The essential workbook for Level 1 NCEA Science students

sciPad™

Level 1 Science

Externals

Mechanics
Acids and Bases
Genetic Variation

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Produced here.
Taught here.

This sciPAD belongs to:

NCEA Level 1 Science sciPAD - The Externals

Student Workbook

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AS 90940 UNDERSTANDING OF

Mechanics

SCIENCE 1.1

Science 1.1 Demonstrate understanding of aspects of mechanics

Level: 1 Credits: 4 Assessment: External

Achievement	Achievement with Merit	Achievement with Excellence
Demonstrate understanding of aspects of mechanics.	Demonstrate in-depth understanding of aspects of mechanics.	Demonstrate comprehensive understanding of aspects of mechanics.

Explanatory Notes

1 Demonstrate understanding of aspects of mechanics typically involves providing evidence that shows awareness of how simple facets of phenomena, concepts or principles relate to given situations. This may include using methods for solving problems involving aspects of mechanics.

2 Demonstrate in-depth understanding of aspects of mechanics typically involves providing evidence that shows how or why phenomena, concepts or principles relate to given situations.

3 Demonstrate comprehensive understanding of aspects of mechanics typically involves providing evidence that shows how or why phenomena, concepts and principles are connected in the context of given situations. Statements must demonstrate understanding of connections between concepts.

4 Evidence may be written, mathematical, graphical or diagrammatic.

5 Aspects of mechanics will be limited to a selection from the following:

- Distance, speed, interpretation of distance and speed time graphs, average acceleration and deceleration in the context of everyday experiences such as journeys, sport, getting going. The relationships: $v = \frac{\Delta d}{\Delta t}$ $a = \frac{\Delta v}{\Delta t}$
- Mass, weight and the acceleration due to gravity, balanced and unbalanced forces, in the context of everyday experiences such as being stationary, moving at constant speed, accelerating. The relationship $F_{net} = ma$.
- Force and pressure in the context of everyday experiences. The relationship: $P = \frac{F}{A}$
- Work and power, gravitational potential energy, kinetic energy, and the conservation of mechanical energy in free fall situations in the context of everyday experiences such as sports performance, dropping things, tossing balls.

  The relationships: $\Delta E_P = mg\Delta h$ $E_K = \frac{1}{2}mv^2$ $W = Fd$ $P = \frac{W}{t}$

MOTION

By the end of this chapter you should be able to:

	I KNOW THIS ALREADY	I LEARNED THIS	I REVISED THIS
Define the term '*speed*'.			
Use formulae to calculate *speed*, *distance* and *time*.			
State the *SI units* for speed, distance, time and acceleration.			
Use a *distance-time graph* to describe the *motion* of an object.			
Calculate the *speed* of an object using the *gradient* of a *distance-time graph*.			
Define the term '*acceleration*'.			
Use formulae to calculate acceleration, change in speed, or change in time.			
Use a *speed-time graph* to describe the *motion* of an object.			
Calculate *acceleration* using the gradient of a speed-time graph.			
Calculate *distance* travelled from the area under a speed-time graph.			

Key Terms

Distance

My Definition: _____

_____

Time

My Definition: _____

_____

Speed

My Definition: _____

_____

Velocity

My Definition: _____

_____

Acceleration

My Definition: _____

_____

Deceleration

My Definition: _____

_____

Distance-time graph

My Definition: _____

_____

Speed-time graph

My Definition: _____

_____

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Units of Speed

Speed is calculated using both *time* and *distance*. Before you can answer questions about speed, you need to make sure you understand these variables.

Time

In everyday life, time can be measured in seconds, minutes, hours, days, months or years.

1. Complete the following by filling in the gaps.
   (a) There are _____ seconds in a minute.
   (b) There are _____ minutes in an hour.
   (c) There are _____ hours in a day.
   (d) There are _____ days in a calendar year.
   (e) There are _____ months in a calendar year.

In science, time is often measured in seconds or even smaller units called milliseconds or even microseconds. There are 1 000 milliseconds in one second and there are 1 000 000 microseconds in one second.

2. Complete the following calculations. Show all your working.
   (a) How many seconds are there in one hour? _____
   (b) How many minutes are there in one day? _____
   (c) How many milliseconds in one minute? _____
   (d) How many seconds in half a day? _____
   (e) How many hours in the month of October? _____

Distance

In everyday life we use millimetres, centimetres, metres and kilometres to measure distance.

3. Complete the following by filling in the gaps.
   (a) There are _____ metres in a kilometre.
   (b) There are _____ millimetres in a centimetre.
   (c) There are _____ centimetres in a metre.
   (d) There are_____ millimetres in a metre.

4. Complete the following calculations. Show all your working.
   (a) How many metres in five kilometres? _____
   (b) How many kilometres in 3 500 metres? _____
   (c) How many centimetres in two metres? _____
   (d) How many metres in 300 centimetres? _____
   (e) How many millimetres in 150 centimetres? _____

5. Complete the following by filling in the units that we usually use in science.
   (a) Distance is usually measured in _____
   (b) Time is usually measured in _____

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Calculating Speed

Speed is a measure of how far an object can travel in a certain amount of time. We often use kilometres per hour in everyday life. However, scientists generally use metres per second as it is a more useful measure of speed. To calculate speed, we need to know two variables: distance travelled and time taken to travel that distance.

For example, if a pickup truck travels 20 meters in 1 second, its speed is 20 meters per second ('per' means 'each'). Scientist express this as 20 m s^{-1}.

To calculate speed, scientists use the formula: Speed (v) = $\frac{\Delta d \text{ (change in distance)}}{\Delta t \text{ (change in time)}}$

The 'v' stands for *velocity*, and the 'Δ' is a delta symbol. It means *change*.

A Worked Example

Forces and Motion School Test

1. A car travels 120 metres in 16 seconds. Calculate the speed of the car

$v = \Delta d / \Delta t$

$= 120m / 16s$

$= 7.5 \text{ m s}^{-1}$

You should ALWAYS show
- formula
- working
- answer
- units

1. Calculate the speed of the following objects.

(a) A car travels 12 m in 3 seconds.
Formula = _____
Working = _____
Speed = _____ _____ (units)

(b) A girl runs 20 m in 5 seconds.
Formula = _____
Working = _____
Speed = _____ _____ (units)

(c) A fish swims 30 m in 80 seconds.
Formula = _____
Working = _____
Speed = _____ _____ (units)

(d) A 4000 m cycle ride takes 1600 s.
Formula = _____
Working = _____
Speed = _____ _____ (units)

(e) A 2000 m horse trek takes 2500 s.
Formula = _____
Working = _____
Speed = _____ _____ (units)

(f) A woman runs 100 m in 12 seconds.
Formula = _____
Working = _____
Speed = _____ _____ (units)

(g) A cat runs 50 m in 8 seconds.
Formula = _____
Working = _____
Speed = _____ _____ (units)

(h) A man runs 400 m in 160 seconds.
Formula = _____
Working = _____
Speed = _____ _____ (units)

(i) A kiwi walks 5 m in 20 seconds.
Formula = _____
Working = _____
Speed = _____ _____ (units)

(j) A baby crawls 4 m in 20 seconds.
Formula = _____
Working = _____
Speed = _____ _____ (units)

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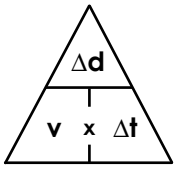
Using Formula Triangles

Being able to use and manipulate formulae is an important skill in science. Most of the formulae you will use contain three variables. Two of these variables are used to calculate the third. For example, if you have distance and time you can calculate speed. But what if you had speed and distance and wanted to calculate time? This is where formula triangles can help.

$$v = \frac{\Delta d}{\Delta t}$$

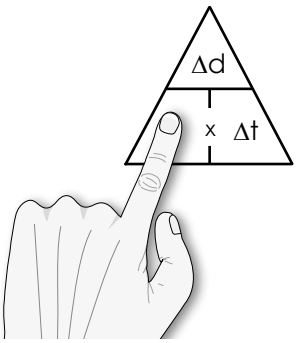
v = velocity (m s^{-1})
Δd = change in distance (m)
Δt = change in time (s)

which is converted to the formula triangle



To use the triangle, simply cover up the variable you are asked to calculate and the triangle will tell you how to do it. For example:

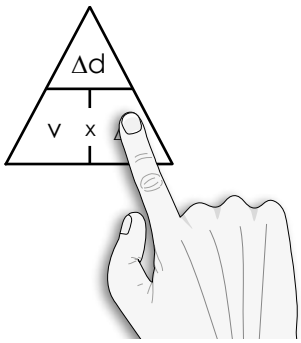
To calculate v



The triangle tells you to divide 'Δd' by 'Δt', so

$$v = \frac{\Delta d}{\Delta t}$$

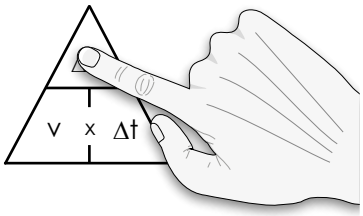
To calculate Δt



The triangle tells you to divide 'Δd' by 'v', so

$$\Delta t = \frac{\Delta d}{v}$$

To calculate Δd



The triangle tells you to multiply 'v' by 't', so

$$\Delta d = v \times \Delta t$$

1. Use the formula triangles to complete the table by filling in the blank sections.

Distance	Time	Speed
100 m	10 s	
1.5 m	5 s	
10 m	4 s	
0.5 m	1 s	
	10 s	10 m s^{-1}
	18 s	2 m s^{-1}
	2 s	12 m s^{-1}
	30 s	1 m s^{-1}
10 m		10 m s^{-1}
15 m		0.5 m s^{-1}
100 m		10 m s^{-1}
1 m		2 m s^{-1}

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More Speed Calculations

1. Calculate the speed of the following:

(a) A skateboarder travels 20 metres in 6 seconds.

Formula: _____

Working: _____

Answer: _____

(b) An athlete runs 800 metres in 200 seconds.

Formula: _____

Working: _____

Answer: _____

(c) A bird flies 4.2 metres in 2.4 seconds.

Formula: _____

Working: _____

Answer: _____

(d) A car travels 196 metres in 56 seconds.

Formula: _____

Working: _____

Answer: _____

(e) A bus travels 267 metres in 300 s.

Formula: _____

Working: _____

Answer: _____

2. Calculate the distance travelled.

(a) A ball takes 16 s to roll down a slope with an average speed of 0.6 m s^{-1}.

Formula: _____

Working: _____

Answer: _____

(b) A cyclist takes 186 s to ride up a slope with an average speed of 0.8 m s^{-1}.

Formula: _____

Working: _____

Answer: _____

(c) A cat takes 6 seconds to climb a tree with an average speed of 0.4 m s^{-1}.

Formula: _____

Working: _____

Answer: _____

(d) A teacher takes 124 seconds to walk from the staff room to the lab, with an average speed of 1.5 m s^{-1}.

Formula: _____

Working: _____

Answer: _____

(e) A skateboarder takes 16 seconds to roll down a slope with an average speed of 2 m s^{-1}.

Formula: _____

Working: _____

Answer: _____

3. Calculate the time taken.

(a) A skier travels 256 m down a slope with an average speed of 4 m s^{-1}.

Formula: _____

Working: _____

Answer: _____

(b) A tramper hikes 3567 m with an average speed of 0.6 m s^{-1}.

Formula: _____

Working: _____

Answer: _____

(c) A surfer rides a wave for 48 m with an average speed of 4 m s^{-1}.

Formula: _____

Working: _____

Answer: _____

(d) A shopping trolley rolls 4.8 m into a car with an average speed of 1.2 m s^{-1}.

Formula: _____

Working: _____

Answer: _____

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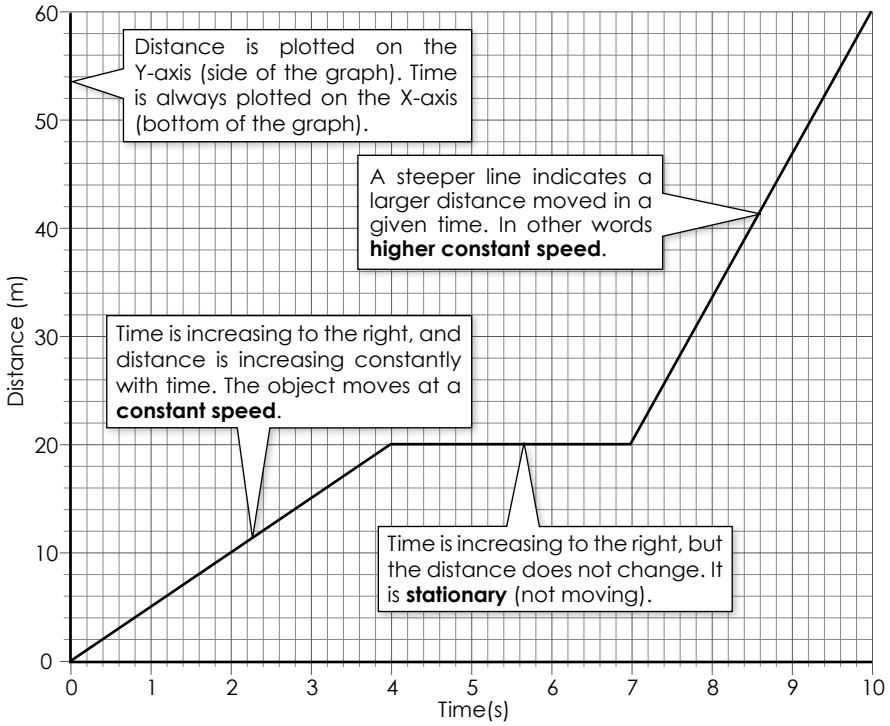
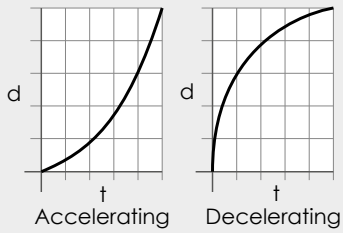
Distance-Time Graphs

Describing the motion of an object is occasionally hard to do with words. Sometimes graphs help make motion easier to picture, and therefore understand.

Features of a Distance-Time Graph



Graphs that Curve

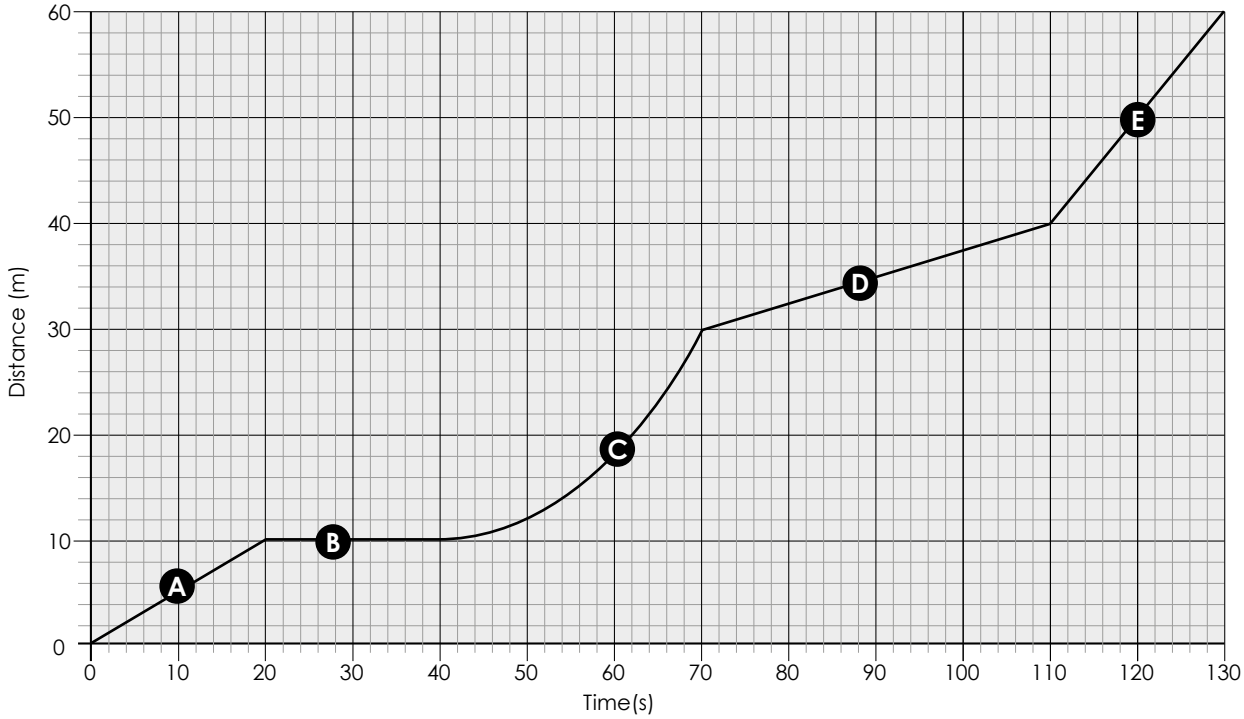


Sometimes the graph is not a straight line.

If it curves towards the vertical (upwards) it is *accelerating*. In each successive time interval, the distance the object moves is getting larger.

If it curves towards the horizontal, it is *decelerating* because, in a given time, the distance the object moves is getting smaller.

1. Describe the motion of the object shown below during the various stages of its journey.



A = _____

B = _____

C = _____

D = _____

E = _____

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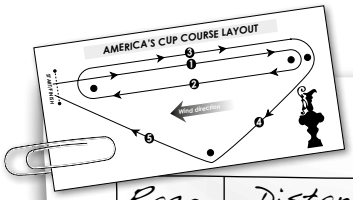
Team New Zealand Secondary Schools

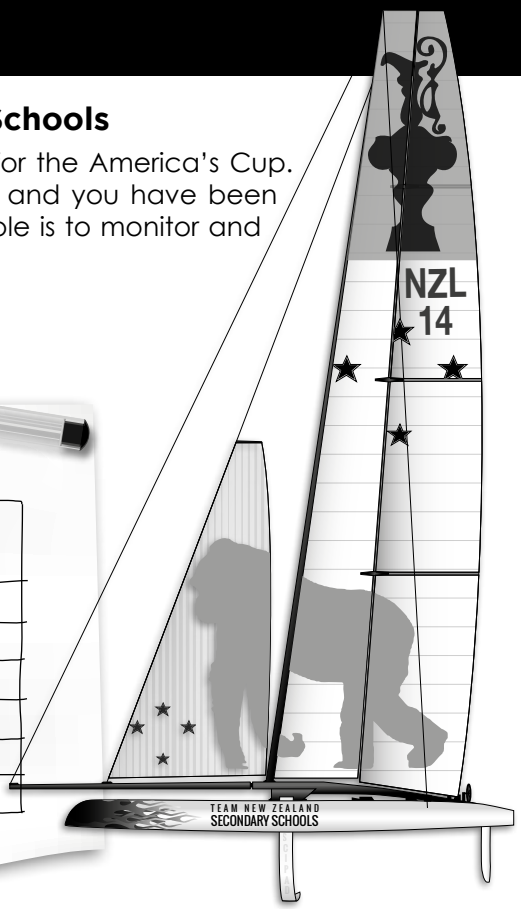
New Zealand Secondary Schools have decided to challenge for the America's Cup. Team members have been selected from all over the country and you have been appointed as the team's Head Scientific Analyst. Part of your role is to monitor and report on the boat's speed around various parts of the course.

Your rough notes from the last race are shown below.



Race Notes

Race Leg	Distance from the start (metres)	Time from the start (seconds)
Start	0	0
1	5,000	800
2	19,000	1200
3	30,000	3200
4	35,000	3600
5	43,000	4000



1. Plot a line graph of this data on the graph paper below. Ensure that you use most of the graph paper and give the graph a title.

Distance from start (m)

Time from start (s)

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2. (a) Place an 'X' on the graph where you think the boat was travelling the fastest.

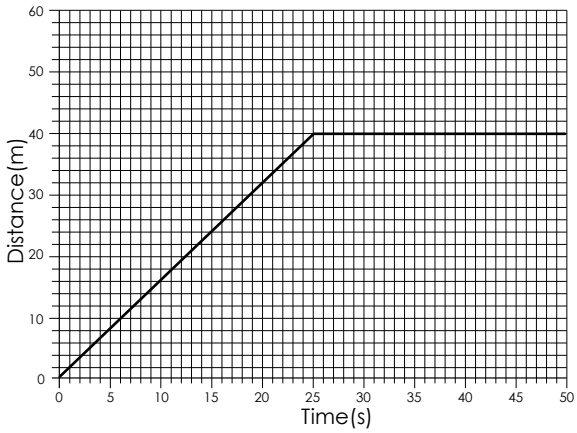
   (b) Explain why you placed the 'X' in the position you did. _____

   _____

3. Calculate the average speed of the boat for each leg of the race. One of the answers has been done for you.

	Distance (m)	Time (s)	Speed
Leg 1			
Leg 2	14000	400	35 m s^{-1}
Leg 3			
Leg 4			
Leg 5			

4. A number of distance-time graphs from various stages of the campaign are shown below. Describe the motion of the boat for each part of the race shown on the graph. You should quote numbers from the graph in your answers.



(a) Description of the boat's motion:

_____

_____

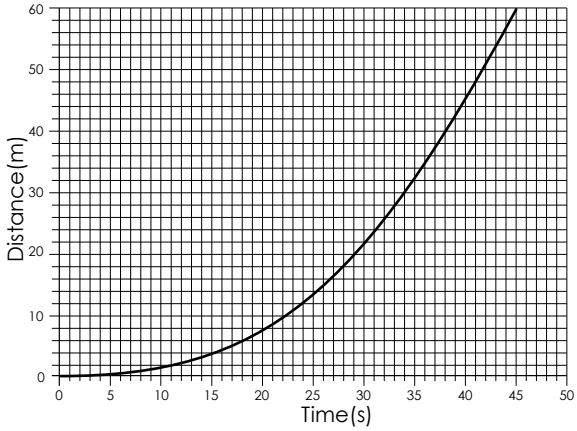
_____

_____

_____

_____

_____



(b) Description of the boat's motion:

_____

_____

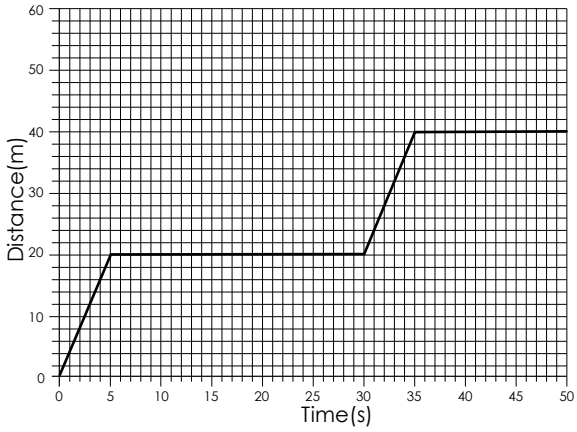
_____

_____

_____

_____

_____



(c) Description of the boat's motion:

_____

_____

_____

_____

_____

_____

_____

_____

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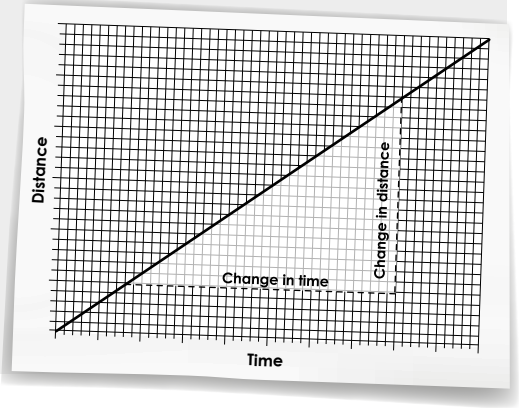
Calculating Speed from a Distance-Time Graph

The slope (*gradient*) of a distance-time graph can be used to calculate the speed of an object. The slope of any graph can be calculated using the following formula:

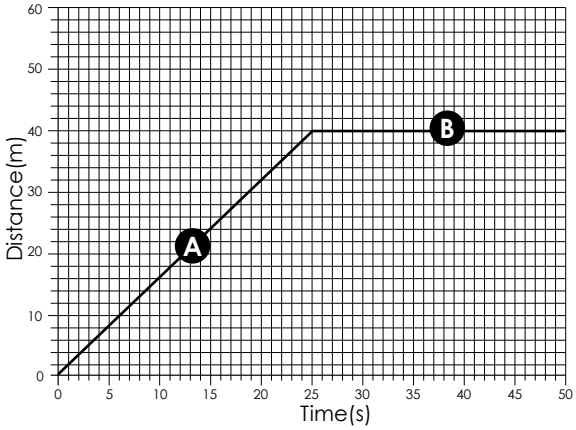
$$\text{Gradient} = \frac{\text{Change in the Y-axis variable}}{\text{Change in the X-axis variable}}$$

Therefore, on a distance-time graph:

$$\text{Gradient} = \frac{\text{Change in distance } (\Delta d)}{\text{Change in time } (\Delta t)} \quad \text{or} \quad \frac{(\Delta d)}{(\Delta t)}$$



1. Use the gradient to calculate the various speeds shown on each distance-time graph.



Section A

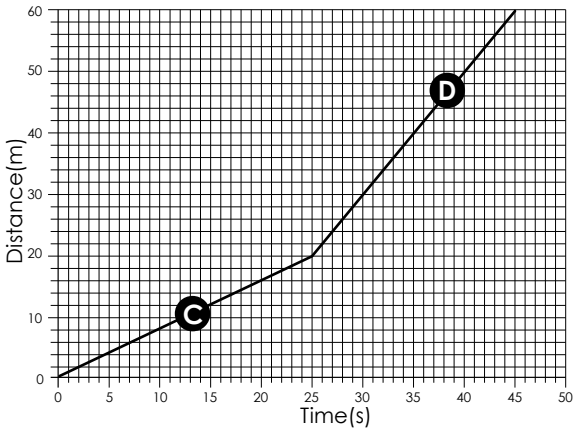
Gradient =

Speed = _____ _____ (units)

Section B

Gradient =

Speed = _____ _____ (units)



Section C

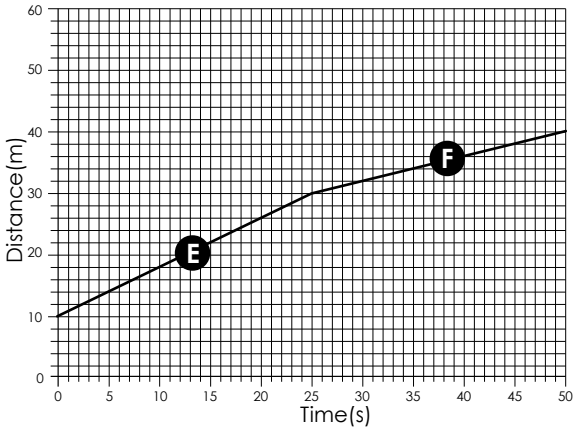
Gradient =

Speed = _____ _____ (units)

Section D

Gradient =

Speed = _____ _____ (units)



Section E

Gradient =

Speed = _____ _____ (units)

Section F

Gradient =

Speed = _____ _____ (units)

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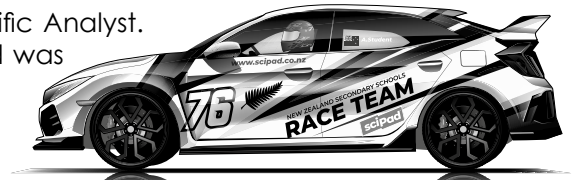
New Zealand Secondary Schools Rally Team

You have been employed by the NZSS Rally Team as a Scientific Analyst. One of your jobs is to tell the drivers what their average speed was at various checkpoints. The team manager has handed you the latest pace notes sheet from the local stage of the Rally of New Zealand.



NZSS Rally Team Pace Notes

	Distance from start (km)	Time from start (hr)
Checkpoint 1	40 km	1 hr
Checkpoint 2	100 km	2 hr
Checkpoint 3	175 km	2.5 hr
Checkpoint 4	210 km	3.5 hr
Checkpoint 5	225 km	4.5 hr

1. (a) Plot a line graph of this data on the graph paper below.

Distance from start (km)

Time from start (hr)

(b) Place an 'X' on the graph where you think the car is travelling the fastest.

(c) Justify why you placed the 'X' where you did. _____

_____

(d) Use the graph to calculate the average speed of the car during the various stages of the rally.

Checkpoint 1: _____ Checkpoint 2: _____

Checkpoint 3: _____ Checkpoint 4: _____

Checkpoint 5: _____

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Acceleration

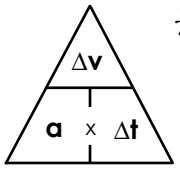
Acceleration is the rate at which an object changes its speed. Acceleration can be a positive value (i.e. an object is speeding up) or a negative value (i.e. the object is slowing down). Negative acceleration is often called *deceleration*.

Acceleration can be calculated using the following formula:

$$a = \frac{\Delta v}{\Delta t}$$

a = acceleration (m s^{-2})
Δv = change in velocity (m s^{-1})
Δt = change in time (s)

OR



To calculate Δv you will need to subtract the initial speed from the final speed.
Δv = final speed – initial speed
A negative Δv means the object is decelerating.

The SI units for acceleration are metres per second per second (m s^{-2}).

NZPQA
NCEA Level 1 Science - Mechanics Exam

1. A car increases its speed from 10 m s^{-1} to 30 m s^{-1}. It takes 5 seconds for this change in speed to occur. Calculate the car's acceleration.

$$\text{Acceleration} = \frac{\text{Change in Speed}}{\text{Change in Time}}$$

Always show the formula you are using.

$$= \frac{30 \text{ m s}^{-1} - 10 \text{ m s}^{-1}}{5 \text{ seconds}}$$

Show **all** your working.

$$= 4 \text{ m s}^{-2}$$

The answer is clearly written and includes the appropriate **units**.

1. Complete the table by filling in the blank sections.

	Acceleration	Change in Speed	Change in Time
(a)		20 m s^{-1}	2 s
(b)		400 m s^{-1}	5 s
(c)		96 m s^{-1}	12 s
(d)		120 m s^{-1}	240 s
(e)		1 300 m s^{-1}	50 s
(f)	3 m s^{-2}	9 m s^{-1}	
(g)	60 m s^{-2}	300 m s^{-1}	
(h)	14 m s^{-2}	21 m s^{-1}	
(i)	0.96 m s^{-2}	48 m s^{-1}	
(j)	12 m s^{-2}		2 s
(k)	15 m s^{-2}		10 s
(l)	79 m s^{-2}		5 s
(m)	29 m s^{-2}		5.6 s

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Acceleration Problems

1. From a stationary position, the NZSS Formula 1 car reaches its top speed of 85 m s^{-1} after 5 seconds. Calculate the car's acceleration.

Answer = _____

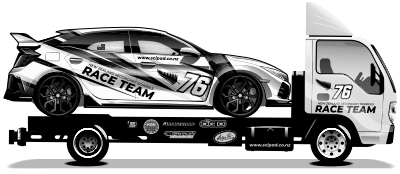
2. The rally car is travelling at 27 m s^{-1}. It increases its speed to 32 m s^{-1} in 2.5 seconds. Calculate the car's acceleration.

Answer = _____

3. A support vehicle enters the motorway. Its previous speed was 50 kilometres per hour (14 m s^{-1}). The speed limit on the motorway is 100 kilometres per hour (28 m s^{-1}). It takes the car 10 seconds to reach this new speed. Calculate the car's acceleration.

Answer = _____

4. The transport truck is travelling at 24 m s^{-1}. As it enters Takapuna it changes speed to 10 m s^{-1}. It takes 8 seconds to make this change. Calculate the truck's acceleration.



Answer = _____

5. The support truck is travelling at 5 m s^{-1}. It then accelerates to 20 m s^{-1}. Calculate how long it would take to reach this new speed if its rate of acceleration was 2.5 m s^{-2}.

Answer = _____

6. After stopping at the traffic lights, the driver transport vehicle accelerates at a rate of 2 m s^{-2} for 12 s. Calculate the car's new speed.

Answer = _____

7. One of the support vehicles goes from 15 m s^{-1} to 0 m s^{-1} after hitting a wall. Its rate of acceleration is -50 m s^{-2}. Calculate how long it takes to decelerate.

