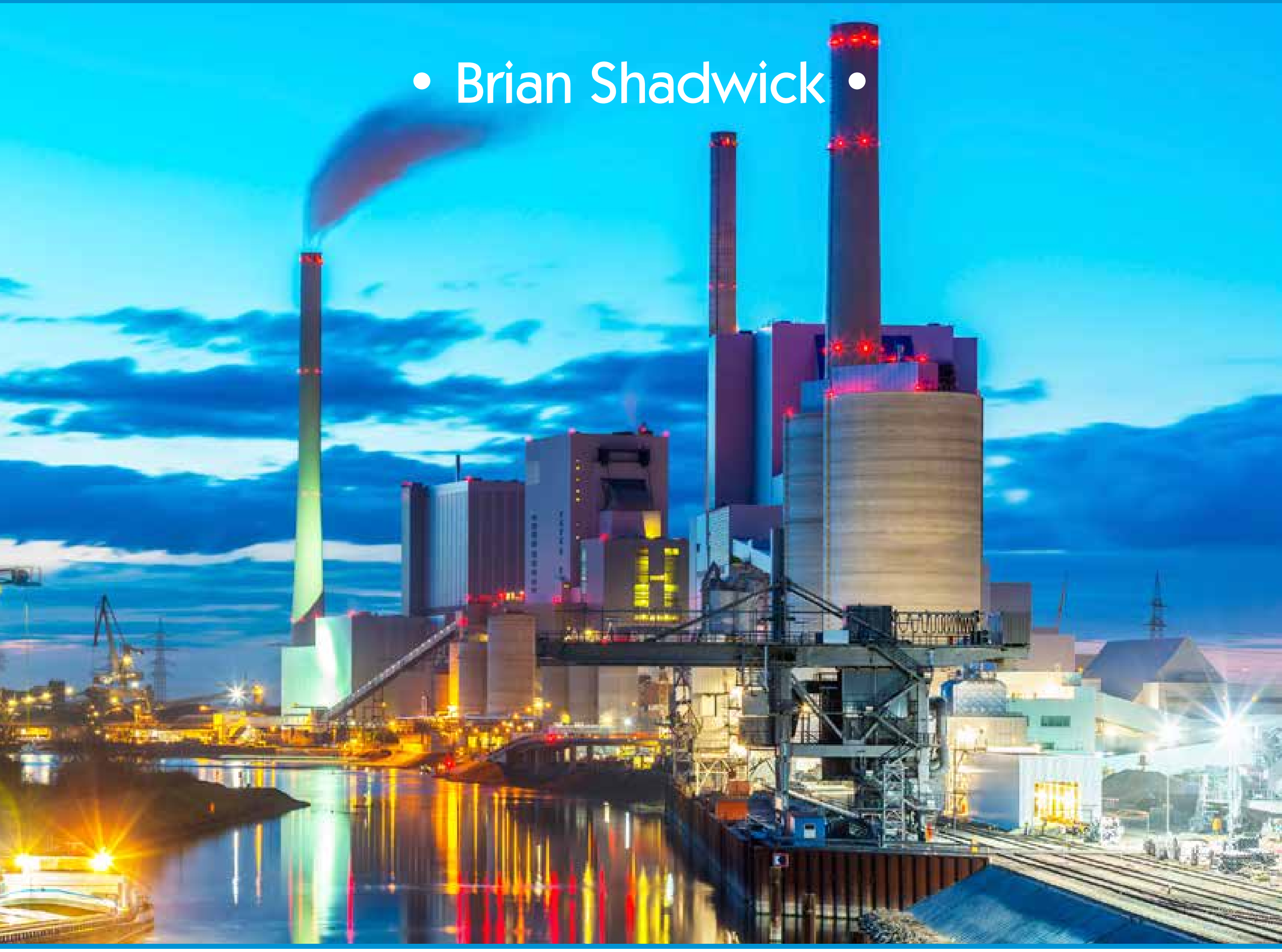
Surfing

NATIONAL PHYSICS

Unit 1 Thermal, Nuclear and Electrical Physics



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Contents

Use the table of contents to record your progress through this book. As you complete each chapter, write the date completed, then tick one of the three remaining columns to guide your revision for later. The column headers use the following codes:

?? = Don't understand this very well at all. RR = Need to revise this. OK = Know this.

Introduction

Each book in the *Surfing* series contains a summary, with occasional more detailed sections, of all the mandatory parts of the syllabus, along with questions and answers.

All types of questions – multiple choice, short response, structured response and free response – are provided. Questions are written in exam style so that you will become familiar with the concepts of the topic and answering questions in the required way.

Answers to all questions are included.

A topic test at the end of the book contains an extensive set of summary questions. These cover every aspect of the topic, and are useful for revision and exam practice.

Words To Watch

account, account for State reasons for, report on, give an account of, narrate a series of events or transactions.

analyse Interpret data to reach conclusions.

annotate Add brief notes to a diagram or graph.

apply Put to use in a particular situation.

assess Make a judgement about the value of something.

calculate Find a numerical answer.

clarify Make clear or plain.

classify Arrange into classes, groups or categories.

comment Give a judgement based on a given statement or result of a calculation.

compare Estimate, measure or note how things are similar or different.

conctruct Represent or develop in graphical form.

contrast Show how things are different or opposite.

create Originate or bring into existence.

deduce Reach a conclusion from given information.

define Give the precise meaning of a word, phrase or physical quantity.

demonstrate Show by example.

derive Manipulate a mathematical relationship(s) to give a new equation or relationship.

describe Give a detailed account.

design Produce a plan, simulation or model.

determine Find the only possible answer.

discuss Talk or write about a topic, taking into account different issues or ideas.

distinguish Give differences between two or more different items.

draw Represent by means of pencil lines.

estimate Find an approximate value for an unknown quantity.

evaluate Assess the implications and limitations.

examine Inquire into.

explain Make something clear or easy to understand.

extract Choose relevant and/or appropriate details.

extrapolate Infer from what is known.

hypothesise Suggest an explanation for a group of facts or phenomena.

identify Recognise and name.

interpret Draw meaning from.

investigate Plan, inquire into and draw conclusions about.

justify Support an argument or conclusion.

label Add labels to a diagram.

list Give a sequence of names or other brief answers.

measure Find a value for a quantity.

outline Give a brief account or summary.

plan Use strategies to develop a series of steps or processes.

predict Give an expected result.

propose Put forward a plan or suggestion for consideration or action.

recall Present remembered ideas, facts or experiences.

relate Tell or report about happenings, events or circumstances.

represent Use words, images or symbols to convey meaning.

select Choose in preference to another or others.

sequence Arrange in order.

show Give the steps in a calculation or derivation.

sketch Make a quick, rough drawing of something.

solve Work out the answer to a problem.

state Give a specific name, value or other brief answer.

suggest Put forward an idea for consideration.

summarise Give a brief statement of the main points.

synthesise Combine various elements to make a whole.

1 The Kinetic Theory of Matter

To understand why solids, liquids and gases behave differently, scientists have developed a theory called the **kinetic theory** or the **particle theory of matter**. We can use this theory to explain why the properties of the states of matter are so different. There are three main ideas in the kinetic theory of matter as outlined below.

The kinetic theory

- All matter is made up of small particles.
- These particles are always moving except at absolute zero which is defined as the temperature at which all particle motion ceases.
- The particles are held together by forces which vary in strength.

