Energy transfer by heating

Heat can be transferred from place to place by *conduction* [conduction: *The transfer of heat energy through a material - without the material itself moving.* **], *convection* [convection:** *The transfer of heat energy through a moving liquid or gas.* **] and *radiation* [infrared radiation:** *Electromagnetic radiation emitted from a hot object.* **]. Dark matt surfaces are better at absorbing heat energy than light shiny surfaces. Heat energy can be lost from homes in many different ways and there are ways of reducing these heat losses.**

Infrared radiation

All objects emit (give out) and absorb (take in) thermal radiation, which is also called infrared radiation. The hotter an object is, the more infrared radiation it emits.

Light from the sun reaching earth

Infrared radiation is a type of electromagnetic radiation, which involves waves rather than particles. This means

that, unlike conduction and convection, radiation can even pass through the vacuum of space. This is why we can still feel the heat of the Sun, although it is 150 million km away from the Earth.

Some surfaces are better than others at emitting and absorbing infrared radiation. This table summarises the differences.

Comparison of surfaces abilities to reflect and absorb radiation

Type of surface	Ability to emit infrared radiation	Ability to absorb infrared radiation
dark, matt (dull)	good	good
light, shiny	poor	poor

Light, shiny surfaces are also good reflectors of infrared radiation.

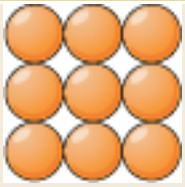
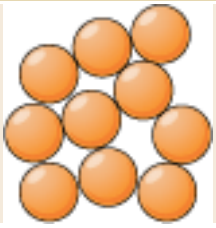
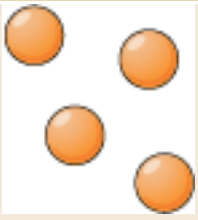
Kinetic theory

The kinetic particle theory explains the properties of the different states of matter. The particles in solids, liquids and gases have different amounts of energy. They are arranged differently and move in different ways.

This table summarises the arrangement and movement of the particles in solids, liquids and gases, and shows

simple diagrams of the arrangement of the particles that you should be able to recognise.

Diagram of particle arrangement and movement

	Solid	Liquid	Gas
Arrangement of particles	close together regular pattern	close together random	far apart random
movement of particles	vibrate about a fixed position	move around each other	move quickly in any direction
diagram			

Solids

The table shows some of the properties of solids and why they are like this.

Property of solids	Why they are like this
They have a fixed shape and cannot flow	The particles cannot move from place to place
They cannot be compressed or squashed	The particles are close together and have no space to move into

Liquids

Some of the properties of liquids and why they are like this

Property of liquids	Why they are like this
They flow and take the shape of their container	The particles can move around each other
They cannot be compressed or squashed	The particles are close together and have no space to move into

