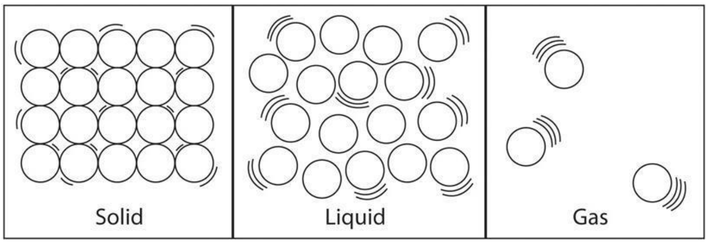
Chapter 2 Thermal Physics

2.1 Kinetic particle model of matter

2.1.1 States of matter

Core	Supplement
1 Know the distinguishing properties of solids, liquids and gases 2 Know the terms for the changes in state between solids, liquids and gases (gas to solid and solid to gas transfers are **not** required)	



- Matter exist in one of four different states.

State	Characteristics
Solid	• Fixed shape and volume. • Strong forces of attraction between particles. • Have a fixed pattern (lattice) • Atoms vibrate but cannot change position.
Liquid	• Fixed volume but changes shape depending on container • Weaker attractive forces that solids • No fixed pattern • Particles slide past each other
Gases	• No fixed shape volume, gases fill up their containers • Almost no intermolecular forces • Particles are far apart, and move quickly, gases spread out to fill up the container and exert equal pressure on all surfaces. • They collide with each other and bounce in all directions.

- Matter can change from solid to liquid via melting and liquid to solid via freezing.
- These changes occur at the melting point.
- Liquid can also change to gas via boiling and gas to liquid via condensing.
- These occur at the boiling point.

2.1.2 Particle model

Core

1. Describe the particle structure of solids, liquids and gases in terms of the arrangement, separation and motion of the particles, and represent these states using simple particle diagrams
2. Describe the relationship between the motion of particles and temperature, including the idea that there is a lowest possible temperature (–273 °C), known as absolute zero, where the particles have least kinetic energy
3. Describe the pressure and the changes in pressure of a gas in terms of the motion of its particles and their collisions with a surface
4. Know that the random motion of microscopic particles in a suspension is evidence for the kinetic particle model of matter
5. Describe and explain this motion (sometimes known as Brownian motion) in terms of random collisions between the microscopic particles in a suspension and the particles of the gas or liquid

Supplement

6. Know that the forces and distances between particles (atoms, molecules, ions and electrons) and the motion of the particles affects the properties of solids, liquids and gases
7. Describe the pressure and the changes in pressure of a gas in terms of the forces exerted by particles colliding with surfaces, creating a force per unit area
8. Know that microscopic particles may be moved by collisions with light fast-moving molecules and correctly use the terms atoms or molecules as distinct from microscopic particles

2.1.3 Gases and the absolute scale of temperature

Core

1. Describe qualitatively, in terms of particles, the effect on the pressure of a fixed mass of gas of:
   (a) a change of temperature at constant volume
   (b) a change of volume at constant temperature
2. Convert temperatures between kelvin and degrees Celsius; recall and use the equation
   T (in K) = θ (in °C) + 273

Supplement

3. Recall and use the equation
   pV = constant
   for a fixed mass of gas at constant temperature, including a graphical representation of this relationship

- Molecules in a gas move around randomly and very quickly.
- The temperature of a gas is related to the average kinetic energy of the molecules.
- The higher the KE of the molecules, the higher its temperature.

- For example, the average KE of a glass of water at 80 °C is higher than the average KE of a glass of water at 30 °C.
- Hence, the lowest possible temperature that can be achieved in this universe is -273 °C (not infinity!)
- At this temperature all molecules cease moving hence, the average KE = 0
- The motion of the molecules often cause them to collide with the surface of nearby walls.
- This collision causes a change in momentum when the molecule bounces off the wall (recall from previous chapter change in momentum over time gives you force).
- Each collision applies a force across a surface area of the walls.
- Recall from previous chapter force per unit area is pressure.
- Recall Brownian motion is the erratic motion of small particles when observed through a microscope which is caused by collision between said particles and the molecules of the gas (liquid).
- The SI unit of temperature is in Kelvin. However, Celsius is more frequently used.
- You can convert Celsius to Kelvin by using

