Thermal Physics

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Matter is defined as any substance in the Universe which takes up space and mass. We are able to further classify matter into 3 states, namely Solid, Liquid and Gas.

P.S: Classification helps both scientist and people all over the world as it helps develop in depth understanding of each state and help also to identify and differentiate different types of matter.

Solid	Liquid	Gas
Fixed shape	Takes up the shape of the container	Takes up the shape of the container
Fixed volume	Fixed volume (In higher level, liquids can be so slightly compressed)	No fixed volume
Regular arrangement	Irregular arrangement	No fixed shape
Particles vibrate in its **fixed position**	Particles **slide** over one another	Particles move randomly in **zig-zag** motion
Strong forces of attraction	Weak forces of attraction	Negligible force of attraction (Theoretically speaking)

During heating, an object can undergo changes in state. This is due to their physical properties, namely melting and boiling point.

Key Takeaways:

1) As objects gain heat energy, its particles move in a greater velocity which enables it to break its force of attraction
2) During melting and boiling, as seen from the graph, temperature is constant. This is due to the fact that when boiling or melting occurs, all of the energy absorbed are used to break its forces of attraction and not to raise its temperature.
3) Pure substances will have one boiling and melting point. Impurities may cause substances to boil or melt at a range of temperatures

Kinetic Particle Theory

1) All matter consist of small and very many particles in constant motion. The degree of speed of this motion varies with temperature as well as its state.
2) Gasses have the highest amount of energy and solid the least. This is due to the fact gasses have minimal forces of attractions and hence can move in random motion in high speed
3) When particles gain energy, they may be able to change state from solid – liquid –gas. When particles lose energy, vice versa occurs. Hence, we can say that melting and boiling absorb energy whereas freezing and condensation release energy.

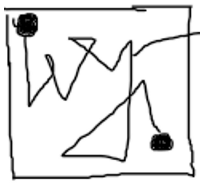
Question that appear consistently in the Exams:

1) Explain, with respect to the Kinetic Particle Theory, what happens when ice, when heated melts to water

Ice is initially in solid state. As it is being heated, thermal energy is converted to kinetic energy. The kinetic energy enables the particles to vibrate at greater velocity up to melting point where temperature remains constant and all energy being absorbed is used to break the forces of attraction. By the time the movement of particles no longer vibrates it its fixed position but rather slide over one another, the process is complete.

Brownian Motion is an experimented conducted in order to be able to provide evidence that our atmosphere consist of tiny gas particles that are always in constant, random motion.

When grain of pollens are suspended under a microscope, these pollen grains demonstrated a very abstract path of motion. They travel in zig-zag lines as if being collided by something. This something is what we know as air and air consist of a mixture of gasses.
From this experiments, we are able to conclude that although we can't see it, gas is present all around us. Not only that, it also travels in constant, random motion at high speed.



Zig Zag pattern Caused by Collision with gases

Temperature is a measure for the average kinetic energy of particles in a substance. When particle experience an increase in temperature, their particles move faster. Solids will vibrate more in its fixed position, liquids will slide more vigorously and gas particle will travel faster and move further away from each other.

When gas particles collide against the walls of their container, they exert pressure. This can be explained with the following derivation.

When gas particles collide against the wall with velocity v, they will bounce back with velocity of (-v)

1) There is Δp

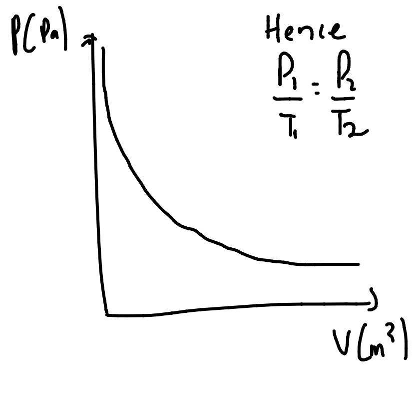
2) Since $\Delta p = m \times \Delta v =$ Impulse,

$m \times \Delta v = f \times \Delta t$

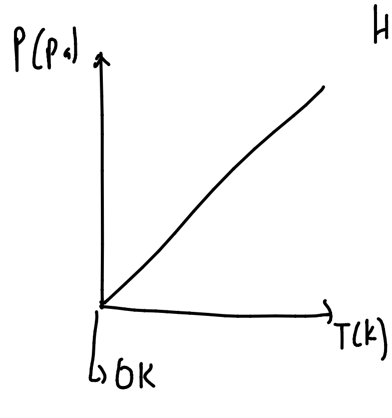
3) $f = \frac{m \times \Delta v}{\Delta t}$

4) Since gas particles will collide the wall in a specific area, $P = \frac{F}{A} = \frac{m \times \Delta v}{\Delta t\, A}$

Pressure is directly proportional to temperature but inversely proportional to volume. At absolute zero, OK or -273 degrees Celsius, particles stop moving.



