…

$$\boxed{C = m_1c_1 + m_2c_2}$$

Where 1 and 2 represent the two materials making up an object.

Alternatively, if we assume the glass and water increase by the same change in temperature, we can say the total energy given to the glass plus water is given by…

$$\boxed{\Delta Q = m_1c_1\Delta T + m_2c_2\Delta T}$$

Specific Latent Heat

If a substance is heated to its melting or boiling point, any further heat supplied to the substance will be used to do work on the molecules, overcoming the forces that hold them together and causing a change of state. This all occurs at a constant temperature.

The heat supplied to cause this change of state is called *latent heat*.

The specific latent heat of a material is the amount of energy needed to change one kilogram of mass of the material from one state of matter to another, *without change in temperature*.

<u>Q.</u> Explain why supply of latent heat causes a change in potential energy but not kinetic energy.

<u>A.</u> Kelvin temperature is proportional to the KE of the molecules. Thus if the temperature hasn't increased then the KE has also not increased.

Work has been done against forces, changing the position of the molecules. Thus the PE of the molecules must change.

NOTE: We are interested in…

i. Specific latent heat of vaporisation (L_v) - from liquid to vapour

ii. Specific latent heat of fusion (L_f) - from solid to liquid

Heat supplied = mass of substance x specific latent heat

So… $\boxed{\Delta Q = mL_v}$

and… $\boxed{\Delta Q = mL_f}$

ΔQ = Amount of heat energy (J)
L = Specific latent heat (Jkg^{-1})
m = mass (kg)

E.g. 0.5kg of ice at 0°C is heated…

i. … until it has all melted to water at 0°C

ii. … until it reaches it's boiling point at 100°C

iii. … until it has vaporised to steam at 100°C

Calculate the heat supplied at each stage and in total.