Gases

Some of the properties of gases and why they are like this

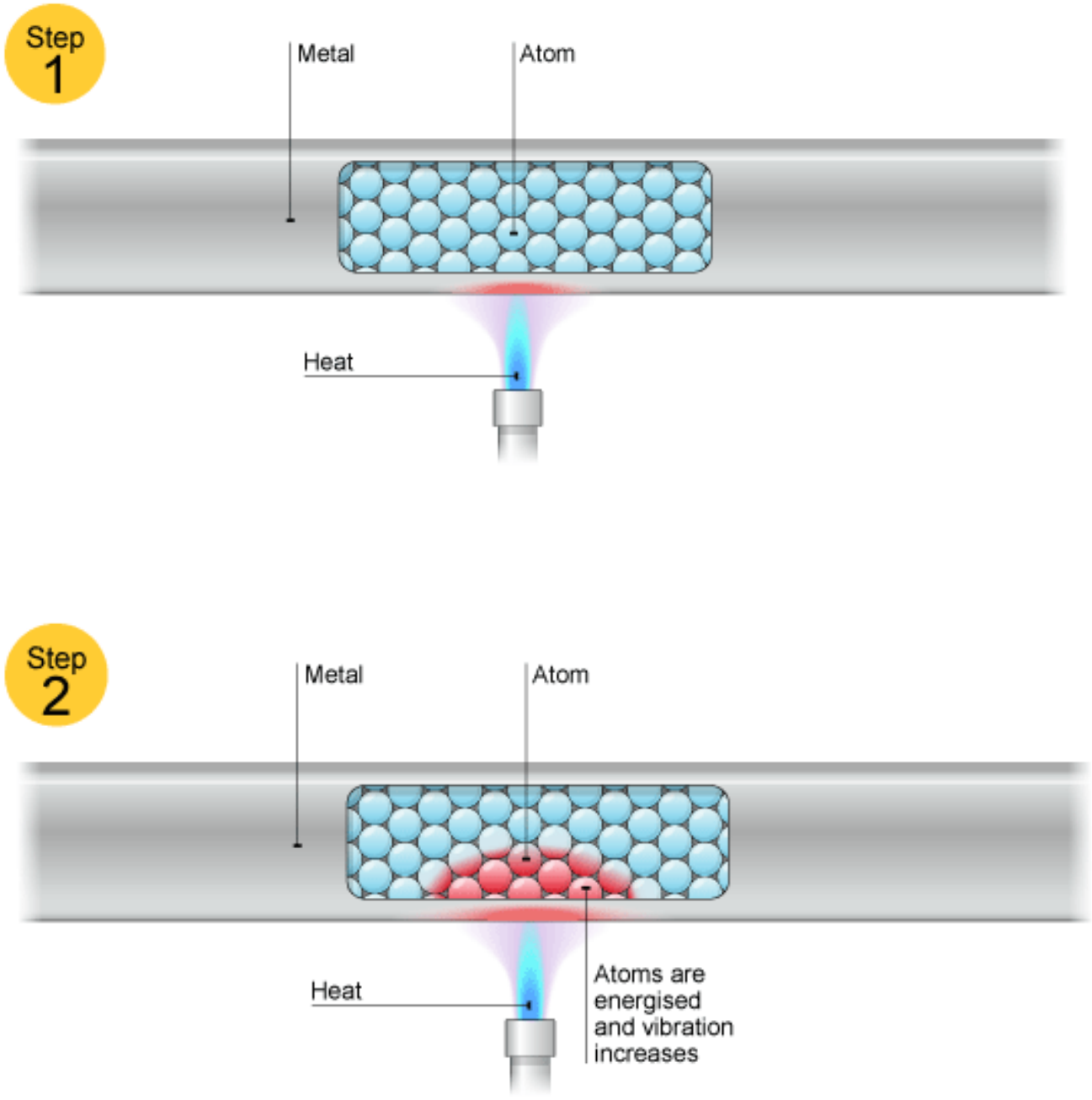
Property of gases	Why they are like this
They flow and completely fill their container	The particles can move quickly in all directions
They can be compressed or squashed	The particles are far apart and have space to move into

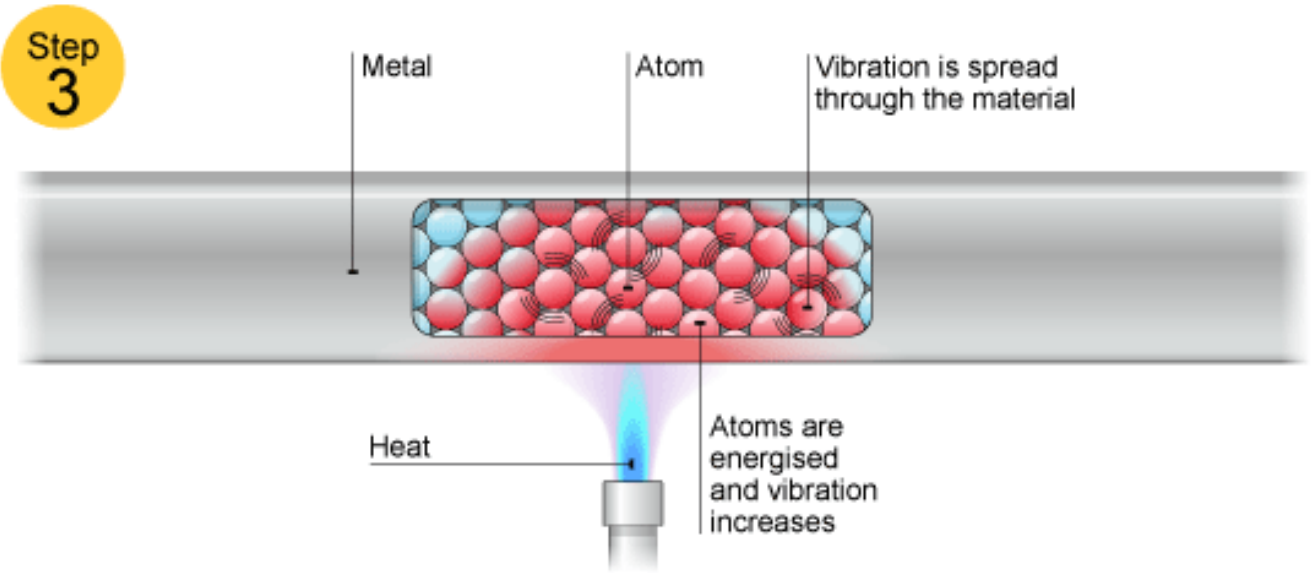
Conduction

Heat energy can move through a substance by *conduction* [**conduction**: *The transfer of heat energy through a material - without the material itself moving.*].

