IGCSE **MY NOTES**
Chapter 2 Thermal Physics
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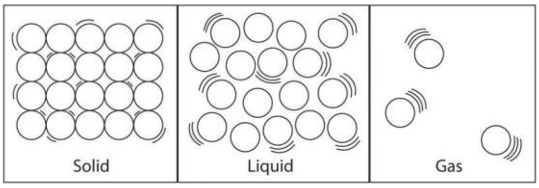
2.1 Molecules



Solid: fixed shape and volume

1) Strong forces of attraction between particles
2) Have a fixed pattern (lattice)
3) Atoms vibrate but can't change position.

Liquid: has fixed volume but changes shape depending on its container

1) Weaker attractive forces than solids
2) No fixed pattern
3) Particles slide past each other.

Gases: no fixed shape or volume, gases fill up their containers

1) Almost no intermolecular forces
2) Particles are far apart, and move quickly, gases spread out to fill up the container and exert equal pressure on all surfaces.
3) They collide with each other and bounce in all directions.

Evaporation

Evaporation: constantly occurs on the surface of liquids. It is the escape of the more energetic particles. If the more energetic particles escape, the liquid contains fewer high energy particles and lower energy particles so the average temperature decreases. Evaporation can be accelerated by:

1) increasing temperature: more particles have enough energy to escape
2) increasing surface area: more molecules are close to the surface
3) reduce the humidity level in the air: molecules in the water vapour return to the liquid at around the same rate that particles escape the liquid, when the air is humid. If the air is less humid, fewer particles are condensing.
4) blow air across the surface: removes molecules before they can return to the liquid

Hint: You should be able to tell the difference between temperature and heat.

The air is said to be **saturated** if it cannot hold anymore evaporated water. While the air is said to be **unsatured** if it can still hold more water.

2.2 Expansion of solids, liquids and gases

Solids, liquids and gasses expand when they are heated as the atoms vibrate more and this causes them to become further apart, taking up a greater volume. Everyday applications and consequences:

1) hot water is used to heat up a lid of a jar, to make it expand, so that it is easier to remove
2) the liquid in **thermometers** expand and contract when temperature changes, the volume of the liquid taken up in the tube can be used to find out the temperature
3) **bimetal thermostat**: when the temperature gets too high, the bimetal strip bends, to make contacts separate until the temperature falls enough, then the metal strip will become straight again and the contacts touch, to maintain a steady temperature
4) overhead cables have to be slack so that on cold days, when they contract, they don't snap or detach.
5) gaps have to be left in bridge to allow for expansion (rollers allow the bridge to expand)

Expansion is highest in gases, then liquids and lowest in solids.

Do you Feel the Heat?

To do well in this chapter you must first understand the difference between temperature and heat. Temperature is a numerical measure of hot and cold. It is related to the average kinetic energy of individual atoms. The SI unit for temperature is in ___________. Heat is a form of energy (not a force). As such its SI unit is in ________ (similar to kinetic and gravitational potential energy). Two facts about heat:

1) Heat transfers at a faster rate from a hot (higher temperature) to a cold object (lower temperature).
2) Heat transfers at a slower rate from a cold to a hot object.

Thermal equilibrium is achieved when the *rates* of heat transfer from 2 objects are *equal* meaning the net heat transfer is 0 Joules. Two things happen when *thermal equilibrium* is achieved:

1) The temperatures of all objects are equal.
2) No net gain or loss of energy between the objects.

Object A and B are very close to each other. Which direction does heat transfer to if

Object A has a higher temperature than object B?

____

Object A has a smaller mass but higher temperature than object B?

____

A has a bigger mass but the same temperature as B?

____

A has a greater heat energy but the same temperature as B?

____

An application of thermal equilibrium can be seen in the thermometer. A thermometer is an instrument used to measure the temperature. Mercury is usually used because it is

1) Opaque: Easier to see.
2) Expands and contracts uniformly: Can use scales.
3) Does not stick to the glass: Can use scales.
4) Good thermal conductivity: Achieves thermal equilibrium at a faster rate.