Answer = _____

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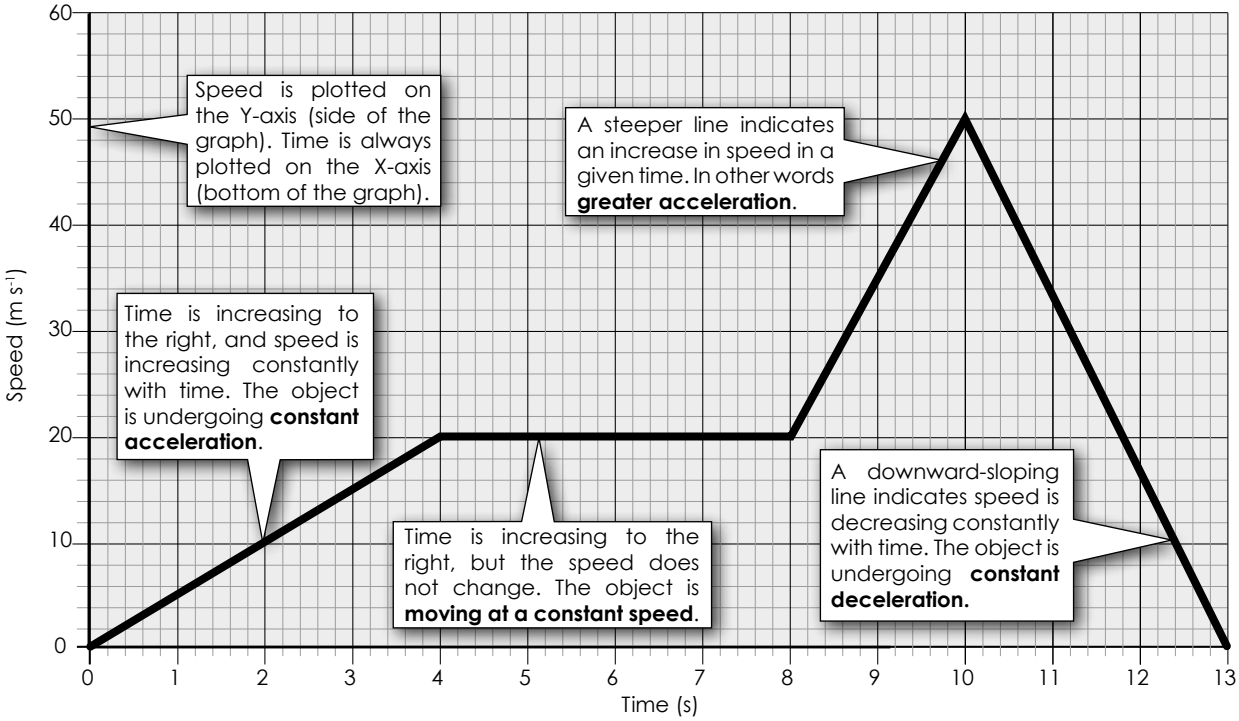
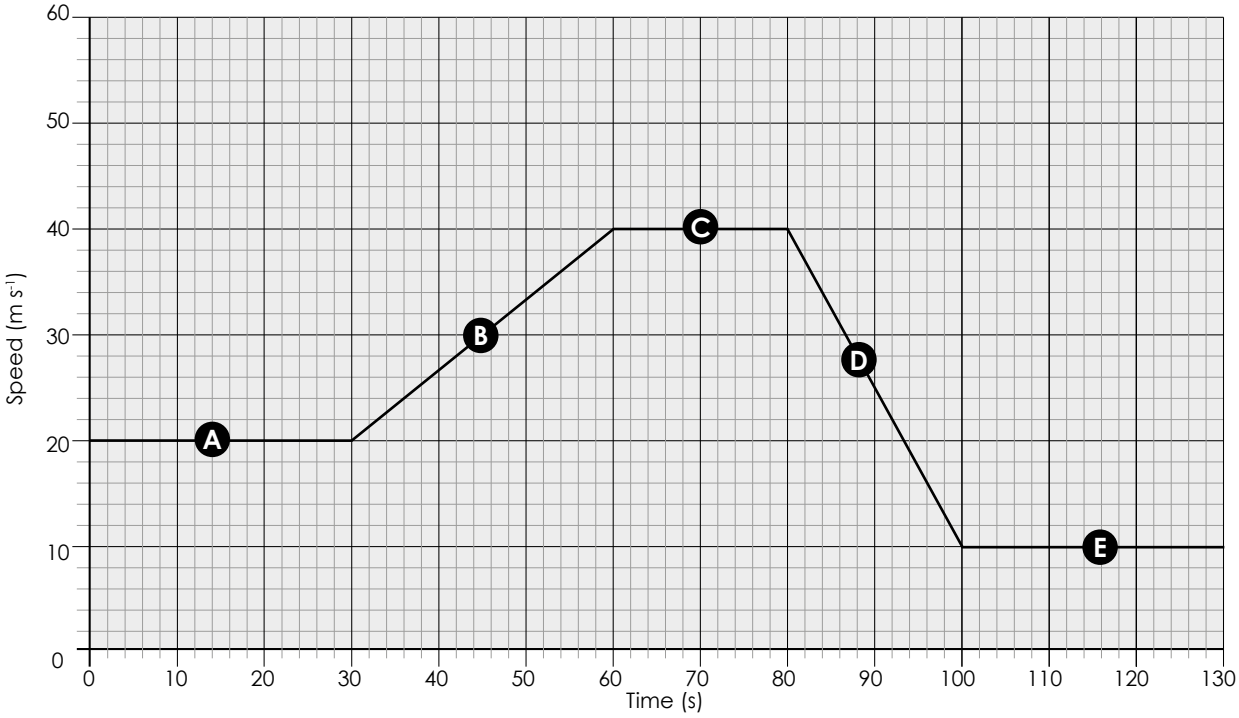
Speed-Time Graphs

Describing the acceleration of an object is occasionally hard to do with words. Sometimes graphs help make acceleration easier to picture, and therefore understand. A speed-time graph tells us how the speed of an object changes over time.

Features of a Speed-Time Graph



1. Describe the acceleration of the object shown below by using the terms *accelerating*, moving at a *constant speed*, and *decelerating*.



A = _____

B = _____

C = _____

D = _____

E = _____

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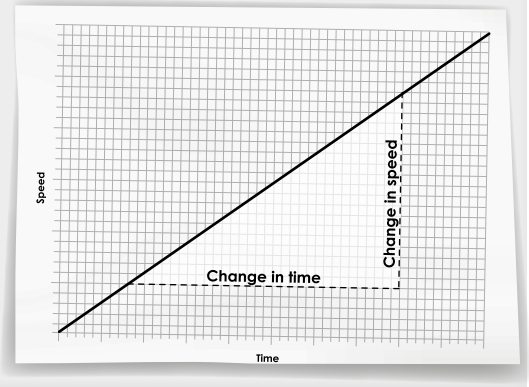
Calculating Acceleration from a Speed-Time Graph

The slope (*gradient*) of a speed-time graph can be used to calculate the acceleration of an object. The slope of any graph can be calculated using the following formula:

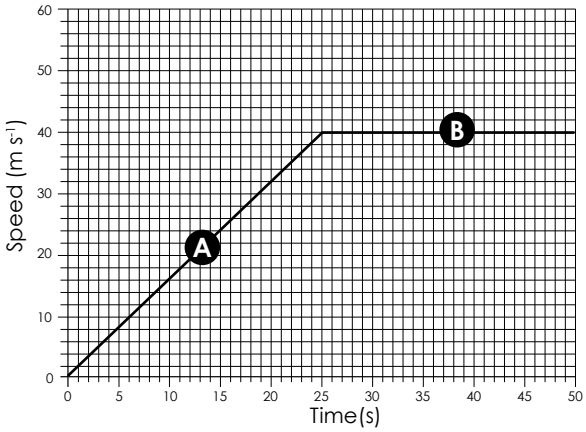
$$\text{Gradient} = \frac{\text{Change in the Y-axis variable}}{\text{Change in the X-axis variable}}$$

Therefore, on a speed-time graph:

$$\text{Gradient} = \frac{\text{Change in speed } (\Delta v)}{\text{Change in time } (\Delta t)} \quad \text{or} \quad \frac{(\Delta v)}{(\Delta t)}$$

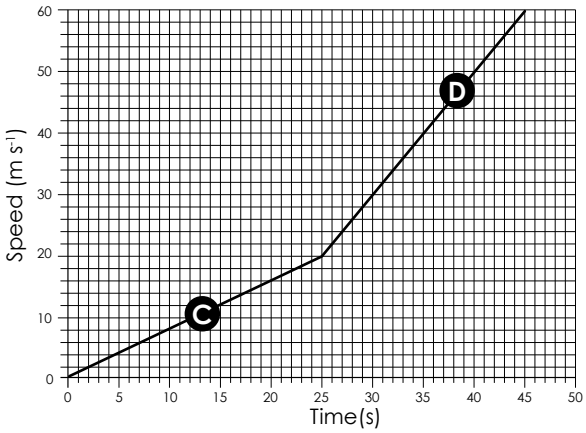


1. Use the gradient of the lines to calculate the acceleration shown on each speed-time graph.



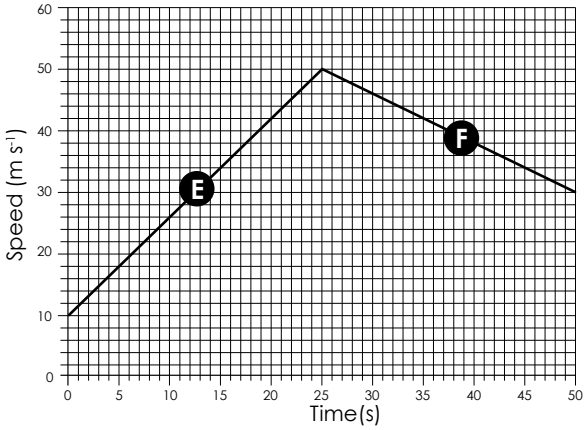
Section A
Gradient =
Acceleration = _____ _____ (units)

Section B
Gradient =
Acceleration = _____ _____ (units)



Section C
Gradient =
Acceleration = _____ _____ (units)

Section D
Gradient =
Acceleration = _____ _____ (units)



Section E
Gradient =
Acceleration = _____ _____ (units)

Section F
Gradient =
Acceleration = _____ _____ (units)

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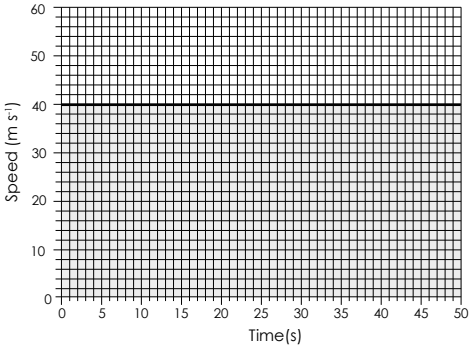
Distance Travelled I

Speed-time graphs can be used to calculate the distance an object has travelled. The area underneath the line on the graph, between any two points, shows the total distance travelled.



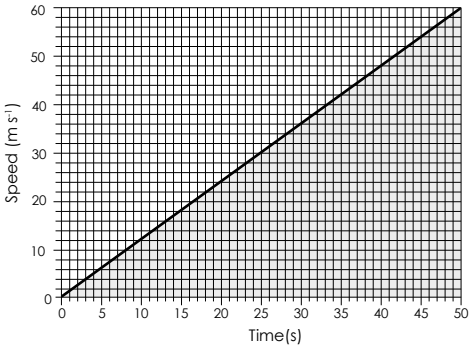
The area under the line is a rectangle, therefore the formula required to work out the area is:

Area = base x height

Therefore :

Distance travelled = 50 x 40

= 2 000 m



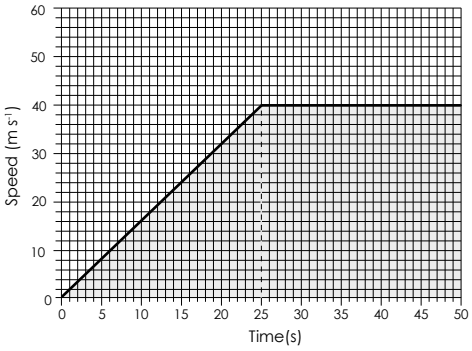
The area under the line is a triangle, therefore the formula required to work out the area is:

Area = ½ x base x height

Therefore :

Distance travelled = ½ x 50 x 60

= 1 500 m



The area under the line consists of a triangle and a rectangle, so the formula required to work out the area is:

Area = (½ x base x height) + (base x height)

Therefore :

Distance travelled = (½ x 25 x 40) + (25 x 40)

= 500 + 1000

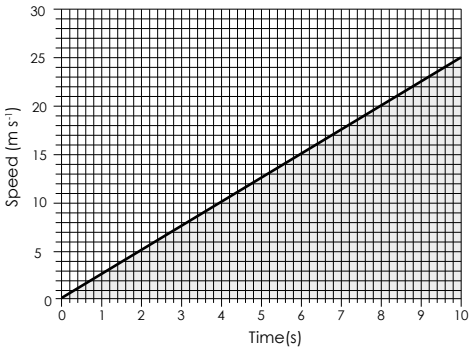
= 1 500 m

1. Calculate the total distance covered by the object shown in the following speed-time graphs

(a) Formula = _____

Working =

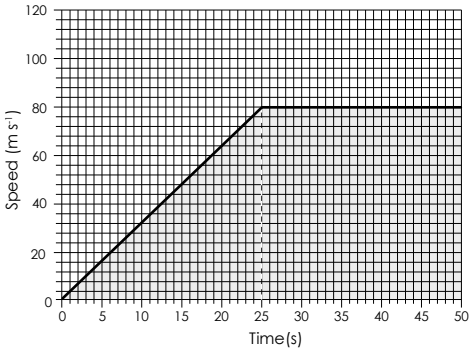
Answer = _____



(b) Formula = _____

Working =

Answer = _____



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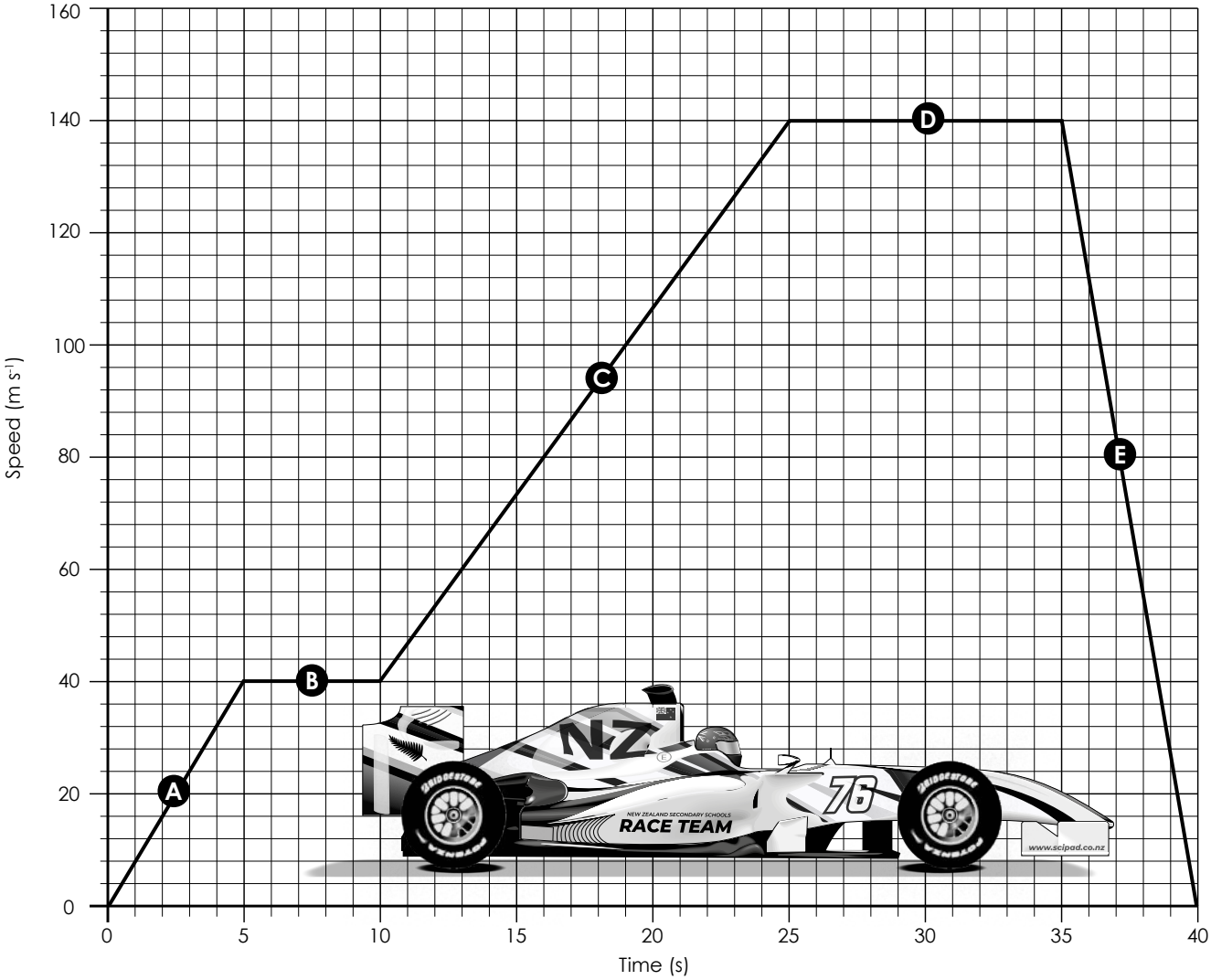
Distance Travelled II

1. The on-board computer system from the NZSS F1 car has produced the following speed-time graph. Use it to calculate the distance travelled at each of the various stages, before calculating the total distance travelled.

Speed-Time Graph (NZSS F1 Car Testing - Taupo 2019)



Distance travelled during A = _____

Distance travelled during B = _____

Distance travelled during C = _____

Distance travelled during D = _____

Distance travelled during E = _____

Total distance travelled = _____

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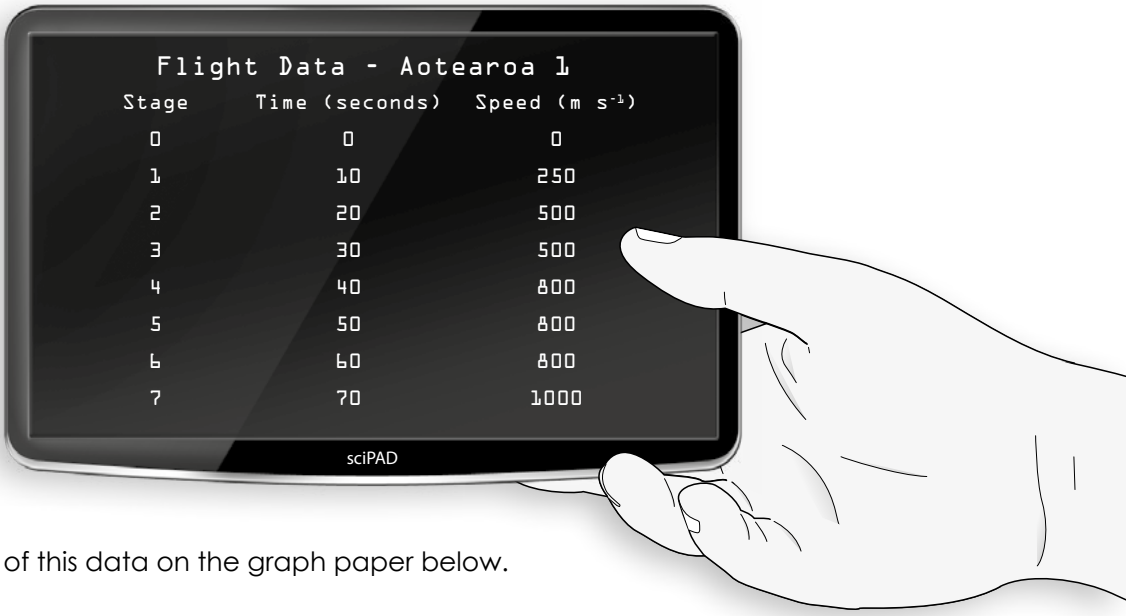
New Zealand Secondary Schools Space Program

Schools from around the country have pooled together all their funds raised from mufti days, school socials, car washes and workdays in order to build and launch "Aotearoa One" - New Zealand's first space rocket capable of carrying students into space. You have been employed as the Space Program's Head Scientific Analyst. Your job is to process some of the raw data gathered during Aotearoa One's first test flight.



Flight Data - Aotearoa 1

Stage	Time (seconds)	Speed (m s^{-1})
0	0	0
1	10	250
2	20	500
3	30	500
4	40	800
5	50	800
6	60	800
7	70	1000

sciPAD

1. Plot a line graph of this data on the graph paper below.

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2. Using data from the graph, calculate the acceleration of the rocket at each flight stage. Show all formula and working.

Flight Stage	Acceleration (m s^{-2})

3. Using data from the graph calculate the distance covered by the rocket at each flight stage. Show all formula and working.

Flight Stage	Distance Covered (m)
Total Distance Covered	

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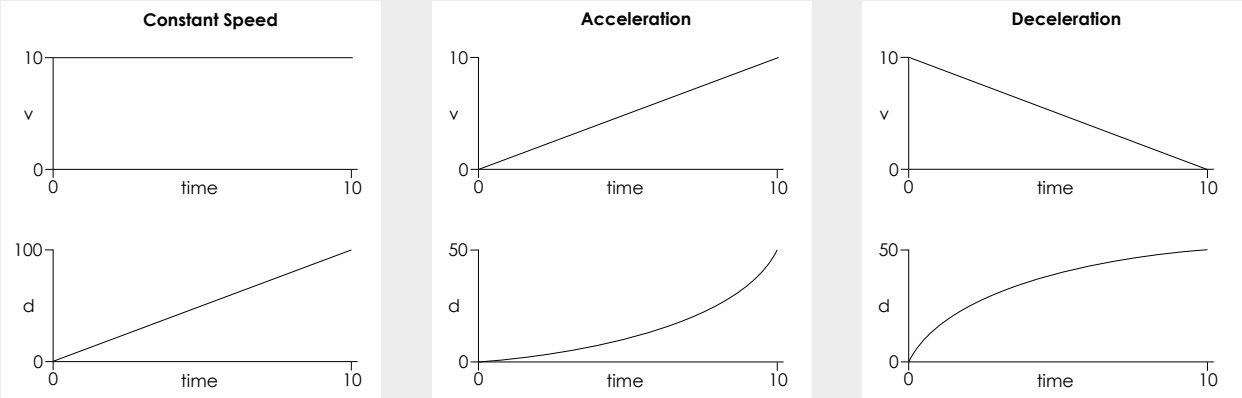
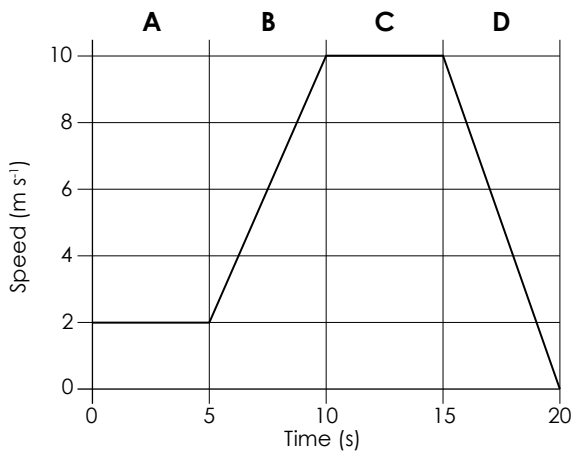
Converting Speed-Time Graphs To Distance-Time Graphs

The area under the line of a speed-time graph gives the distance that the object has travelled. Therefore, when converting a speed-time graph to a distance-time graph, the area of each section of the speed-time graph is used to plot the key points on the distance-time graph.

Once the points have been plotted they must be connected by the *appropriately shaped line*. To do this the following relationships are used.

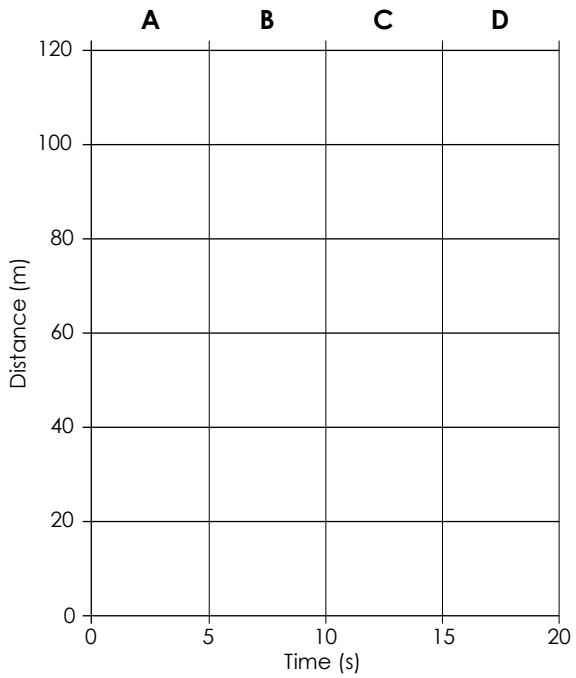


1. The motion of a car is shown on the speed-time graph below.



(a) Calculate the distance travelled in each of the four sections of the car's motion.

Section	Distance Travelled	Cumulative Distance
A		
B		
C		
D		



(b) On the axes provided plot the cumulative distances calculated in part (a).

(c) Using the appropriately shaped lines, join the plotted points together.

(d) In words, describe the motion of the car over its 20 s journey.

_____

_____

_____

_____

_____

_____

_____

_____

_____

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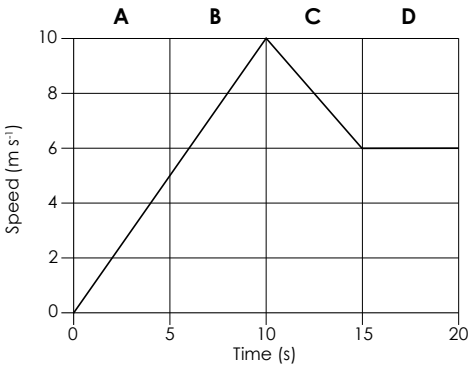
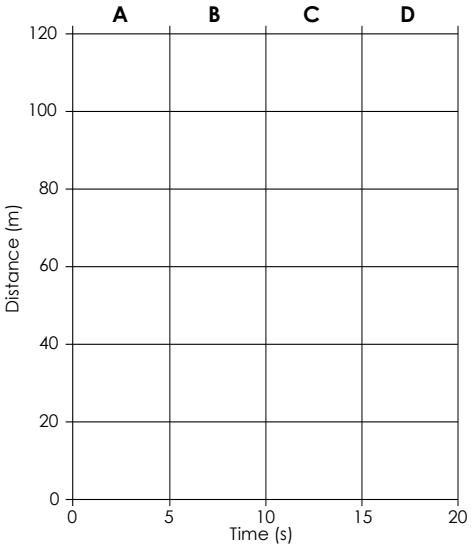
2. A runner's speed is graphed below.



(a) Calculate the distance travelled in each of the four sections of the runner's motion.

Section	Distance Travelled	Cumulative Distance
A		
B		
C		
D		



(b) On the axes provided plot the cumulative distances calculated in part (a).

(c) Using the appropriately shaped lines, join the plotted points together.

(d) Describe the runner's motion. _____

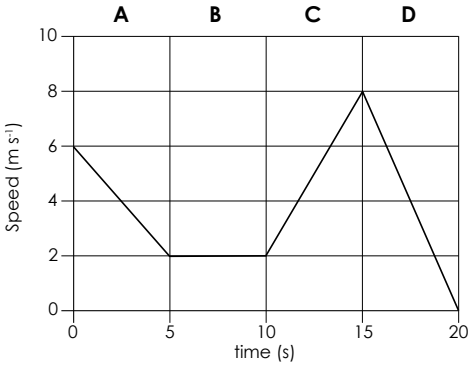
_____

_____

_____

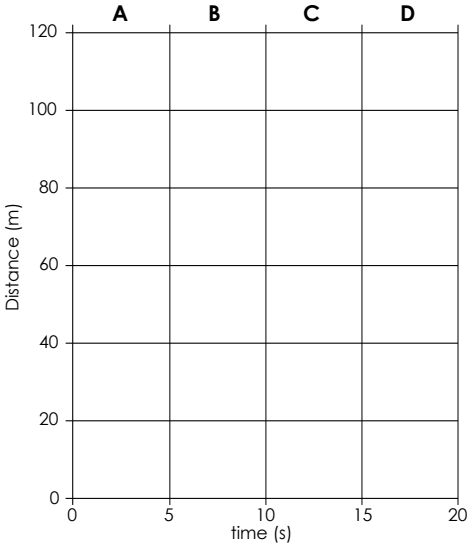
_____

3. Below is the speed-time graph of a car driving around town.



(a) Calculate the distance travelled in each of the four sections of the car's motion.

Section	Distance Travelled	Cumulative Distance
A		
B		
C		
D		



(b) On the axes provided, plot the cumulative distances calculated in part (a).

(c) Using the appropriately shaped lines, join the plotted points together.

(d) Describe the car's motion. _____

_____

_____

_____

_____

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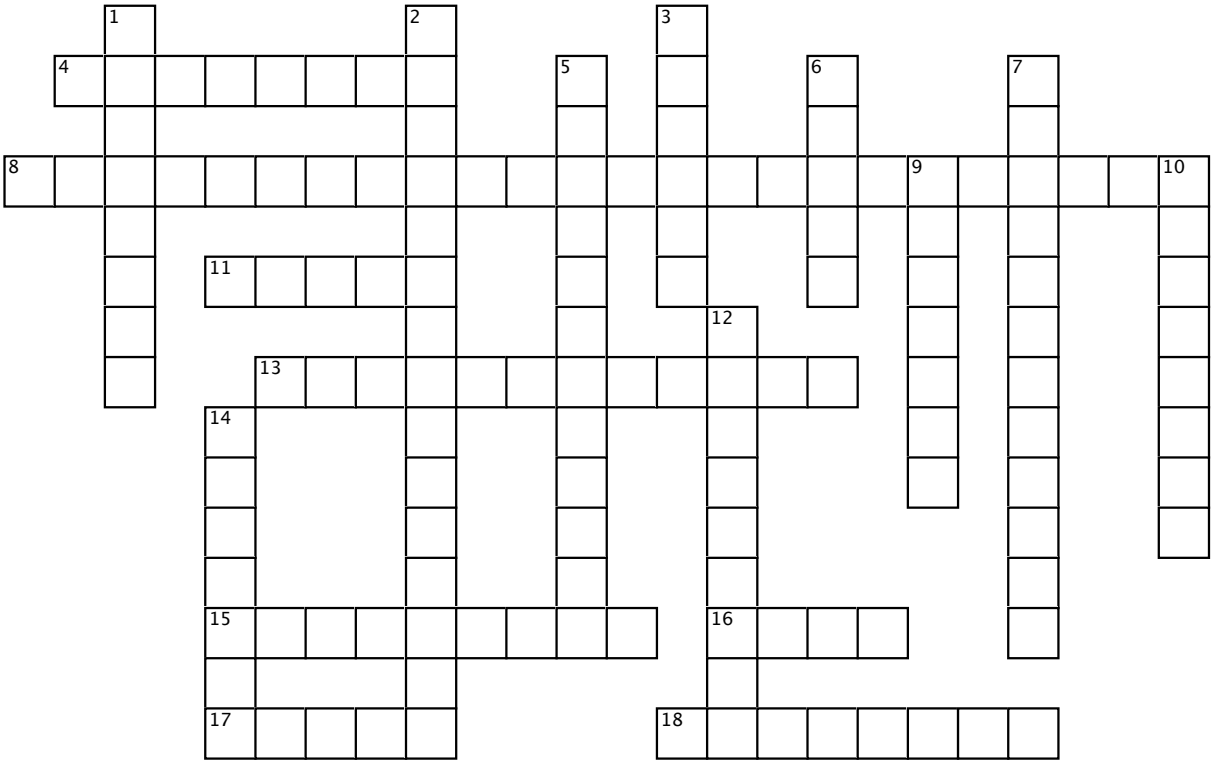
End of Chapter Puzzles

1. Use the clues to solve the crossword.



Across

4. In the formula for speed, it is given the abbreviation 'd'.
8. SI units for acceleration.
11. Twenty-four of these occur in a day.
13. Can be calculated by measuring the gradient of a speed-time graph.
15. On a distance-time graph, if the line is horizontal then the object is doing this.
16. In the formula for calculating speed, it is given the abbreviation 't'.
17. How fast you are going.
18. Given the abbreviation 'v'.

Down

1. How far you have travelled.
2. SI unit for speed.
3. The delta in Δv means this.
5. Negative acceleration is often called this.
6. Can be calculated from a distance-time graph.
7. The rate at which an object changes speed in a certain time.
9. A measure of time.
10. Can be calculated by measuring the area under the line of a speed-time graph.
12. Equivalent to 1000 metres.
14. There are sixty of these in a minute.

2. There are 10 misspelt words in the following paragraph. Circle the incorrect words and write them correctly in the space provided below.

Speed is a meazure of how far an objeck can travel in a certain amount of time. We often use kilametres per hour in everyday life. However, scientists often use metres per second as it is a more useful messure of sped. To calculate speed, we need to know two variables: distanze travellled and time taken to travel that distance. Acelleration is the rate at which an object changes its speed in a certain time. To kalculate accelleration we need to know the change in speed and the change in time.