Hence $\frac{P_1}{T_1} = \frac{P_2}{T_2}$



Hence, $P_1V_1 = P_2V_2$

Evaporation

Why evaporation occurs:

Evaporation occurs when the molecules on the surface of a liquid has enough kinetic energy to break the intermolecular force of the liquid where it leaves the surface of the liquid.

Differences between evaporation and boiling:
1) Boiling only occurs at boiling point but evaporation can occur at any point before
2) Evaporation only occurs in the surface unlike boiling
3) During boiling, temperature remains constant but in evaporation, temperature decreases
4) Boiling requires greater magnitude of energy unlike evaporation

Factors affecting rate of evaporation:
1) Temperature: Increase in temperature will cause particles to have more kinetic energy hence greater portion of particles will possess enough kinetic energy to break the intermolecular force and leave the liquid
2) Surface area: If surface area increases, more molecules will be 'on the surface' and hence, more molecules are able to escape
3) Wind speed: Increase in wind speed will give the liquid particle more kinetic energy
4) Humidity: Increase in humidity will decrease rate of evaporation as it decreases capacity to hold water vapor
5) Atmospheric pressure: Increase in atm will decrease rate of evaporation as particles would need to have more kinetic energy to evaporate

Why do evaporation has a cooling effect:
Take an example when you just got out of the pool. You feel very cold despite the very hot weather. This is because evaporation has a cooling effect. The water molecules on the surface of your skin will have different amount of kinetic energy. The ones that have adequate amount will break the intermolecular force and leave as gas. **This leaves water molecules with less amount of energy and hence, there is a cooling effect.**

Thermal Expansion of Solids, Liquids and Gasses

When substances are heated, they gain kinetic energy and hence move faster. When this occurs, the particles are able to take up a greater volume(take up more space).

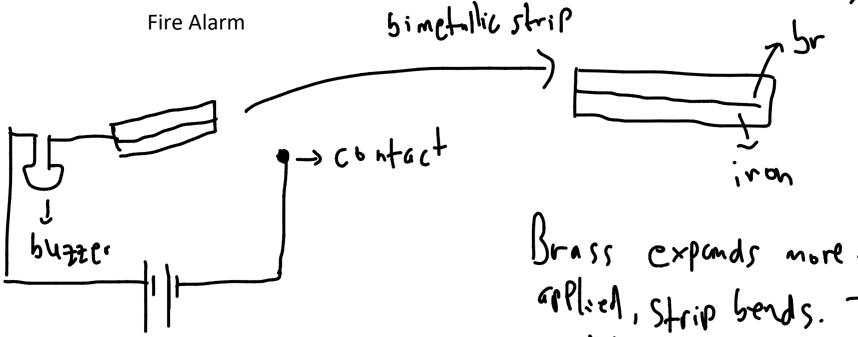
Do take note that when this occurs, the volume occupied increases but NOT THE SIZE OF THE PARTICLES.

Expansion in the 3 states of matter:
1) Solids: In solids, since particles only vibrate in its fixed position, the effect of expansion is very minimal. We can see this applied in our daily lives. Notice how wires usually sag down in order to prevent it to break down when they expand. Rail tracks also have spaces in between segments in order to prevent it from expanding into each other and breaking.
2) Liquids: Liquids can be seen expanding with the naked eye but they expand less than gasses. A common example is a liquid-in-glass thermometer
3) Gas: Gas expands the most. Take note that when gas expands, its volume is directly proportional to its temperature under constant pressure.

Using thermal expansion in our favor. ass

Using thermal expansion in our favor.

Fire Alarm



Brass expands more. When heat is applied, strip bends. The circuit is complete and buzzer will ring

Measurement of temperature

Expansion can be used to measure temperature (thermometer)

Thermometers have distinct features.

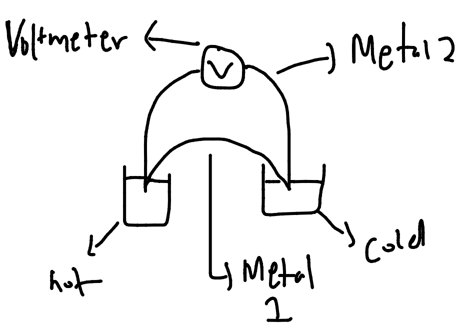
1) Sensitivity: The smaller the diameter of bore, the greater rise in liquid for the same change in temperature
2) Range: The max and min of a thermometer.
3) Linearity: Whether or not expansion is directly proportional to temperature

Thermometers have 2 fixed point. Boiling and freezing point of pure water.