Our concept of the temperature of matter is also tied to our understanding of the kinetic theory as follows.

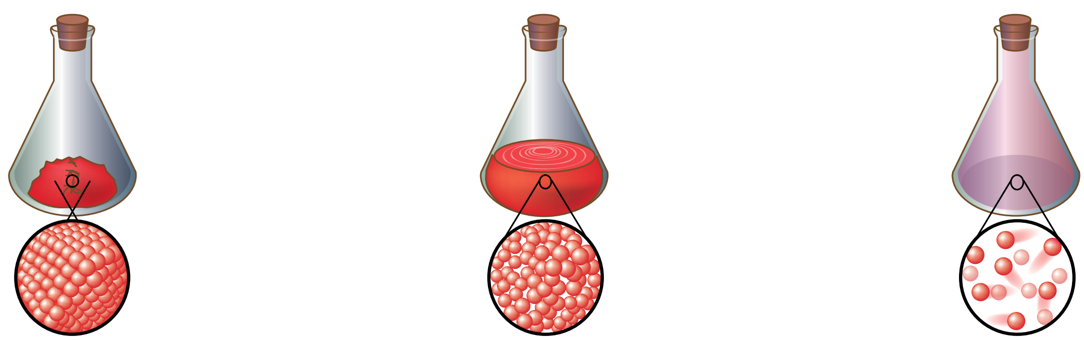
Temperature is a measure of the average kinetic energy of the particles of matter.

It is important to remember that the ideas in the kinetic theory represent a **model** only.

- The particles of matter are too small to be seen, so we are not describing what they do from observations of the particles themselves. We deduce their behaviour from the properties of matter.
- We use the kinetic theory to explain and predict the behaviour of matter.
- Any model in science is only as good as its ability to explain and predict accurately, and so far, the kinetic theory model has worked extremely well.
- If we discover properties of matter that we cannot explain using the kinetic theory, then we will need to rethink the theory, perhaps modifying it so that these new properties are also explained.

QUESTIONS

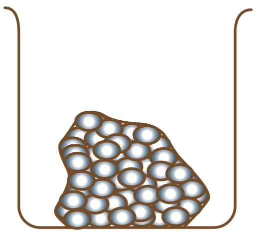
1. Complete the sentences about the kinetic theory by writing one word in each space.
   (a) Particles in .... are held .... by strong ....
   (b) The particles in solids cannot move .... because they are .... in .... positions.
   (c) In liquids, the .... are not held together as .... as in solids, so they can .... over one another. This is why liquids can be ....
   (d) In gases particles are .... held together and are therefore .... to move in any .... This is why gases .... readily and always completely .... their containers.
2. We often use diagrams to help us understand kinetic theory. In these diagrams each circle or square, or triangle, or whatever shape is used, represents one particle of matter.
   Complete the labels on the diagrams shown to firstly identify which state of matter each represents, and then describe the properties of the particles that make up each state. One has been done for you as a guide.



Solids		
	• Particles are close together. • Particles are held less tightly than in solids. • Particles are not free to move, but • Particles can roll over one another.	

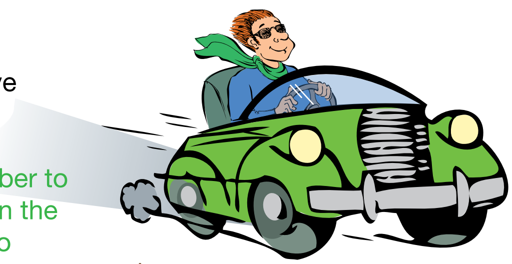
2 Kinetic Theory and Properties of Matter

The kinetic theory explains the behaviour of matter by saying that matter is made up of small particles which are constantly in motion and are held together by forces which vary in strength. Consider the examples below.

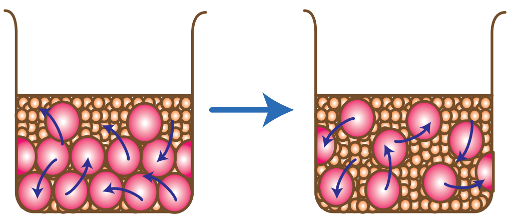


Solids have a constant shape because …
Their particles are in contact and are held together by strong forces and the particles can only vibrate in their fixed positions.

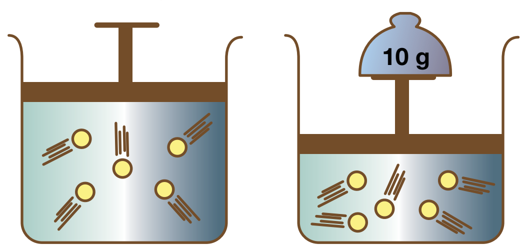
The tyres on cars wear away as we drive along because …
Friction between the tyres and the road causes some of the particles of the rubber to break away from each other and stay on the road surface (they are, of course, far too small to be seen).

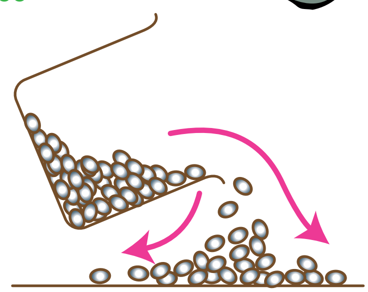


Liquids can diffuse into each other because …
Their particles are in contact but can move past one another.

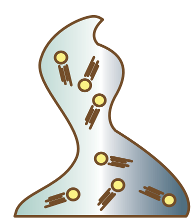


Gases can be compressed because …
Their particles are not in contact and can be forced closer together.





Liquids (and gases) can flow because …
Their particles are in contact and can move past one another.



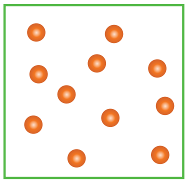
Gases fill their containers because …
Their particles are not held together and can move freely.

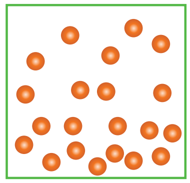
QUESTIONS

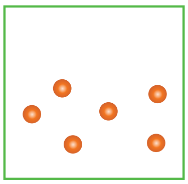
1. Why are gases easier to compress than liquids?
   (A) They are less dense.
   (B) Their particles are held together less tightly.
   (C) Their particles are further apart.
   (D) Their particles move randomly.
2. What is a consequence of the particles in liquids being able to slide over one another?
   (A) They cannot be compressed.
   (B) They can be poured.
   (C) They fill the container.
   (D) They expand when heated.
3. What causes particles of matter to move faster?
   (A) Weaker forces between them.
   (B) Heating the matter.
   (C) Cooling the matter.
   (D) Shaking the matter.
4. When matter expands its particles:
   (A) Get larger and occupy more space.
   (B) Get hotter and increase in volume.
   (C) Break the forces holding them together and spread out into a larger volume.
   (D) Move faster, collide more violently, and need more room to move in.

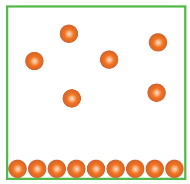
5. Between which particles would you expect the forces to be strongest?
(A) Between air particles.
(B) Between water particles.
(C) Between ice particles.
(D) Between lemonade particles.