(a) _____ (f) _____

(b) _____ (g) _____

(c) _____ (h) _____

(d) _____ (i) _____

(e) _____ (j) _____

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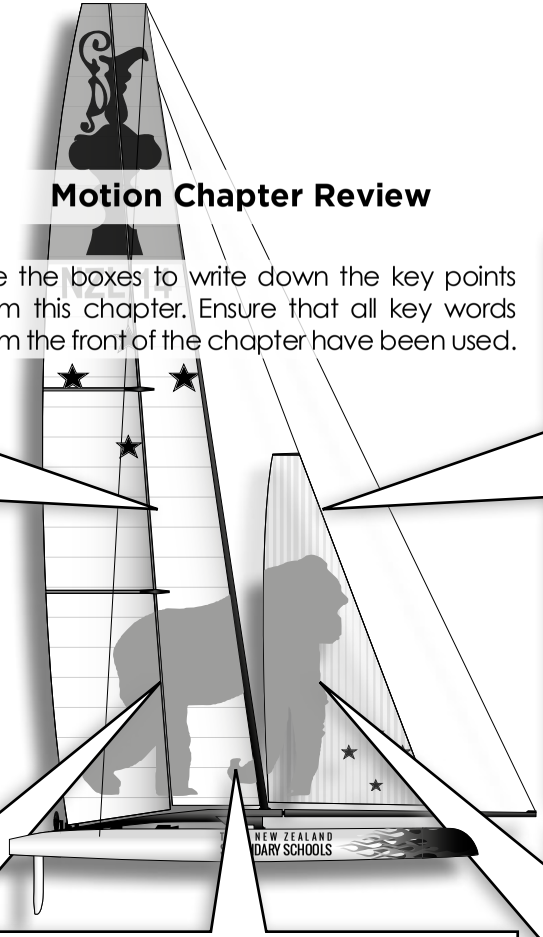
Motion Chapter Review

Use the boxes to write down the key points from this chapter. Ensure that all key words from the front of the chapter have been used.



Speed

Acceleration

Distance-Time Graphs

SI Units for Motion

Speed-Time Graphs

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End of Chapter Review Questions

1. Match the following words to their definitions.

Speed •	• A unit of speed.
Acceleration •	• The SI unit for acceleration.
Distance •	• Negative acceleration.
Metres per second •	• The rate at which an object changes its speed.
Deceleration •	• Measure of how far an object has gone.
m s^{-2} •	• A measure of the distance an object can travel in a certain amount of time.

2. Complete the tables by filling in the blank sections.

	Distance	Time	Speed
(a)	0.8 m	2 s	
(b)	3.5 m	5 s	
(c)		1.5 s	10 m s^{-1}
(d)		24 s	2 m s^{-1}
(e)	1.2 m		10 m s^{-1}
(f)	15 m		0.5 m s^{-1}

	Acceleration	Change in Speed	Change in Time
(g)		200 m s^{-1}	40 s
(h)		1 300 m s^{-1}	50 s
(i)		4.5 m s^{-1}	9 s
(j)	0.6 m s^{-2}	30 m s^{-1}	
(k)	8 m s^{-2}	58 m s^{-1}	
(l)	0.2 m s^{-2}	16 m s^{-1}	
(m)	60 m s^{-2}		3.5 s
(n)	16 m s^{-2}		0.4 s
(o)	0.75 m s^{-2}		8 s

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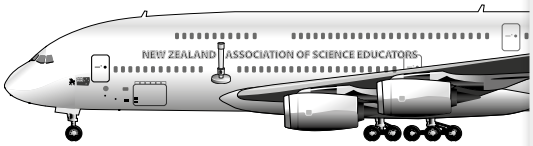
3. While waiting to catch a plane to Fiji for a science teachers' retreat, your teacher records the movement of the plane as it moves along the ground to the terminal.

(a) The plane starts from rest at the hangar and travels a distance of 40 metres in 16 seconds to the refuelling depot.

Calculate the average speed of the plane.



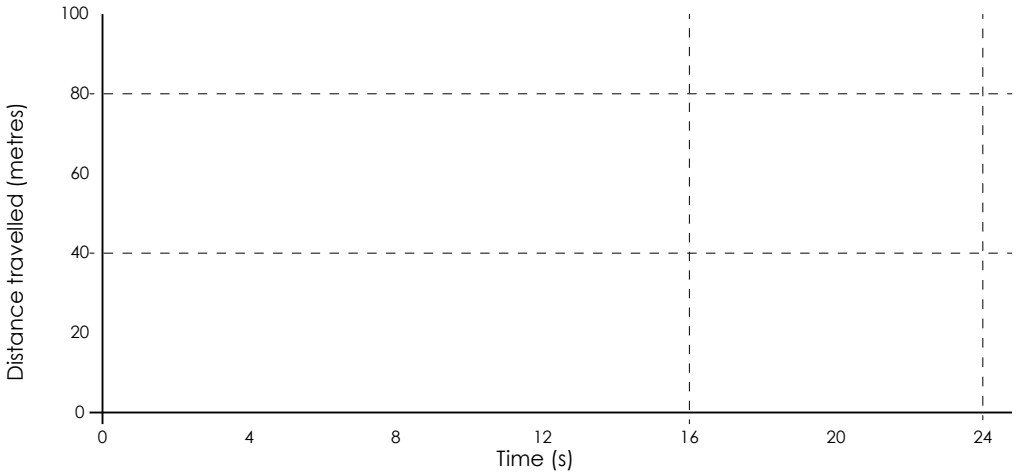
Average speed _____

(b) The plane then moves down the runway to the terminal at a constant speed. The distance from the refuelling depot to the terminal is 40 metres. The plane takes 8 seconds to complete the journey.

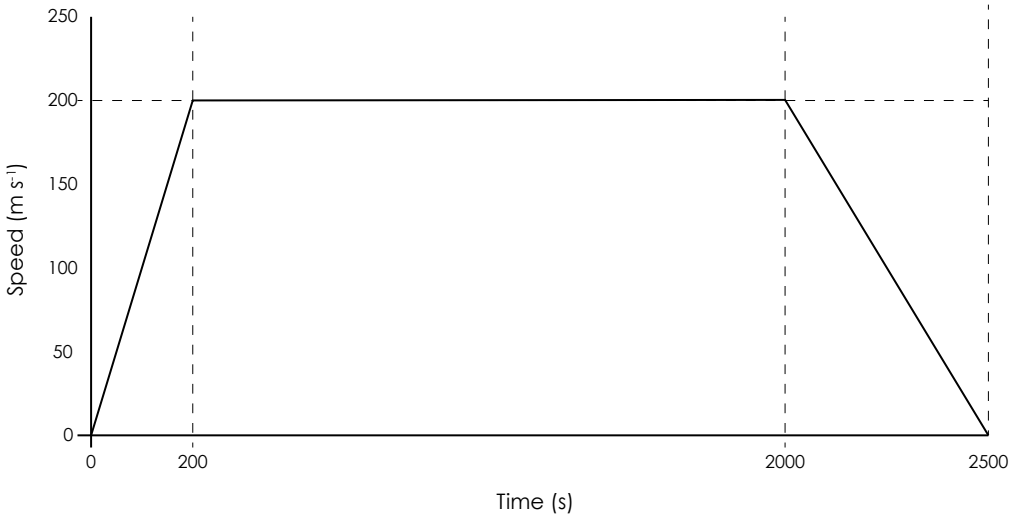
(i) Calculate the plane's average speed for this part of the journey.

Average speed _____

(ii) Using the information given in (a) and (b), draw in the *appropriate* lines on the distance-time graph below to represent the journey of the plane during the first 24 seconds.



(c) The speed-time graph below represents the motion of the plane during a short flight, from takeoff to landing. The horizontal axis is not to scale.



(i) Describe the motion of the plane during the first 200 s of the flight.

_____

_____

_____

Hints for answering these NCEA style questions

Write down:

- the formula you are using,
- your working,
- the units with your answer.

Appropriately shaped is key here.

Because it is accelerating at the start the graph should be curving upwards from 0 s until it reaches 16 s.

From 16 s to 24 s it is travelling at a constant speed so the line should be ruled.

You are expected to describe the motion using a statement and a calculation (i.e. Calculate the acceleration).

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(ii) Describe the motion of the plane between 2 000 s and 2 500 s.

_____

_____

_____

(iii) Calculate the total distance travelled during the entire flight.

_____

_____

_____

_____

_____

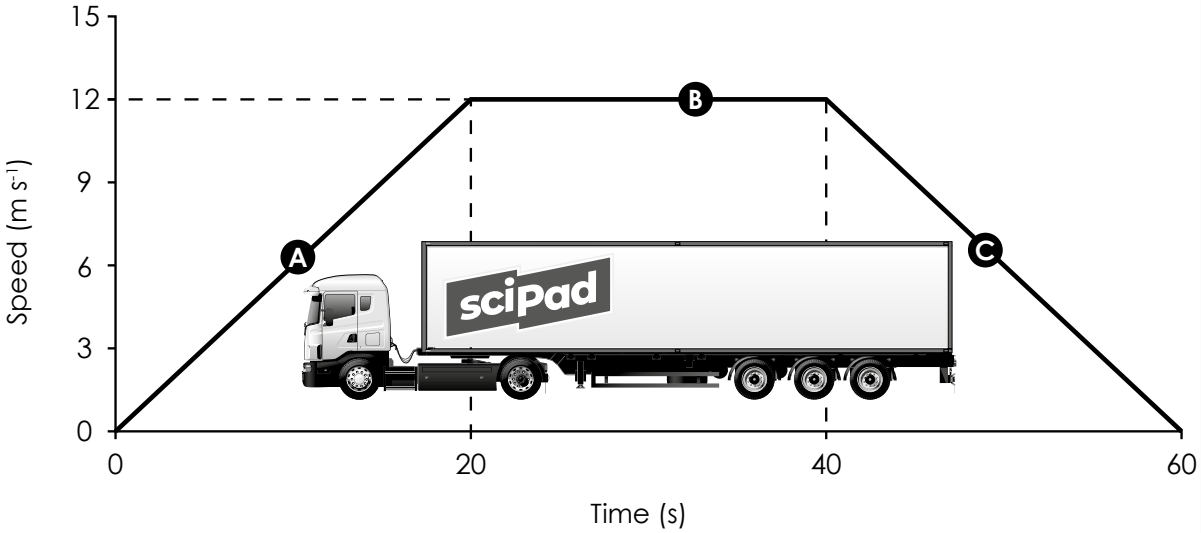
_____

_____

_____

4. The Silverback Trucking Company delivers textbooks throughout the country. The truck and trailer has a mass of 14 000 kg.

The speed-time graph below represents part of the truck's journey.



(a) Describe the motion of the truck during each section.

Your answers should include descriptions AND any relevant calculations.

(i) Section A: _____

_____

_____

(ii) Section B: _____

_____

_____

(iii) Section C: _____

_____

_____

Hints for answering these NCEA style questions

You are expected to describe the motion using a statement and a calculation (i.e. Calculate the acceleration).

To calculate the distance travelled from a speed time graph you need to work out the area under the graph. To calculate the area of triangle use:

Area = $\frac{1}{2}$ b x h

To calculate the area of square or rectangle use:

Area = b x h

Use scientific terms such as constant speed, acceleration, deceleration and stationary.

Calculate the truck acceleration and/ or speed for each section.

Acceleration is the gradient of the graph. Use change in speed divided by change in time.

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(b) Calculate the total distance the truck travels.

(i) Distance travelled, section A: _____

_____

_____

(ii) Distance travelled, section B: _____

_____

_____

(iii) Distance travelled, section C: _____

_____

_____

(iv) Total distance travelled: _____

5. A child plays with a remote control car on concrete.

The mass of the car is 400 grams (0.4 kg).

(a) The car starts from rest and travels a distance of 6 m in 3 seconds. Calculate the average speed of the car over 3 seconds.

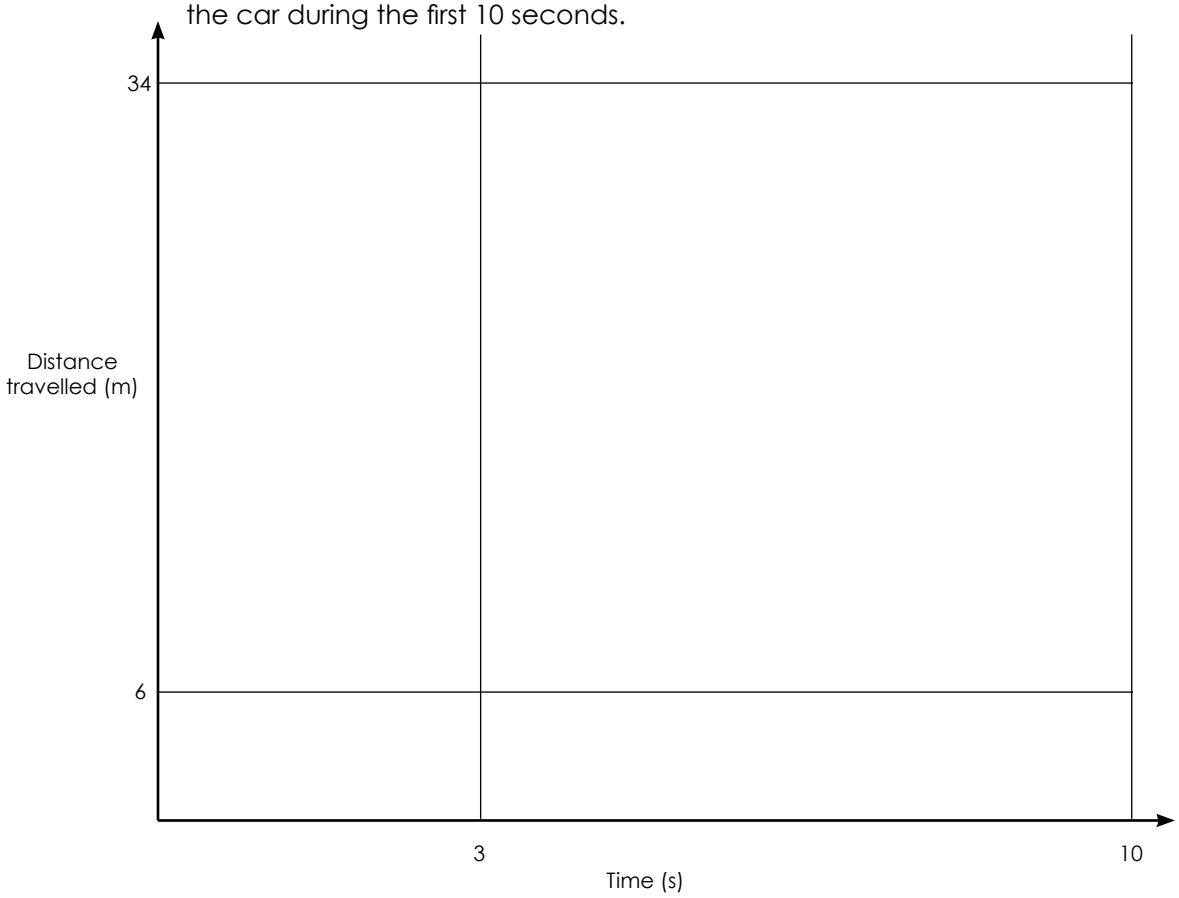
_____

_____

_____

Average speed = _____ m s^{-1}

(b) The car then travels a further 28 m at a constant speed of 4 m s^{-1} for 7 seconds. Using the information given in (a) and above, draw in the *appropriately shaped* lines on the distance-time graph below to represent the journey of the car during the first 10 seconds.



Hints for answering these NCEA style questions

Calculate the area under the line of each section.

Ensure all of your calculations contain the appropriate SI units.

Use v = d/t.

Don't be confused by the mass of the car (400 g) because that is exactly what it is there to do!

Appropriately shaped is key here.

Because it is accelerating at the start the graph should be curving upwards from 0 s until it reaches 3 s.

From 3 s to 10 s it is travelling at a constant speed so the line should be ruled.

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FORCES

By the end of this chapter you should be able to:

	I KNOW THIS ALREADY	I LEARNED THIS	I REVISED THIS
Define the term '*force*'.			
Name four forces that act on many everyday objects.			
Describe the effect of *balanced* and *unbalanced* forces on motion.			
Calculate force using $F_{net} = ma$.			
Rearrange $F_{net} = ma$ to solve an unknown variable.			
Explain the difference between '*mass*' and '*weight*'.			
Define *friction*, and describe its effect on motion.			
Define the term '*pressure*'.			
Calculate pressure using P = F/A.			
Rearrange P = F/A to solve an unknown variable.			

Key Terms

Force

My Definition: _____

_____

Balanced forces

My Definition: _____

_____

Unbalanced forces

My Definition: _____

_____

Newton

My Definition: _____

_____

Thrust

My Definition: _____

_____

Mass

My Definition: _____

_____

Weight

My Definition: _____

_____

Friction

My Definition: _____

_____

Drag

My Definition: _____

_____

Pressure

My Definition: _____

_____

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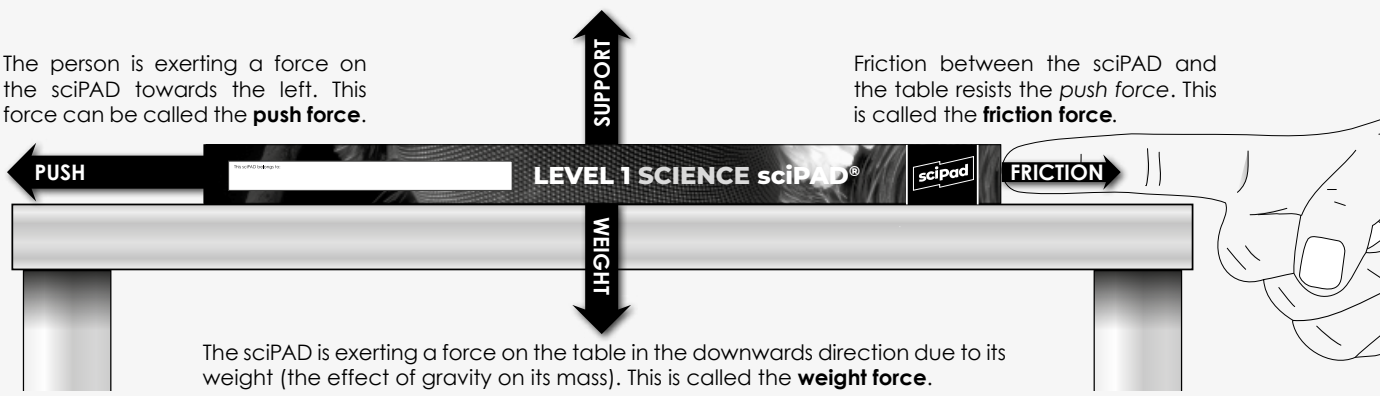
Introduction to Forces

A *force* is a push or a pull and is measured in newtons (N), named after Sir Isaac Newton. Forces are measured using a newton meter and have both a size and a direction.

You cannot see a force but often you can see what it does. Forces can make things move, speed up or make already moving objects slow down, change the direction they are moving in, and change the shape of things.

Note how the size of the arrows can be used to show the relative SIZE of the forces



1. Define the term '*force*'. _____

_____

2. Name the unit in which forces are measured. _____

3. Refer to the diagram above when answering the following questions.

   (a) Name the force that acts in the:

   Downwards direction. _____

   Upwards direction. _____

   (b) Suggest what would happen to the sciPAD if there was no support force.

   _____

   (c) Suggest what would happen to the sciPAD if:

   (i) The push force was greater than the friction force. _____

   _____

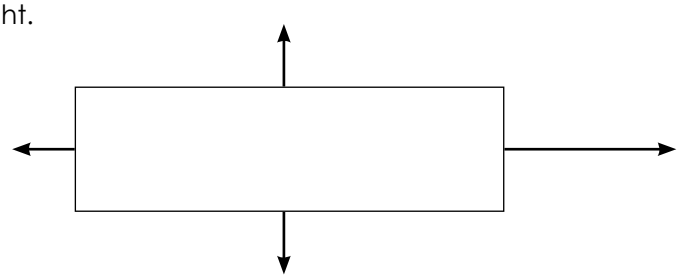
   (ii) The push force was equal to the friction force. _____

   _____

   (d) When the sciPAD is pushed horizontally, are the *weight force* and the *support force* still present?

   _____

   (e) Complete the diagram by adding labelled arrows that show the relative size and direction of the forces present on a sciPAD that is being pushed across the table from left to right.



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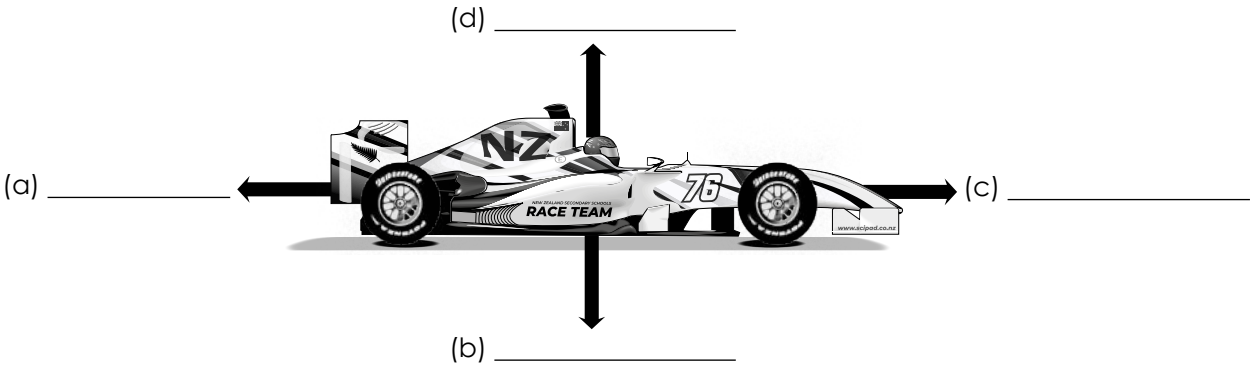
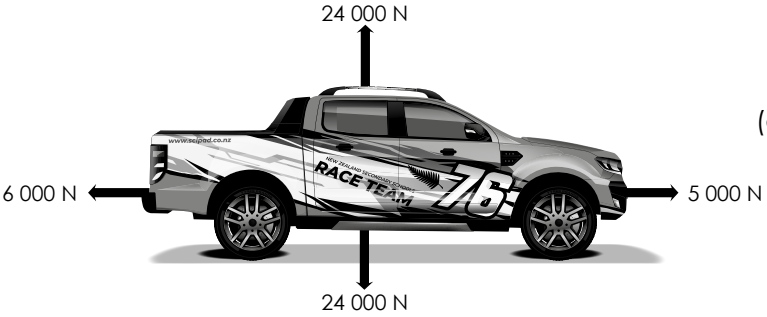
Force Problems

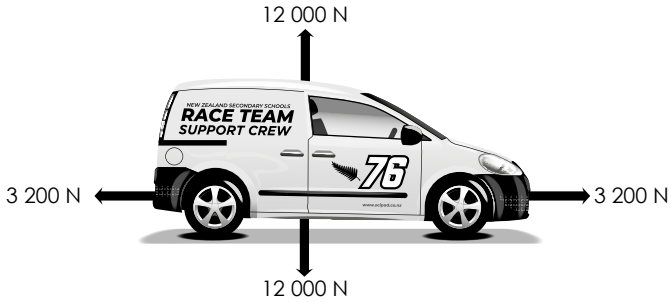
1. Label the four forces acting on the moving NZSS F1 car.



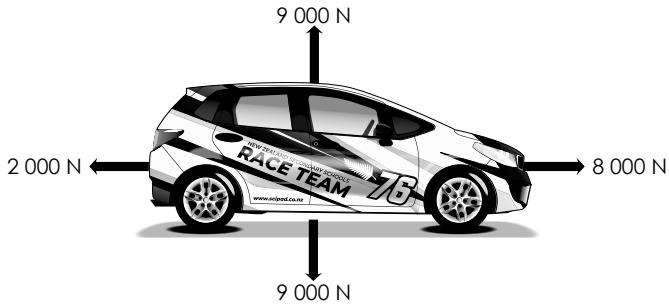
2. Calculate the size and give the direction (use an arrow) of the net force in the following examples.



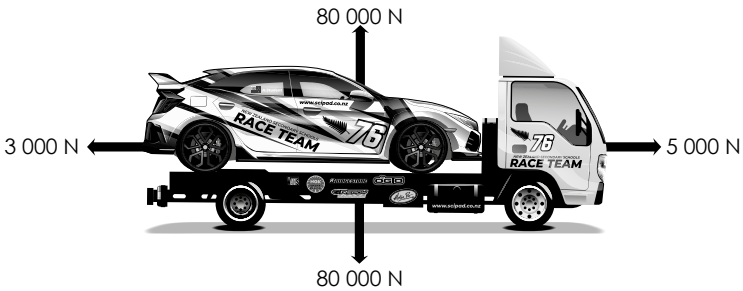
(a) Size of force: _____
Direction of force: _____



(b) Size of force: _____
Direction of force: _____



(c) Size of force: _____
Direction of force: _____



(d) Size of force: _____
Direction of force: _____

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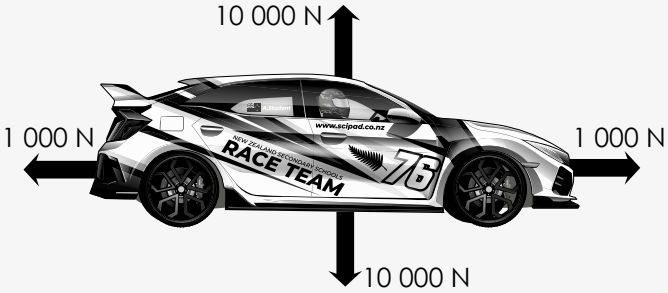
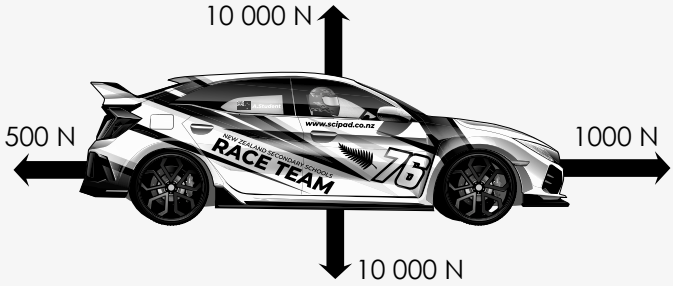
Balanced and Unbalanced Forces

Balanced forces are forces that act on an object but cancel each other out because they are the same size and are acting in opposite directions. This means that there will be no *net force* on the object. If the forces acting on an object are acting in opposite directions, and are different sizes they are said to be *unbalanced*.



When forces on an object are **balanced** there is no net force. If the object is moving, it will be moving at a constant speed. If it is not moving, it will remain stationary.

Zero net force



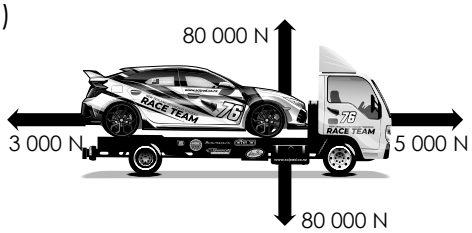
When forces on an object are **unbalanced** there is a net force and the object will accelerate or decelerate. The example shows that the car will be accelerating because there is a net force of 500 N.

500 N net force →

Remember to show forces with both a SIZE and DIRECTION

1. Calculate the size and direction of the net force in the following examples.

(a)

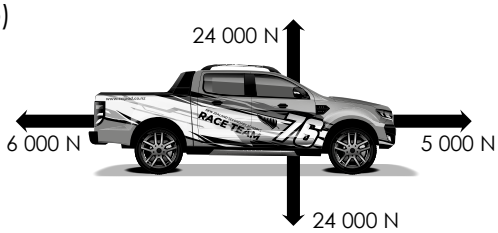


Size of force: _____

Direction of force: _____

Forces are balanced / unbalanced

(b)

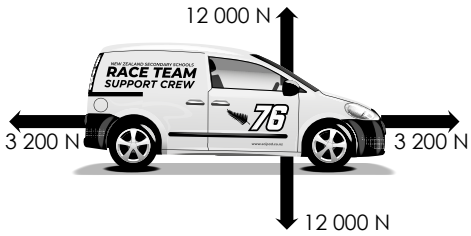


Size of force: _____

Direction of force: _____

Forces are balanced / unbalanced

(c)

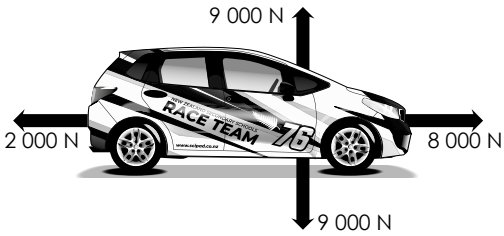


Size of force: _____

Direction of force: _____

Forces are balanced / unbalanced

(d)



Size of force: _____

Direction of force: _____

Forces are balanced / unbalanced

2. Complete the following sentences by crossing out the incorrect words.

(a) If an object is moving at a constant speed and the forces are balanced, the object will: *keep moving at a constant speed/accelerate/stop moving*.

(b) If an object is not moving and the forces are balanced, the object will: *accelerate/ decelerate/ remain stationary*.

(c) In order for an object to accelerate, the forces must be: *balanced/unbalanced*.

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Sarah's Ride to School

1. Sarah rides her bike to and from school.

   On the diagrams below, draw and label the **thrust** and **friction** forces acting on Sarah as she travels at a constant speed AND as she accelerates.

   In your answer you should use arrows to show the relative size and direction of the forces.

Travelling at a **constant speed**

Accelerating

2. Describe what is meant by the term '*net force*'.

_____

_____

_____

_____

_____

3. Discuss the *direction of the net force* and the *direction of motion* when Sarah is:

   (a) Travelling at a constant speed: _____

   _____

   _____

   _____

   _____

   _____

   _____

   (b) Accelerating: _____

   _____

   _____

   _____

   _____

   _____

   _____

   (c) Decelerating: _____

   _____

   _____

   _____

   _____

   _____

   _____

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Force, Mass and Acceleration

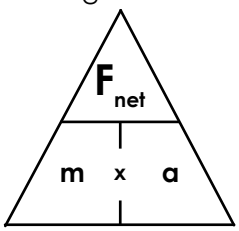
The amount of force acting on an object can be calculated using its *mass* and its *acceleration*. In simple terms, if a car and a bus were accelerating at the same rate, the bus would have a greater force acting on it (think about it hitting the wall) than the car, because the bus has a greater mass.

Scientists express the relationship between force, mass and acceleration using the formula:

$$F_{net} = ma$$

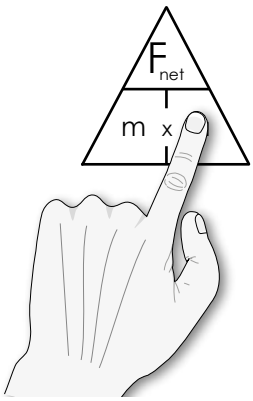
F_{net} = net force (N)
m = mass (kg)
a = acceleration (m s^{-2})

which can be arranged into the formula triangle



To use the triangle, simply cover up the variable you are trying to calculate and the triangle will tell you how to do it. For example:

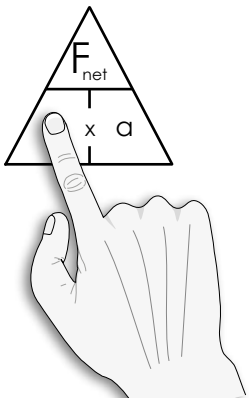
To calculate 'a'



The triangle tells you to divide 'F_{net}' by 'm', so

$$a = \frac{F_{net}}{m}$$

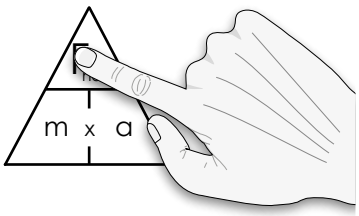
To calculate 'm'



The triangle tells you to divide 'F_{net}' by 'a', so

$$m = \frac{F_{net}}{a}$$

To calculate F_{net}



The triangle tells you to multiply 'm' by 'a', so

$$F_{net} = m \times a$$

1. Use the formula triangles to complete the table:

	Force (N)	Mass (kg)	Acceleration (m s^{-2})
(a)		10 kg	10 m s^{-2}
(b)		5 kg	2.5 m s^{-2}
(c)		4 kg	0.2 m s^{-2}
(d)	20 N	1 kg	
(e)	2.5 N	10 kg	
(f)	1.7 N	3.4 kg	
(g)	12 N		2 m s^{-2}
(h)	4.8 N		3 m s^{-2}

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Force, Mass and Acceleration Problems

Use $\mathbf{F_{net} = ma}$ to complete the following problems. Ensure you state the formula you are using, show your working, and give the appropriate units on your answers.

1. An object with a mass of 4.5 kg accelerates at 2 m s^{-2}. Calculate the net force acting on the object.

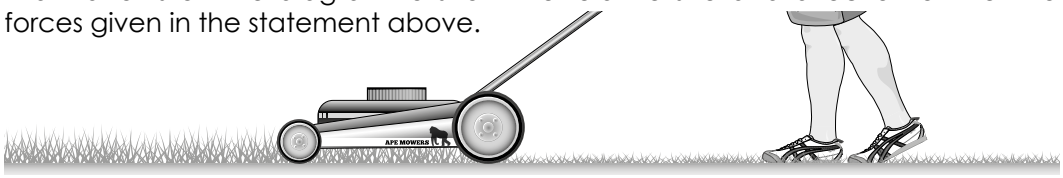
2. A net force of 2 N acts upon an object with a mass of 5 kg. Calculate the acceleration of the object.