$$K = T^{O}C + 273$$

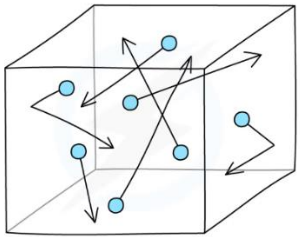
Convert the following to Kelvin

a) -273 ^{O}C

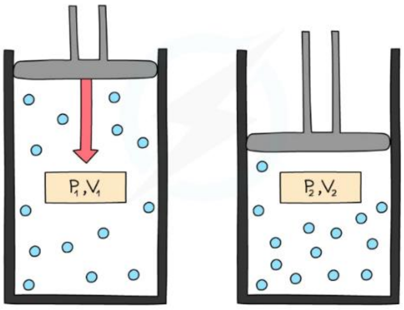
b) 0 ^{O}C

c) 100 ^{O}C

- When the temperature of a gas in a fixed container is increased, the KE (speed) of molecules increase.
- This causes the molecules to collide more frequently against the container thus increasing pressure.

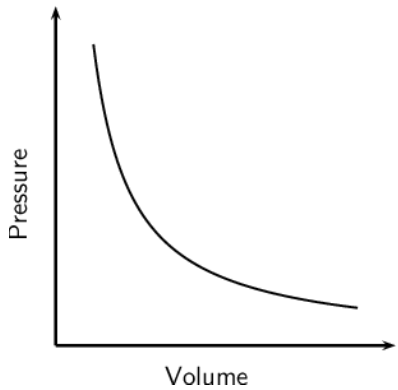


- However, if you decrease the volume while keeping the temperature of the gas constant (as in the case of the piston below) the pressure will increase.
- This is due to more collisions of the molecules with the container.



- This phenomenon can be described using Boyle's Law

$$P_1V_1 = P_2V_2$$



- The graph above shows the inverse relationship between pressure and volume of an ideal gas at constant temperature.

2.2 Thermal properties and temperature

2.2.1 Thermal expansion of solids, liquids and gases

Core

1 Describe, qualitatively, the thermal expansion of solids, liquids and gases at constant pressure

2 Describe some of the everyday applications and consequences of thermal expansion

Supplement

3 Explain, in terms of the motion and arrangement of particles, the relative order of magnitudes of the expansion of solids, liquids and gases as their temperatures rise

2.2.2 Specific heat capacity

Core

1 Know that a rise in the temperature of an object increases its internal energy

Supplement

2 Describe an increase in temperature of an object in terms of an increase in the average kinetic energies of all of the particles in the object

3 Define specific heat capacity as the energy required per unit mass per unit temperature increase; recall and use the equation

$$c = \frac{\Delta E}{m\Delta\theta}$$

4 Describe experiments to measure the specific heat capacity of a solid and a liquid

2.2.3 Melting, boiling and evaporation

Core

1 Describe melting and boiling in terms of energy input without a change in temperature

2 Know the melting and boiling temperatures for water at standard atmospheric pressure

3 Describe condensation and solidification in terms of particles

4 Describe evaporation in terms of the escape of more energetic particles from the surface of a liquid

5 Know that evaporation causes cooling of a liquid

Supplement

6 Describe the differences between boiling and evaporation

7 Describe how temperature, surface area and air movement over a surface affect evaporation

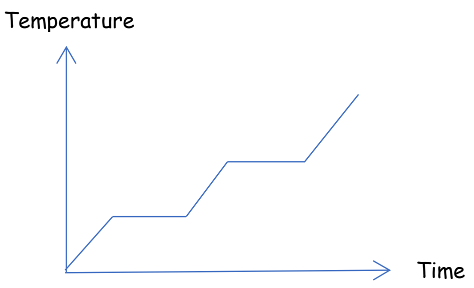
8 Explain the cooling of an object in contact with an evaporating liquid

- When most substance is heated, they expand due to higher average KE.
- The molecules start knocking into each other and push each other apart.
- Solids expand a <u>little</u> due to the stronger bonds holding each molecule.
- Liquids expand <u>more than solid but less that gas</u> since the molecular bond strength holding them is between solid and gas.
- Gas expands the <u>most</u> due to it have the weakest molecular bonds.
- Best example of this phenomenon is a thermometer.