6. Which diagram correctly shows the particles of a gas in a closed container?

(A)


(B)


(C)


(D)


7. Which is *not* an example of diffusion?
(A) Pool chlorine tablets slowly dissolving into the pool water.
(B) Noticing the perfume your friend is wearing.
(C) Volcanic gases spreading throughout the atmosphere.
(D) Biro smudging when your hand rubs over it.

8. Considering what you know about lipstick, which statement is correct?
(A) Forces between lipstick particles and lip particles are stronger than those between lipstick particles.
(B) Forces between lipstick particles are stronger than those between lipstick and lip particles.
(C) Forces between lipstick particles are equal to those between lipstick and lip particles.
(D) Forces between lipstick particles are equal to those between lip particles.

9. Which particles will have the greatest energy?
(A) Water liquid particles at 50°C.
(B) Water vapour particles at 50°C.
(C) Water liquid particles at 60°C.
(D) Water vapour particles at 60°C.

10. Why do gases diffuse more quickly than liquids?
(A) They are less dense.
(B) Their particles are not held together.
(C) Their particles are smaller.
(D) Their particles move more quickly.

11. Why can't solids and liquids be compressed?
(A) Their particles are held together too strongly.
(B) Their particles are not held together.
(C) Their particles are in fixed positions.
(D) Their particles are as close together as they can be.

12. Use the kinetic theory in the same way as the examples above to explain each of the following facts.

	Fact	Kinetic theory explanation
(a)	Wood cannot be compressed.	
(b)	Rocks do not diffuse.	
(c)	Petrol fumes can be smelt at a service station.	
(d)	Spilt juice soaks into a paper towel.	
(e)	Drops of ink will spread through a glass of water.	
(f)	A metal bar is stronger than a wooden rod the same size.	
(g)	You can tear one sheet of paper in half easily, but cannot tear a phone book in half.	
(h)	Gases diffuse faster than liquids.	
(i)	Liquids take the shape of their container.	
(j)	Glue from a glue stick is easy to rub onto paper.	
(k)	Compressed air pumps are used to pump up car tyres.	
(l)	Hairspray cans spray the hairspray out when the button is pushed down.	
(m)	Car windows can fog over on the inside on a cloudy day.	
(n)	You should not leave a spray can of oil in the sun on the barbecue.	

3 Temperature and the Kinetic Theory

An important idea in the kinetic theory of matter is the concept of temperature, and what happens to the particles of matter when matter is heated or cooled.

Temperature

- Temperature is a measure of how fast the particles of matter are moving.
- Temperature is a measure of the average kinetic energy of the particles of matter.

When matter is heated its particles absorb energy and move faster.

When matter is cooled its particles lose energy and slow down.

Note: Gas particles have more energy due to their state than liquid particles at the same temperature. Similarly, liquid particles have more energy than solid particles at the same temperature. In both cases this is due to the extra energy they have because the particles move more freely.

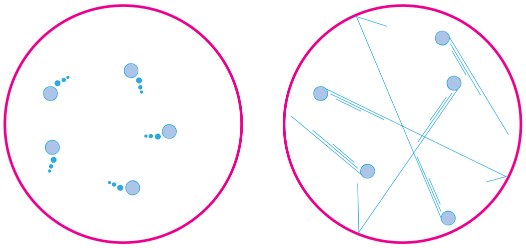
QUESTIONS

1. Knowing temperature or heat energy is a measure of the average kinetic energy of motion of the particles of matter, explain how this leads to the idea of an absolute zero temperature.
2. Consider the four different pictures of water below.

(A) Boiling water (B) Iceblocks (C) Shower water (D) Steam

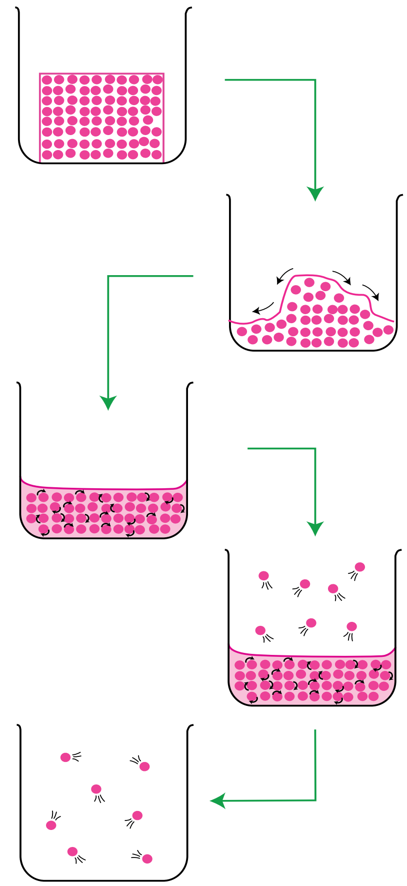
   (a) In which picture will the water particles be moving most slowly? Justify your answer.
   (b) In which picture will the particles have the most kinetic energy? Justify your answer.
   (c) Rank the particles in the four states of water in order from slowest to fastest.
   (d) Steam at 100°C will actually cause more severe burns to a person than water at 100°C. Suggest an hypothesis as to why this is so.
3. Explain, in terms of the motion of particles, why an aerosol spray can left in the sun could explode.
4. Before going on a long journey in summer, car owners are encouraged to let some of the air out of their tyres. Explain why this could make the journey safer.
5. The diagram shows the particles of matter in the same balloon before and after something happened.
   (a) What inference can you make about the particles in the balloon in Y compared to X?
   (b) Infer from this what has happened to the balloon.
   (c) Explain, in terms of the kinetic theory, why this happened.

X : Before Y : After



4 Changes of State and the Kinetic Theory

Particles in a solid
- Particles are touching.
- Particles are held together by strong forces.
- Particles cannot move freely.
- Particles vibrate in fixed positions.
- The solid has a fixed shape and volume.



- As a solid is heated, its particles vibrate more violently, absorbing energy to weaken the bonds holding them together
- until they have enough energy to totally overcome the forces holding them in fixed positions, then
- they slide over one another as the solid starts to melt and becomes a liquid.

Particles in a liquid
- Particles are touching.
- Particles are held together by weaker forces.
- Particles cannot move freely.
- Particles can slide over one another.
- Liquids have fixed volume but take the shape of their container.

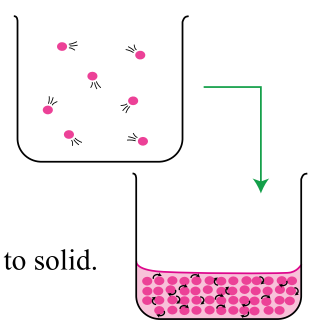
- As a liquid is heated its particles roll faster and faster
- until they have enough energy to overcome the forces holding them together,
- then they can break away from each other and move freely as the liquid becomes a gas.

Particles in a gas
- Particles are far apart.
- Particles are not held together.
- Particles move freely in all directions.
- Particles collide with the walls of the container.
- Gases have no fixed volume and fill their containers.

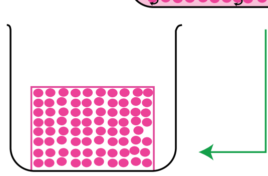
QUESTIONS

1. What causes the particles in matter to move faster?
2. The information above describes, in terms of the kinetic theory, what happens when a solid is heated to become a liquid then a gas. Write similar captions to describe what happens when a gas is firstly changed into a liquid, and then the liquid into a solid.