3. A netball has a mass of 0.45 kg. A player wanted to accelerate it horizontally towards a teammate at a rate of 2 m s^{-2} . Calculate the force required.

4. A bullet is fired from a gun with a force of 25 N. It accelerates at 1000 m s^{-2}. Calculate the mass of the bullet.

5. A lawnmower (m = 36 kg) is being pushed forward with a horizontal force of 20 N. The grass provides a frictional force of 2 N.

   (a) Draw arrows on the diagram to show the relative size and direction of the two forces given in the statement above.



   (b) Calculate the acceleration of the lawnmower.

6. (a) A 2 kg brick is pulled across a table by a horizontal force of 10 N. Friction from the table produces a force of 4 N. Calculate the acceleration of the brick.

   (b) Another identical brick is placed on top of the first brick. Assuming the frictional forces and the pulling force remain the same, describe the effect of doubling the mass on the acceleration of the two bricks. You should include a calculation in your answer.

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7. The diagram below shows the New Zealand Secondary Schools rally car in action.

(a) Draw labelled arrows to show the four forces acting on the moving car.

(b) The car is moving forward, but not accelerating. Comment on the relative sizes of all the forces acting on the car. _____

_____

8. This rally car has a mass of 1 500 kg (including the mass of the driver and navigator). The engine is producing a thrust force of 7 500 N. Ignoring the effect of friction, explain how the following changes would affect the acceleration of the car. You should use calculations (before and after) to support your answer.

(a) The thrust force of the engine was doubled. _____

_____

_____

_____

_____

(b) The mass of the car is reduced to 750 kg when a carbon fibre body kit is fitted.

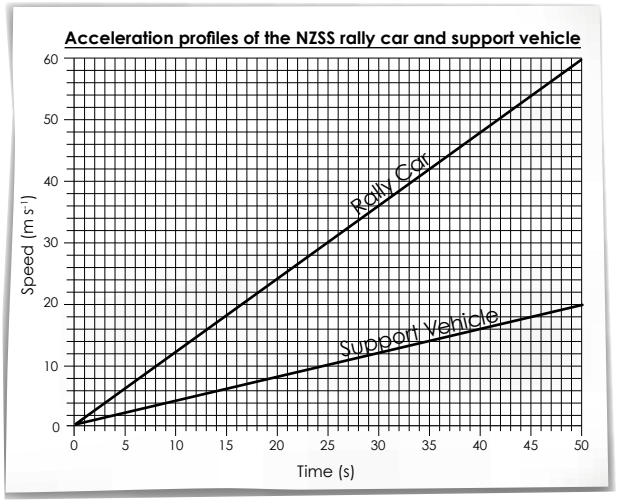
_____

_____

_____

_____

9. The graph on the right was drawn using data from the NZSS rally car and a support vehicle.



(a) The rally car accelerates at a rate of 1.2 m s^{-2}. If the mass of the car is 1 500 kg, calculate the thrust force produced by the engine.

Force _____

(b) The engine in the support vehicle produces a force of 3 000 N, causing it to accelerate at a rate of 0.4 m s^{-2}. Calculate the mass of this vehicle.

Mass _____

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Mass and Weight

In everyday language, we often confuse the terms *mass* and *weight*.

In science, *mass* is a measure of the amount of matter in an object. It is measured in kilograms (kg). The mass of an object does not change if the object changes its location.

Weight is a measure of the *force* on an object and is caused by the effect of gravity on that object. Like all forces, weight is measured in newtons (N).

If you drop an object, it will accelerate towards the centre of Earth at approximately 10 metres per second for every second it is falling.

Because weight is a force, we can use the formula:

$$F_{net} = ma$$

F_{net} = net force (N)
m = mass (kg)
a = acceleration (m s^{-2})

When calculating the weight of an object on Earth, acceleration (a) is due to gravity (g). Acceleration due to gravity is constant (10 m s^{-2} or alternatively 10 N kg^{-1} - either way, use the number 10 in your calculations).

A Worked Example

NZPQA
NCEA Level 1 - Mechanics Exam

1. Sarah has a mass of 75 kg. Calculate her weight.

$F_{net} = ma$
$= 75\ kg \times 10\ N\ kg^{-1}$
$= 750\ N$

Do not forget to show:
- formula
- working
- answer
- units

NCEA Examiner's report : "Many candidates could not calculate weight when given mass".

1. Explain the difference between the terms *mass* and *weight*. _____

2. What is the size of the acceleration due to gravity on Earth? _____

3. Calculate the weight of the following objects. Show all your working.

(a) A baseball bat has a mass of 1 kg.

Weight = _____

(b) A small dog has a mass of 7 kg.

Weight = _____

(c) A car has a mass of 1 200 kg.

Weight = _____

(d) A pumpkin has a mass of 0.8 kg.

Weight = _____

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4. A student knocks a Bunsen burner off the bench. The Bunsen has a mass of 0.2 kg.

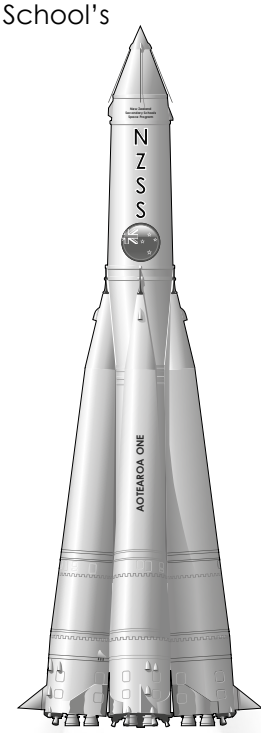
(a) State the rate at which the Bunsen will accelerate towards the ground.

_____

(b) Calculate the force of gravity pulling downwards on the Bunsen.

_____

5. During a flight of *Aotearoa One,* the first rocket from the New Zealand Secondary School's Space Program, the astronauts experience different gravitational strengths.



Location	Strength of Gravity
Earth	10.0 N kg^{-1}
Moon	1.6 N kg^{-1}
Mars	4.0 N kg^{-1}

Calculate the *weight* of an astronaut (mass = 60 kg) when they are:

(a) On the launch pad prior to takeoff.

(b) On the surface of the Moon.

(c) On the surface of Mars.

(d) Do the masses of the astronauts change when they travel to space?

Explain your answer. _____

_____

_____

_____

6. Aotearoa One has a mass of 100 000 kg. When it launches, the initial thrust produced by the engines is 5 000 000 N. Calculate the rocket's acceleration at this point.

Acceleration = _____

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Friction

Friction is a force that occurs when an object moves, or tries to move, against another object or fluid. Friction often acts to *oppose* (prevent or stop) the movement of an object. Friction can generate heat, causes wear and tear, and slow moving objects down. The effects of friction can be reduced if the surfaces of the two materials are lubricated (with water or oil, etc). Friction can be increased by making one or more of the surfaces rougher or by pressing them together more strongly.

1. Complete the following table to identify when friction is wanted or not wanted. If it is wanted, outline how the force of friction can be increased. If it is not wanted, outline how the force of friction can be decreased.

Example	Friction wanted or not wanted?	How can it be increased/decreased?
Wheels on the road		
Hands on the steering wheel		
Brakes		
Air on the windscreen		
Moving parts inside the engine		

2. Four of the NZSS Race Team vehicles are shown below.

(a) Define the term '*drag*'._____

(b) (i) Identify which vehicle would create the *least* amount of drag when moving.

(ii) Outline why you chose this vehicle. _____

(c) (i) Identify which vehicle would create the *most* amount of drag when moving.

(ii) Outline why you chose this vehicle. _____

3. Give two ways in which friction could be reduced between two solid surfaces.

(a) _____

(b) _____

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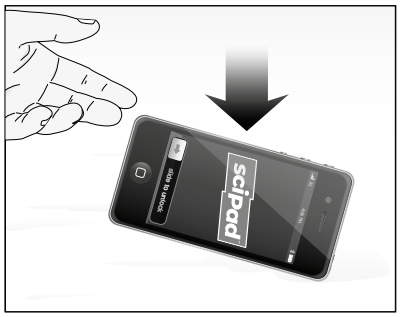
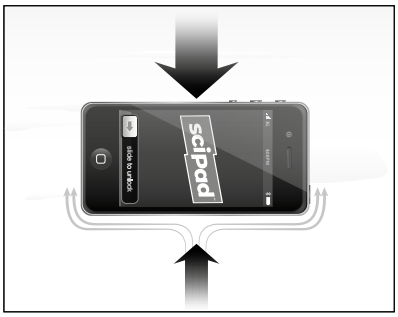
Air Resistance

When an object falls there are two main forces acting on it:

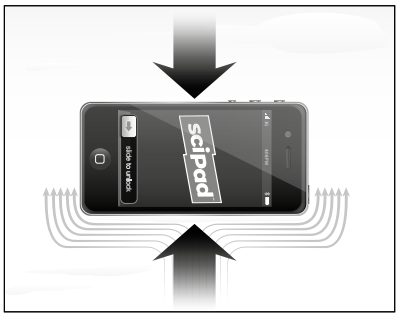
- The weight of the object is the force acting downwards. Weight force is caused by the effect of Earth's gravity on the object's mass.
- Friction caused by air resistance is the force acting in an upwards direction. This force opposes the movement of the object. Air resistance is the result of collisions of the object's leading surface with air molecules. The more air molecules that an object collides with, the greater the air resistance force. Subsequently, the amount of air resistance is dependent upon the speed of the falling object and the surface area of the falling object.



When an object falls through air, it initially accelerates due to the effect of gravity (10 N kg $^{-1}$). At first, the amount of air resistance is very low.



As the object moves faster, the air resistance increases. As a result the net force gets smaller. It is still accelerating as the forces are unbalanced.



Eventually the downwards force is balanced by the upwards force of the air resistance and the object falls at a constant rate (no acceleration) called its *terminal velocity*.

1. Name the two forces acting on an object falling in air.

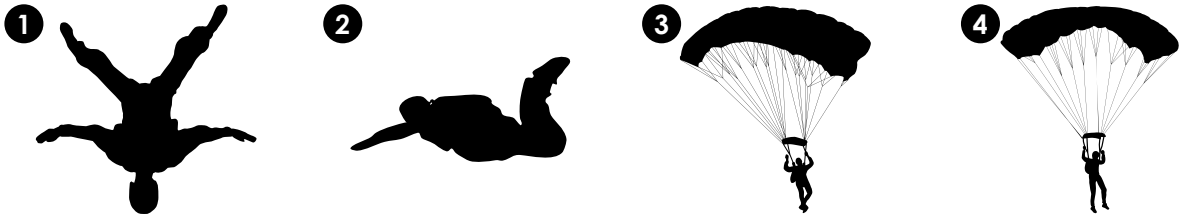
   (a) _____ (b) _____

2. Describe the relationship between a falling object's speed, leading surface and air resistance. _____

   _____

   _____

3. Add labelled arrows to the four diagrams below to show the relative size of the forces acting on the skydiver as he falls.



4. In terms of the forces involved, outline why the skydiver is:

   (a) Accelerating in 1. _____

   _____

   (b) Falling at a constant speed in 2. _____

   _____

   (c) Decelerating in 3. _____

   _____

   (d) Falling at a constant speed in 4. _____

   _____

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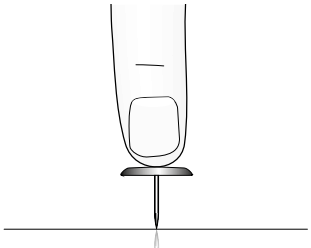
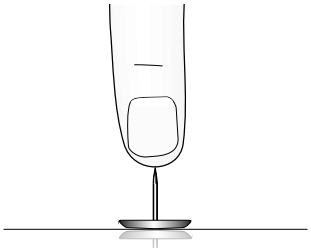
Pressure

Pressure is how much *force* is put onto a particular *area*. Think about these two situations:



1 Pushing on a drawing pin with pointy end facing down.



2 Pushing on a drawing pin with pointy end facing up.

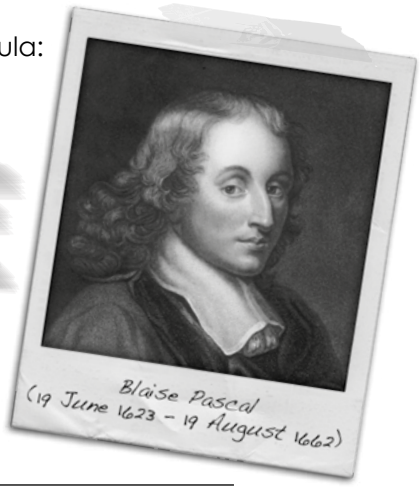
Assuming that you push down on each drawing pin with the same force, the end result will be quite different. In diagram 1, the finger pushes on a large area so the force is spread out and the pressure on the finger tip is low. In diagram 2, the force is concentrated on a small area so the pressure on the finger tip is much higher.

Scientists express the relation between pressure, force and area using the formula:

$$P = \frac{F}{A}$$

P = pressure (N m^{-2})
F = force (N)
A = area (m^2)

The unit for pressure can be expressed as N m^{-2} (newtons per square metre) or as a pascal (Pa) – named after Blaise Pascal, a French scientist who did a lot of experiments involving pressure.



1. Show how you could rearrange the formula to find:
   (a) Force (F): _____
   (b) Area (A): _____

2. State two different units of pressure.
   (a) _____
   (b) _____

3. Complete the table by filling in the blank sections.

	Pressure (N m^{-2})	Force (N)	Area (m^2)
(a)		10 N	10 m^2
(b)		5 N	2.5 m^2
(c)		4 N	0.2 m^2
(d)	20 N m^{-2}	1 N	
(e)	2.5 N m^{-2}	10 N	
(f)	1.7 N m^{-2}	3.4 N	
(g)	12 N m^{-2}		2 m^2
(h)	4.8 N m^{-2}		3 m^2
(i)	1.5 N m^{-2}		0.7 m^2

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Under Pressure

Method:

1. Use scales to measure your mass and then calculate your weight.

   Mass = _____ kg
   Weight = _____ N

2. Place one of your shoes on the grid (right).

3. Using a pencil, carefully outline the area of your shoe.

4. Count the number of full (1 cm^2) squares in the outlined area, and estimate the number of whole squares that the part squares add up to.

   Foot area = _____ cm^2

5. Convert to your answer to (4) to metres squared (m^2) by dividing by 10 000 = _____ m^2

6. Multiply this number by two to calculate the area of both of your shoes.

   (Answer from 5) x 2 = _____ m^2

7. Use the formula P = F / A to calculate the effective pressure you exert on the ground when standing on two feet.

   _____
   _____
   _____
   _____
   _____

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Pressure Problems

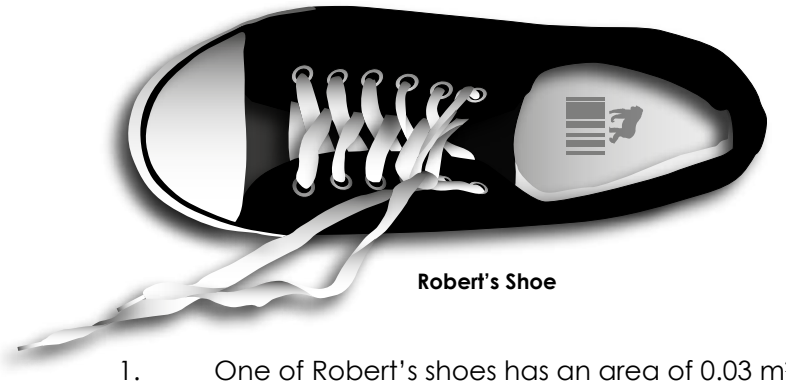
1. Complete the following sentences using the word list provided.

greater	spread out	less	concentrated

The pressure is _____ when a force is applied over a large area because the force is _____ over that area.

The pressure is _____ when a force is applied over a small area because the force is _____ over that area.

2. Two shoes are shown below. One shoe belongs to Robert and the other belongs to Judith.



Robert's Shoe

Judith's Shoe

1. One of Robert's shoes has an area of 0.03 m^2 and he weighs 900 N.

   (a) Calculate the amount of pressure he exerts on the ground if he stands on one foot.

   _____

   _____

   (b) How much pressure would Robert exert on the ground if he stood on both feet?

   _____

2. One of Judith's shoes has an area of 0.013 m^2 and she has a mass of 65 kg.

   (c) Calculate the force she exerts on the ground. _____

   _____

   (d) Use your answer from (c) to calculate the amount of pressure she exerts on the ground when she is standing on both feet. _____

   _____

   _____

3. Use your knowledge of pressure to explain why:

   (a) Scissors have sharp blades. _____

   _____

   _____

(b) High-heeled shoes leave marks on wooden floors. _____

_____

_____

4. A wooden block is resting on the ground. The amount of pressure it is exerting on the ground is 8 000 N m^{-2}. The bottom of the block has an area of 0.8 m^2. Calculate the weight of the block. _____

_____

_____

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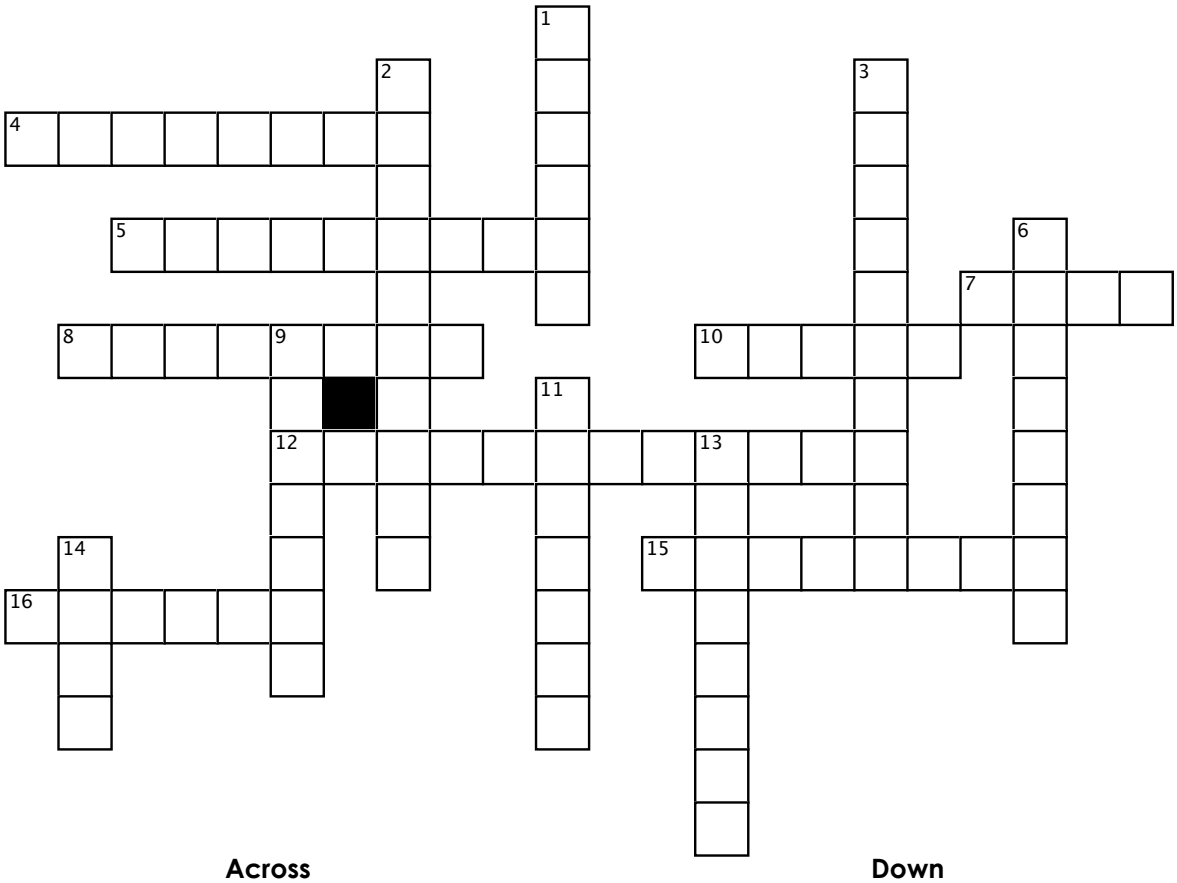
End of Chapter Puzzles

1. Carol and Vicky are hanging out in Auckland. Complete the cartoon by writing in an answer to Carol's question.

2. Use the clues at the bottom of the page to solve the crossword.



Across

4. A force that always opposes the forward movement of an object.
5. If the force of gravity is greater than the support force, an object will accelerate in this direction.
7. A term used to describe the amount of matter inside an object.
8. The SI units for mass.
10. A push or pull.
12. The 'a' in $F_{net} = ma$.
15. Measured in pascals or N m^{-2}.
16. A term used to describe the effect of gravity on an object's mass.

Down

1. A force that moves an object forward.
2. When forces are unequal we say they are this.
3. These substances reduce friction.
6. When forces are equal we say they are this.
9. The downward acting force is the force due to this.
11. The unit in which forces are measured.
13. An object which is falling at its maximum rate is said to be moving at this velocity.
14. A type of energy created by friction.

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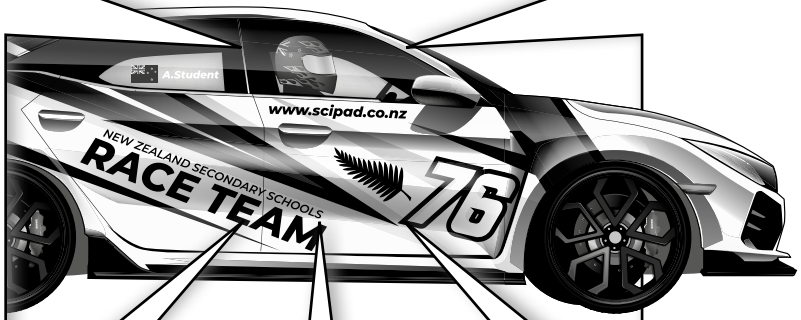
Forces Chapter Review

Use the boxes to write down the key points from this chapter. Ensure that all key words from the front of the chapter have been used.

Types of Forces

Pressure



Forces and Motion

Mass and Weight

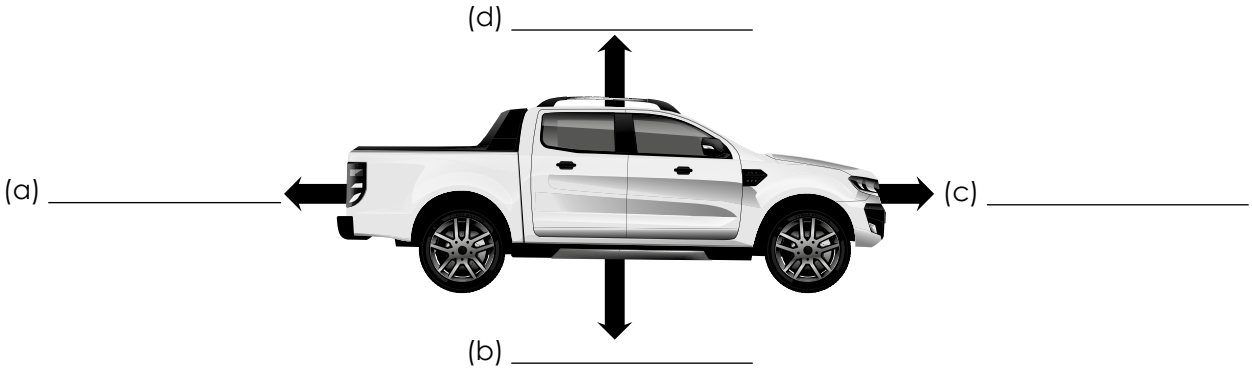
Friction

End of Chapter Review Questions

1. Match the following words to their definitions.

Force •	• Force applied to a particular area.
Newton •	• A force that resists movement.
Pressure •	• A push or pull on an object.
Friction •	• The SI unit for force.
Mass •	• Effect of gravity on a mass.
Weight •	• Amount of matter in an object.

2. Label the four forces acting on the moving vehicle.



3. Describe the difference between *balanced* and *unbalanced* forces. _____

_____

_____

_____

_____

4. In relation to an object that is moving at a constant speed, describe the affect on the objects motion if:

   (a) The forces are unbalanced. _____

   (b) the forces are balanced. _____

   _____

5. Describe the difference between '*mass*' and '*weight*'. _____

_____

_____

6. (a) Calculate the weight of an object that has a mass of 2.4 kg. Show all your working.

   Formula = _____ Working = _____

   Answer = _____

   (b) Calculate the mass of an object that has a weight of 480 N. Show all your working.

   Formula = _____ Working = _____

   Answer = _____

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7. A truck and trailer unit has a mass of 36 000 kg

(a) Calculate the weight of the truck and trailer unit.

Weight: _____

(b) The engine produces a force of 63 000 N. Calculate the acceleration of the truck and trailer unit.

Acceleration: _____

(c) Whenever the truck moves, the effects of friction can be observed. Outline how friction affects the movement of the truck. In your answer you should:

- Define friction.
- Give examples of how friction is both helpful and unhelpful in terms of the truck's motion.
- Explain how friction can be increased or reduced.

_____

_____

_____

_____

_____

_____

_____

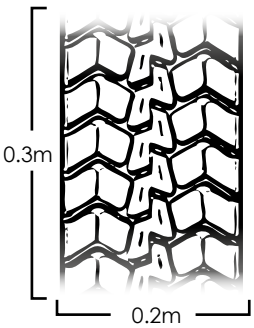
_____

_____

_____

(d) The truck has 10 tyres. Each tyre is in contact with a 0.30 m x 0.20 m area of the road.

(i) Calculate the total area of road that all the tyres are in contact with.



Total Area: _____

(ii) Calculate the total pressure exerted by the truck on the road.

Pressure: _____

Hints for answering these NCEA style questions

Write down:
- the formula you are using,
- your working,
- the units with your answer,

You will need to rearrange $F_{net} = ma$

Define 'friction'.

Give at least two examples of when friction is useful and when it is unhelpful.

For the helpful friction, explain how it can be increased.

For the unhelpful friction, explain how it can be reduced.

Calculate the area of one tyre. Then multiply this number by the total number of tyres.

Use your answers from (a) and 4d(i) to calculate the total pressure.

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8. A parachutist with of mass of 75 kg jumps from a plane at a height of 4 000 m above sea level.

(a) The parachutist falls through a distance of 2 400 m during the first 60 seconds. Calculate the average speed of the parachutist during this time.

Average speed _____ = m s $^{-1}$

(b) Explain the vertical motion of the parachutist just after she jumps out of the plane (before the parachute opens).

In your answer you should:

- Draw and label the vertical force(s) acting on the parachutist and show their relative sizes on the image below.
- Describe the net vertical force and state whether the force(s) are balanced or unbalanced.
- Describe the vertical motion of the parachutist.
- Explain how the net vertical force affects the vertical motion.

Hints for answering these NCEA style questions

Use V = d / t.
Show
- Formula
- Working
- Answer

Use arrows of different sizes to indicate the relative size of the forces acting on the parachutist.

Because she is travelling through air, you should use "air resistance" rather than "support force" when labelling your arrows.

Describe the arrows you have drawn.

Comment on the relative sizes of the forces.

Comment on whether or not the forces are balanced.

Discuss what this means in terms of the net force.

Explain what this means in terms of the motion of the parachutist.

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(c) After the 60 seconds, the parachutist pulls the cord and opens her parachute.

Explain how the parachute reduces the speed of the parachutist when it is first opened.

In your answer you should consider:

- How the motion of the parachutist changes when the parachute is opened.
- The effect of the size of the parachute on the motion.
- The effect of the parachute on the net vertical force.

_____

_____

_____

_____

_____

_____

_____

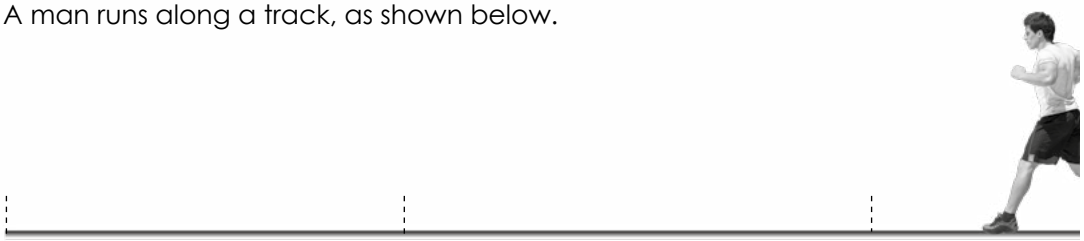
_____

_____

_____

_____

9. A man runs along a track, as shown below.



During section X, he runs with a *constant speed* of 2 m s^{-1} for 15 seconds.

During section Y, he runs with a *constant acceleration* of 0.2 m s^{-2}.

(a) Calculate the net force acting on the man (mass 60 kg) during section Y.

Give an appropriate unit with your answer.

_____

_____

_____

Net force acting on the man during section Y : _____ (_____)

Hints for answering these NCEA style questions

Use arrows of different sizes to indicate the relative size of the forces acting on the parachutist.

Because she is travelling through air, you should use "air resistance" rather than "support force" when labelling your arrows.

Describe how opening the parachute changes the relative sizes of the forces.

Comment on whether or not the forces are now balanced.

Discuss what this means in terms of the net force.

Explain what this means in terms of the motion of the parachutist.

Use F = m.a
Show
- Formula
- Working
- Answer

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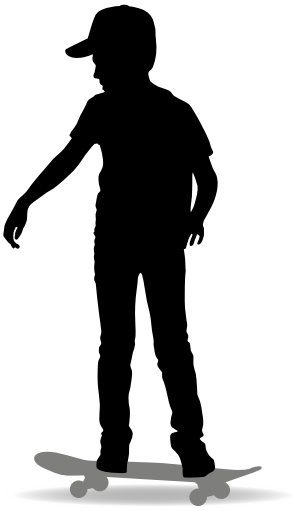
10. Jett likes to skateboard to school.

(a) On the diagrams below, draw and label the *thrust* and *friction* forces acting on Jett as he travels at a constant speed AND as he accelerates. In your answer you should use arrows to show the relative size and direction of the forces.



Travelling at a **constant speed**

Accelerating

(b) Describe what is meant by '*net force*'. _____

_____

_____

_____

_____

(c) Describe the *direction of the net force* and *direction of motion* when Jett is:

(i) Travelling at a constant speed: _____

_____

_____

_____

_____

_____

(ii) Accelerating: _____

_____

_____

_____

_____

_____

(iii) Decelerating: _____

_____

_____

_____

_____

_____

Hints for answering these NCEA style questions

Constant speed means forces are balanced.

Accelerating means the forces are not balanced (the forward arrow should be longer/bigger than backwards force).

Define '*net force*'.

Describe the conditions in which the forces are *added* together to give a larger net force.

Describe the conditions in which forces are *subtracted* resulting in a smaller net force.

For all three answers

State the:

- Direction of the two forces.
- Size of the two forces.
- Whether these forces are added or subtracted from each other based on their direction.

Use your answers from the statements above, to describe the net force and relate this to his motion.

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POWER, WORK AND ENERGY

By the end of this chapter you should be able to:

	I KNOW THIS ALREADY	I LEARNED THIS	I REVISED THIS
Describe different forms of *energy*.			
Identify *energy transformations*.			
Define the term *gravitational potential energy*.			
Use the formula $E_P = mgh$ to calculate gravitational potential energy.			
Define the term '*kinetic energy*'.			
Use the formula $E_K = ½mv^2$ to calculate kinetic energy.			
Rearrange the formula $E_P = mgh$ or $E_K = ½mv^2$ to solve a range of problems.			
Define the term '*work*'.			
Use the formula W = F x d to calculate work, force or distance.			
Define the term '*power*'.			
Use the formula P = W/t to calculate power, work, or time.			

Key Terms

Energy

My Definition: _____

_____

Joule

My Definition: _____

_____

Gravitational potential energy

My Definition: _____

_____

Kinetic energy

My Definition: _____

_____

Work

My Definition: _____

_____

Power

My Definition: _____

_____

Watt

My Definition: _____

_____

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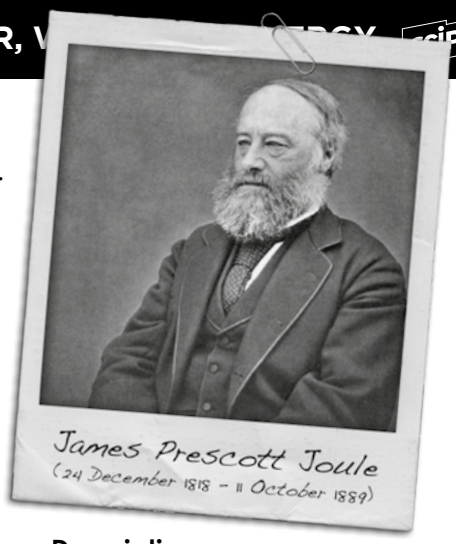
Introduction to Energy



Energy lets us do *work* and is required to make anything happen. Energy is not a substance that you can see or touch but we can often observe its effects. Energy is measured in joules (J).