A

$$\text{i. } \Delta Q = mL_f$$

$$= 0.5 \times 334 \times 10^3$$

$$= \underline{1.67 \times 10^5 \text{ J}}$$

$$\text{ii. } \Delta Q = mc\Delta T$$

$$= 0.5 \times 4200 \times 100$$

$$= \underline{2.10 \times 10^5 \text{ J}}$$

$$\text{iii. } \Delta Q = mL_v$$

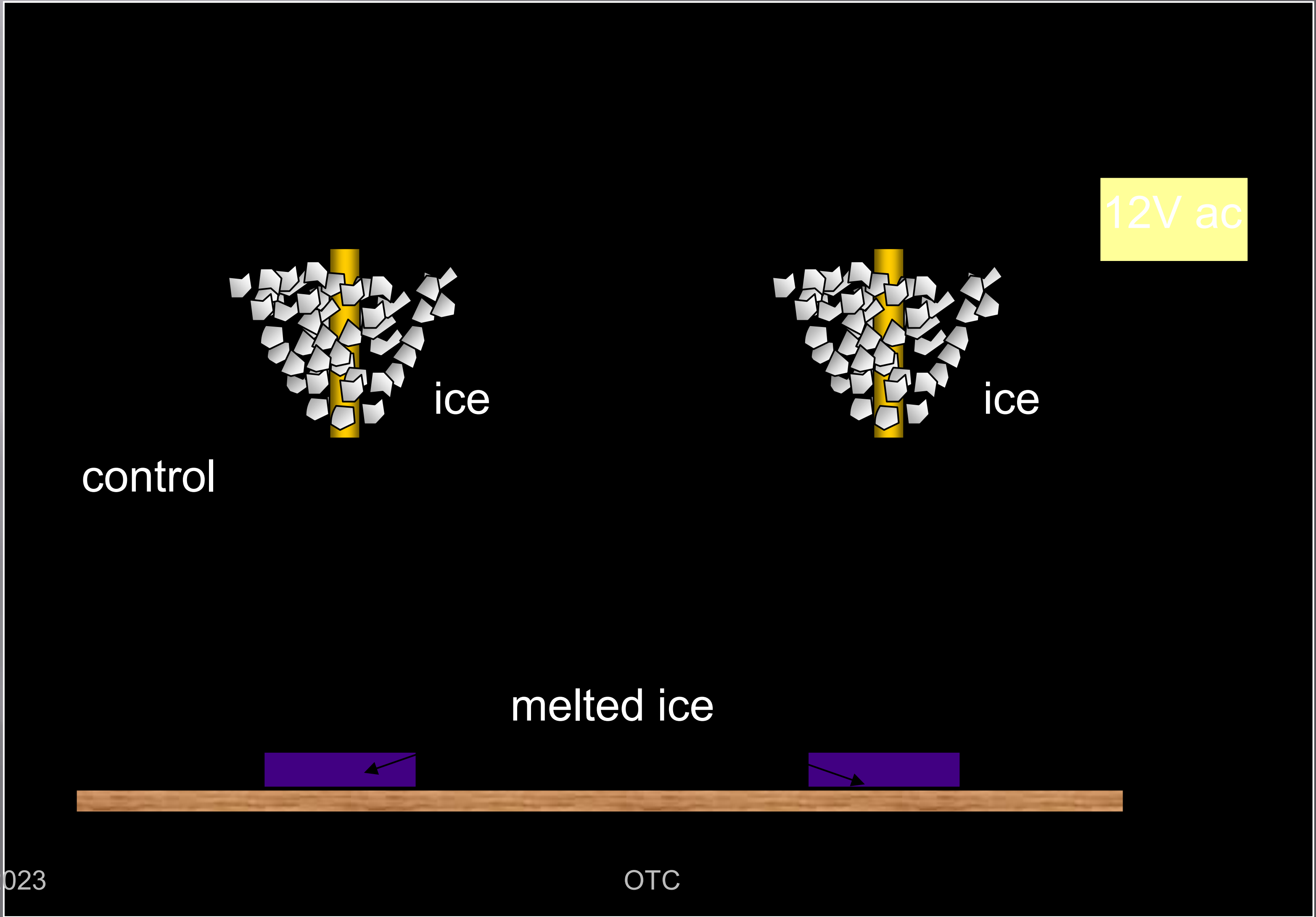
$$= 0.5 \times 2258 \times 10^3$$

$$= \underline{1.13 \times 10^6 \text{ J}}$$

$$\text{Total} = \underline{1.51 \times 10^6 \text{ J}} \quad (= 1.51 \text{ MJ})$$

Experimental determination of latent heat

(See sheet).



Note: Sources of error…

i. Heat from air will also melt ice $\therefore$ use control

ii. Water vapour will condense and add to the water, giving out latent heat $\therefore$ use control

iii. Ammeter and wires have resistance, using some power $\therefore$ L_f will be lower

iv. Heater may not cool to ice temp $\therefore$ energy supplied is less $\therefore$ L_f will be lower

Evaporation

Task: Read the extract about evaporation from ‘A-level physics’ by Muncaster. Underneath, make a few notes about how evaporation is different from boiling.

A.

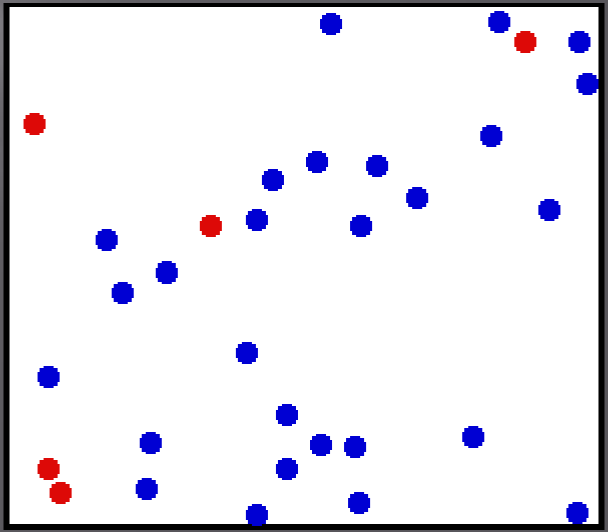
- Boiling occurs at a fixed temperature while evaporation occurs at any temperature.
- During boiling, molecules can escape from anywhere in the liquid. Evaporation occurs only at the surface.

Specific Heat Capacity and Latent Heat Link

The Kinetic Theory of an Ideal Gas

We can explain the properties of gases by using a simple model, suggesting that all gases are made up of a large number of molecules, moving at varying speeds in random directions and experiencing regular collisions.

This model assumes…



1. **** No forces apart from those that occur during collisions ****.
2. All collisions including with the container walls are elastic $\therefore$ KE is conserved.
3. The gas is made up of a large number of molecules.
4. These are ‘point molecules’. i.e. volume of molecules is negligible compared to volume of gas.
5. Completely random movement of molecules (giving uniform effects such as pressure) at varying speeds.
6. All the molecules obey Newton’s Laws.

Q.

Explain why the internal energy of an ideal gas is kinetic energy only.

A.

We assume there are no forces occurring between the gas particles while they are moving around. Thus there is no potential energy.

Internal energy = total KE + total PE

If PE is zero then internal energy is KE only.

Pressure and Ideal Gases

We can explain macroscopic behaviour of gases (e.g. pressure changes) by considering the kinetic theory.

E.g. Why do gas particles exert a pressure on the walls of a container?

- The particles experience a change in momentum when they collide with the container walls. Thus they experience a force and the walls experience an equal and opposite force. The total force (due to the many collisions at any instant) over the area of the wall results in a pressure.

Q. Why doesn't the wall accelerate if it experiences these forces?!

Q. Explain why a gas pressure will increase if its volume is decreased (like in a bicycle pump)?

A. In a smaller volume, molecules hit the walls of the container more often. This results in a greater total force over the area of the wall and thus a greater pressure.

Q. Explain why a gas temperature will increase if its volume is quickly decreased (again, like in a bicycle pump)?

A. When the molecules hit the moving wall their KE will increase. Average KE of the molecules is proportional to Kelvin temperature, thus temperature goes up.

Subtitle

Text