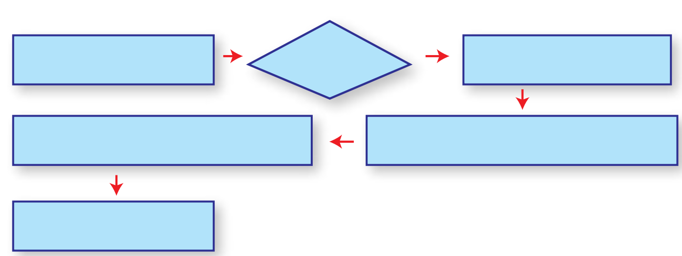
   (a) Gas to liquid.



   (b) Liquid to solid.



3. If you keep a chocolate bar in your shirt pocket, when you come to eat it, it will be softer than when you put it into the pocket. Explain, in terms of the kinetic theory, what has happened.
4. It is much easier to notice the perfume a lady wears on a summer's day than on a winter's day. Explain.
5. What is expansion and when does it occur? Explain expansion in terms of the particle theory.
6. What is contraction and when does it occur? Explain contraction in terms of the particle theory.
7. Place the following labels in the flow chart: Heat, Liquid expands, Particles bump into each other more violently, Particles in liquid, Particles move more quickly, Particles push each other further apart



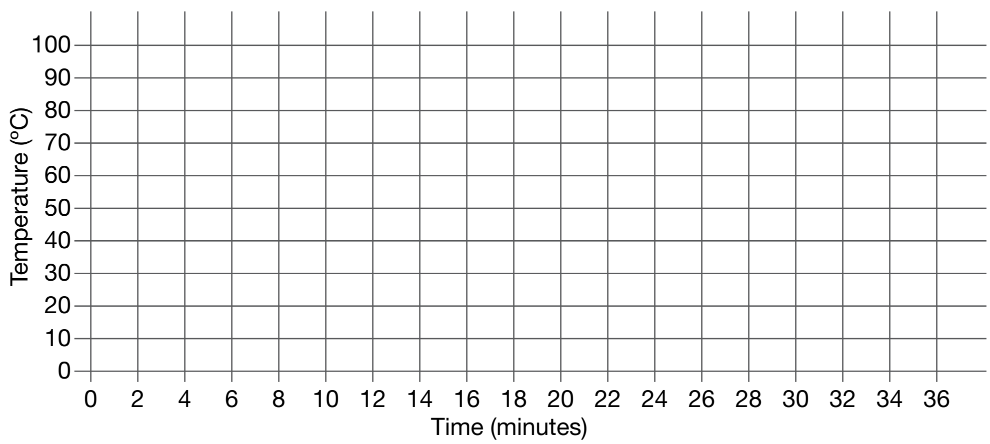
5 Changes of State and Latent Energy

The table shows the results of an experiment done by students who heated 200 g of ice gently until it turned into water and the water boiled and evaporated away. All the water had evaporated by time 35 minutes. Use the data to answer the questions below.

Time (min)	Temp (°C)	Time (min)	Temp (°C)	Time (min)	Temp (°C)	Time (min)	Temp (°C)
0	0	9	7	18	49	27	94
1	0	10	11	19	55	28	98
2	0	11	15	20	60	29	100
3	0	12	19	21	65	30	100
4	0	13	24	22	70	31	100
5	0	14	29	23	74	32	100
6	0	15	34	24	79	33	100
7	0	16	39	25	84	34	100
8	3	17	44	26	89	35	100

QUESTIONS

1. Graph the results of the experiment on the axes below.



2. Place the following labels on your graph in the appropriate positions.
   - Ice melting, temperature constant
   - All ice has melted
   - Water heated, temperature rising
   - Water starts boiling
   - Water boiling, temperature constant
3. During time 0 to time 7 minutes, the ice is being heated gently, but the temperature does not rise. Suggest a reason for this.
4. During time 28 to time 35 minutes, the water is being gently heated still, but the temperature does not rise. Suggest a reason for this.
5. Consider the following definition.

> **Latent heat of fusion**, L_f is the energy required to change the state of a substance from solid to liquid. Also referred to as the specific heat of fusion.
>
> **Latent energy** in fusion is used to overcome the forces holding the particles of a solid in their fixed, lattice positions, enabling them to roll over one another. Measured in kJ kg^{-1}.

   (a) Explain how this experiment is illustrating latent heat of fusion.

   (b) While the ice is melting, its temperature does not rise until it has all melted, and yet it is still being heated. In terms of the kinetic theory, explain where the added heat energy is going.

6. Consider the following definition.

> **Latent heat of vaporisation**, L_v is the energy required to change the state of a substance from liquid to gas. Also referred to as the specific heat of vaporisation.
>
> **Latent energy** in evaporation is used to overcome the forces holding the particles of a liquid together enabling them to break away from each other and move independently. Measured in kJ kg^{-1}.

(a) Explain how this experiment is illustrating latent heat of vaporisation.
(b) While the water is boiling, its temperature does not rise, and yet it is still being heated. In terms of the kinetic theory, explain where the added heat energy is going.

From this we can derive the following formulas that we can use to study the heat energy transferring between objects.

> When an object changes from solid to liquid, the total amount of energy involved, Q, is given by:
>
> Q = mass of solid × latent heat of fusion of the solid
>
> $\boldsymbol{Q = m \times L_f}$

> When an object changes from liquid to gas, the total amount of energy involved, Q, is given by:
>
> Q = mass of liquid × latent heat of vaporisation of the liquid
>
> $\boldsymbol{Q = m \times L_v}$

> When any object changes temperature, the total amount of energy involved, Q, is given by:
>
> Q = mass of object × specific heat of object × temperature change
>
> $\boldsymbol{Q = m \times c \times \Delta T}$

> *Note:* c = specific heat capacity of a material
>
> = amount of energy required to raise the temperature of 1.0 kg of the substance by 1°C
>
> = 4.18 kJ kg^{-1} $°C^{-1}$ (often rounded to 4.2)

Example 1:
A 1500 W electric jug supplies 1.5 kJ of energy each second. The jug has 800 mL of water in it and the water is at its boiling point (100°C). If the latent heat of vaporisation of water is 2260 kJ kg^{-1}:
(a) Find the energy required to evaporate all the water.
(b) Calculate how long this will take.

Solution:
(a) From $Q = m \times L_{vt}$
$Q = 0.8 \times 2260 = 1808$ kJ
(b) The jug supplies 1.5 kJ per second.
So, 1808 kJ will take = 1808/1.5 = 1205.3 s = 20 minutes.

Example 2:
Energy is supplied at a uniform rate to 400 g of ice at 0°C. It melts totally in exactly 5.0 minutes. If the latent heat of fusion of ice is 334 kJ kg^{-1}, the specific heat of the water is 4.2 J kg^{-1} $°C^{-1}$ and the latent heat of vaporisation of water is 2260 kJ kg^{-1}, find:
(a) The total energy required to melt the ice.
(b) The rate at which the energy is supplied to the ice.
(c) The additional energy needed to raise the temperature of the water to 100°C.
(d) How long this will take if energy is supplied at the same rate.
(e) The additional energy required to evaporate all the water once it is at 100°C.
(f) How long this will take if energy is supplied at the same rate.