Energy exists in many forms and it can be transformed from one form to another. However, it cannot be created or destroyed. This means whenever there is an energy transformation no extra energy is created and no energy disappears, it just changes into a new form.

1. Match the forms of energy with the correct description.

Form of Energy	Description
Chemical Potential Energy •	• Energy stored in objects due to their height above the ground.
Electrical Energy •	• Caused by the movement of particles. Found inside all hot objects.
Gravitational Potential Energy •	• Energy that is stored in the bonds between atoms. Found in substances such as petrol and food.
Heat Energy •	• Energy of an object due to its motion. Examples include moving cars, running and swimming.
Light Energy •	• The movement of electrically charged particles. Found in wires, generators and lightning.
Sound Energy •	• The energy of electromagnetic waves. Found in microwaves, X-rays, and visible light.
Kinetic Energy •	• Energy stored in stretched or squashed objects. Examples include springs and rubber bands.
Elastic Potential Energy •	• Energy produced by vibrating objects. Examples include speech, ultrasound, and music.

2. Energy is measured in _____ symbol (_____).

3. Give an example of each type of energy listed:

   (a) Heat energy: _____

   (b) Light energy: _____

   (c) Sound energy: _____

   (d) Gravitational potential energy: _____

   (e) Electrical energy: _____

   (f) Chemical potential energy: _____

   (g) Kinetic energy: _____

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Energy Transformations

Energy is most important to us when it is transformed from one form to another. These energy transformations cause all of the change that occurs around you.

For example, when you turn on your phone chemical potential energy in the battery is transformed into electrical energy. The electrical energy is then transformed into light energy by the screen and sound energy by the speaker. These changes can be summarised in an energy transformation diagram.

Chemical potential energy ⟶ Electrical energy ⟶ Light energy + Sound energy

1. Give an example of an object or a situation that could be responsible for the following energy transformations.

   (a) _____ converts electrical energy to light energy.

   (b) _____ converts chemical potential energy to kinetic energy.

   (c) _____ converts sound energy to electrical energy.

   (d) _____ converts chemical potential energy to heat energy.

   (e) _____ converts electrical energy to sound energy.

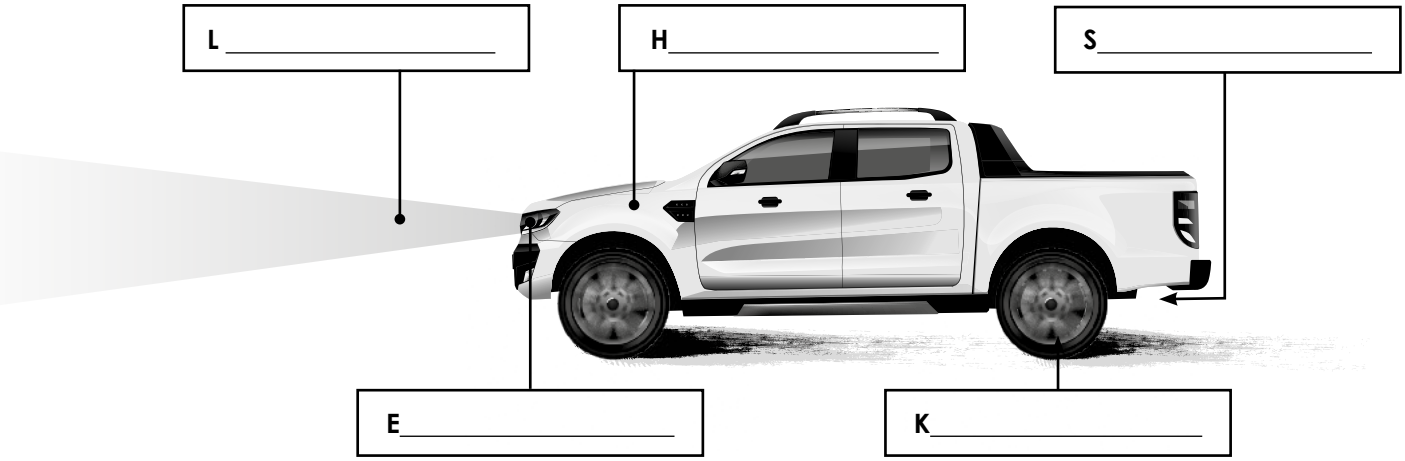
   (f) _____ converts electrical energy to heat energy.

   (g) _____ converts electrical energy to kinetic energy.

   (h) _____ converts elastic potential energy to kinetic energy.

   (i) _____ converts kinetic energy to gravitational potential energy.

2. Using the energy definitions on the opposite page, identify the types of energy in the diagram below. The first letter of each type has been done for you.



   (a) State the primary source of energy for the car. _____

   (b) State type of energy is contained in your answer for (a). _____

   (c) Write an energy transformation equation for the following:

      (i) Petrol in the engine burns, resulting in the car moving forward.

      _____

      (ii) Energy from the battery powers the car stereo.

      _____

      (iii) The car driving up a hill and stopping at the top.

      _____

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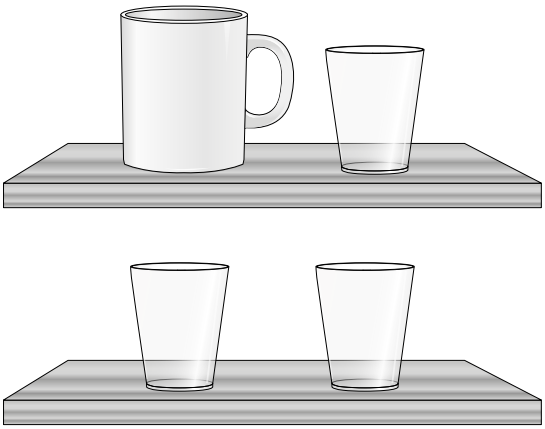
Calculating Gravitational Potential Energy

When an object is lifted up against the force of gravity it gains *gravitational potential energy*. For example, if you place a cup on a shelf you have to do work against the force of gravity. The cup has gained gravitational potential energy. The amount of gravitational potential energy depends on its height above Earth and its *mass*.



The cup and glasses on the two shelves have gravitational potential energy.

The cup and glass on the top shelf have more gravitational potential energy than the glasses on the bottom because they are *higher*.

The cup on the top shelf has more gravitational potential energy than the glass on the same shelf because it has more *mass*.

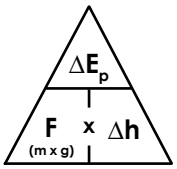
The glasses on the bottom shelf have the same amount of gravitational potential energy because they have the same mass and are the *same* height above the Earth.

Gravitational Potential Energy can be calculated using the following formula:

$$\Delta E_P = mg\Delta h$$

ΔE_P	=	**change in gravitational potential energy (J)**
m	=	**mass (kg)**
g	=	**gravity (10 N kg^{-1})**
Δh	=	**change in height (m)**

Because m x g is the calculation for weight force, the formula can also be expressed as : ΔE_P **= force x** Δ**height**. This formula can then be arranged into a formula triangle.



1. Define the term '*gravitational potential energy*'. _____

_____

_____

2. Calculate the gain in E_P of the objects in the following scenarios.

(a) A ball (mass = 0.5 kg) is kicked onto a roof which is 3 m high.

Formula: _____

Working: _____

Answer: _____

(b) A weightlifter lifts a 100 kg barbell from the floor to a height of 2 m.

Formula: _____

Working: _____

Answer: _____

(c) A cat (mass = 4 kg) climbs a tree to a height of 5 metres.

Formula: _____

Working: _____

Answer: _____

(d) A bird (300 g) flies up to a power line 4 m higher than its current position.

Formula: _____

Working: _____

Answer: _____

3. Rearrange the formula to solve the following problems.

(a) A ball that weighs 5 N gains 30 J of gravitational potential energy. Calculate how high the ball went.

Formula: _____

Working: _____

Answer: _____

(b) A skyrocket gains 2 000 J of gravitational potential energy as it travels to a height of 100 m. Calculate the rocket's weight.

Formula: _____

Working: _____

Answer: _____

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Calculating Kinetic Energy

Kinetic energy is the energy an object has because of its *motion*. Any object that is moving has kinetic energy. The amount of kinetic energy a moving object has depends on its:

- Mass - If you were hit by a ping-pong ball travelling at 1 m s^{-1}, you would hardly feel it. However, you'd certainly feel it if you were hit by a lead ball of the same size travelling at the same speed.
- Velocity - Imagine being hit in the head by a ping-pong ball travelling at 1 m s^{-1} compared to a ping-pong ball travelling at 10 m s^{-1}.

Scientists express this relationship using the formula:

$$E_K = \frac{1}{2}mv^2$$

E_K = kinetic energy (J)
m = mass (kg)
v = speed (ms^{-1})

A Worked Example

The NZSS rally car has a mass of 1200 kg and is moving at a constant speed of 10 m s^{-1}. Calculate the kinetic energy of the car.

$E_K = \frac{1}{2}mv^2$
$= \frac{1}{2} \times 1200\ kg \times (10\ m\ s^{-1})^2$
$= \frac{1}{2} \times 1200\ kg \times 100$
$= 60\ 000\ J$

Don't forget to show formula, working and put units on your answer.

1. Define '*kinetic energy*': _____

2. Outline two factors that influence the amount of kinetic energy in a moving object.
   (a) _____ (b) _____

3. A cyclist and her bike have a mass of 70 kg. Calculate her kinetic energy when she is riding at a speed of 5 m s^{-1}. _____

4. A ten-pin bowling ball (mass = 1.1 kg) is bowled down the lane at a rate of 4.5 m s^{-1}. Calculate the ball's kinetic energy. _____

5. A car has a mass of 1 300 kg. Calculate the kinetic energy of the car when it's moving at a speed of 15 m s^{-1}. _____

6. Calculate the kinetic energy of a ball (mass = 0.80 kg) that is kicked at a speed of 15 m s^{-1}.

7. A 50 kg girl and her 85 kg mother are jogging. They are both running at a rate of 2.5 m s^{-1}. Discuss who has the most kinetic energy. You should use calculations in your answer.

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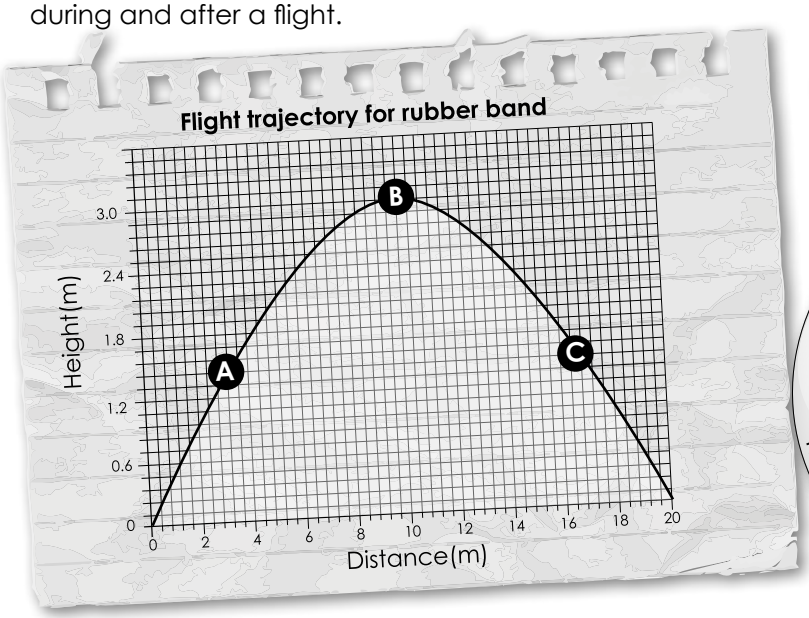
New Zealand Secondary Schools Rubber Band Shooting Team

You have been employed by the NZSS Rubber Band Shooting Team as a Scientific Analyst. One of your jobs is to analyse the energy transformations of the athlete's rubber bands before, during and after a flight.



1. Describe the energy transformations as the rubber band:

   (a) is pulled back into a stretched position.

   _____

   (b) is let go and it begins its flight diagonally upwards. Position A on the graph.

   _____

   (c) approaches the apex (top) of its flight. Position B on the graph.

   _____

   (d) falls to the ground after reaching the apex (i.e. Position C).

   _____

2. The graph above shows the flight trajectory of the Black Bands' winning shot during the recent Bandisloe Cup against the Rubber-Roos. It reached a maximum height of 3.0 m. The International Rubber Band Shooting Federation states that a competitive rubber band must have a mass of 0.01 kg.

   (a) Calculate the gravitational potential energy of the rubber band at the apex of its flight. _____

   _____

   _____

   (b) The maximum velocity of the rubber band was 8 m s^{-1}. Calculate the kinetic energy of the rubber band at this point. _____

   _____

   _____

   (c) The Rubber-Roos were caught using a rubber band with a mass of 0.03 kg. Assuming the rubber band was shot at the same velocity as the Black Bands' rubber band (8 m s^{-1}), explain the effect using the heavier rubber band has on its kinetic energy. You should use calculations in your answer.

   _____

   _____

   _____

   _____

   _____

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Using Kinetic Energy to Calculate Velocity

The formula for kinetic energy can be rearranged to find the velocity of an object. The following steps show how this can be done.

$$\frac{E_K}{1} = \frac{1}{2} m v^2$$

1 The 'E_K in the formula can be expressed as $E_K/1$.

$$\frac{E_K}{1} = \frac{1}{2} m v^2$$

2 Cross multiply to remove the fraction (i.e. the $\frac{1}{2}$).

$$2E_K = m v^2$$

3 The result of this cross multiplying is shown above.

$$\frac{2E_K}{m} = \frac{m v^2}{m}$$

4 Remove the 'm' from the right-hand side by dividing both sides by 'm'.

$$\sqrt{\frac{2E_K}{m}} = \sqrt{v^2}$$

5 'Square root' both sides to convert 'v^2' to 'v'.

$$v = \sqrt{\frac{2E_K}{m}}$$

6 The final equation is:

1. Use the kinetic energy formula to complete the table below.

	Kinetic Energy	Mass	Speed
(a)	150 000 J	120 kg	
(b)	16 000 J	5 kg	
(c)	2 500 J	8 kg	
(d)	270 J	60 kg	
(e)	20 000 J	4 kg	
(f)	25 J	0.02 kg	

2. A 2 kg ball is moving with 49 J of kinetic energy. Find the ball's speed.

3. A 2 000 kg SUV is travelling at 14 m s^{-1}. A 1 000 kg car is travelling in the lane outside the SUV, with the same amount of kinetic energy.

   (a) Calculate the SUV's kinetic energy.

   (b) Calculate the car's speed.

4. A 2.5 kg mass is held above the ground and has 50 J of gravitational potential energy. The mass is then dropped and accelerates to the ground.

   Find the speed that the mass has when it collides with the ground.

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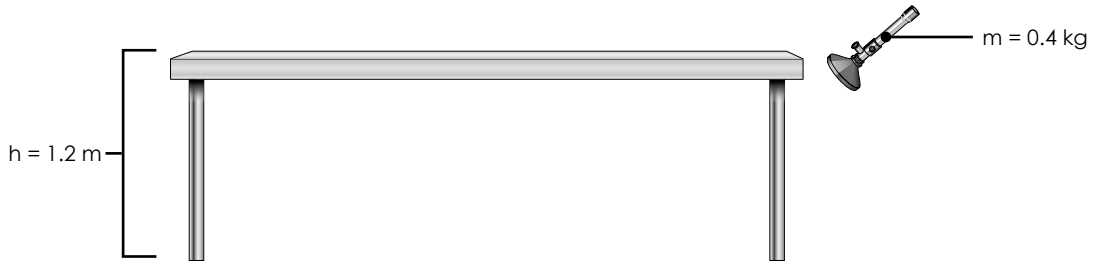
5. While setting up an experiment a student knocks an unlit Bunsen burner off of their work bench. The bench is 1.2 m high and the Bunsen burner has a mass of 0.4 kg.



(a) Show that the Bunsen burner has 4.8 J of gravitational potential energy when at the same height as the bench.

(b) Assuming there are no losses, state the kinetic energy of the Bunsen burner at the moment it collides with the ground.

(c) Calculate the speed of the Bunsen burner at the instant that it collides with the ground.

(d) Explain how the Bunsen burner's actual speed would vary from your answer to (c).

(e) (i) Describe the types of energy that the Bunsen burner has when it is halfway between the bench and the ground.

(ii) Calculate the Bunsen burner's speed at this point.

6. A 9 kg ball is dropped and reaches a maximum velocity of 6 m s^{-1} when it collides with the ground.

(a) Assuming there are no losses, calculate the height the ball is dropped from.

(b) Some of the ball's energy is lost to friction as it falls through the air. In order to reach the same maximum velocity (6 m s^{-1}), would the ball need to be dropped from a greater or lesser height than you calculated in (a) above? Justify your answer.

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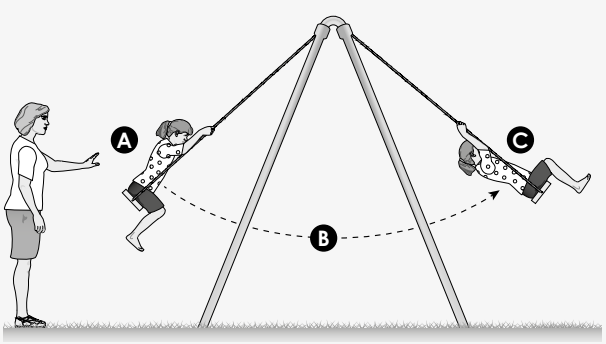
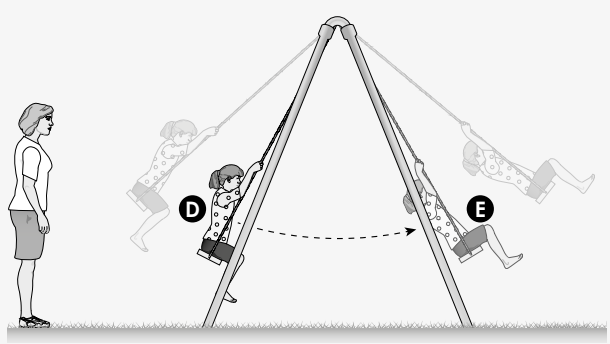
Conservation of Energy

Energy cannot be created or destroyed, it can only be transformed from one form to other forms. It is impossible to create energy from nothing. In most situations, when an object is moving, some of its kinetic energy will be 'lost' as friction causes some energy to be converted into heat and sound energy.



If the woman keeps pushing the child with a force equal to the resistive (frictional) forces, all of the E_p at A will get converted to E_k at B. This E_k is then converted back into E_p as she moves to C.



Because some of the energy is being lost as heat and sound, if the woman stops pushing the child then her E_p and therefore E_k will gradually decrease and she will eventually stop. However, the total energy transformed will still equal the total energy she had at the start.

1. Describe the principle of the '*conservation of energy*'. _____

_____

_____

_____

2. In order to relieve stress, a science teacher takes a folder of marking from ground level to the top floor of the science block. He then drops it over the side of the building. The folder has a mass of 0.5 kg and the science block is 10 m high.

   (a) In terms of E_p and E_K, state the energy transformations occurring as the folder is carried to the top of the building and falls down again.

   _____

   _____

   (b) Calculate the gravitational potential energy of the folder when it is on top of the building.

   _____

   _____

   (c) The folder hits the ground travelling at 13 m s^{-1}. Calculate the kinetic energy of the folder when it hits the ground.

   _____

   _____

   (d) Explain why the kinetic energy of the folder when it hits the ground is not equal to the amount of gravitational potential energy it had at the top of the building.

   _____

   _____

   _____

   _____

   _____

   (e) Calculate how much energy was 'lost'. _____

   _____

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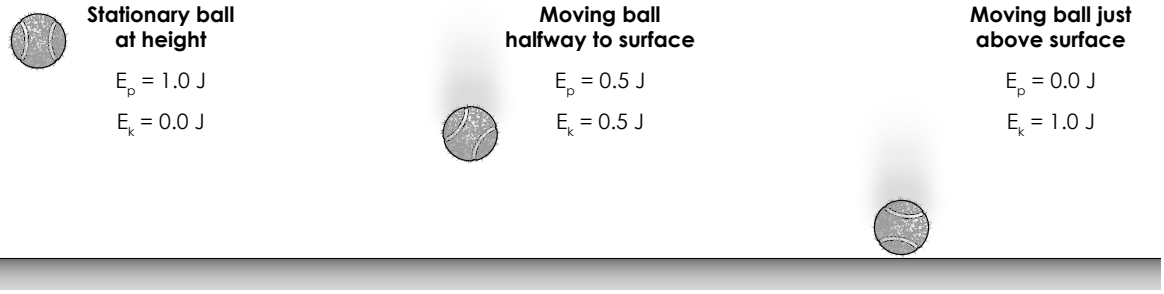
Dropping Balls

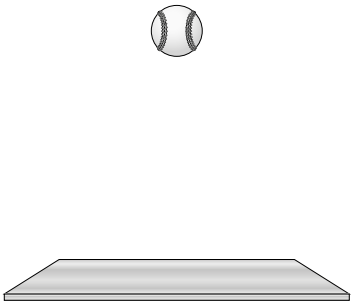
Gravitational potential energy (E_p) is the energy stored in an object by lifting it to a height above the Earth. When an object is lifted above a surface, it possesses a specific amount of E_p because of its mass and its height above the ground. When an object is dropped, the E_p is converted into kinetic energy (E_k).



The diagram above, assumes that all of the E_p is converted to E_k. In reality, as the ball falls, some of its E_k is lost due to air resistance (friction) as the ball hits air particles, resulting in some of the E_k being converted into heat energy and/or sound.

1. Hannah lifts a ball (m = 200 g) to a height above the floor. Before the ball is dropped, it is not moving and only has gravitational potential energy (E_p). Once the ball is released, the gravitational potential energy is converted into kinetic energy (E_K).

   (a) Complete the labels for the diagrams to show the *energy changes* as the ball is dropped. Assume that the gravitational energy is **only** changed into kinetic energy.



At the top: E_p = 1.6 J E_K = 0.0 J

Halfway: E_p = _____ E_K = _____

Just before it hits: E_p = _____ E_K = _____

   (b) Just before the ball hits the surface it is travelling at 3.9 m s^{-1}. Hannah believes that this velocity would give the ball 1.6 J of kinetic energy.

   (i) Use $E_k = ½mv^2$ to show that Hannah is **incorrect**.

_____

_____

_____

_____

   (ii) Outline why Hannah is incorrect.

_____

_____

_____

_____

_____

_____

_____

_____

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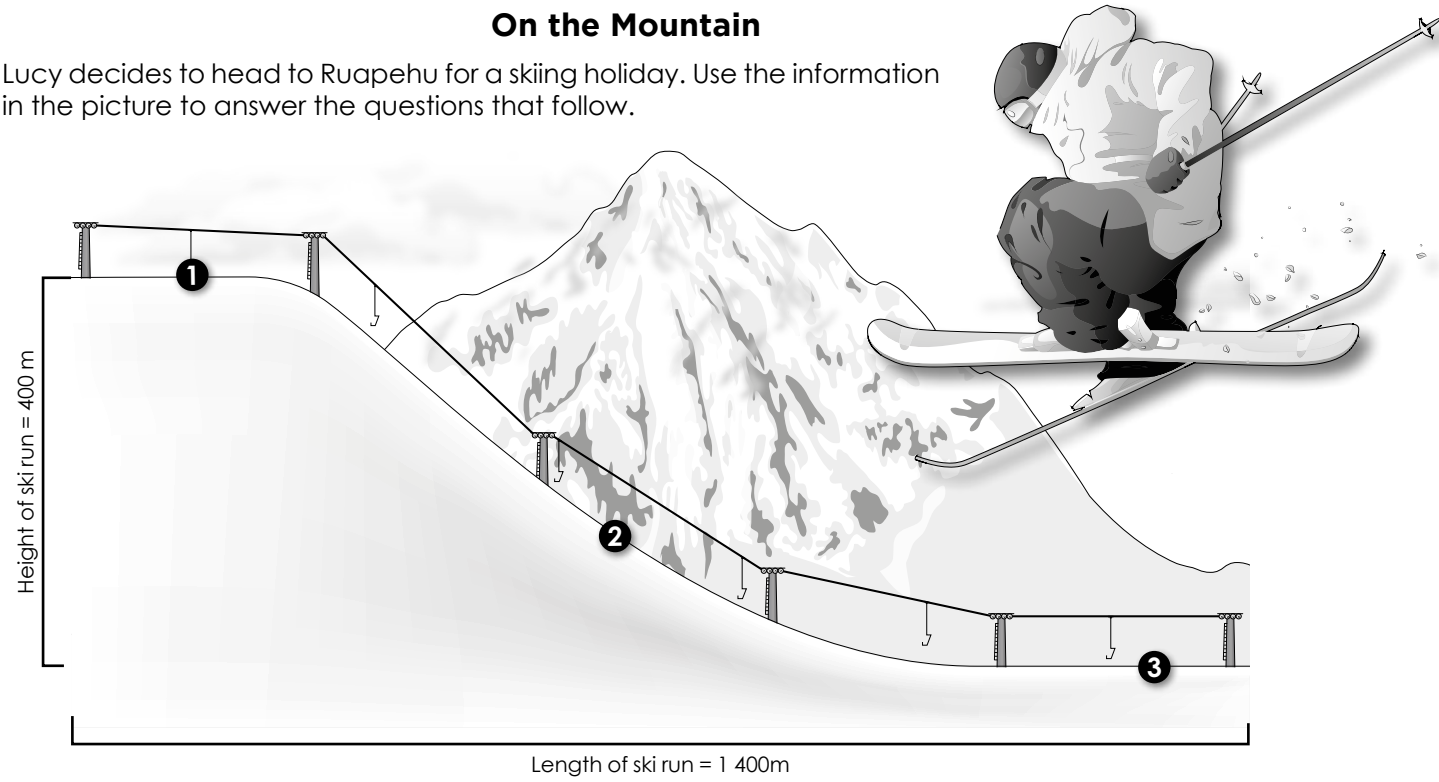
On the Mountain

Lucy decides to head to Ruapehu for a skiing holiday. Use the information in the picture to answer the questions that follow.



1. Lucy and her skis have a combined mass of 60 kg. The length of the chairlift is 1 400 m and it climbs 400 m vertically up the mountain. Calculate the increase in Lucy's gravitational potential energy as she travels from the bottom of the chairlift to the top.

2. Once she gets off the lift she travels along section 1 at a constant speed. Comment on the size of the forces acting on Lucy during this section of the ski run.

3. As Lucy goes from section 1 to section 2 she starts to accelerate. Identify the correct statement from the list below.

   (a) As she accelerates her gravitational potential energy transforms into kinetic energy.

   (b) As she accelerates her kinetic energy transforms into gravitational potential energy.

4. Lucy's maximum speed during her descent of section 2 is 8 m s^{-1}. Calculate how much kinetic energy she has at this point.

5. Lucy's friend Phil rides on the chairlift with her. He gains 300 000 J of gravitational potential energy. Calculate the combined weight of Phil and his skis.

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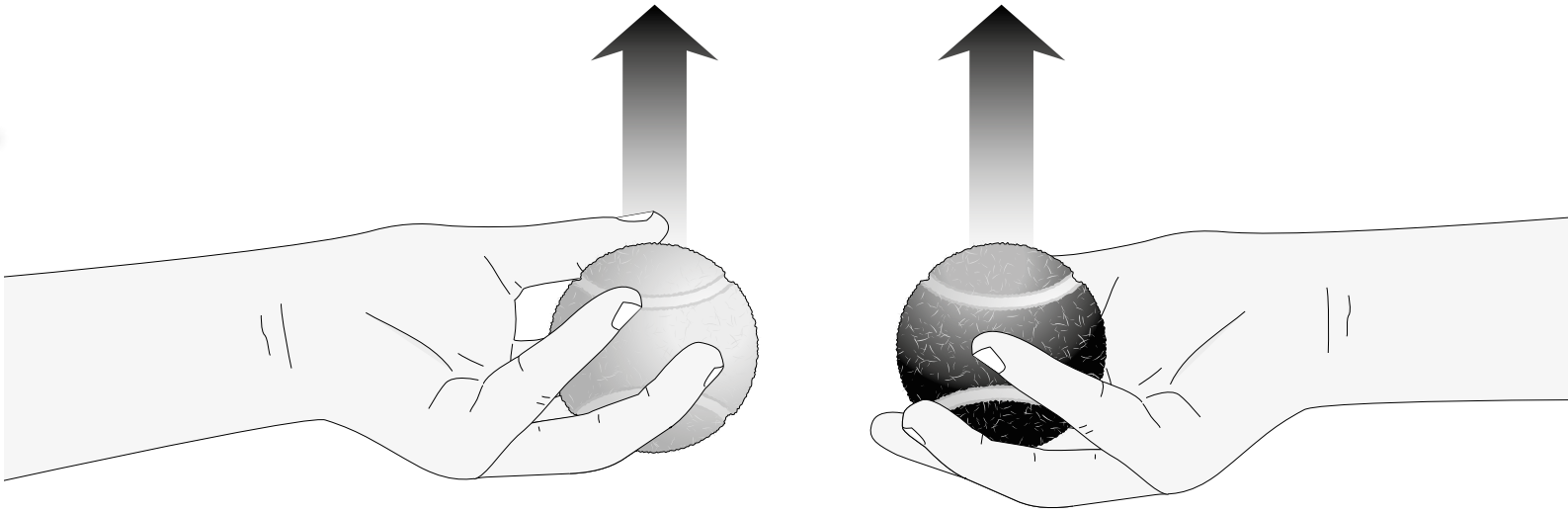
Throwing Balls

Two balls of the same *size* and *shape* but with different masses are thrown from the ground vertically upwards. Ball 1 has a mass of 0.05 kg and Ball 2 has a mass of 0.08 kg.



Ball 1 mass = 0.05 kg **Ball 2 mass = 0.08 kg**

1. Both balls reach their maximum heights and have the same amount of gravitational potential energy. Comment on the relative maximum *heights* reached by each ball.

2. Compare the relative initial *velocity* of the two balls.

3. Both balls reach their maximum heights, and have 0.4 J of gravitational potential energy.

   (a) Assuming there is no losses, calculate the starting velocity of the first ball (mass = 0.05 kg).

   (b) In reality the ball's total energy at ground height and at its maximum height will not be the same. Explain how and why the ball's total energy changes.

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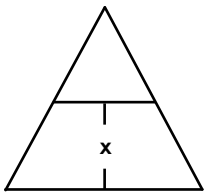
Work

In science we say that work is done on an object when energy is *transferred* to that object. The amount of work done on an object depends on the force applied to that object and the distance the object travels. Work is only done when the object moves in the direction of the force. Scientists show this relationship with the formula:

W = Fd

W = work (J)
F = force (N)
d = distance (m)

This formula can then be arranged into a formula triangle.



1. Define the term *'work'*: _____

_____

2. Complete the formula triangle by placing the correct variable in the appropriate space.

3. Use the formula triangle to give the equation required to calculate:

   (a) Force: _____

   (b) Distance: _____

4. Complete the table by filling in the blank sections.

	Work	Force	Distance
(a)		20 N	2 m
(b)		400 N	5 m
(c)		96 N	12 m
(d)		120 N	240 m
(e)		1 300 N	50 m
(f)		2 000 N	0.5 m
(g)	90 J	9 N	
(h)	60 J	300 N	
(i)	14 J	28 N	
(j)	0.5 J	0.2 N	
(k)	48 J	12 N	
(l)	14 000 J	700 N	
(m)	12 J		2 m
(n)	15 J		10 m
(o)	80 J		5 m
(p)	25.2 J		5.6 m
(q)	10 000 J		50 m
(r)	180 000 J		4 000 m

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REMEMBER!
*Formula
*Working
*Answer with units

Work Problems

1. Calculate the work done in the following scenarios.

   (a) A book that weighs 4 N is lifted onto a shelf 3 m higher than its original position.

   (b) A weightlifter lifts a 1 000 N barbell from the floor to a height of 2m.

   (c) A boy walks up a flight of stairs to a level 10 m higher. His weight is 750 N.

   (d) A cat that weighs 20 N jumps up onto a fence that is 1.8 m high.

   (e) A car which weighs 12 000 N is lifted up by a crane to a height of 6 m.

2. Rearrange the formula to solve the following problems:

   (a) Calculate the distance travelled by a ball when 300 J of work is done to it. The ball weighs 10 N.

   (b) A car drives 20 m up a hill. 250 000 J of work was done. Calculate the weight of the car.

   (c) A skyrocket does 20 000 J of work as it travels upwards 1 000 m. Calculate the weight force of the rocket.

   (d) A chicken farmer does 2 500 J of work lifting a sack of feed with a force of 3 125 N. Calculate the height the sack was moved.

3. Calculate the amount of work done when a bag with a mass of 5 kg is lifted 5 m.

4. Explain why no work is done by holding a 1 kg sign in your hand, with your arm outstretched. You should use a calculation in your answer.