- As the temperature of thermometer increases, the liquid inside of the thermometer expands.
- To do well in this chapter you must first understand the difference between temperature and heat.
- Temperature is related to the average speed (or KE) of individual molecules.
- The SI unit for temperature is in Kelvin.
- Heat is a form of energy (not a force).
- As such its SI unit is Joules.
- **Specific heat capacity** is the amount of heat required to change the temperature by 1°C or 1K for a mass of 1kg of the substance.
- A lower heat capacity means the object heats up easier, while a higher heat capacity means an object heats slower.
- The specific heat capacity (c) can be calculated by using

$$c = \frac{Q}{\theta m}$$

  Here Q is the thermal energy (heat), θ is the change in temperature and m is the mass of the substance.
- The SI unit of c is Joules $^{O}C^{-1}kg^{-1}$ (definitely the longest unit in physics so far!)



- The above is a familiar plot of temperature vs time
- When a substance is heated its temperate would normally increase due to the average KE increasing (sloped part of the graph)
- However, when the substance is changing phase either solid to liquid or liquid to gas, the temperature stays the same (flat part of the graph)
- This happens because the energy is being used to break the bonds between the molecules instead of increasing the KE (hence temperature)

- Liquid can change to gas through either **boiling** or **evaporation**.
- The difference between both is as follows:

Boiling	Evaporation
Occurs at fixed temperature	Occurs at any temperature
Quick process	Slow process
Takes place throughout the liquid	Takes place only at the surface of the liquid
Bubbles are formed in the liquid	No bubbles are formed
Temperature remains constant	Temperature may change
Thermal energy supplied by an energy source	Heat supplied by surroundings

- 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:

  -increasing temperature: more particles have enough energy to escape

  -increasing surface area: more molecules are close to the surface

  -reduce the humidity level in the air: if the air is less humid, fewer particles are condensing.

  -blow air across the surface: removes molecules before they can return to the liquid
- Evaporation can cool objects down if the surface of the object is in contact with the liquid.
- Best example is sweating.

2.3 Transfer of thermal energy

2.3.1 Conduction

Core

1 Describe experiments to demonstrate the properties of good thermal conductors and bad thermal conductors (thermal insulators)

Supplement

2 Describe thermal conduction in all solids in terms of atomic or molecular lattice vibrations and also in terms of the movement of free (delocalised) electrons in metallic conductors

3 Describe, in terms of particles, why thermal conduction is bad in gases and most liquids

4 Know that there are many solids that conduct thermal energy better than thermal insulators but do so less well than good thermal conductors

2.3.2 Convection

Core

1 Know that convection is an important method of thermal energy transfer in liquids and gases

2 Explain convection in liquids and gases in terms of density changes and describe experiments to illustrate convection

Supplement

2.3.3 Radiation

Core

1 Know that thermal radiation is infrared radiation and that all objects emit this radiation

2 Know that thermal energy transfer by thermal radiation does not require a medium

3 Describe the effect of surface colour (black or white) and texture (dull or shiny) on the emission, absorption and reflection of infrared radiation

Supplement

4 Know that for an object to be at a constant temperature it needs to transfer energy away from the object at the same rate that it receives energy

5 Know what happens to an object if the rate at which it receives energy is less or more than the rate at which it transfers energy away from the object

6 Know how the temperature of the Earth is affected by factors controlling the balance between incoming radiation and radiation emitted from the Earth's surface

- Thermal energy is transferred via 3 mechanisms:

Mechanism	Method
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
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.
Radiation	• Thermal radiation is mainly infra-red waves (chapter 3) but very hot objects also give out light waves. • Infra-red radiation is part of the electromagnetic spectrum.

2.3.3 Radiation continued

Core

Supplement

7 Describe experiments to distinguish between good and bad emitters of infrared radiation

8 Describe experiments to distinguish between good and bad absorbers of infrared radiation

9 Describe how the rate of emission of radiation depends on the surface temperature and surface area of an object

2.3.4 Consequences of thermal energy transfer

Core

1 Explain some of the basic everyday applications and consequences of conduction, convection and radiation, including:

(a) heating objects such as kitchen pans

(b) heating a room by convection

Supplement

2 Explain some of the complex applications and consequences of conduction, convection and radiation where more than one type of thermal energy transfer is significant, including:

(a) a fire burning wood or coal

(b) a radiator in a car

- 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.
- Unlike the other two mechanism, thermal radiation can travel through a vacuum and does not need a medium.
- 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
- The color of an object affects how good it is at emitting and absorbing thermal radiation as shown below:

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

- Factors affecting thermal radiation is
  -temperature of the object (hotter = more radiation)
  -color of the object (black = more radiation)
  -surface area of the object (greater surface area = more area for radiation to emit from)