Solution:

(a) Energy to melt ice, $Q = m \times L_f$

Therefore $Q = 0.4 \times 334 = 133.6$ kJ

(b) Rate of energy supply $= 133.6/(5 \times 60) = 0.455$ kJ s^{-1}

$= 455$ J s^{-1} $= 455$ W.

(c) From $Q = m \times c \times \Delta T$

$Q = 0.4 \times 4.2 \times 100 = 168$ kJ

(d) Time to supply this energy $= 168/0.455 = 369.2$ s

$= 6.15$ minutes.

(e) From $Q = m \times L_v$

$Q = 0.4 \times 2260 = 904$ kJ

(f) Time needed $= 904/0.455 = 1986.7$ s $= 33.1$ minutes.

QUESTIONS

7. Explain what happens to the particles of matter when a solid is melting.

8. Explain what happens to the particles of matter when a liquid evaporates.

9. Explain what happens to the particles of matter when a liquid freezes and becomes solid.

10. Explain what happens to the particles of matter when a gas condenses to form a liquid.

11. When we get hot we perspire. This is a mechanism our bodies use to prevent our core temperature rising to a dangerous level. Explain how perspiration cools us down.

12. Although temperature is a measure of the average kinetic energy of the particles of matter, steam at 100°C can cause more severe burns to our skin than water at 100°C. Explain, in terms of the kinetic theory of matter, why this happens.

13. If 8400 J of energy is required to evaporate 10 g of ethanol, find the specific heat of vaporisation of ethanol.

14. A 2100 W electric jug supplies 2.1 kJ of energy each second. Two litres of water in a 2100 W electric jug is at 100°C. If the latent heat of vaporisation of water is 2260 kJ kg^{-1}:

(a) Find the energy required to evaporate all the water.

(b) Calculate how long this will take.

15. An iceblock tray in a refrigerator holds 250 mL of water. It was filled with water from the tap at 18°C and placed in the freezer. After 1.5 hours the last of the water froze to complete the iceblocks. The latent heat of fusion of ice is 334 kJ kg^{-1} and the specific heat of water is 4.18 kJ kg^{-1} °C^{-1}.

(a) How much energy was removed from the water in this process?

(b) At what rate was the refrigerator removing energy from the water?

16. Energy is supplied at a uniform rate to 200 g of ice at 0°C. It melts totally in exactly 10.0 minutes. If the latent heat of fusion of ice is 334 kJ kg^{-1}, the specific heat of the water is 4.2 J kg^{-1} °C^{-1} and the latent heat of vaporisation of water is 2260 kJ kg^{-1}, find:

(a) The total energy required to melt the ice.

(b) The rate at which the energy is supplied to the ice.

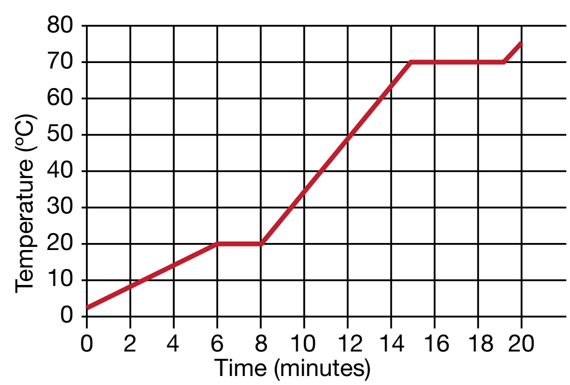
(c) The additional energy needed to raise the temperature of the water to 100°C.

(d) How long this will take if energy is supplied at the same rate.

(e) The additional energy required to evaporate all the water once it is at 100°C.

(f) How long this will take if energy is supplied at the same rate.

17. The graph shows the temperature-time curve for a 60 g solid which was placed in a well insulated, massless container and heated uniformly by a 200 W heater.



(a) What is the melting point of the solid?

(b) What was the total energy supplied by the heater from the start of the experiment until the last of the water was evaporated?

(c) If the heater was a 240 V heater, what current did it deliver to the heating coil?

(d) Without making any calculations, predict which is larger, the latent heat of fusion, or the latent heat of vaporisation of the substance. Justify your prediction.

(e) Calculate the latent heat of fusion of the substance.

(f) Calculate the latent heat of vaporisation of the substance.

(g) Calculate the specific heat of the liquid substance.

6 Transferring Heat Energy

In a closed system, whenever heat energy transfers from one section of the system to another, the law of conservation of energy must hold. For example, if hot water is put into a cold container in a well insulated environment, the amount of energy transferring from the hot water will equal the amount of energy transferring into the cold container. They will both end up at the same temperature.

> In a closed system:
>
> **Energy transferred from A = energy received by B**

Example: 250 mL of water at 90°C is added to 400 mL of water at 20°C.

What will be the final temperature of the mixture?

Solution: Energy lost by hot water = energy gained by cold water

$(m \times c \times \Delta T)_{\text{hot water}} = (m \times c \times \Delta T)_{\text{cold water}}$

Because we don't know the change in temperature, let the final temperature = T.

Therefore, temperature change for hot water $= 90 - T$ (It gets cooler)

And temperature change for cold water $= T - 20$ (It gets warmer)

Substituting $250 \times 4.18 \times (90 - T) = 400 \times 4.18 \times (T - 20)$ (Conversion of mass to kg cancels)

$94\,050 - 1045T = 1672T - 33\,440$

$127\,490 = 2717T$

Therefore final temperature, $T = 46.9$°C

QUESTIONS

1. 400 mL of boiling water is poured into a container which already contains 600 mL of water at 20°C.
   (a) Ignoring any heat energy transferred to the container, what will be the final temperature of the water?
   (b) If the container has a mass of 500 g and its specific heat capacity is 3.5 kJ kg^{-1} °C^{-1}, what would be the actual final temperature of the water and the container?
2. In an espresso coffee machine steam at 100°C is bubbled through 200 g of coffee flavoured milk which was initially at 2°C until it reached 90°C. If the specific heat of the milk is 4.2 kJ kg^{-1} °C^{-1}, what mass of steam was condensed? The latent heat of vaporisation of water is 2260 kJ kg^{-1}.
3. 200 g of water at 20°C is poured into a glass at the same temperature, and 50 g of crushed ice at 0°C is added. The glass has a mass of 120 g and a specific heat of 0.84 kJ kg^{-1} °C^{-1}, and water has a specific heat of 4.2 kJ kg^{-1} °C^{-1}, and the latent heat of fusion of ice is 334 kJ kg^{-1} °C^{-1}. Find the final temperature of the glass and the water.
4. 250 g of ice is taken from a freezer at –8°C and heated until it became steam at 105°C. Taking the specific heats of water as 4.18 kJ kg^{-1} °C^{-1}, ice as 2.06 kJ kg^{-1} °C^{-1}, steam as 2.02 kJ kg^{-1} °C^{-1}, and the latent heat of fusion of ice as 334 kJ kg^{-1} °C^{-1} and the latent heat of vaporisation of water as 2260 kJ kg^{-1} °C^{-1}, calculate the total heat energy absorbed by the ice.
5. 500 g of water at 90°C is mixed with 400 g of water at 60°C in a glass jug which has a mass of 300 g, is at 20°C, and a specific heat of 0.84 kJ kg^{-1} °C^{-1}. Taking the specific heat of water as 4.2 kJ kg^{-1} °C^{-1}, what would be the final temperature of the jug and its contents?