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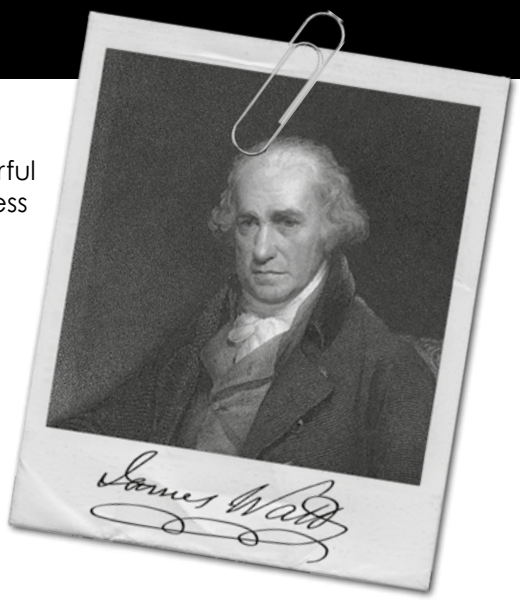


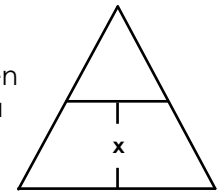
Power

The rate at which work is done is called *power* (P). This means a powerful machine will do a lot of work in a short period of time. Scientists express the relationship between power, work and time using the equation:

$$P = \frac{W}{t}$$

P = Power (Watts)
W = Work (J)
t = Time (s)

This formula can then be arranged into a formula triangle.



Power is measured in joules per second (J s^{-1}) or watts (W) named after the Scottish engineer James Watt.

1. Define the term *'power'*: _____

_____

2. Complete the formula triangle by placing the correct variable in the appropriate place.

3. Use the formula triangle to give the equation required to calculate:

   (a) Work: _____

   (b) Time: _____

4. Complete the table by filling in the blank sections.

	Power (W)	Work (J)	Time (s)
(a)		3 000 J	50 s
(b)		3 000 J	25 s
(c)		120 J	3 s
(d)		500 J	25 s
(e)		10 000 J	20 s
(f)		2 500 J	50 s
(g)	80 W		20 s
(h)	900 W		10 s
(i)	3 500 W		30 s
(j)	15 W		50 s
(k)	5 W		20 s
(l)	75 W		15 s
(m)	500 W	2 000 J	
(n)	1 000 W	25 000 J	
(o)	600 W	3 000 J	
(p)	15 W	45 J	
(q)	10 W	1 000 J	
(r)	500 W	25 000 J	

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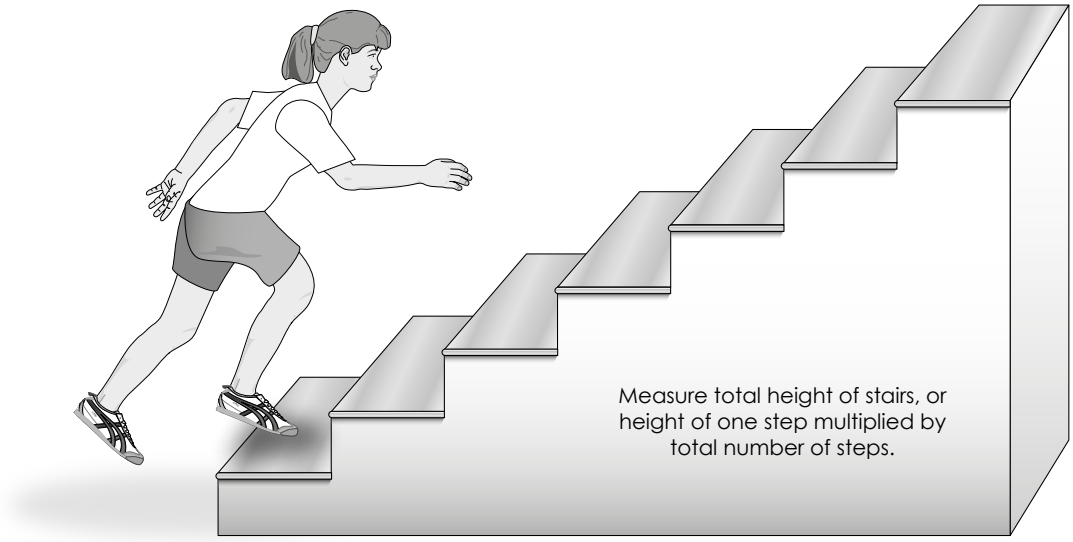
Measuring Your Power

Aim: To measure your personal power output by running up a flight of stairs.

Equipment: Stopwatch - ruler (or tape measure) - scales - flight of stairs.

Method:

1. Use the scales to record your mass in kilograms.
2. Measure the height of the staircase in metres. This can either be done by measuring the total height using a tape measure, or by measuring the height of one step and multiplying by the total number of steps.



3. Working in pairs, one student stands at the bottom of the stairs. The other stands at the top of the stairs with the stopwatch. When this student says "go", the student at the bottom of the stairs runs up them as quickly as they can.
4. Repeat step 2. two more times. Record your results in the table below.

Results:

My mass: _____ kg My weight: _____ N

	Trial 1	Trial 2	Trial 3	Average
Time (s)				

Calculations:

Work:

_____

_____

_____

_____

Power:

_____

_____

_____

_____

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Power Problems

1. Calculate the power generated in the following scenarios:

   (a) A dog does 400 J of work in 20 seconds running along a beach. _____

   (b) An electric drill does 50 J of work in 2.5 seconds. _____

   (c) A heater does 540 000 J of work after being switched on for an hour (3 600 seconds). _____

2. Rearrange the formula for power to solve the following problems:

   (a) An 80 W light bulb is left on for 60 seconds. Calculate the amount of work done.____

   (b) An LCD TV has a power rating of 120 W. It is left running for 4 hours (14 400 seconds). Calculate the amount of work done. _____

3. A weightlifter lifts a 100 kg barbell from the ground to his chest (total distance is 1.5 m). It takes him 3 seconds to complete the lift.

   (a) Calculate the weight of the barbell. _____

   (b) Calculate how much work he does lifting the barbell. _____

   (c) Calculate how much gravitational energy the barbell gains. _____

   (d) Calculate how much power he develops lifting the barbell. _____

4. A woman has a mass of 60 kg. She climbs a 3 metre high ladder in 6 seconds.

   (a) Calculate her weight. _____

   (b) Calculate how much work she does climbing the ladder. _____

   (c) Calculate how much gravitational potential energy she gains at the top of the ladder. _____

   (d) Calculate how much power she developed climbing the ladder. _____

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sciPAD HQ

At sciPAD HQ boxes of sciPAD workbooks are shifted on pallets using a forklift.

A pallet of books has a mass of 800 kg. The forklift lifts the pallet to a height of 2.4 metres. It takes the forklift 4 seconds to lift the pallet.

1. Calculate the *weight* of a pallet of sciPADs.

2. Calculate the *work* done by the forklift to lift the pallet.

3. Calculate the *power* needed by the forklift to lift the pallet.

4. Once the pallet has reached a height of 2.4 m, the driver decides to go for lunch leaving the pallet motionless. Explain why *no work* is done to the pallet, even though the forklift is still applying a force of 8 000 N.

5. After his lunch break the driver returns to the forklift. He drives it a short distance before lowering the pallet to the ground.

   Calculate the gravitational potential energy lost by the pallet as it is lowered to the ground.

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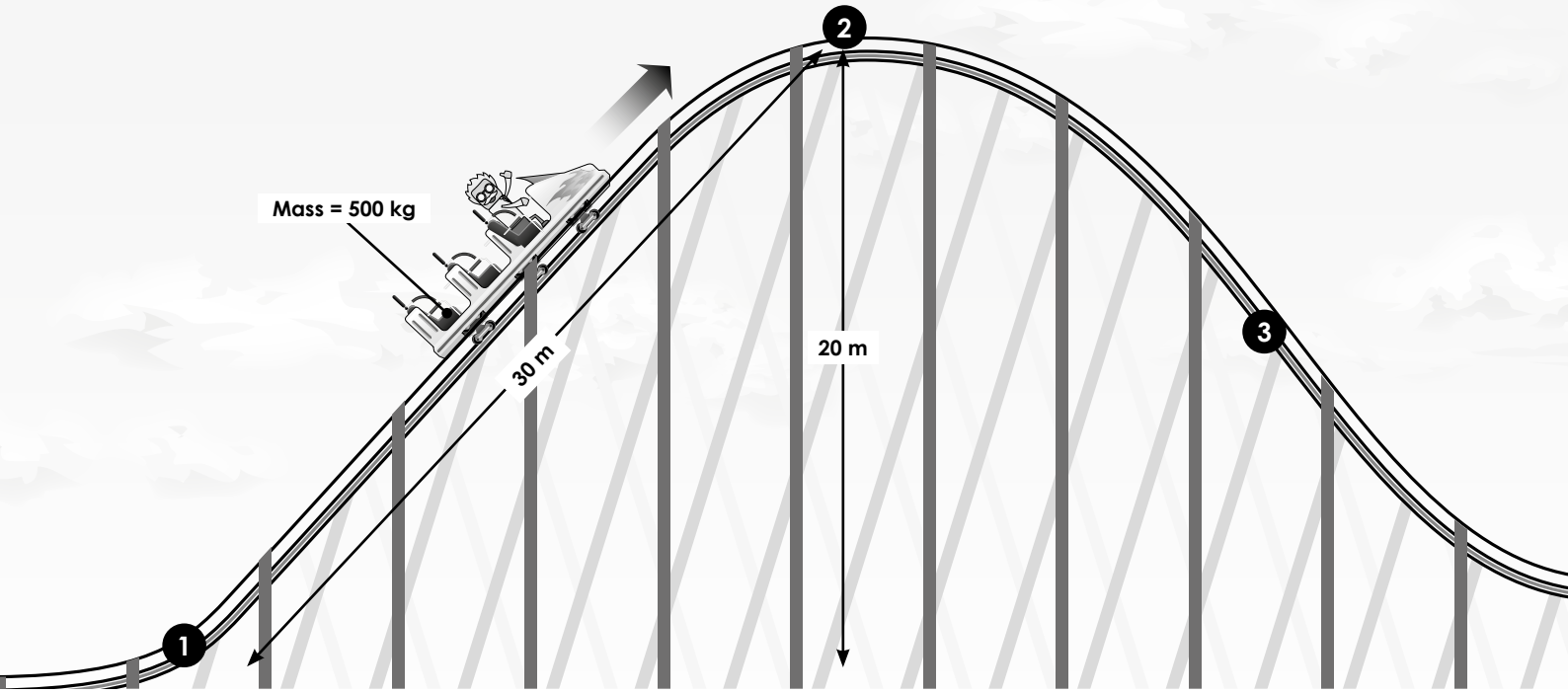
The Roller-Coaster

A roller-coaster car (mass = 500 kg) is pulled up from position ❶ to the first peak (position ❷) on a roller-coaster ride by a motor. The motor pulls the car with a force of 4 000 N.



1. Calculate the *work* done by the motor pulling the car from position ❶ to the top of the first peak (position ❷).

Work done: _____ J

2. It takes 20 seconds for the car to be pulled from position ❶ to the top of the first peak. Calculate the *power* of the motor.

Power: _____ _____

3. Calculate the amount of *gravitational potential energy* the car has at position ❷.

Gravitational potential energy: _____ _____

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4. Explain why the gravitational potential energy gained by the car at the top of the peak (position ❷) is not equal to the amount of work done by the motor to pull the car up there.

5. Explain in terms of *time* and *energy* why it is easier to pull the car up the ramp than lift it straight up.

6. At position ❸ the car is moving at 15 m s^{-1}. Calculate the *kinetic energy* of the car at this point.

Kinetic energy: _____ _____

7. (a) After travelling down the ramp, past position ❸, the car encounters a second ramp and the motor provides no driving force to help the car travel up this ramp. State whether the peak at the top of this second ramp should be '*higher*', '*lower*' or the '*same height*' as the first peak (position ❷). _____

(b) Justify your answer to (a).

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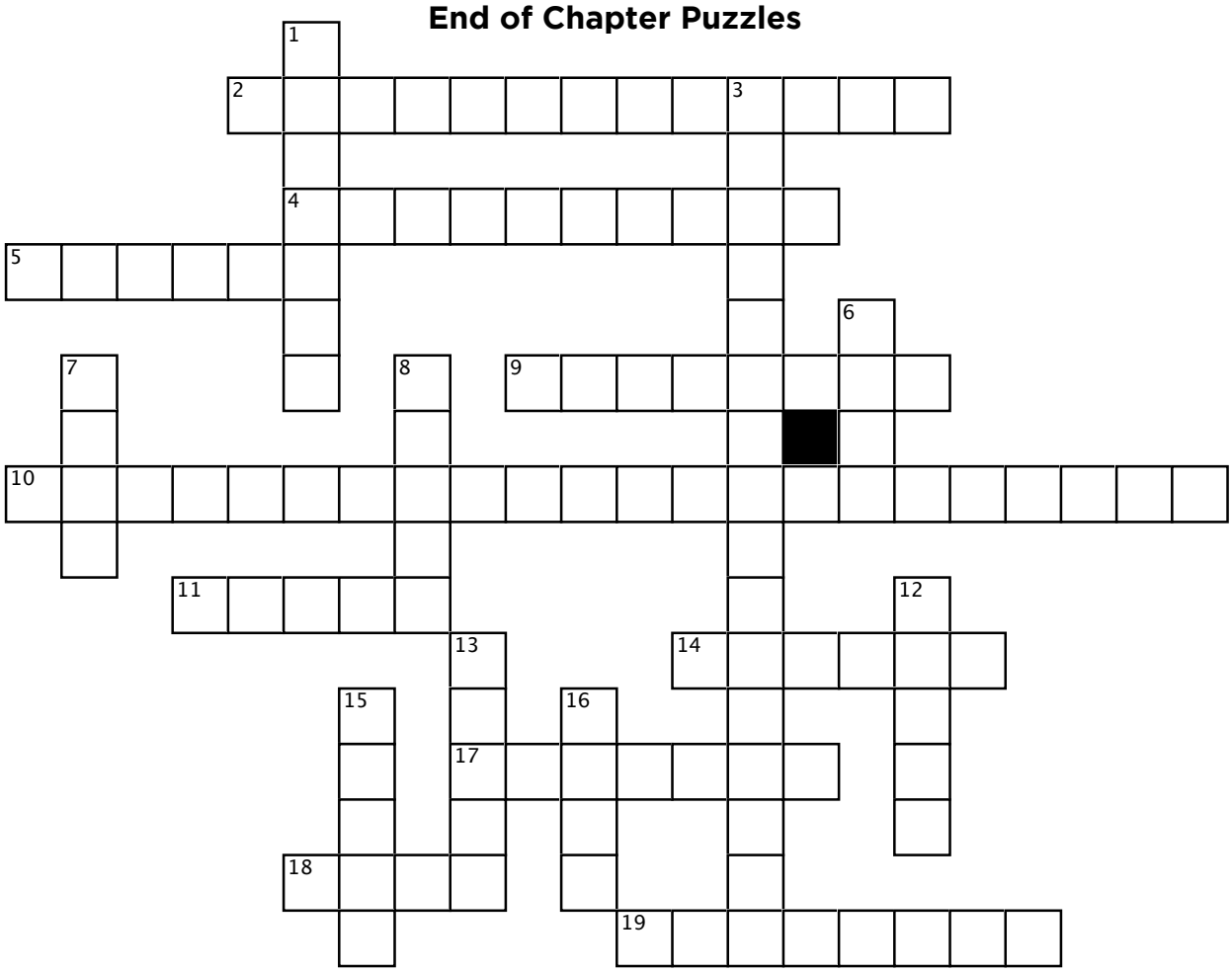
End of Chapter Puzzles



Across

2. Given the symbol E_K.
4. Energy transferred by the movement of electrically charged particles.
5. Force exerted on a mass by gravity.
9. Energy that is stored in the bonds between atoms. Found in substances such as petrol and food.
10. Energy stored in objects due to their height above the ground.
11. The unit for energy.
14. The unit of force.
17. The 'g' in E_P= mgh.
18. Type of energy found inside hot objects.
19. The unit for mass.

Down

1. Moving objects have this type of energy.
3. Energy stored in stretched or squashed objects.
6. The unit of power.
7. Calculated by multiplying the force applied to an object, by the distance the object travels.
8. The unit for distance.
12. Energy emitted by vibrating objects. Examples include speech and music.
13. A type of energy given off by the Sun.
15. This is calculated by dividing the amount of work done by the time taken.
16. Amount of matter inside an object.

Unscramble the following key terms from this chapter.

1. KOWR _____
2. WPOER _____
3. ROFCE _____
4. ERGENY _____
5. JLEOU _____
6. GIWEHT _____
7. KITICNE _____
8. TENPOTIAL _____
9. LASETIC _____
10. VIGRATY _____
11. ATHE _____
12. SAMS _____

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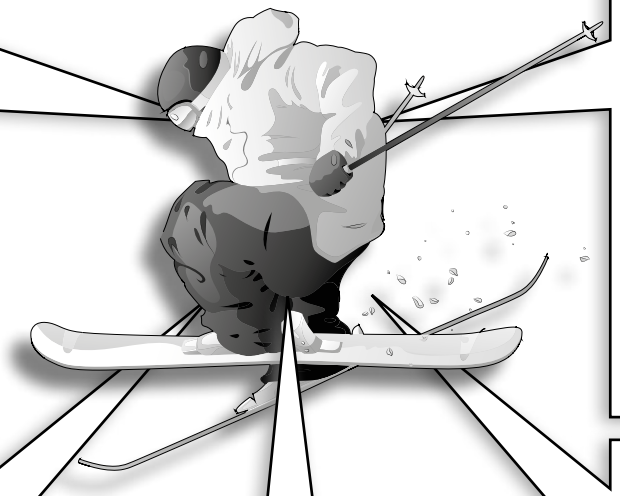
Power, Work and Energy Chapter Review

Use the boxes to write down the key points from this chapter. Ensure that all key words from the front of the chapter have been used.



Energy and Energy Transformations

Kinetic Energy

Gravitational Potential Energy

Power

Work

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End of Chapter Review Questions

1. Match the following units to their description.

Joule •	• The SI unit for force.
Watt •	• The SI unit for mass.
Kilogram •	• The SI unit for energy.
Newton •	• The SI unit for power.

2. Describe the energy transformation occurring in the following scenarios:

   (a) A rugby ball is kicked from the ground to a height of 10 m, before returning to the ground. _____

   (b) Turning your phone on. _____

   _____

3. Use the appropriate formula to complete the tables.

	Work	Force	Distance
(a)		120 N	50 m
(b)		6 000 N	25 m
(c)		3 000 N	25 m
(d)	270 J		3 m
(e)	20 000 J		20 m
(f)	1 000 J		50 m
(g)	4 000 J	40 N	
(h)	1 400 J	0.7 N	
(i)	580 J	40 N	

	Power	Work	Time
(j)		900 J	25 s
(k)		140 J	0.7 s
(l)		30 J	3 s
(m)	90 W		25 s
(n)	3 W		20 s
(o)	18 W		50 s
(p)	40 W	360 J	
(q)	6 W	42 J	
(r)	40 W	920 J	

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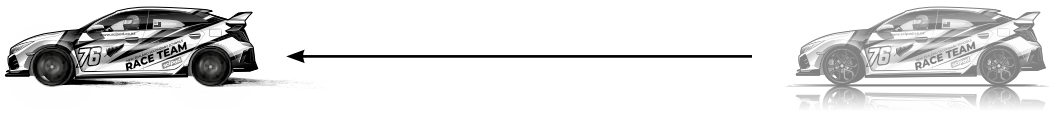
4. The NZSS Rally Car has a mass of 1 200 kg. Use the information in the diagram to answer the questions that follow.



Time = 5 seconds
Speed = 20 m s^{-1}

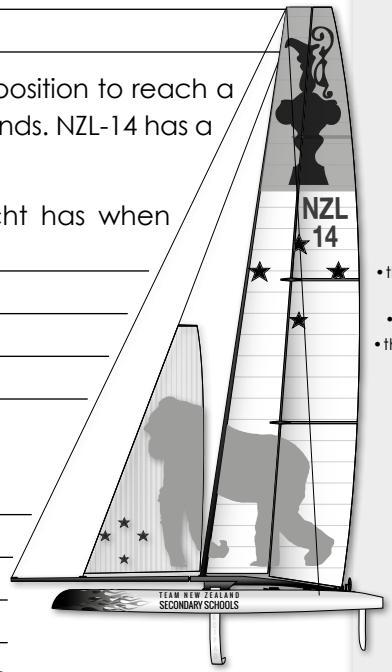
Time = 0 seconds
Speed = 0 m s^{-1}

(a) Calculate the amount of kinetic energy the car has gained when it is travelling at 20 m s^{-1}. _____

(b) State the amount of work the motor did when it accelerated the car. _____

(c) Calculate the power output of the engine. _____

5. During a yacht race NZL-14 accelerates from a stationary position to reach a speed of 12 m s^{-1}. The boat reaches this speed after 20 seconds. NZL-14 has a mass of 5 900 kg.



(a) Calculate the amount of kinetic energy the yacht has when travelling at 12 m s^{-1}. _____

(b) Calculate the power output of the boat.

(c) In order to look for wind, a grinder hoists the bowman (mass = 75 kg) to the top of the mast (height = 34 m). **Ignoring the effect of friction**, explain why the bowman's gain in gravitational potential energy is equal to the amount of work done by the grinder in getting him to the top of the mast.

Hints for answering these NCEA style questions

Write down:
- the formula you are using,
- your working,
- the units for your answer,

Work is energy. In this case work is equal to E_K.

Write down:
- the formula you are using,
- your working,
- the units for your answer,

Calculate the E_P of the bowman using the formula E_P=mgh.

In a separate calculation, work out the work the grinder has done using the formula W=Fd.

Write a sentence linking and comparing these values.

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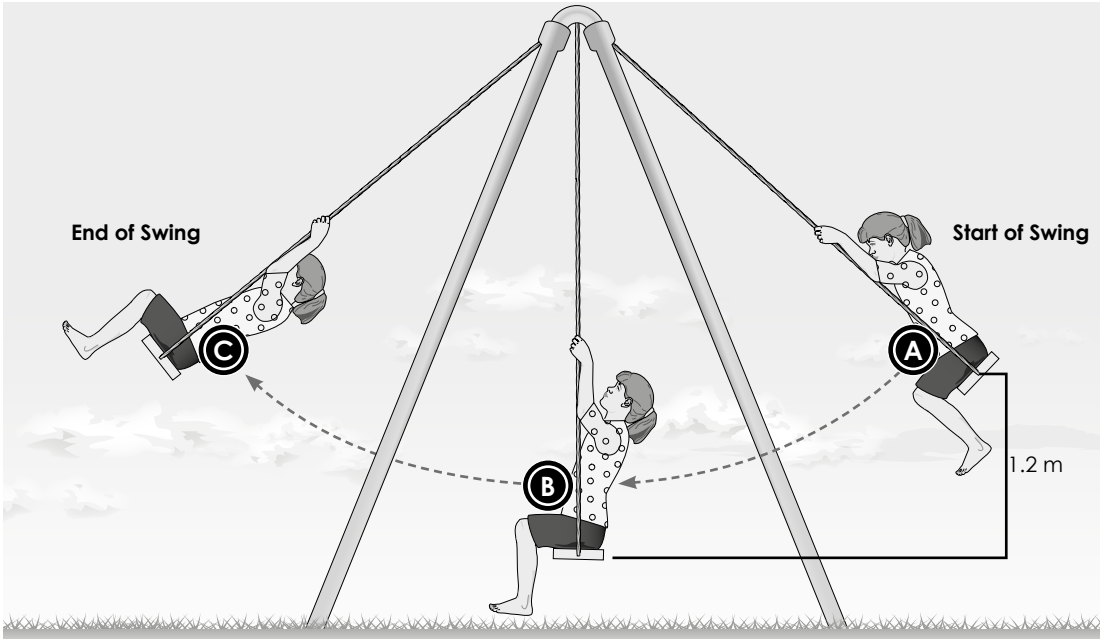
6. A girl is playing on a swing at the park. Positions A and C are the maximum height achieved by the girl.



(a) Discuss the energy changes that occur as she completes a full swing (A - C).

(b) At position A she is 1.2 m higher than at position B. She has a mass of 50 kg. Calculate the difference in gravitational potential energy between these two positions.

(c) At B she is travelling at 4.8 m s^{-1}. Calculate her kinetic energy.

(d) Explain why there is a difference between the gravitational potential energy she has at A and the kinetic energy she has at B.

Hints for answering these NCEA style questions

Describe the type of energy she has at A and how this changes as she moves to B.
Repeat this process for B to C.

Calculate her E_pGrav at A using h = 1.2
Calculate E_pGrav at B using h = 0).
Subtract (B) from (A) to show difference.

Use the formula for kinetic energy.
Remember:
- formula
- working,
- units

Discuss the energy 'losses' in terms of the resistive forces on the swing and the girl.

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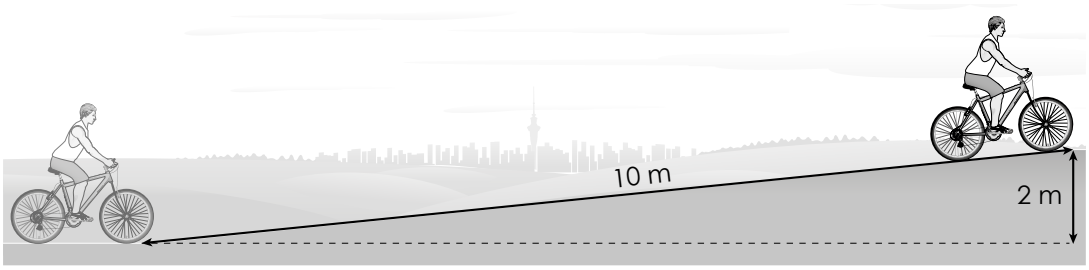
(e) Assuming that the energy 'lost' between A and B is the same as the energy lost travelling between B and C, calculate her gravitational potential energy at C.

(f) Use your answer from (e) to calculate her maximum height at position C.

7. A cyclist rides up a small slope. He applies a net force of 200 N.



(a) Calculate the work done to ride the bike up the hill.

(b) The energy gained by the bike and rider (m = 75 kg) at the top of the hill does not equal the work done.

Explain why these two values are not equal.

In your answer you should:

- Name the type of energy the bike and rider have when they reach the top of the ramp
- Calculate the difference between the work done and the energy at the top of the ramp
- Explain where the "missing" energy has gone and why this occurs.

Hints for answering these NCEA style questions

Calculate the difference in her E_p and E_k by subtracting your answer for (c) from your answer for (b).

Then subtract this number from your answer for (c).

Rearrange the formula for E_P to solve for h.

Use your answer from (e) as the value for E_P.

Use the formula for work and the distance of the slope.

Calculate the bike and rider's E_p at the top of the slope.

Work = energy so calculate the difference between the amount of work done and the E_p at the top of the slope.

Explain why work done does not equal E_P gained.

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Mechanics (90940) Practice Exam

NZPQA

NEW ZEALAND **PRETEND** QUALIFICATION AUTHORITY

Level 1 Science

90940 (1.1): Demonstrate understanding of aspects of mechanics

Credits: Not this time.

You should answer ALL parts of ALL questions in this booklet.

If you need more space for any answer, use some refill paper (Ideally, you should concentrate on trying to write more concise answers).

You will find the following formulae useful:

$$v = \frac{\Delta d}{\Delta t} \qquad a = \frac{\Delta v}{\Delta t} \qquad P = \frac{F}{A}$$

$$W = Fd \qquad F_{net} = ma \qquad E_K = \tfrac{1}{2}mv^2$$

$$g = 10\ \text{N kg}^{-1} \qquad P = \frac{W}{t} \qquad \Delta E_P = mg\Delta h$$

For Assessor's use only	**Achievement Criteria**	
Achievement	**Achievement with Merit**	**Achievement with Excellence**
Demonstrate understanding of aspects of mechanics. ☐	Demonstrate an in-depth understanding of aspects of mechanics. ☐	Demonstrate comprehensive understanding of aspects of mechanics. ☐
Overall Level of Performance ☐		

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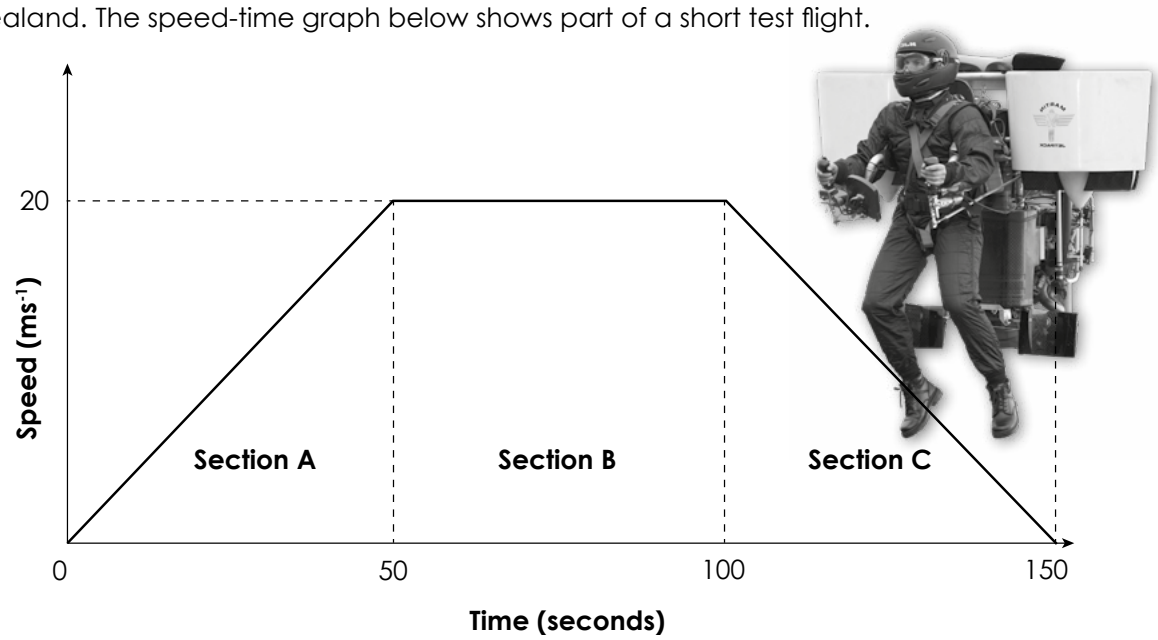
QUESTION ONE

The Martin Jetpack is an experimental aircraft developed by the Martin Aircraft Company of New Zealand. The speed-time graph below shows part of a short test flight.



(a) Calculate the acceleration of the jetpack and pilot in section A of the graph above. Give an appropriate unit for your answer.

Acceleration = _____ _____

(units)

(b) Explain whether the forces in section B of the graph are balanced or unbalanced, and how this results in the type of motion produced.

In your answer you should:

- Name the forces involved and describe their relative sizes (you may draw a labelled diagram in the box on the next page to support your answer).
- Link the net force to the type of motion in section B.

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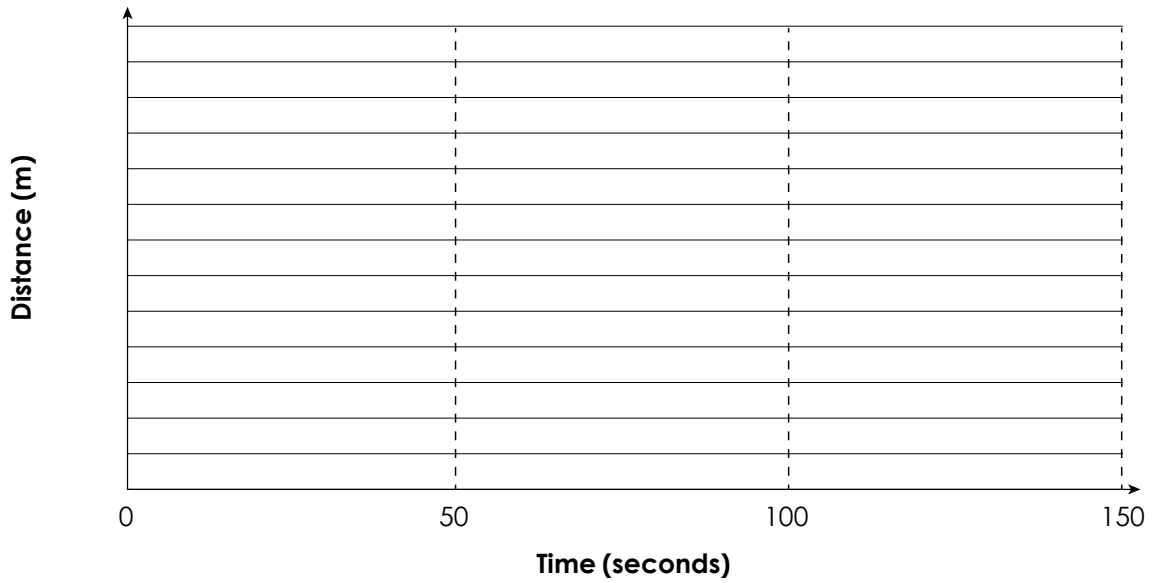
(c) Calculate the distance travelled in EACH section of the speed-time graph shown on the previous page, and use the calculations to draw a distance-time graph for the jetpack's journey.