Metals are good conductors of heat but non-metals and gases are usually poor conductors of heat. Poor conductors of heat are called **insulators**. Heat energy is conducted from the hot end of an object to the cold end.

Heat transfer by conduction





Heat conduction in metals

The electrons in piece of metal can leave their atoms and move about in the metal as free electrons. The parts of the metal atoms left behind are now charged metal ions. The ions are packed closely together and they vibrate continually. The hotter the metal, the more *kinetic energy* [**kinetic energy**: *The energy that moving objects have.*] these vibrations have. This kinetic energy is transferred from hot parts of the metal to cooler parts by the free electrons. These move through the structure of the metal, colliding with ions as they go.

Convection

Liquids and gases are fluids. The particles in these fluids can move from place to place. Convection occurs when particles with a lot of heat energy in a liquid or gas move and take the place of particles with less heat

energy. Heat energy is transferred from hot places to cooler places by convection.

Liquids and gases expand when they are heated. This is because the particles in liquids and gases move faster when they are heated than they do when they are cold. As a result, the particles take up more volume. This is because the gap between particles widens, while the particles themselves stay the same size.

The liquid or gas in hot areas is less dense than the liquid or gas in cold areas, so it rises into the cold areas. The denser cold liquid or gas falls into the warm areas. In this way, convection currents that transfer heat from place to place are set up.

Evaporation and condensation

Evaporation and condensation are changes of state:

a) evaporation involves a liquid changing to a gas
b) condensation involves a gas changing to a liquid.

Evaporation is the reason why damp clothes dry on a washing line. Condensation is the reason why windows become foggy on a cold day.

Evaporation

The particles in a liquid have different energies. Some will have enough energy to escape from the liquid and

become a gas. The remaining particles in the liquid have a lower average kinetic energy than before, so the liquid cools down as evaporation happens. This is why sweating cools you down. The sweat absorbs energy from your skin so that it can continue to evaporate.

Condensation

The particles in a gas have different energies. Some may not have enough energy to remain as separate particles, particularly if the gas is cooled down. They come close together and bonds form between them. Energy is released when this happens. This is why steam touching your skin can cause scalds: not only is the steam hot, but energy is released into your skin as the steam condenses.

Factors affecting the rate of condensation and evaporation

The rate of condensation increases if the temperature of the gas is decreased. On the other hand, the rate of evaporation increases if the temperature of the liquid is increased. It is also increased if:

a) the surface area of the liquid is increased
b) air is moving over the surface of the liquid.

Keeping warm or cool

The bigger the difference in temperature between an object and its surroundings, the greater the rate at

which heat energy is transferred. Other factors also affect the rate at which an object transfers energy by heating. These include the:

a) surface area and volume of the object
b) material used to make the object
c) nature of the surface that the object is touching.

Animal adaptations

Small animals like mice have a large surface area compared to their volume. They lose heat to their surroundings very quickly and must eat a lot of food to replace the energy lost. Large animals like elephants have a different problem. They have a small surface area compared to their volume. They lose heat to their surroundings more slowly and may even have difficulty avoiding overheating.

Elephants have large ears with a large surface area compared to their volume. These allow heat to be transferred from the elephant to its surroundings, helping to keep the animal cool.

In general, similar animals have different ear sizes depending on the climate in which they live. The arctic fox has much smaller ears than the fennec fox, which lives in the desert. The arctic fox must conserve its heat energy in the cold climate, while the fennec fox must avoid overheating in the hot climate.

Engineering design

Engineers design heat transfer devices so that they gain or lose heat energy efficiently. For example, car radiators are flat, with many small fins to provide a large surface area. Similarly, household radiators are thin and flat, and may have fins so that heat energy is transferred to the room quickly.

Heating and cooling
Energy transfer by heating - Test

1.What substances can convection happen in?

a) In solids and gases
b) In solids and liquids
c) In liquids and gases

2.What type of radiation do all hot objects emit?

a) Infra-red radiation
b) Microwave radiation
c) Gamma radiation

3.What are the best absorbers of thermal radiation?

a) Light, dull surfaces
b) Black, shiny surfaces
c) Black, dull surfaces

4.What are the worst emitters of thermal radiation?

a) Light, shiny surfaces
b) Light, dull surfaces
c) Black, dull surfaces

5.How does heat pass through a single pane of window glass?

a) By conduction and convection
b) By conduction and radiation
c) By convection and radiation

6.Which statement about liquids is correct?

a) They can be compressed because their particles are free to move
b) They expand to fill their container because their particles are free to move
c) They cannot be compressed because their particles are close together