7 Heat Conduction

When we are cooking and need to stir food, we usually use a wooden rather than a metal spoon. A metal spoon would get hot because heat energy from the food can transfer easily into it. This happens because metals are **good conductors** of heat.

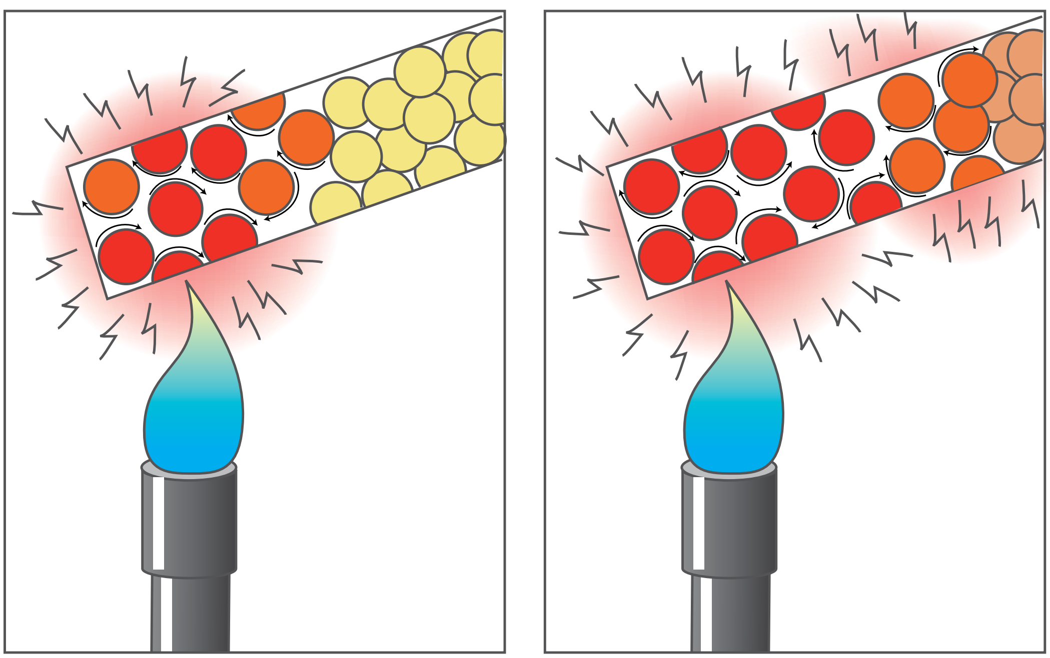
We use conductors when we want heat to travel quickly through something. We use metals to make saucepans, barbecue plates, kettles, radiators in cars and homes, and cooling coils at the back of refrigerators and freezers.

Non-metals, like wood, are non-conductors of heat: heat energy does not pass through them. Non-conductors of heat are also called heat **insulators**. For example, one of the best insulators is air. Many substances that contain a lot of air – such as cork, polystyrene foam, fibreglass and wool – are therefore good insulators.

We use insulators when we don't want heat travelling through something. We use wood or plastic handles on saucepans, fibreglass lagging on hot water pipes, air cavities in the walls, and polystyrene in picnic baskets.

QUESTIONS

1. Fill in the missing words from these sentences.
   (a) Metals are .... conductors of heat energy.
   (b) Metals allow heat energy to pass through them ....
   (c) The transfer of heat energy through a solid is called ....
   (d) .... are substances that do not allow heat energy to pass through them.
   (e) Non-metals are good heat ....
2. (a) Name five heat conductors.
   (b) Name five heat insulators.
3. Why does the end of a teaspoon get hot when you stir coffee? Why doesn't the end of a plastic spoon get hot?
4. If you want to check the water in a car radiator after a drive, always remove the cap with a cloth. How does the radiator cap get so hot?
5. The diagram shows how heat conduction occurs as explained by the kinetic theory.



   (a) Use your knowledge of the kinetic theory of matter to explain what the diagrams are showing.
   (b) Use another idea from the kinetic theory to explain why metals conduct but non-metals don't.

6. Match the sentence halves below to summarise of some of the concepts involved in the conduction of heat through metallic substances.

First half of sentence

1. Metals and metal alloys allow heat energy
2. For this reason they are
3. Non-metallic substances do not readily allow heat
4. These substances are called
5. Conduction of heat occurs because any applied
6. This increased vibration causes these particles to bump
7. Gradually the heat energy is passed through
8. In addition to resulting in conduction of heat, the increased
9. This happens because the particles

Second half of sentence

(a) known as heat conductors.
(b) into the particles next to them and cause these to vibrate more as well.
(c) heat insulators.
(d) energy causes the particles of the metal to vibrate more violently.
(e) need more space in which to vibrate.
(f) the metal from particle to particle.
(g) to transfer through them.
(h) energy to pass through them.
(i) vibrations cause the metal to expand.

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Answers

1 The Kinetic Theory of Matter

1. (a) solids, together, forces
   (b) freely, held, fixed
   (c) particles, strongly, slide, poured
   (d) not, free, direction, diffuse, fill
2.

Solids	Liquids	Gases
• Particles are close together. • Particles are held tightly together. • Particles are not free to move. • Particles can only vibrate in their fixed positions.	• Particles are close together. • Particles are held less tightly than in solids. • Particles are not free to move, but • Particles can roll over one another.	• Particles are much further apart. • Particles are not held together. • Particles are free to move. • Particle collisions with container walls cause gas pressure.

2 Kinetic Theory and Properties of Matter

1. C
2. B
3. B
4. D
5. C
6. A
7. D
8. A
9. D
10. B
11. D
12. (a) Because the particles in wood (as in any solid) are as close together as they can be.
    (b) Because the particles in rocks (as in any solid) are held together in fixed positions by strong forces.
    (c) The particles in the gaseous petrol are not held together and are free to move so they spread out (diffuse) quickly.
    (d) Particles in liquids slide over one another and are not held as tightly as in solids, so they can spread out into the holes in the paper towel.
    (e) Particles in the liquid ink slide over one another and are not held together strongly, so they can diffuse into the water
    (f) The particles in the metal are held together by stronger forces than the particles in the wood.
    (g) In tearing one sheet of paper you are breaking the forces between one layer of paper particles which is easy to do, but in trying to tear a phone book in half there are hundreds of pages and too many forces for you to be able to overcome them.
    (h) Particles in gases are not held together by forces and so are free to move through spaces between particles. Particles in liquids are held together by forces which enable them to slide over one another but have to push other particles out of the way and diffuse more slowly than gas particles.
    (i) Particles in liquids can slide over one another and so spread out across the bottom of their container and take whatever shape it is.
    (j) Forces between glue and paper particles are stronger than forces between glue particles.
    (k) Compressed air is air in which the particles have been forced into a much smaller volume. They collide with each other and their container producing a high pressure. When connected to a car tyre where the pressure is lower (due to fewer particles not as close together), collisions between the compressed air particles pushes them into the tyre to equalise the pressures.
    (l) Compressed hairspray has particles which have been forced into a much smaller volume. They collide with each other and their container producing a high pressure. When the button is pushed down it provides an outlet to a region where the pressure is lower (due to fewer particles not as close together). Collisions between the particles from the compressed spray push them into the air to equalise the pressures.
    (m) Particles of water moisture in our breath hit the colder glass of the window, slow down and change state to form water liquid.
    (n) Heat energy from the sun will transfer into the can, make the particles of the compressed propellant inside the can move faster (it gets warmer), they collide more energetically with each other and the can causing pressure to build up inside the can to the point where it can burst the can.