In your answer you should:

- Show all your working for the calculations.
- Clearly label the y-axis of the distance-time graph with the distance travelled.
- Draw an appropriate shape for EACH section of the jetpack's journey.



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QUESTION TWO

During a promotional photo shoot a crane is used to suspend the jetpack and pilot in the air. The diagram below shows a crane lifting the jetpack and pilot.

The cable of the crane pulls the jetpack and pilot with a force of 1 400 N for 25 seconds so it hangs motionless in the air.

(a) Explain why no work has been done on the jetpack and pilot even though the cable pulls with a force of 1400 N for 25 s.

(b) A force of 1600 N is then used to pull the jetpack and pilot upwards. They are lifted 8 m over a period of 40 s.

Calculate the power output of the crane to pull the jetpack and pilot up 8 m. Give an appropriate unit for your answer.

Power = _____

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(c) The jetpack and pilot now hang motionless on the end of the crane's cable. The force applied by the crane is 1400 N.

Use the value of the crane's force to determine the mass of the jetpack and pilot. Give an appropriate unit for you answer.

In your answer you should include an explanation of the difference between mass and weight.

Mass of jetpack and pilot =

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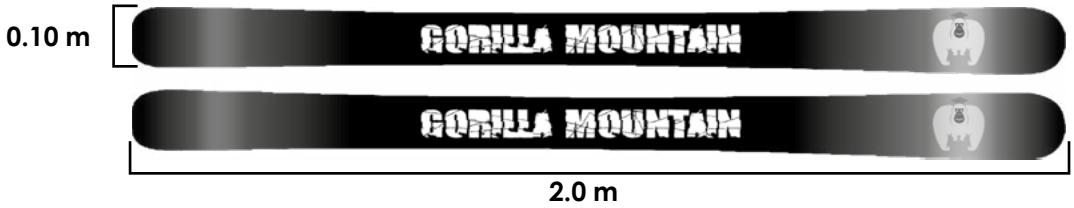
QUESTION THREE

The diagram below shows two skis each with a length of 2.0 m and an average width of 0.10 m.



Carol stands upright on the skis in the snow.

The combined mass of Carol and the skis is 65 kg.

(a) Calculate the pressure that Carol exerts on the snow when she stands upright on the skis. Give an appropriate unit for your answer.

Pressure = _____ _____

(units)

(b) Her friend David stands on his snowboard in the snow. The snowboard has a length of 1.60 m and an average width of 0.40 m, as shown in the diagram below.

The combined mass of David and his snowboard is 80 kg.

State whether Carol OR David will sink deeper into the snow. Explain your choice using appropriate physics principles.

In your answer you should consider:

- The contact area of the skis and snowboard.
- The relationship between pressure and surface area.
- The mathematical relationship between pressure, force and area.

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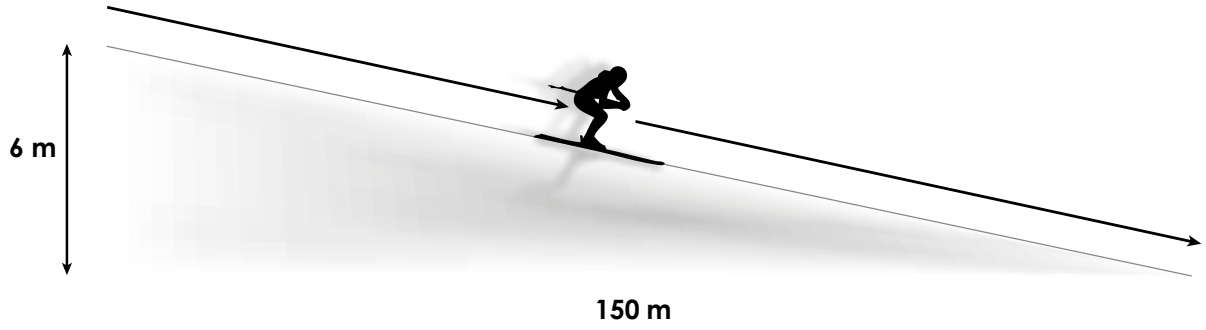
QUESTION FOUR

Carol skis down a slope in a straight line, as shown in the diagram below. At the bottom of the slope her speed is 10 m s^{-1}. The combined mass of Carol and her skis is 65 kg.



(a) Carol was stationary before she started skiing down the slope, and it took her 40 s to travel 150 m.

Calculate her average speed down the slope.

Average speed = _____ m s^{-1}

(b) Calculate the kinetic energy of Carol and her skis as she reaches the bottom of the slope when she is moving at 10 m s^{-1}. Give an appropriate unit for your answer.

Kinetic energy = _____ _____ (units)

(c) The kinetic energy gained by Carol when she reached the bottom of the slope does not equal the energy she had when she was stationary at the top of the slope.

Explain, using the principles of physics, why her energy at the top of the slope and her energy at the bottom of the slope are not equal.

In your answer you should:

- Name the type of energy Carol has at the top of the slope.
- Calculate the difference between her kinetic energy at the bottom of the slope and her energy at the top of the slope.
- Justify the difference between her kinetic energy at the bottom of the slope and her energy at the top of the slope.

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AS 90944 UNDERSTANDING OF

Acids and Bases

SCIENCE 1.5

Science 1.5 Demonstrate understanding of aspects of acids and bases

Level: 1 Credits: 4 Assessment: External

Achievement	Achievement with Merit	Achievement with Excellence
Demonstrate understanding of aspects of acids and bases.	Demonstrate in-depth understanding of aspects of acids and bases.	Demonstrate comprehensive understanding of aspects of acids and bases.

Explanatory Notes

1 Demonstrate understanding typically involves describing, identifying, naming, drawing, or giving an account of aspects of acids and bases. This may require the use of chemistry vocabulary, symbols and conventions (including names and formulae), and completing word equations.

2 Demonstrate in-depth understanding typically involves explaining aspects of acids and bases. This may require explanations that use chemistry vocabulary, symbols and conventions (including names and formulae) and writing word equations or completing given symbol equations.

3 Demonstrate comprehensive understanding typically involves linking aspects of acids and bases. It may involve explaining, elaborating, justifying, relating, evaluating, comparing and contrasting, or analysing. This may require the use of chemistry vocabulary, symbols and conventions (including names and formulae), and writing balanced symbol equations.

4 Aspects of acids and bases will be selected from:

- Atomic structure
  - Electron arrangement of atoms and monatomic ions of the first 20 elements.
  - Ionic bonding.
  - Names and formulae of ionic compounds using a given table of ions.
- Properties
  - Acids release hydrogen ions in water.
  - Reactions (of acids with bases) to form salts.
  - pH and effects on indicators.
- Rates of reaction and particle theory.
- Uses
  - Neutralisation.
  - Carbon dioxide formation.
  - Salt formation.

5 Acids and bases are restricted to HCl, H_2SO_4, HNO_3, metal oxides, hydroxides, carbonates and hydrogen carbonates. Other acids may be included in examination questions. The names and formulae of any such acids will be given in the question.

Most of this chapter contains material you should recall from year 10 science.

FOUNDATION CHEMISTRY

By the end of this chapter you should be able to:

	I KNOW THIS ALREADY	I LEARNED THIS	I REVISED THIS
Describe the structure of the *atom*.			
Discuss the key differences between the three *sub-atomic particles*.			
Define the term '*element*'.			
Name and write *symbols* for common elements.			
Discuss of the structure of the *Periodic Table*.			
Determine the *structure* of an atom based on data from the Periodic Table.			
Draw the *arrangement of electrons* around any given atom.			
Use the electron arrangement of an atom to identify which *group* on the Periodic Table it belongs to.			
Describe the role of *electrons* in chemical reactions.			
Explain how *positive* and *negative ions* are formed.			
Write the *name* and *formula* of common ions.			
Use ions to name and write the formula of *compounds*.			
Describe *ionic bonding*.			
Determine the number of atoms in a compound given its chemical formula.			
Write *word equations* for chemical reactions.			
Write balanced *symbol equations*.			

Key Terms

Atom

My Definition: _____

_____

Electron

My Definition: _____

_____

Proton

My Definition: _____

_____

Neutron

My Definition: _____

_____

Nucleus

My Definition: _____

_____

Atomic number

My Definition: _____

_____

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Mass number

My Definition: _____

_____

Element

My Definition: _____

_____

Compound

My Definition: _____

_____

Ion

My Definition: _____

_____

Cation

My Definition: _____

_____

Anion

My Definition: _____

_____

Monatomic ion

My Definition: _____

_____

Polyatomic ion

My Definition: _____

_____

Chemical formula

My Definition: _____

_____

Reactant

My Definition: _____

_____

Product

My Definition: _____

_____

Word equation

My Definition: _____

_____

Chemical equation

My Definition: _____

_____

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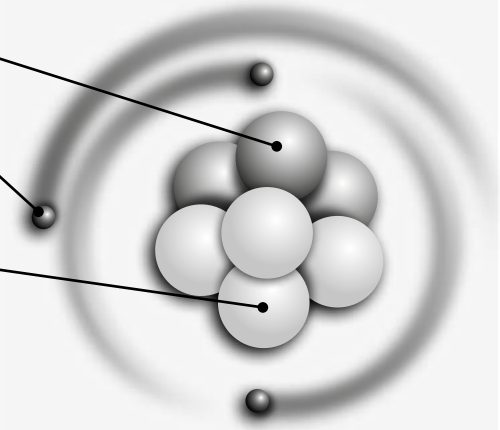
Atoms

Protons are much larger and heavier than electrons and have the opposite charge. Protons have a positive charge (+) and a relative mass of 1.

Electrons are extremely small particles that have a negative electrical charge (-). They exist outside the centre (nucleus) of the atom. Electrons have a relative mass of 1/2000.

Neutrons are large and have a similar mass to protons (1). However, neutrons have no electrical charge (0)

An atom's mass is made up of the mass of the protons and neutrons. Most of the mass of an element is found in the nucleus. Electrons have virtually no mass so they don't really contribute to an atom's mass.



1. Using your own words, describe an *atom*: _____

_____

_____

2. (a) Name the three *particles* found inside atoms: _____

_____

(b) Which of the three particles is the smallest?_____

(c) What two particles are found in the centre of an atom?_____

(d) What is the name given to the centre of an atom? _____

3. Complete the table.

Particle	Charge	Relative mass

Elements

An element is a substance consisting of atoms that are the same (i.e. they have the same atomic number). Elements are chemically the simplest substances and therefore cannot be broken down using chemical methods. Scientists have arranged all the known elements onto a table called 'The Periodic Table of Elements' (refer to the back of this sciPAD).

1. Write down the symbols of the following elements.

(a) Lithium _____ (b) Boron _____

(c) Carbon _____ (d) Calcium _____

(e) Zinc _____ (f) Nitrogen _____

(g) Fluorine _____ (h) Hydrogen _____

(i) Helium _____ (j) Oxygen _____

2. Write down the name of the following elements.

(a) Na _____ (b) K _____

(c) Pb _____ (d) Hg _____

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Getting To Know The Periodic Table

If you look at the NCEA Periodic Table, you will notice that each element has a number associated with it. The number is called the *atomic number* and represents the number of protons found in the nucleus of a single atom of that element. Since the number of *protons* is equal to the number of *electrons*, the atomic number also tells you how many electrons there are in the energy levels around the nucleus.

Another important number you will not find on the NCEA Periodic Table is called the *mass number*. This tells you the total number of particles, protons plus neutrons, found in the nucleus of an atom. So, if you know the mass number and the atomic number of an element, it is possible to work out the number of neutrons in the nucleus. By subtracting the number of protons from the mass number, you can calculate the total number of neutrons.

Worked Example

3
Li
Lithium

1. A lithium atom has a mass number of 7. State the number of protons, neutrons and electrons found in this atom.

   Number of protons or electrons = The atomic number. Therefore, the lithium atom has 3 protons and 3 electrons.

   Number of neutrons = Mass number − Atomic number. Therefore, the lithium atom has 7 − 3 = 4 neutrons.

1. Use the Periodic Table to complete the table below. The data for the element lithium has been done for you.

Element	Atomic Number	Mass Number	Number of Protons	Number of Electrons	Number of Neutrons
Hydrogen	1	1			
Helium	2	4			
Lithium	3	7	3	3	4
Beryllium	4	9			
Boron	5	11			6
Carbon	6				6
Nitrogen	7				7
Oxygen	8				8
Fluorine	9				10
Neon		20			
Sodium		23			
Magnesium		24			
Aluminium		27			
Silicon		28			
Phosphorus		31			
Sulfur		32			
Chlorine		35			
Argon		40			
Potassium		39			
Calcium		40			

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Patterns of the Periodic Table

The elements of the Periodic Table are not just randomly placed on the table. They are placed in order according to their *atomic number*. For example, the 12th element on the Periodic Table is magnesium. Remember that the atomic number is a measure of the number of protons in an atom of that element, so the 12th element has 12 protons in the nuclei of its atoms.
Elements are also arranged by *group* and by *period*. Groups are the vertical columns of elements whereas a period is a horizontal row.

Magnesium is found on the Periodic Table in group 2, period 3, whereas silver is found in group 11, period 5.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H Hydrogen 1.0																	2 He Helium 4.0
3 Li Lithium 6.9	4 Be Beryllium 9.0											5 B Boron 10.8	6 C Carbon 12.0	7 N Nitrogen 14.0	8 O Oxygen 16.0	9 F Fluorine 19.0	10 Ne Neon 20.2
11 Na Sodium 23.0	12 Mg Magnesium 24.3											13 Al Aluminium 27.0	14 Si Silicon 28.1	15 P Phosphorus 31.0	16 S Sulfur 32.1	17 Cl Chlorine 35.5	18 Ar Argon 40.0
19 K Potassium 39.1	20 Ca Calcium 40.1	21 Sc Scandium 45.0	22 Ti Titanium 47.9	23 V Vanadium 50.9	24 Cr Chromium 52.0	25 Mn Manganese 54.9	26 Fe Iron 55.9	27 Co Cobalt 58.9	28 Ni Nickel 58.7	29 Cu Copper 63.5	30 Zn Zinc 65.4	31 Ga Gallium 69.7	32 Ge Germanium 72.6	33 As Arsenic 74.9	34 Se Selenium 79.0	35 Br Bromine 79.9	36 Kr Krypton 83.8
37 Rb Rubidium 85.5	38 Sr Strontium 87.6	39 Y Yttrium 88.9	40 Zr Zirconium 91.2	41 Nb Niobium 92.9	42 Mo Molybdenum 95.9	43 Tc Technetium 98.9	44 Ru Ruthenium 101	45 Rh Rhodium 103	46 Pd Palladium 106	47 Ag Silver 108	48 Cd Cadmium 112	49 In Indium 115	50 Sn Tin 119	51 Sb Antimony 122	52 Te Tellurium 128	53 I Iodine 127	54 Xe Xenon 131
55 Cs Caesium 133	56 Ba Barium 137	71 Lu Lutetium 175	72 Hf Hafnium 179	73 Ta Tantalum 181	74 W Tungsten 184	75 Re Rhenium 186	76 Os Osmium 190	77 Ir Iridium 192	78 Pt Platinum 195	79 Au Gold 197	80 Hg Mercury 201	81 Tl Thallium 204	82 Pb Lead 207	83 Bi Bismuth 209	84 Po Polonium 210	85 At Astatine 210	86 Rn Radon 222

1. Using the Periodic Table, identify the group and period of the following elements.

(a) Hydrogen: _____
(b) Carbon: _____
(c) Sulfur: _____
(d) Fluorine: _____
(e) Calcium: _____
(f) Lithium: _____
(g) Chromium: _____
(h) Aluminium: _____
(i) Neon: _____
(j) Lead: _____
(k) Tin: _____
(l) Radon: _____
(m) Caesium: _____

An easy way to remember that columns are the 'groups' on the Periodic Table is to remember that "groups go to the ground".

2. Identify the element described by the following group and period numbers.

(a) Group 2, period 2: _____
(b) Group 5, period 4: _____
(c) Group 1, period 5: _____
(d) Group 4, period 4: _____
(e) Group 1, period 1: _____
(f) Group 5, period 5: _____
(g) Group 6, period 6: _____
(h) Group 14, period 2: _____
(i) Group 17, period 3: _____
(j) Group 18, period 3: _____
(k) Group 13, period 3: _____
(l) Group 16, period 2: _____
(m) Group 14, period 3: _____

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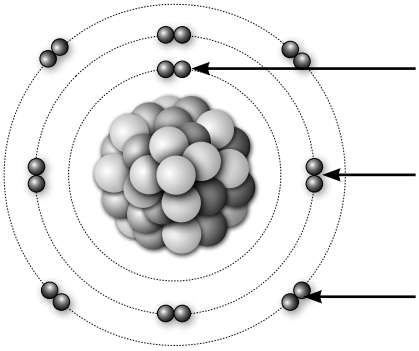
A Closer Look at Electrons

Chemical reactions are occurring all around us. Metals are corroding, food is cooking, plants are photosynthesising, etc. But how can we tell if two chemicals are going to react? The answer depends on their electrons.

Electrons surround the nucleus of an atom in various energy levels (often referred to as '*shells*' or '*layers*'). Each energy level can only contain a certain number of electrons.

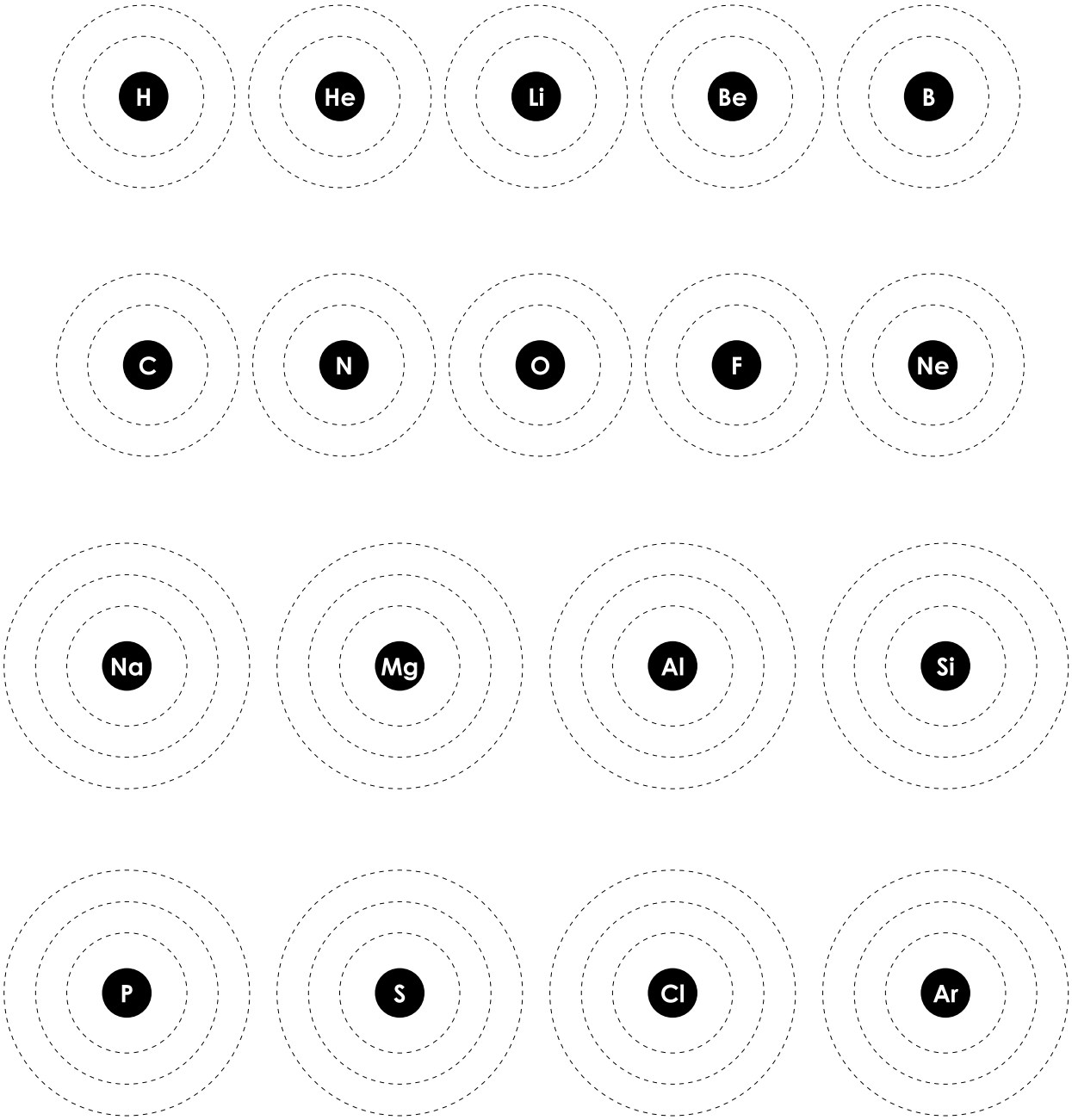


The first level (closest to the nucleus) can hold **2** electrons.

The second level can hold **8** electrons.

The third level can hold **8** electrons.

1. Use the Periodic Table to complete the following diagrams by adding the correct number of electrons in the appropriate shells.



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Electron Arrangement Shorthand

Scientists don't use drawings to show the arrangement of electrons. Instead they have devised a quicker method. To write the electron arrangement of a magnesium atom with 12 electrons you would write Mg 2,8,2. This means magnesium has 2 electrons in its innermost energy level, then 8 in the next level and 2 in its outermost level (or ***valence shell***).

1. Write down the electron arrangement of the following elements, using the shorthand technique describe above.

(a)	Hydrogen	_____	(k)	Lithium	_____
(b)	Beryllium	_____	(l)	Helium	_____
(c)	Neon	_____	(m)	Carbon	_____
(d)	Sulfur	_____	(n)	Oxygen	_____
(e)	Chlorine	_____	(o)	Fluorine	_____
(f)	Silicon	_____	(p)	Boron	_____
(g)	Magnesium	_____	(q)	Sodium	_____
(h)	Nitrogen	_____	(r)	Aluminium	_____
(i)	Phosphorus	_____	(s)	Potassium	_____
(j)	Argon	_____	(t)	Calcium	_____

2. What is the maximum number of electrons that are able to be held in:

(a) The first shell: _____

(b) The second shell: _____

(c) The third shell: _____

3. Identify the following elements based on the electron arrangements given below.

(a)	2,8	_____	(g)	2,8,1	_____
(b)	2,1	_____	(h)	2,8,4	_____
(c)	1	_____	(i)	2,6	_____
(d)	2,8,8	_____	(j)	2	_____
(e)	2,8,8,2	_____	(k)	2,5	_____
(f)	2,3	_____	(l)	2,8,8,1	_____

4. (a) Write down the electron arrangement for the first three elements in:

(i) Group 1: H _____ Li _____ Na _____

(ii) Group 2: Be _____ Mg _____ Ca _____

(b) What do you notice about the electron arrangement of the elements in group 1?

_____

(c) What do you notice about the electron arrangement of the elements in group 2?

_____

5. (a) Define the term '*valence shell*':_____

_____

(b) Write the number of valence electrons in the following elements.

(i)	Ca	_____	(v)	F	_____
(ii)	C	_____	(vi)	O	_____
(iii)	B	_____	(vii)	Al	_____
(iv)	P	_____	(viii)	He	_____

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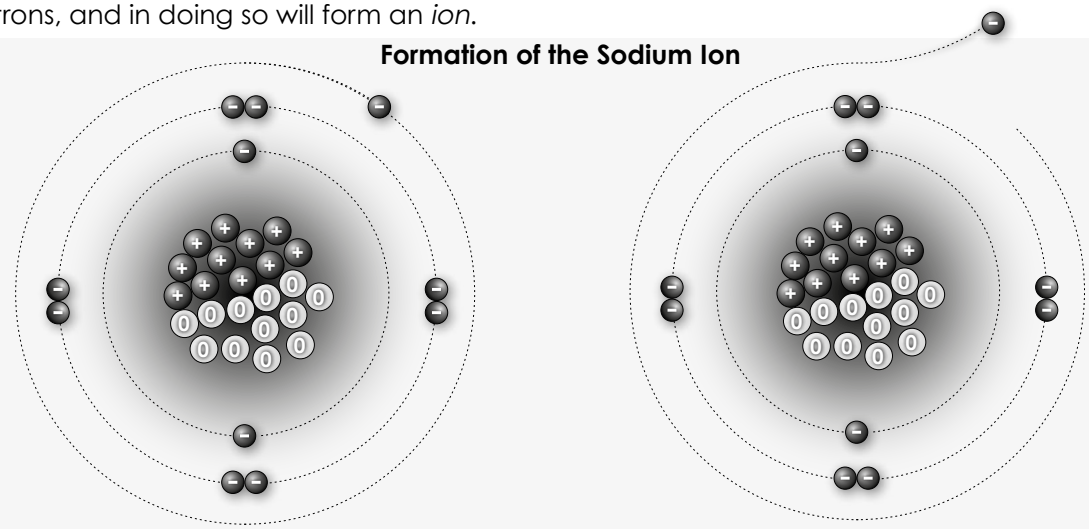
The Role of the Electron - Ion Formation

During a chemical reaction, an atom wants to get a full valence (outer) shell of electrons. Once an atom has a full valence shell it is stable. Atoms get full valence shells by losing or gaining electrons, and in doing so will form an *ion*.

Formation of the Sodium Ion



A sodium atom has 1 electron in its valence shell. It can gain 7 electrons to get a full valence shell of 8, or it can lose 1 electron and have a 'full' second shell. It is easier for the atom to lose one electron than gain 7.

Prior to a chemical reaction the atom has no electrical charge because:

11	Protons	=	+11
12	Neutrons	=	0
11	Electrons	=	-11
Total charge		=	0

During a reaction the sodium atom loses its valence shell electron and forms an ion. An ion is an atom with an electrical charge - either positive (+) or negative (-).

After the reaction an ion with an electrical charge has formed because:

11	Protons	=	+11
12	Neutrons	=	0
10	Electrons	=	-10
Total charge		=	**+1**

Sodium goes from an electron configuration of **2,8,1** with **no charge**, to an ion with an electron arrangement of **2,8** and a charge of **+1**.

1. Define the term '*ion*': _____

_____

2. Why do atoms gain or lose electrons? _____

_____

3. Magnesium has an atomic number of 12. It has 12 electrons arranged as 2,8,2.

   (a) How many electrons are there in magnesium's outer shell? _____

   (b) How many electrons does it need to gain to have a full outer shell? _____

   (c) How many electrons does it need to lose to have a full outer shell? _____

   (d) Is it going to be easier for a magnesium atom to gain or lose electrons?_____

   (e) What will be the final charge of the magnesium ion? _____

4. Chlorine has an atomic number of 17. It has 17 electrons arranged as 2,8,7.

   (a) How many electrons are there in chlorine's outer shell? _____

   (b) How many electrons does it need to gain to have a full outer shell? _____

   (c) How many electrons does it need to lose to have a full outer shell? _____

   (d) Is it going to be easier for a chlorine atom to gain or lose electrons? _____

   (e) What will be the final charge of the chloride ion? _____

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Electrons are negatively charged so an atom that gains an electron will develop a negative charge, whereas an atom that loses an electron will become positively charged.

5. Use a Periodic Table to complete the following table.

Atom	Electron arrangement	Number of electrons lost or gained	Formula of ion formed	Electron arrangement of the ion
Hydrogen				
Helium				
Lithium				
Beryllium				
Boron				
Nitrogen				
Oxygen				
Fluorine				
Sodium				
Magnesium				
Aluminium				
Phosphorus				
Sulfur				
Chlorine				
Potassium				
Calcium				

6. Complete the following paragraph by filling in the missing words.

A _____ ion is formed when an _____, or group of atoms, loses one or more _____. For example, when _____ loses its two valence _____ it forms Mg^{2+}.

A _____ ion is formed when an _____, or group of atoms, gains one or more _____. For example, when _____ gains two valence _____ it forms O^{2-}.

7. Outline why atoms form ions? _____

_____

8. Describe why beryllium and calcium atoms both form ions with a charge of +2. _____

_____

_____

_____

_____

9. Neon has an atomic number of 10. It has 10 electrons arranged as 2,8. Suggest why neon is very *unreactive*. _____

_____

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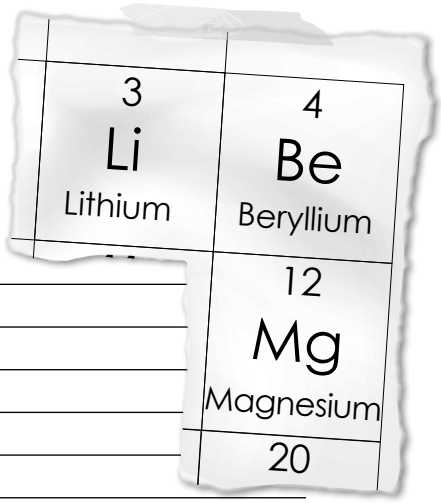
Atoms and Ions



Use the elements lithium, beryllium and magnesium to answer the following questions.

1. Explain why atoms are electrically **neutral**. In your answer, you should fully describe the atomic structure of lithium, beryllium and magnesium, including their electron configurations.

2. Explain why lithium and beryllium form ions with **different** charges.

3. Explain why beryllium and magnesium form ions with the **same** charge.

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Naming Ions

When naming ions, you must adhere to the following rules:

- Positive ions (i.e. the metals and hydrogen) are usually named after the element they are formed from. For example, the ion formed when calcium loses two electrons is also called the calcium ion (Ca^{2+}).
- Negative monatomic ions ('*mono*' means one, so monatomic means 'ions made of only one atom') are usually named using the suffix **- ide**. For example, chlorine (Cl) forms the negative ion chlor<u>ide</u> (Cl^-), and oxygen (O) forms the ox<u>ide</u> ion (O^{2-})
- Polyatomic ions ('*poly*' means many, so polyatomic means 'ions made of many atoms') are usually named using the suffix **-ate**. For example, SO_4^{2-} is the sulf<u>ate</u> ion and CO_3^{2-} is called the carbon<u>ate</u> ion. Exceptions to this rule include the hydroxide ion (OH^-) and the ammonium ion (NH_4^+).
- Some ions can have more than one charge. For example, iron can be Fe^{2+} or Fe^{3+}. Chemists use roman numerals to distinguish (tell the difference) between them. Therefore, Fe^{2+} is written as Iron(II) and Fe^{3+} is written as iron(III).

An easy way to remember your -ides from your -ates is to think of the 'i' in -ide standing for 'individual' or a 'one', and to think of the 'a' in -ate standing for 'add oxygen'.

1. Write the name of the ion that would form from the following atoms.

   (a) Hydrogen atoms form _____ ions.

   (b) Lithium atoms form _____ ions.

   (c) Oxygen atoms form _____ ions.

   (d) Potassium atoms form _____ ions.

   (e) Chlorine atoms form _____ ions.

   (f) Silver atoms form _____ ions.

   (g) Sulfur atoms form _____ ions.

   (h) Zinc atoms form _____ ions.

   (i) Fluorine atoms form _____ ions.

   (j) Iodine atoms form _____ ions.

2. Match the formula of the polyatomic ions to their names.

Formula of ion	Name of Ion
NH_4^+ •	• Carbonate
CO_3^{2-} •	• Hydroxide
SO_4^{2-} •	• Nitrate
OH^- •	• Sulfate
NO_3^- •	• Hydrogen carbonate
HCO_3^- •	• Ammonium

The formula of these ions will be given to you in the exam, however, their names will not. You will need to memorise them.

3. Copper can form two ions with different charges. What is the formula of the:

   (a) Copper(I) ion? _____ (b) Copper(II) ion? _____

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Ionic Compounds

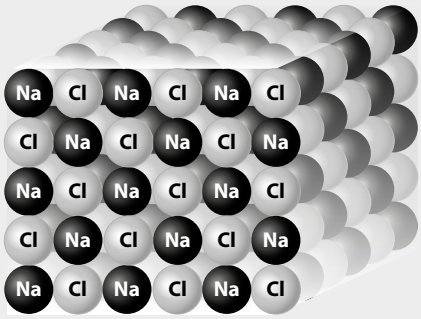
Chemists call positive ions, such as Mg^{2+}, *cations*. Negative ions, such as O^{2-}, are called *anions*. When a cation bonds to an anion, the resulting compound is called an *ionic compound*. The bond between a cation and an anion is called an *ionic bond*.

This means that when a metal reacts with a non-metal, an ionic compound will form.

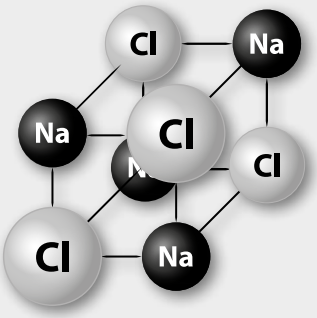
The ions within an ionic compound are arranged in a three-dimensional lattice. This means each positive ion is surrounded by negative ions, and in turn, each negative ion is surrounded by positive ions.

