Topic 2 – Thermal physics

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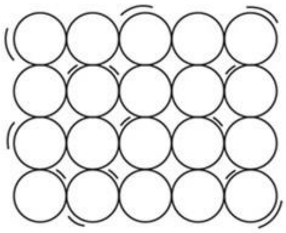
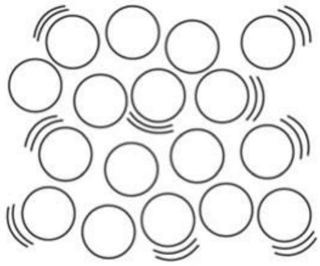
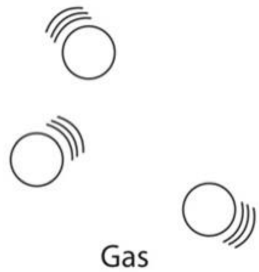
2.1 Simple kinetic molecular model of matter

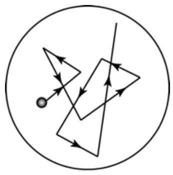
2.1.1 States of matter

 Solid	 Liquid	 Gas
• Close together in regular pattern • Strong intermolecular force of attraction • Vibrate at fixed position • Fixed shape & volume	• Close together in random pattern • Further apart than solid • Weaker intermolecular force of attraction • Slide past each other • Can't be compressed **Why can't compress?** • Large intermolecular forces when molecules moved closer	• Far apart in random pattern • Weaker intermolecular force of attraction Move • quickly in all directions • Can flow or compress

2.1.2 Molecular model

Brownian motion

- Smoke particles bombard with air molecules
- Smoke move in zig-zag paths in all directions
- Air gain KE & move faster randomly in all directions



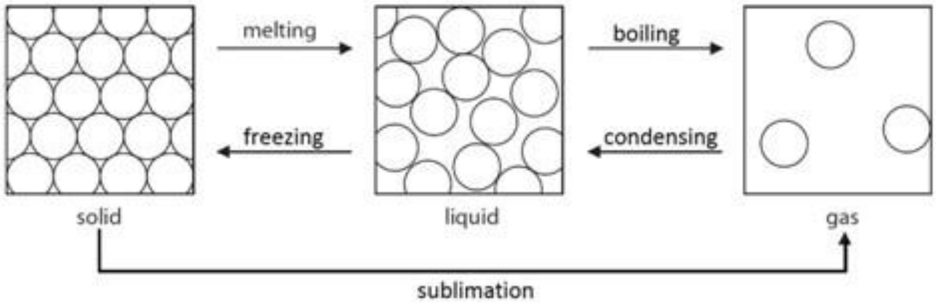
2.1.3 Evaporation

- Most energetic molecules overcome intermolecular force, escape from surface escape & become gas
- Less energetic molecules left behind → ↓ KE of molecules → ↓ temp → thermal energy lost

Evaporation can be accelerated by

- ↑ temp - more particles have energy to escape
- ↑ surface area - more molecules are close to the surface
- ↓ humidity - more molecules escape

State changes



- Whilst a substance changes its state, temp of material remains constant

2.1.4 Pressure changes

- Pressure is inversely proportional to the volume given a constant temperature.
- If the volume increases and the temperature stays constant, the particles hit the surface less often, thus decreasing the pressure

$$PP_1VV_1 = PP_2VV_2$$

For a fixed mass of gas at constant temperature
$PPVV = cccccccccccccccc$

- As the temperature increases of a fixed mass of gas, the pressure increases as the average kinetic energy increases

2.2 Thermal properties and temperature

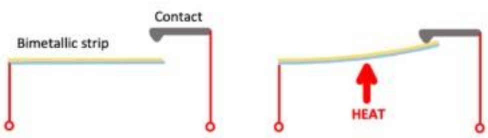
2.2.1 Thermal expansion of solids, liquids and gases

- Expand when heated coz atoms vibrate more → move further apart, take up greater volume

State	Expansion
Solid	Expand slightly – due to strong bonds holding molecules tgt
Liquid	Expand more than solids – due to weaker bonds between molecules
Gas	Expand significantly – due to no bonds holding molecules tgt

Applications & Consequences
Applications:

- Expansion of liquid in **thermometer** - measure temperature.
- **Bimetallic strip**, consisting of two metals that expand at different rates, can be made to bend at a given temperature, forming a temperature-activated switch.