3 Temperature and the Kinetic Theory

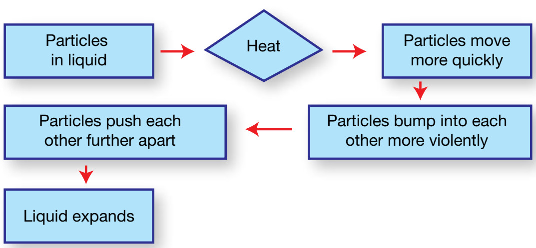
1. Kinetic energy is given by the equation $E_K = \frac{1}{2}mv^2$. If the motion of particles is zero, i.e. $v = o$, then their kinetic energy will be zero, and therefore by definition, the temperature of the matter will be zero. This is defined as an absolute zero, because particles cannot go slower than stationary! When matter is cooled, particles lose energy and slow down. When they slow down so that all motion stops we have reached absolute zero.
2. (a) (B) It is the coldest, so according to the concept of temperature as a measure of average kinetic energy of particles, they are all water particles. They all have the same mass, so the speed of the ice particles will be the slowest.
   (b) If the steam is at 100°C, then the particles in A and D will have the highest temperature and therefore the highest kinetic energy. However, if the steam is hotter than 100°C, then its particles will have the most kinetic energy.
   (c) B < C < A < (or perhaps equal to) D
   (d) Steam particles move more freely than water particles and are not held to other steam particles, so they can penetrate pores in our skin much more effectively and give a deeper burn.
3. Heat energy from the Sun will conduct through the can and heat up the gas particles inside. This will increase their rate of movement and the number of collisions they make with the wall of the can. The pressure may build up enough to break the seams in the material of the can. The can 'explodes' apart.
4. Friction between the tyres and the road makes the tyres, and the air in them hotter. Pressure builds up inside the tyre and this can cause a blow out and an accident if the pressure is not lowered before the trip starts.
5. (a) Particles in Y have been drawn moving faster, and the balloon has been drawn expanded so it would seem they are colliding more often and with more energy with the balloon walls than the particles in X.
   (b) The temperature of the balloon has been increased.
   (c) As the balloon is heated, the particles move faster making more collisions per second with the walls. This increases the pressure and the balloon expands.

4 Changes of State and the Kinetic Theory

1. Heating the matter increases the average kinetic energy of the particles.
2. (a) Gas to liquid.
   - As a gas is cooled its particles move more and more slowly
   - until the forces between them are able to overcome their freedom and hold them together,
   - then they stop moving freely and start to group together and slide over one another.

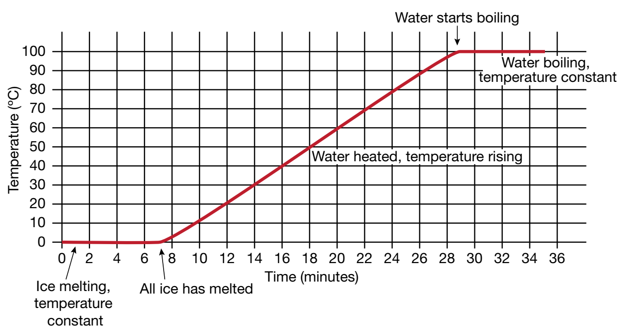
(b) Liquid to solid.
- As a liquid is cooled, its particles move more slowly and slide over one another with less energy
- until the forces of attraction between them are able to overcome their kinetic motion, and then
- they stop sliding and become fixed in position as the liquid turns into a solid.

3. Heat energy transfers from your body to the chocolate bar resulting in the particles moving faster and therefore able to slide over one another more freely. The temperature of the bar rises, the chocolate becomes softer (more runny – 'slidy' in terms of particle movement).
4. On a summer's day, the perfume particles gain more energy from their surroundings and can evaporate more quickly. There are therefore more vaporised particles moving more quickly and further through the air and so they reach observers more quickly – i.e. the perfume is easier to notice.
5. Expansion refers to the increase in the volume of a substance when it is heated. Expansion occurs because the heating process increases the kinetic energy of the particles of matter. For example, with a solid they vibrate more vigorously thus taking up more space. The substance expands.
6. Contraction refers to the decrease in the volume of a substance when it is cooled. Contraction occurs because the cooling process takes energy away from the particles of matter. For example, with a solid the particles vibrate less vigorously thus taking up less space. The substance contracts.
7.



5 Changes of State and Latent Energy

1.



2. See graph above.
3. The energy is being absorbed by the ice to melt it.
4. The energy is being absorbed to evaporate the water.
5. (a) The temperature of the ice does not change while it is melting despite a steady heat energy input. This illustrates the latent heat of fusion.
   (b) The energy is being taken in by the particles of ice to overcome the forces holding them in fixed positions, and allowing them to break away from the solid lattice and slide over one another.
6. (a) The temperature of the water does not change while it is boiling despite a steady heat energy input. This illustrates the latent heat of vaporisation.
   (b) The energy is being taken in by the particles of water to overcome the forces holding them together, and allowing them to break away from each other and escape into the environment (evaporate).
7. The energy is taken in by the particles of the solid to overcome the forces holding them in fixed positions, and allowing them to break away from the solid lattice and slide over one another.
8. The energy is being taken in by the particles of the liquid to overcome the forces holding them together, and allowing them to break away from each other and escape into the environment (evaporate).
9. Energy is released from the particles of the liquid as they slow down (matter becomes cooler). Eventually the motion of the liquid particles is not sufficient to overcome the forces between them and they become locked into fixed (solid) positions.
10. As the gas particles cool and slow down, interparticle forces can pull them closer together. Eventually, the kinetic energy of the particles will not be sufficient to keep them free from each other and they will join together to form the liquid form of the matter.
11. Droplets of perspiration on our skin absorb energy (latent heat of vaporisation) from the skin to evaporate. This lowers the temperature of the skin.
12. Within the liquid droplets making up steam are gaseous water particles which are smaller than the liquid water particles and so, even though their rate of movement is the same (temperature is the same), they can penetrate the pores in our skin more easily and give us deeper burns.
13. $Q = 8.4$ kJ; $m = 10^{-2}$ kg; $Q = mL$; $L = \frac{Q}{m} = \frac{8.4}{10^{-2}} = 840$ kJ kg^{-1}
14. (a) $Q = mL = 2 \times 2260 = 4520$ kJ
    (b) $t = \frac{4520}{2.1} = 2152.4$ s $= 35.9$ minutes
15. $m = 0.25$ kg; $\Delta T = 18$°C; $c = 4.18$ kJ kg^{-1} °C^{-1}; $L = 334$ kJ kg^{-1}; $t = 90$ min
    (a) $Q = mc\Delta T + mL = 0.25 \times 4.18 \times 18 + 0.25 \times 334 = 102.31$ kJ
    (b) Rate $= \frac{Q}{t} = \frac{102.31}{90} = 1.14$ kJ min^{-1}
16. $M = 0.2$ kg; $t = 10.0$ min; $L_f = 334$ kJ kg^{-1}; $L_v = 2260$ kJ kg^{-1}; $\Delta T = 18$°C; $c = 4.18$ kJ kg^{-1} °C^{-1}
    (a) $Q = mL_f = 0.2 \times 334 = 66.8$ kJ
    (b) $W = \frac{Q}{t} = \frac{66.8}{10} = 6.68$ kJ min^{-1}
    (c) $Q = mc\Delta T = 0.2 \times 4.18 \times 100 = 83.6$ kJ
    (d) $t = \frac{Q}{W} = \frac{83.6}{6.68} = 12.5$ minutes
    (e) $Q = mL_v = 0.2 \times 2260 = 452$ kJ
    (f) $t = \frac{Q}{W} = \frac{452}{6.68} = 67.7$ minutes
17. (a) 20°C
    (b) $m = 0.06$ kg; $W = 200$ W (200 J s^{-1}); $t = 20$ min $= 1200$ s (from graph)
    $Q = W \times t = 200 \times 1200 = 240\,000$ J
    (c) $I = \frac{W}{V} = \frac{200}{240} = 0.83$ A
    (d) Latent heat of vaporisation is larger. The heating is uniform and it takes longer to evaporate the water than to melt the ice.
    (e) $Q = W \times t = 200 \times 120 = 24\,000$ J
    $L_f = \frac{Q}{m} = \frac{24\,000}{0.06} = 400$ kJ kg^{-1}
    (f) $Q = W \times t = 200 \times 240 = 48\,000$ J
    $L_v = \frac{Q}{m} = \frac{48\,000}{0.06} = 800$ kJ kg^{-1}
    (g) $m = 0.06$ kg ; $c = ?$; $\Delta T = 70 - 21 = 49$°C
    $Q = W \times t = 200 \times 420 = 84\,000$ J
    $c = \frac{Q}{m\Delta T} = \frac{84\,000}{0.06 \times 49} = 28.6$ kJ kg^{-1} °C^{-1}