Thermometers use alcohol or mercury as water possess inconsistent or irregular expansion

Thermocouples:

Electrical thermometer



Metal 1 and 2 must be of different types. Thermocouples are used as it can measure very low and high temperatures and can detect the rise and fall in temperature quickly.

The output of the voltmeter is proportional to the temperature difference between hot and cold junction

Thermal Capacity

When heat is supplied to a substance, its temperature increases. With respect to that, its internal energy also increases.

Thermal capacity refers to the amount of energy required to raise the temperature of a substance by 1 degrees Celsius or by 1K. $Q = C\Delta T$

The higher the value of thermal capacity, the more energy is required to raise its temperature.

On the other hand, specific heat capacity refers to the amount of energy required to raise **1kg of a substance by 1 degrees Celsius or by 1K.** Take note the difference that one is per unit mass and the other is not.

$Q = mc\Delta T$

$Q = J$ Hence, $C = J/kg°C$

$m = kg$

$\Delta T = °C$

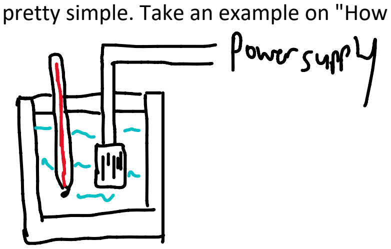
ΔT can be in K or °C, there is no difference

eg: If initial $T = 25°C$ and final is $30°C$,

$\Delta T = 5°C$

$\Delta T = (273+30) - (273+25)$
$= 5K$

In the exams, it is often asked on how to measure the specific heat capacity of a substance. The setup is pretty simple. Take an example on "How to find specific heat capacity of water."



1) Measure out a fixed mass of water and place it in a container.
2) Measure initial temperature of water
3) Place a heater with known power.
4) Turn it on for 5 minutes and record final temperature
5) Calculate change in temperature
6) Repeat thrice

Since we know $P = \frac{W}{t}$

$W(J) = P \times (5 \times 60) \rightarrow$ to be in s

Hence,
$C = \frac{Q}{m \times \Delta T}$

To improve the experiment, **insulate the container with cotton or use digital thermometer for accurate results.**

Melting and Boiling

Melting point refers to a fixed temperature when a solid turns into liquid whereas boiling point refers to a fixed temperature when a liquid turns into gas.

Latent heat

Latent heat of fusion refers to the energy at which is needed in order to completely turn a solid into liquid. This is under **constant temperature.**

Latent heat of vaporization refers to the energy at which is needed in order to completely turn a liquid into gas. This is under **constant temperature.**

It is under constant temperature as when melting or boiling occurs, all of the heat energy supplied is used to break the attractive forces. The particles do not gain kinetic energy and hence, temperature is constant

Specific latent heat is the amount of energy required to completely change the state of 1kg of substance at constant temperature.

$Q = mL$

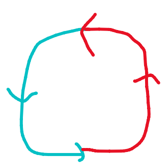
L can be L_f / L_v

Conduction, Convection and Radiation

Conduction:
When particles are heated, they gain kinetic energy. Heating through conduction occurs as when particles are heat, they can transfer it to their neighboring particles. This is why conduction primarily occurs in solids as in liquids and gasses, particles are too far apart.

Metals are good conductors of heat and electricity as they have free moving electrons which can carry the energy throughout the metal.

Convection:
Transfer of heat in a fluid by movement of the fluid itself.
Heating through convection is when hot fluids rise and cold fluids fall. This is know as a convection current.



Hot fluids rise as when fluids are heated, they expand ($V\uparrow$)

Hence, $\downarrow D = \frac{M}{V\uparrow}$ If $D\downarrow$, it "floats" hence it rises

Radiation:
Transfer of heat through infrared radiation, which is part of the electromagnetic spectrum, which can travel in vacuum.

We have 2 terms which are:
1) Emitters
2) Absorbers

In physics, there is no such thing as a good emitter but a poor absorber. If a substance is a good absorber, it is a good emitter.

The better the emitter/absorber, the easier it is for the material to absorb or lose heat.

Dull and black surfaces are best emitters and absorbers whereas shiny and white surfaces are the worse.

Real life application:
1) People use white coloured clothing during a sunny day.
2) In a thermos, there is a vacuum between the walls of the container to reduce heat transfer through conduction and convection but not radiation.

General exam tips:
1) Always convert units to SI unit during calculation
2) Remember that the experiment to calculate specific heat capacity can be improved by using insulator
3) Take note that there is no such thing as a good absorber but a bad emitter
4) Understand the advantages of using thermocouple

5) Understand why evaporation causes cooling effect