The bimetallic strip will bend upwards when heated, closing the circuit

Consequences

- The expansion of solid materials can cause them to buckle if they get too hot.
- Eg metal railway tracks, bridges
- Things that are prone to buckling in this way often have gaps built into them, providing room for expansion

2.2.2 Measurement of temperature

- When a substance is heated, volume, density & electrical resistance of substance can change

Thermometers

- **Fixed points** - lower: 0°C, upper: 100°C
- **Sensitivity** - change in length when temp ↑/↓
- **Range** - difference between highest & lowest temp
- **Linearity** - when given change in temp causes same change in length, liquid expands uniformly
- **Responsiveness** - time it takes to react to change in temp

Liquid-in-glass thermometer

- As temperature rises or falls, the liquid (mercury or alcohol) expands or contracts

To increase…

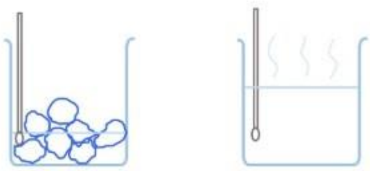
Sensitivity	• Narrow tube - quicker change on scale • Bigger bulb • Alcohol expands more than mercury
Range	• Longer tube
Linearity	• Expands uniformly for each degree of temperature rise

Alcohol

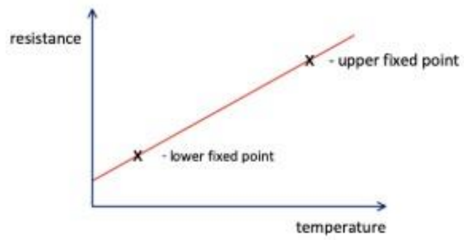
- High expansivity - reading easily observed
- Linear expansion - expands uniformly over wide range of temp
- Low melting / freezing pt
- Non-toxic

Building a thermometer

- In order to build a thermometer based on one of these properties, you need to start by measuring the property at some well-defined **fixed points**
- A fixed point is a temperature at which some easily identifiable change occurs, such as the melting of ice (at 0 °c) or the boiling of pure water (at 100 °c)

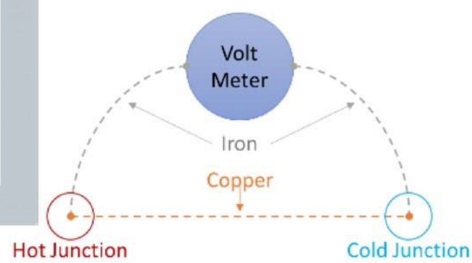


Ice melts and water boils at well-defined temperatures (fixed points) which may be used to calibrate thermometers



- These fixed points allow you to know the temperature without having to measure it directly.
- Usually two fixed points are used:
  - The lower fixed point: **the melting temperature of ice**.
  - The upper fixed point: **the boiling temperature of pure water**.
- Once a property (such as electrical resistance) has been measured at these two fixed points, the values of that property at other temperatures can be worked out

Thermocouple



- Thermocouple thermometers have wires made of two different materials, e.g iron and copper that are joined together. If one junction is at a higher temperature than the other one, an electric current flows, producing a reading on a digital voltmeter, the voltage of the current is directly related to the temperature
- Temp difference causes voltage → reading of meter change
- ↑ temp difference ↑ current

Advantages

- Rapid response - junction small mass, heat faster
- Large range
- Remote reading

2.2.3 Thermal capacity (heat capacity)

- ↑ temp of a body is ↑ internal energy of that body
- Average KE of a gas particle is directly proportional to temp

$ccheeeeeeccee\ cccccccccccccc = eeccccccc \times cccceeccccssccccc\ heecccc$
$cccccccccccccccc$
$ccheeeeeeccee\ cccccccccccccc = eecc$

Thermal capacity of an object

- Amount of heat energy required to raise the temperature of that object by 1°C
- ↑ thermal capacity, ↑heat energy it takes to raise its temperature
- Also equal to the amount of heat energy an object will give out when it cools by 1°C