The sensitivity of a mercury thermometer can be increased by using

1) Smaller/ bigger bulb. Increases surface area for heat conduction.
2) Glass/ wood bulb. Lower specific heat capacity.
3) Narrower/ wider capillary tube. Mercury does not have to expand as much for a small change in temperature.

Steps to calibrate a thermometer

1) Placed in ice cube
2) Mark 0^{o}C
3) Place above steam
4) Mark 100^{o}C
5) Divide 100 equal divisions

Thermal Heat Capacity
Definition: Amount of *heat* required to *change the temperature by 1^{o}C or 1K.*

A lower heat capacity means the object heats up easier. While a higher heat capacity means an object heats slower. You should not confuse temperature with heat. A spoon in hot glass of water may have the same temperature when thermal equilibrium is achieved. However, the amount of heat energy of the hot water in the cup is larger than that on the spoon because the mass of the water is a lot larger!

$$Heat\ Capacity = \frac{?}{change\ in\ temperature} = \frac{Q}{\theta}$$

The units for heat capacity are ____________.

Note: In physics, every time you see the word specific you can change it to per unit mass

Specific Heat Capacity

Definition: Amount of *heat* required to *change the temperature by 1^{o}C or 1K* for a mass of *1kg* of the substance.

$$Specific\ Heat\ Capacity, c = \frac{?}{change\ in\ temperature\ per\ unit\ mass} = \frac{Q}{\theta m}$$

The units for specific heat capacity are_____________.

Find the specific heat capacity given 3kg of *x* with a temperature change from 28^{o}C to 63^{o}C assuming it was supplied with 94500J of heat.
Hint: 1) Identify m, C and θ
2) Which direction is heat transferring to?

Melting and Boiling

When melting or boiling a substance, energy is put in, but there is no change in temperature. The energy absorbed is called the **latent heat of fusion/vaporization**. A change of state happens when the particles have enough energy to overcome the forces between them. In melting, the solid vibrates so much that the particles can break away from their positions.

Melting point is the temperature at which a substance (in solid state) melts (it is equal to the freezing point)
Boiling point is the temperature at which a substance (in liquid state) boils ("you don't say")

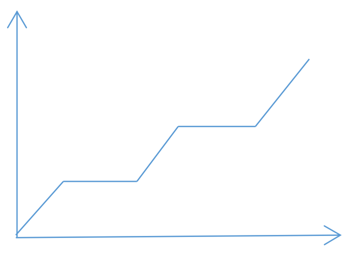
Latent Heat

Definition: *Energy absorbed or released* during *constant temperature*.

As more heat is applied the temperature stops rising and the heat energy is used to break intermolecular forces.

Latent heat of fusion – *solid →liquid*

Latent heat of vaporization – *liquid →gas*



Specific Latent heat

Amount of heat required to change 1kg of substance at constant temperature

$$Specific\ Latent\ Heat, l = \frac{heat}{per\ unit\ mass} =$$

The units for specific latent heat are_______________.

1) Specific latent heat of fusion is the amount of *heat* required to change *1kg* of substance from *solid to liquid without changing the temperature*.
2) ____
____
____

500g of copper @ 90°C placed in 300g of water at 30°C. Assume adiabatic find the final temperature of the water.
Hint:

1) *Identify which direction the heat transfer is*
1) *The heat loss from the copper is gained by the water.*

A 1kw heater is used to heat 250g of water for 1 minute. The temperature of the water changes by 51°C. Calculate the specific heat capacity of water. *Hint: Convert electrical power to heat energy.*

The 3 Gas Laws

1) Boyle's Law

Temperature is constant, $pressure \propto \frac{1}{Volume}$ for a fixed mass of gas.