6 Transferring Heat Energy

1. (a) Energy lost by hot water = energy gained by colder water
$(m \times c \times \Delta T)_{\text{hot water}} = (m \times c \times \Delta T)_{\text{cold water}}$
Let the final temperature = T
Therefore, temperature change for hot water = $100 - T$ (It gets cooler)
And temperature change for cold water = $T - 20$ (It gets warmer)
Substituting $0.4 \times 4.18 \times (100 - T) = 0.6 \times 4.18 \times (T - 20)$
$167.2 - 1.67T = 2.508T - 50.16$
$217.36 = 4.178T$
Therefore final temperature, $T = 52.02$°C

(b) Energy lost by hot water = energy gained by colder water + energy gained by container
$(m \times c \times \Delta T)_{\text{hot water}} = (m \times c \times \Delta T)_{\text{cold water}} + (m \times c \times \Delta T)_{\text{container}}$
Let the final temperature = T
Therefore, temperature change for hot water = $100 - T$ (It gets cooler)
And temperature change for cold water and container = $T - 20$ (It gets warmer)
Substituting
$0.4 \times 4.18 \times (100 - T) = 0.6 \times 4.18 \times (T - 20) + 0.5 \times 3.5 \times (T - 20)$
$167.2 - 1.67T = 2.508T - 50.16 + 1.75T - 35$
$252.36 = 5.928T$
Therefore final temperature, $T = 42.57$°C

2. Energy lost from steam = $mL_v + mc\Delta T = m \times 2260 + m \times 4.2 \times (100 - 90) = 2302m$
Energy gained by milk = $mc\Delta T = 0.2 \times 4.2 \times (90 - 2) = 73.92$
$2302m = 93.92$; mass of steam = 0.0321 kg = 32.1 g
3. Energy lost from glass and water = $0.2 \times 4.2 \times (20 - T) + 0.12 \times 0.84 \times (20 - T) = 18.816 - 0.9408T$
Energy gained by ice and ice water = $0.05 \times 334 + 0.05 \times 4.2 \times (T - 0) = 16.7 + 0.21T$
$18.816 - 0.9408T = 16.7 + 0.21T$; $18.816 - 16.7 = (0.9408 + 0.21)T$; $T = 1.84$°C
4. $Q = (0.25 \times 2.06 \times 8) + (0.25 \times 334) + (0.25 \times 4.18 \times 100) + (0.25 \times 2260) + (0.25 \times 2.02 \times 5) = 759.6$ kJ
5. Heat lost from hot water = $0.5 \times 4.2 \times (90 - T) = 189 - 2.1T$
Heat gained by water and jug = $(0.4 \times 4.2 \times (T - 60)) + (0.3 \times 0.84 \times (T - 20)) = 1.932T - 105.84$
$1.932T - 105.84 = 189 - 2.1T$; $T = 73.1$°C

7 Heat Conduction

1. (a) good
(b) freely
(c) conduction
(d) insulators
(e) insulators
2. (a) For example: copper, tin, zinc, lead, iron (any metal).
(b) For example: wood, wool, concrete, glass, ceramic (any non-metal, except some types of carbon).
3. The metal in the spoon conducts the heat energy from the hot water well. The plastic is an insulator and so does not conduct the heat.
4. Heat energy from the engine transfers into the water (it circulates to keep the engine cooler) and then the heat energy conducts into the metal cap on the radiator.
5. (a) The diagrams are showing how heat energy conducts along a heat conductor as particles absorb energy from the Bunsen flame, vibrate more rapidly and bump into particles next to them more violently, transferring energy to them progressively along the rod.
(b) Particles in non-metals are held together more strongly than those in metals and therefore cannot vibrate as violently in order to transfer energy via the collisions they have with adjacent particles.
6. 1 Metals and metal alloys allow heat energy to transfer through them. (g)
2 For this reason they are known as heat conductors. (a)
3 Non-metallic substances do not readily allow heat energy to pass through them. (h)
4 These substances are called heat insulators. (c)
5 Conduction of heat occurs because any applied energy causes the particles of the metal to vibrate more violently. (d)
6 This increased vibration causes these particles to bump into the particles next to them and cause these to vibrate more as well. (b)
7 Gradually the heat energy is passed through the metal from particle to particle. (f)
8 In addition to resulting in conduction of heat, the increased vibrations cause the metal to expand. (i)
9 This happens because the particles need more space in which to vibrate. (e)

8 Heat Convection

1. (a) energy, fluids
(b) fluids, fixed, positions
(c) slide, past, free, held
(d) particles, circular
(e) expand, dense
(f) more
2. As the fluid is heated, the particles near the source of heat move faster, collide more violently, and because they are not held together, spread out. The fluid becomes less dense and rises upwards, making way for cooler, more dense fluid to move near the source of heat and repeat the process. As the warmer, less dense fluid rises upwards, it loses energy, the particles slow down, move closer together, and the fluid becomes more dense. The denser fluid moves downwards towards the source of energy to take the place of less dense material moving upwards.
3. Particles in solids are held in fixed positions. They are unable to move away from these positions, so when heated, they simply vibrate faster and collide more violently with their neighbours causing heat conduction and expansion but not convection (unless enough energy is added to melt the solid … but then we have a liquid).
4. Particles in gases are free to move and can therefore move about more readily than particles in liquids. Gases can therefore transfer heat energy by convection faster and more efficiently than particles in liquids.
5.