Specific heat capacity - amount of heat energy needed for 1kg of a substance to raise its temp by 1°C

$eeccceeeeeeecc\ cceecccccccsseeeeeeeett = eeccccccc \times cccceeccccssccccc\ heecccc$
$cccccccccccccccc \times cchcccceeee\ cccc\ cceeeecceeeecccccttteeee$

$eecceeeeeeecc\ cceecccccccsseeeeeeeeett = eecc\Delta TT$

Unit specific heat capacity: **(J/kg °C)**

2.2.4 Melting and boiling

- When process starts, there isn't increase in temp of the substance coz thermal energy supplied is being used to break bonds between particles
- Latent Heat: energy required to change the state of a substance.
    - This energy is required to break the bonds holding molecules together
- Specific Latent Heat: energy required to change the state of 1 kg of that substance

$$eecceeeeeeecc\ cceecccccccsseeeeeeeeett = \frac{eecccccc \times ccccceecccccssccccc}{eecccceecccc\ heecccc}$$

$$eecceeeeeeecc\ cceecccccccsseeeeeeeeett = eemm$$

Melting	solid → liquid
Latent heat of fusion	Amount of energy to change 1kg of solid to liquid at constant temp

Boiling	liquid → gas
Latent heat of vaporization	Amount of energy to change 1kg of liquid to gas at constant temp

Evaporation vs Boiling

Similarities	Differences	
	Evaporation	Boiling
• liquid → gas • Gain thermal energy	• No bubbles • Don't need external energy source • Occurs between 0°C & 100°C	• Form bubbles • Need external energy source • Occurs at 100°C

Condensation

- gas → liquid
- When gas cools, particles lose energy & move slower. When bump into each other, they don't have enough energy to bounce away again so they stay closer together & forms bonds → become liquid

Solidification (freezing)

- liquid → solid
- When liquid cools, particles more slower. Eventually they stop moving except for vibrations → become solid

2.3 Thermal processes

2.3.1 Conduction

- In solids or liquids
- Flow of heat through matter from places of higher temperature to places of lower temperature without movement of the matter as a whole

Metals	Non-metal
• Good conductor • Electrons are free to travel randomly & collide neighboring particles and transfer heat energy	• Poor conductor

2.3.2 Convection

- In liquid or gas
- Flow of heat through a fluid from places of higher temperature in places of lower temperature by movement of the fluid itself
- As fluid warms up, warmer particles become less dense and rise up to surface. They then cool and sinks to the heat source to displace it, creating a cycle called convection current

5 Fig. 5.1 shows a cross-section of the inside of a vacuum flask containing a cold liquid. The walls of the vacuum flask are made of glass.

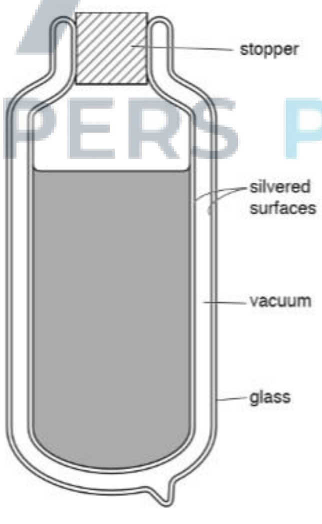


Fig. 5.1

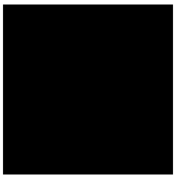
(a) The vacuum flask is being used to keep a liquid cool on a hot day.

Explain how the labelled features of the vacuum flask keep the liquid cool by reducing thermal energy transfer. Include the names of the processes involved.

- Stopper reduces heat gain by convection
- Silvered surfaces reflect thermal radiation and a poor absorber
- Vacuum prevents heat gain by convection
- Glass is a poor conductor

2.3.3 Radiation

- Flow of heat energy from one place to another by infra-red radiation
- Can travel through vacuum
- Doesn't require medium

Emitter / Absorber	Reflector
	
• Sends out / Absorb thermal radiation • Emitter - cools down quickly • Absorber - heats up quickly • Poor reflector	• Reflects thermal radiation • Poor absorber

2.3.4 Consequences of energy transfer