Remember that in order for two variables to be proportional (in this case pressure and the inverse of volume) there must be a constant between them.

$$P_1 = \frac{k}{V_1}$$

k is called the constant of proportionality (Imagine that *k* is the slope between the two variables). If the volume, V_1 is changed to V_2 the value of P would have to change as well following the constant.

$$P_1V_1 = P_2V_2$$

Again rearranging

$$\frac{P_1}{P_2} = \frac{V_2}{V_1}$$

2) Charles Law

Pressure is constant, $volume \propto temperature$ for a fix mass of gas.

Important: Always use the units in Kelvin for temperature involving the 3 Laws.

To convert ^oC to K, always add 273:

$$K = T\ ^oC + 273$$

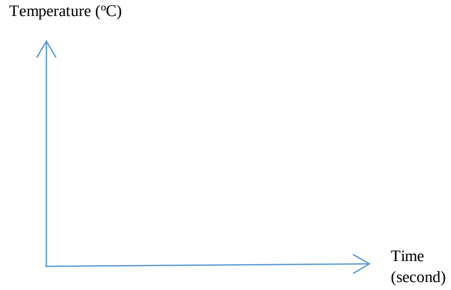
For example

0ºC→
100ºC→

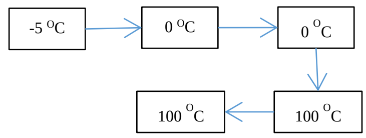
3) Pressure Law

Volume is constant, $pressure \propto temperature$ for a fix mass of gas

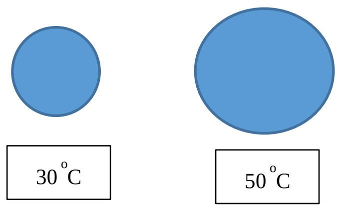
Do this in reverse………



Calculate the total heat to change 1kg of ice to steam. *Hint: The diagram below might help to visualize the problem.*



C_{water} = 4200 $Jkg^{-1}C^{o-1}$
C_{ice} = 2100 $Jkg^{-1}C^{o-1}$
Specific latent heat of fusion = 3.36×10^5 Jkg^{-1}
Specific latent heat of vaporization = 2.26×10^6 Jkg^{-1}



What is the final volume of the ball if its initial volume is 20 cm^3?

2.3 Transfer of Thermal Energy

Thermal energy is transferred via 3 mechanisms (notice that everything is in 3s?):

1) Conduction

In non-metals - when heat is supplied to something, its atoms vibrate faster and pass on their vibrations to the adjacent atoms. In metals – conduction happens in the previous way and in a quicker way – some electrons are free to move, they travel randomly in the metal and collide with atoms and pass on the vibrations

2) Convection

As a fluid (liquid or gas) warms up, the particles which are warmer become less dense and rise. They then cool and fall back to the heat source, creating a cycle called convection current. As particles circulate they transfer energy to other particles. If a cooling object is above a fluid it will create a convection current (like the freezing compartment at the top of a fridge)

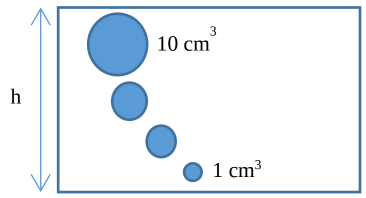
3) Radiation

Thermal radiation is mainly infra-red waves, but very hot objects also give out light waves. Infra-red radiation is part of the electromagnetic spectrum.

	Matt Black	White	Silver
Emitter	Best		Worst
Reflector	Worst		Best
Absorber	best		worst

An emitter sends out thermal radiation. A reflector reflects thermal radiation, therefore is a bad absorber. An emitter will cool down quickly, an absorber will heat up more quickly and a reflector will not heat up quickly

A tyre has air pressure 23 kPa when the temperature is 27°C. What is the pressure of the tyre if the temperature is increased to 57 °C?



Find the height of the aquarium, *h* if 1 atm = 10 m H_2O