An easy way to remember that cations are positive is to look at the 't' of cation, and think of it as a '+' sign. Or you could think of the word anion as an abbreviation of "A Negative ION".

A Closer Look at Sodium Chloride



Space-filling model of NaCl



Simple model of NaCl

Sodium chloride ('table salt') is an *ionic solid*.

It is made of *positively charged sodium ions* and *negatively charged chloride ions* held together in a 3-D lattice.

The word '*lattice*' describes their regular, grid-like distribution pattern.

1. Define the following terms:

   (a) Cation: _____

   (b) Anion: _____

   (c) Lattice: _____

   _____

   (d) Ionic compound: _____

   _____

   (e) Ionic bond: _____

   _____

2. Identify which of the compounds listed below are ionic compounds. Circle your answers.

CO_2	HCl	H_2O	MgO	Na_2O	$ZnCl_2$	NO_2	KCl
Fe_2O_3	SO_2	$CaCl_2$	LiF	CuO	$FeCl_2$	ZnO	SiO_2

3. Write down the names of the ionic compounds you identified in question 2.

   (a) _____

   (b) _____

   (c) _____

   (d) _____

   (e) _____

   (f) _____

   (g) _____

   (h) _____

   (i) _____

   (j) _____

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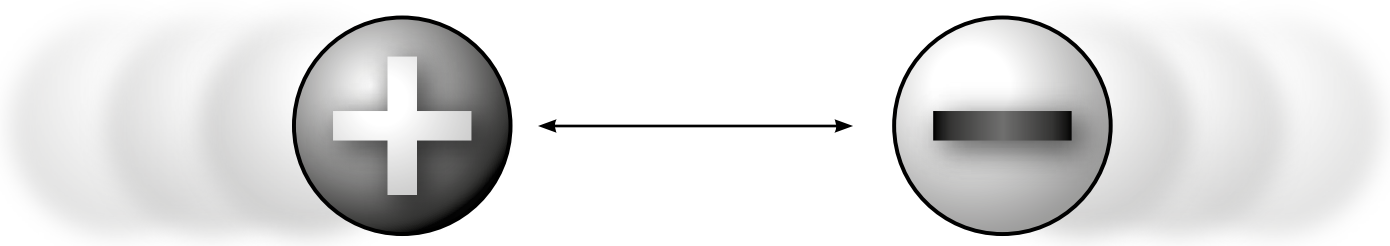
The Ionic Bond

The term 'ionic bond' describes the force of attraction that holds ions together in an ionic substance. These bonds arise because of the strong electrostatic attractions between oppositely charged ions.



The cation, usually a metal atom that has lost one or more electrons, has a positive charge due to the excess number of protons in the nucleus, compared to the number of electrons remaining.

The anion, usually a non-metal atom, or group of atoms, has a negative charge due to having gained one or more electrons. There are more electrons on the ion than protons in the nucleus.

1. A chemical reaction occurs between chlorine gas and sodium metal. The chemical equation is:

$$Cl_2 + 2Na \longrightarrow 2NaCl$$

(a) Identify the *metal* reactant: _____

(b) Identify the *non-metal* reactant: _____

(c) Name the ionic substance formed in the reaction: _____

(d) Complete the following paragraph.

When _____ metal reacts with _____ gas, the _____ loses one valence _____ and that _____ is gained by the _____ atom. The product of the reaction (_____ _____) is made up of sodium _____ and chloride _____.

The c_____ and a_____ are held together by strong e_____forces of a_____.

2. A reaction occurs between hydrochloric acid and magnesium metal.

$$2HCl + Mg \longrightarrow MgCl_2 + H_2$$

(a) Identify the *metal* reactant: _____

(b) Identify the *non-metal* reactant: _____

(c) Name the ionic substance formed in the reaction: _____

3. Describe the bonding in magnesium chloride. Your answer should include a description of the particles involved, and the forces holding the particles together. _____

_____

_____

_____

_____

_____

_____

_____

_____

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Counting Atoms

Chemical compounds and molecules are written in a very specific way according to some universal rules.

Formulae are always written with the positive ion (cation) first. In this example, calcium is the cation.

$$CaCl_2$$

A subscript number applies to the atom in front of the number. In this example there are two chlorine atoms.

Number of different atoms = 2 (calcium and chlorine).

Total number of atoms = 3 (one calcium and two chlorine atoms).

When you come across formulae with brackets around an ion, the subscript number applies to all the atoms within the brackets.

$$Fe(OH)_2$$

Number of different atoms = 3 (iron, oxygen and hydrogen).

Total number of atoms = 5 (one iron, two oxygens, two hydrogens).

An easy way to identify the number of different atoms in a compound is simply to count the capital letters. Each atom, and therefore element, has its own unique symbol which starts with a capital letter.

1. When writing a chemical formula should the cation or the anion be written first?

_____

2. Which ion in the formula Li_2O does the subscript number apply to? _____

_____

3. Count the number of different atoms and the total number of atoms in the compounds.

Compound	Number of different atoms	Total number of atoms
H_2O		
HNO_3		
Na_2O		
HCl		
$FeCl_3$		
H_2SO_4		
MgO		
NH_4Cl		
$LiOH$		
ZnF_2		
Fe_2O_3		
NH_4NO_3		
CO_2		
$CuSO_4$		
Li_2CO_3		
$MgSO_4$		
$MgCl_2$		

Compound	Number of different atoms	Total number of atoms
$Pb(OH)_2$		
$Cu(OH)_2$		
$Fe(NO_3)_2$		
$(NH_4)_2SO_4$		
$Fe(NO_3)_3$		
$Mg(HCO_3)_2$		
$Mg(OH)_2$		
$Cu(NO_3)_2$		
$Fe(OH)_3$		
$Ba(HCO_3)_2$		
$Zn(NO_3)_2$		
$(NH_4)_2CO_3$		
$Zn(OH)_2$		
$Mg(NO_3)_2$		
$Zn(HCO_3)_2$		
$Ba(OH)_2$		
$Fe_2(CO_3)_3$		

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Writing Chemical Formula

A chemical formula is a combination of chemical symbols (such as Na, Cl, or Mg) and subscript numbers, that are used to show the composition of a compound. For example, the chemical formula for water is H_2O. This shows that a water molecule is made up of two hydrogen atoms bonded to a single oxygen atom. Notice that if no number is given, as in the 'O' in H_2O, then only one of that atom/ion is present. Ions with different charges combine during a chemical reaction to form compounds that have equal amounts of positive and negative charge. This means the resulting compound has no electrical charge.

Rules for Writing Simple Chemical Formulae

	An example using Magnesium Oxide	An example using Magnesium Chloride
1 Using the table of ions, identify the ions that are present in the compound. You may wish to write them down on a scrap piece of paper. Make sure the positive ions (+) are always written before the negative ion (-).	$Mg^{2+}\ O^{2-}$	$Mg^{2+}\ Cl^{-}$
2 Cross out the charge symbols, any 1s or numbers that are the same.	$Mg^{\cancel{2}}\ O^{\cancel{2}}$	$Mg^{2}\ Cl$
3 Swap and drop the remaining numbers. If no numbers remain, then that is your formula.	$Mg\ O$	$Mg^{2}\ \cancel{Cl}$
4 Transfer your answer to your question paper.	MgO	$MgCl_2$

Table of Common Ions

The table below shows the ions you may be required to use. You will get a table like this in your exam. However, it won't have the names of the ions on it - you'll need to learn them.

+1	+2	+3	−3	−2	−1
H^+ Hydrogen	Ca^{2+} Calcium	Al^{3+} Aluminium	P^{3-} Phosphide	O^{2-} Oxide	F^- Fluoride
Na^+ Sodium	Mg^{2+} Magnesium	Fe^{3+} Iron(III)	PO_4^{3-} Phosphate	S^{2-} Sulfide	Cl^- Chloride
Li^+ Lithium	Cu^{2+} Copper			CO_3^{2-} Carbonate	Br^- Bromide
K^+ Potassium	Pb^{2+} Lead			SO_4^{2-} Sulfate	I^- Iodide
NH_4^+ Ammonium	Fe^{2+} Iron(II)				OH^- Hydroxide
Ag^+ Silver	Be^{2+} Beryllium				HCO_3^- Hydrogen carbonate
	Zn^{2+} Zinc				NO_3^- Nitrate
	Ba^{2+} Barium				

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1. Complete the table.

Name of compound	**Positive ion** (cation)	**Negative ion** (anion)	**Formula of compound**
Sodium chloride			
Potassium chloride			
Lithium chloride			
Silver chloride			
Sodium hydroxide			
Zinc oxide			
Aluminium chloride			
Magnesium chloride			
Lead oxide			
Copper sulfide			
Zinc chloride			
Beryllium oxide			
Iron(II) oxide			
Lithium oxide			
Potassium oxide			
Copper oxide			
Iron(III) oxide			
Aluminium oxide			
Iron(II) sulfide			
Aluminium sulfide			
Beryllium chloride			
Lithium hydroxide			
Silver oxide			
Iron(III) sulfide			

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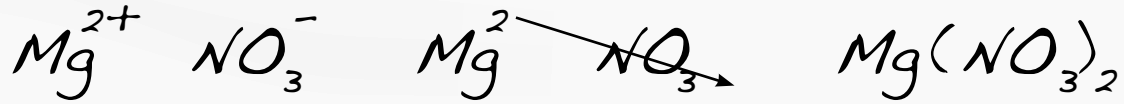
Dealing with Polyatomic Ions

Ions that are made of more than one atom are called *polyatomic* ions (*poly* means 'many'). This year you are expected to be able to deal with the following polyatomic ions:

NH_4^+ Ammonium	OH^- Hydroxide	NO_3^- Nitrate	HCO_3^- Hydrogen carbonate	SO_4^{2-} Sulfate	CO_3^{2-} Carbonate

The small sub-script number associated with many polyatomic ions, such as the '3' in the NO_3^-, are a critical part of the ion and <u>must never</u> be altered. This means when you are constructing chemical formulae you will need to place brackets around the entire polyatomic ion to avoid confusion.

Construction of a compound using polyatomic ions



1. Write down the ions involved. As always, place the positive ion at the front.
2. Follow the rules for writing chemical formula.
3. Place brackets around the polyatomic ion to show that there is more than one of them.

The use of brackets means that the number of atoms inside the brackets is multiplied by the number outside the brackets. For example, in $Mg(NO_3)_2$ there are 9 atoms in total (1 x Mg atom, 2 x N atoms and 6 x O atoms).

1. Name the atoms that make up the following polyatomic ions
   - (a) Ammonium: _____ atoms and _____ atoms
   - (b) Hydroxide: _____ atoms and _____ atoms
   - (c) Nitrate: _____ atoms and _____ atoms
   - (d) Sulfate: _____ atoms and _____ atoms
   - (e) Carbonate: _____ atoms and _____ atoms

2. Complete the sentence by filling in the missing words or numbers.

   The hydrogen carbonate ion is made of one _____ atom, _____ carbon atom and _____ oxygen atoms. Ions such as this are called _____ ions.

3. Name the following compounds. Each compound contains a polyatomic ion.
   - (a) NH_4Cl _____
   - (b) KOH _____
   - (c) $Ba(NO_3)_2$ _____
   - (d) K_2CO_3 _____
   - (e) $Mg(OH)_2$ _____
   - (f) $PbCO_3$ _____
   - (g) $NaOH$ _____
   - (h) $Ca(HCO_3)_2$ _____

4. Count the total number of atoms in the following compounds.
   - (a) $Ba(NO_3)_2$ _____
   - (b) $Ca(OH)_2$ _____
   - (c) K_2CO_3 _____
   - (d) $NaOH$ _____
   - (e) $PbCO_3$ _____
   - (f) NH_4Cl _____
   - (g) $Ba(HCO_3)_2$ _____

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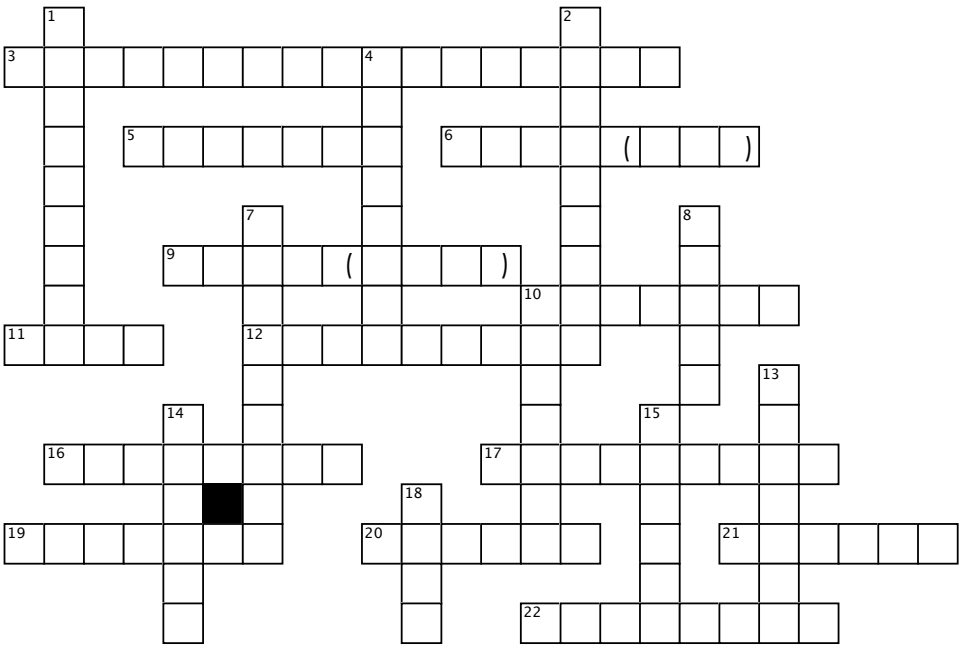
5. Write the formula of the following compounds.

	Compound	Positive ion	Negative ion	Final formula
(a)	Ammonium chloride			
(b)	Calcium hydroxide			
(c)	Silver nitrate			
(d)	Sodium carbonate			
(e)	Potassium sulfate			
(f)	Lead hydroxide			
(g)	Copper hydroxide			
(h)	Iron(II) nitrate			
(i)	Beryllium nitrate			
(j)	Aluminium sulfate			
(k)	Iron(III) carbonate			
(l)	Magnesium hydroxide			
(m)	Beryllium sulfate			
(n)	Potassium hydroxide			
(o)	Ammonium carbonate			
(p)	Sodium hydroxide			
(q)	Iron(III) hydroxide			
(r)	Zinc hydroxide			

6. Complete the crossword by naming the ions.



Across

3. HCO_3^-
5. Li^+
6. Fe^{2+}
9. Fe^{3+}
10. S^{2-}
11. Pb^{2+}
12. Al^{3+}
16. Cl^-
17. CO_3^{2-}
19. Ca^{2+}
20. Ag^+
21. Ba^{2+}
22. H^+

Down

1. OH^-
2. Mg^{2+}
4. NH_4^+
7. K^+
8. O^{2-}
10. SO_4^{2-}
13. NO_3^-
14. Na^+
15. Cu^{2+}
18. Zn^{2+}

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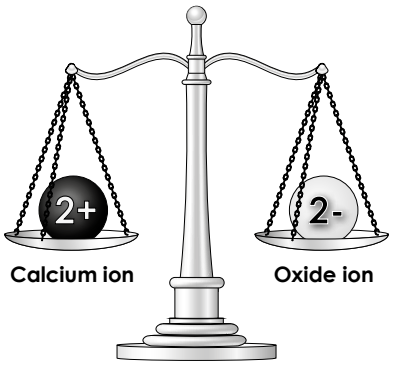
Understanding Chemical Formula

Chemical compounds formed during a chemical reaction have no overall charge. The number of electrons released by the atom(s) forming the cation must equal the number of electrons accepted by the atom(s) forming the anion.

Example 1: $2Ca_{(s)} + O_{2(g)} \longrightarrow 2CaO_{(s)}$

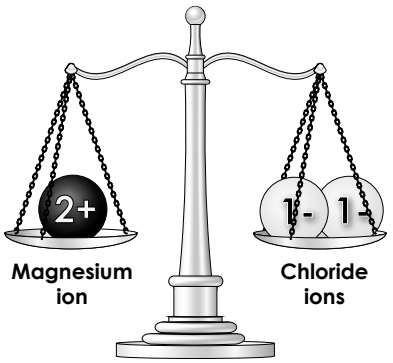
During the reaction between calcium and oxygen, calcium releases two electrons to form the calcium ion (Ca^{2+}). Oxygen gains two electrons to form the oxide ion (O^{2-}). Because the number of electrons released by calcium is equal to the number of electrons gained by oxygen, their charges are equal and opposite. Therefore, the formula of calcium oxide is CaO.



Example 2: $Mg_{(s)} + Cl_{2(g)} \longrightarrow MgCl_{2(s)}$

During the reaction between magnesium and chlorine, magnesium releases two electrons to form the magnesium ion (Mg^{2+}). Chlorine gains one electron to form the chloride ion (Cl^{-}). Because the number of electrons released by magnesium is not equal to the number of electrons gained by chlorine, their charges are opposite but not equal. To balance the formula another chlorine atom ion is required to accept the remaining electron released by magnesium.

Therefore, the formula of magnesium chloride is $MgCl_2$



The following question has been taken from a NZPQA exam. Answer the questions that follow which are designed to help you construct a complete response.

NZPQA

Discuss why sodium fluoride has the chemical formula NaF, whereas sodium oxide has the formula Na_2O.

_____

_____

_____

1. Sodium fluoride
   - (a) Electron arrangement of sodium: _____
   - (b) Number of electrons lost/gained by sodium when it forms an ion: _____
   - (c) Charge on a sodium ion: _____
   - (d) Electron arrangement of fluorine: _____
   - (e) Number of electrons lost/gained by fluorine when it forms an ion: _____
   - (f) Charge on a fluorine ion: _____
   - (g) Number of sodium ions required to balance the charge on the fluoride ion: _____
   - (h) Therefore, the formula of sodium fluoride is: _____
2. Sodium oxide
   - (a) Electron arrangement of sodium: _____
   - (b) Number of electrons lost/gained by sodium when it forms an ion: _____
   - (c) Charge on a sodium ion: _____

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(d) Electron arrangement of oxygen: _____

(e) Number of electrons lost/gained by oxygen when it forms an ion: _____

(f) Charge on a oxide ion: _____

(g) Number of sodium ions required to balance the charge on the oxide ion: _____

(h) Therefore, the formula of sodium oxide is: _____

3. Use the format of the previous question to explain why the formula of calcium chloride is $CaCl_2$ whereas the formula of potassium chloride is KCl.

4. Aluminium is a reactive metal. It reacts readily with oxygen to form aluminium oxide. Determine the formula of aluminium oxide. In your answer you should:

- Outline the electron arrangement of the atoms involved.
- Describe the formation of their ions.
- State the formula of aluminium oxide.
- Discuss the formula in terms of electron transfer and the balanced overall charge on the compound.

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Chemical Word Equations

Chemical reactions (when a chemical change occurs) can be represented by chemical word equations.

- The substances that are reacting together are called the *reactants*.
- The substance or substances produced are called the *products*.
- An *arrow* shows the direction of the reaction.

Reactant + reactant ⟶ product(s)

For example, if sodium reacts with chlorine to form sodium chloride, we would write the word equation as:

Sodium + chlorine ⟶ sodium chloride

1. In the reaction above, what is the name of:
   (a) the product? _____
   (b) the reactants? _____
2. What does the arrow represent in a word equation? _____
   _____
3. What happens to the sodium and the chlorine? Where do they go? _____
   _____
4. Write the following reactions as word equations. Remember to use '+' instead of 'reacts with' or 'and'. Also remember to use an arrow to show the direction of the chemical change.

   (a) Hydrogen reacts with oxygen to form water.
   _____

   (b) Magnesium and hydrochloric acid react to form magnesium chloride and hydrogen.
   _____

   (c) Copper oxide reacts with carbon to form copper and carbon dioxide.
   _____

   (d) Methane reacts with oxygen to form water and carbon dioxide.
   _____

   (e) Iron reacts with oxygen to form iron oxide.
   _____

   (f) Calcium carbonate reacts to form calcium oxide and carbon dioxide.
   _____

   (g) Carbon burns in oxygen to form carbon dioxide.
   _____

   (h) Zinc sulfate and hydrogen gas form when zinc reacts with sulfuric acid.
   _____

   (i) Lead oxide forms when lead reacts with oxygen.
   _____

   (j) Magnesium oxide is produced when magnesium burns in oxygen.
   _____

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Chemical Word Equations - continued

(k) Calcium reacts with sulfuric acid to form calcium sulfate and hydrogen.

(l) Iron reacts with sulfuric acid to form iron sulfate and hydrogen.

(m) Lithium and fluorine react together to produce lithium fluoride.

(n) Propane reacts with oxygen to form water and carbon dioxide.

(o) Beryllium oxide forms when oxygen reacts with beryllium.

(p) Calcium hydroxide and hydrogen are formed when calcium reacts with water.

(q) Glucose reacts with oxygen to form carbon dioxide and water.

(r) Cobalt reacts with hydrochloric acid to form cobalt chloride and hydrogen gas.

(s) Calcium hydroxide is formed when calcium oxide reacts with water.

(t) Sodium and chlorine react vigorously to produce sodium chloride crystals.

(u) Manganese reacts with oxygen to form manganese dioxide.

(v) Potassium reacts with nitric acid to form potassium nitrate and hydrogen gas.

(w) Zinc bromide is formed when zinc is placed into bromine gas.

(x) Aluminium oxide is produced when aluminium and oxygen react.

(y) Calcium sulfate, water and carbon dioxide are produced when calcium carbonate reacts with sulfuric acid.

(z) Plants convert carbon dioxide and water to glucose and oxygen.

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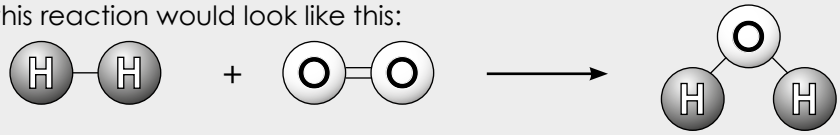
Balancing Chemical Equations

Nearly 2 500 years ago, Greek philosophers (early scientists) came up with the theory that "nothing comes from nothing". Over time many scientists have further refined this theory to suggest that "*matter can not be created or destroyed*" - a statement that scientists refer to as the "*Law of Conservation of Mass*". In simple terms, this means if you weighed the ingredients of a cake, then baked it in a closed system, the mass of the cake at the end would equal the mass of the ingredients. The same is true for chemical reactions. The number of atoms in the reactants will always equal the number of atoms in the products.

Scientists show this by writing *balanced* equations. For example, consider hydrogen gas reacting with oxygen gas to create water.

Graphically this reaction would look like this:



As a chemical equation is would look like this:

$$H_2 + O_2 \longrightarrow H_2O$$

2 atoms of hydrogen + 2 atoms of oxygen → 2 atoms of hydrogen and 1 atom of oxygen

The equation is *unbalanced*. There are 4 atoms in total on the left-hand side of the equation and only 3 atoms on the right hand side - an oxygen atom is missing!

In order to balance an equation there are a couple of rules you must stick to:

- You can **never** add small numbers to a compound (e.g. H_2O cannot become H_2O_2)
- You can only add numbers to the **front** of a compound. This number multiplies all the atoms in that compound.

To fix the example above we need to add a 2 in front of the hydrogen and another 2 in front of the water, so...

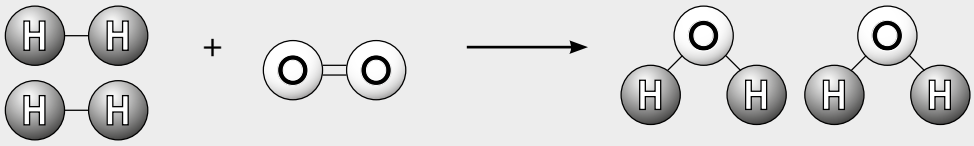
As a chemical equation is would look like this:

$$2H_2 + O_2 \longrightarrow 2H_2O$$

$2H_2$: 2 x 2 = 4 H's; O_2: 2 x 1 = 2 O's — 6 atoms in total

$2H_2O$: 2 x 2 = 4 H's; 2 x 1 = 2 O's — 6 atoms in total

Graphically this reaction would look like this:



1. Balance the following chemical equations.

(a) $C + H_2 \longrightarrow CH_4$

(b) $Zn + O_2 \longrightarrow ZnO$

(c) $H_2 + Cl_2 \longrightarrow HCl$

(d) $Li + O_2 \longrightarrow Li_2O$

(e) $Mg + Cl_2 \longrightarrow MgCl_2$

(f) $Na + O_2 \longrightarrow Na_2O$

(g) $K + I_2 \longrightarrow KI$

(h) $H_2 + F_2 \longrightarrow HF$

(i) $Li + Cl_2 \longrightarrow LiCl$

(j) $Cu + O_2 \longrightarrow CuO$

(k) $K + O_2 \longrightarrow K_2O$

(l) $Fe + O_2 \longrightarrow Fe_2O_2$

(m) $Na + Cl_2 \longrightarrow NaCl$

(n) $P_4 + O_2 \longrightarrow P_4O_{10}$

(o) $Al + O_2 \longrightarrow Al_2O_3$

(p) $V + Cl_2 \longrightarrow VCl_3$

! Only for experts!

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2. Balance the following chemical equations.

(a)	Mg	+	O_2	→	MgO		
(b)	Fe	+	Cl_2	→	$FeCl_2$		
(c)	K	+	O_2	→	K_2O		
(d)	Na	+	O_2	→	Na_2O		
(e)	Li	+	O_2	→	Li_2O		
(f)	Ca	+	O_2	→	CaO		
(g)	Ba	+	O_2	→	BaO		
(h)	Zn	+	O_2	→	ZnO		
(i)	Na	+	O_2	→	Na_2O		
(j)	Fe	+	O_2	→	FeO		
(k)	Ca	+	HCl	→	$CaCl_2$	+	H_2
(l)	Li	+	H_2SO_4	→	Li_2SO_4	+	H_2
(m)	K	+	H_2O	→	KOH	+	H_2
(n)	Mg	+	HNO_3	→	$Mg(NO_3)_2$	+	H_2
(o)	Cu	+	H_2SO_4	→	$CuSO_4$	+	H_2
(p)	Fe	+	HCl	→	$FeCl_2$	+	H_2
(q)	K	+	HNO_3	→	KNO_3	+	H_2
(r)	Pb	+	HNO_3	→	$Pb(NO_3)_2$	+	H_2
(s)	Zn	+	HCl	→	$ZnCl_2$	+	H_2
(t)	Li	+	HCl	→	LiCl	+	H_2
(u)	NaOH	+	HCl	→	NaCl	+	H_2O
(v)	$Ca(OH)_2$	+	HCl	→	$CaCl_2$	+	H_2O
(w)	KOH	+	HNO_3	→	KNO_3	+	H_2O
(x)	LiOH	+	H_2SO_4	→	Li_2SO_4	+	H_2O
(y)	$Ca(OH)_2$	+	H_2SO_4	→	$CaSO_4$	+	H_2O
(z)	$Mg(OH)_2$	+	HNO_3	→	$Mg(NO_3)_2$	+	H_2O

Remember you are counting atoms and trying to balance the number of atoms on each side of the arrow by adding numbers to the FRONT of the reactants or products.

3. Write a balanced chemical equation for the following word equations.

You will get more practice with these in the "Acids and Bases" chapter.

(a) Iron burns in oxygen to form iron(II) oxide.

_____

(b) Lithium reacts with water to form lithium hydroxide and hydrogen gas.

_____

(c) Zinc oxide is formed when zinc reacts with oxygen.

_____

(d) Magnesium reacts with water and forms magnesium hydroxide and hydrogen gas.

_____

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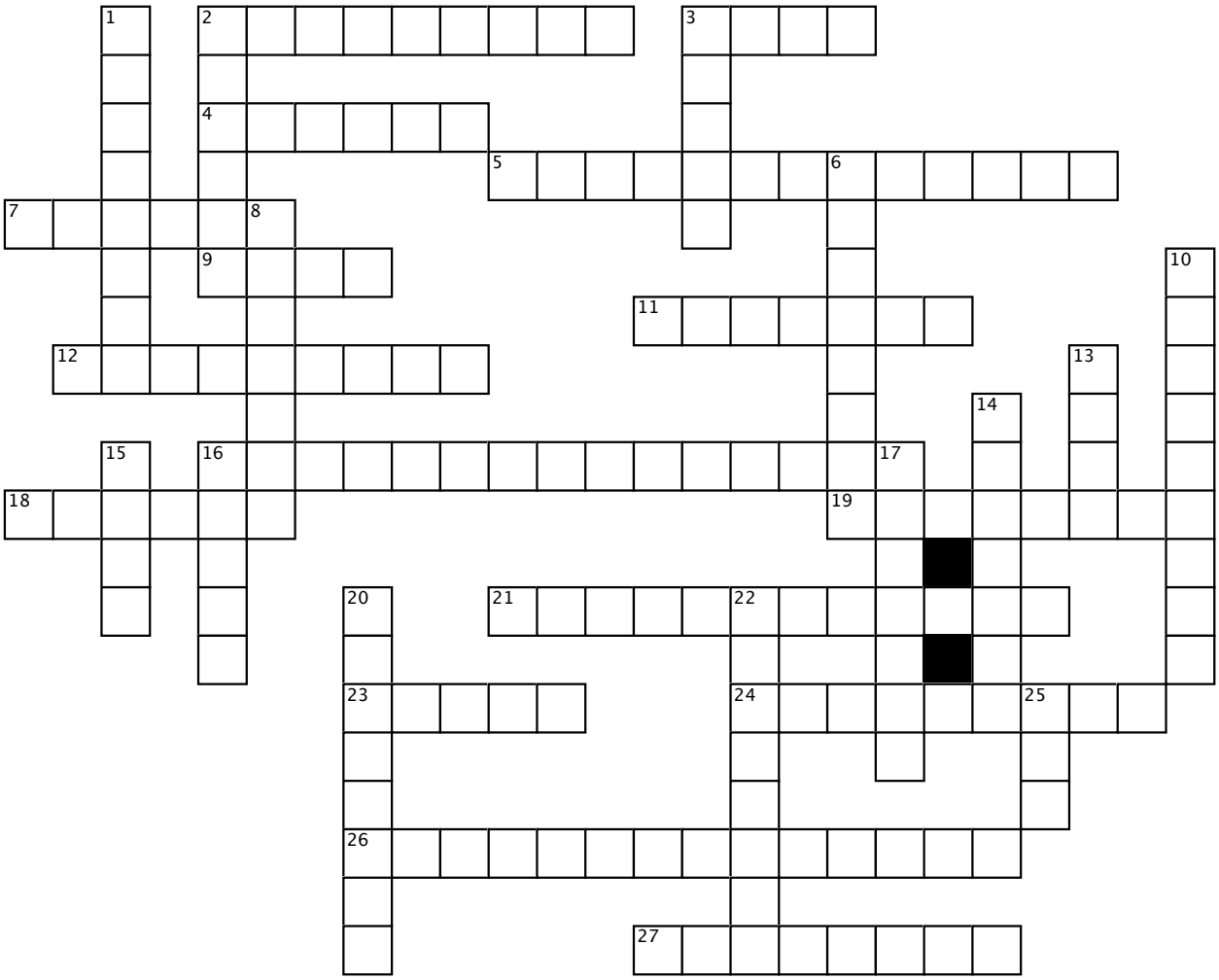
End of Chapter Crossword



Across

2. This element is given the chemical symbol 'K'.
3. Basic building block of all matter.
4. This element has an atomic number of 8.
5. Table used to arrange all the known elements.
7. This element has an atomic number of 6.
9. This element has an electron arrangement of 2.8.
11. Atoms with the same atomic number but different mass numbers.
12. Name for the 'ingredients' of a chemical reaction.
16. Name of the compound with the formula NaOH.
18. Number of electrons in a sodium atom.
19. Negatively charged particle that surrounds the nucleus of an atom.
21. This number, found above an element on the Periodic Table, tells you the number of protons inside that atom.
23. O^{2-}
24. Mg^{2+}
26. Name of the compound with the formula $CaSO_4$.
27. The lightest element on the Periodic Table.

Down

1. This poisonous gas is given the chemical symbol 'Cl'.
2. Positively charged particle in the nucleus of an atom.
3. Used to show the direction of a chemical reaction when writing equations.
6. The name of the ion formed when chlorine gains one electron.
8. Particles inside the nucleus of an atom that have no charge.
10. This element has an electron arrangement of 2,8,3.
13. The group number for an element with four electrons in its outer shell.
14. The middle of an atom is called this.
15. Electrical charge on an atom with an equal number of protons and electrons.
16. Number of atoms in a single H_2SO_4 molecule.
17. A substance made of only one type of atom.
20. Name for the substances that are produced in a chemical reaction.
22. Made of two or more elements chemically combined.
25. An atom which has gained or lost electrons in order to have a full outer shell of electrons.

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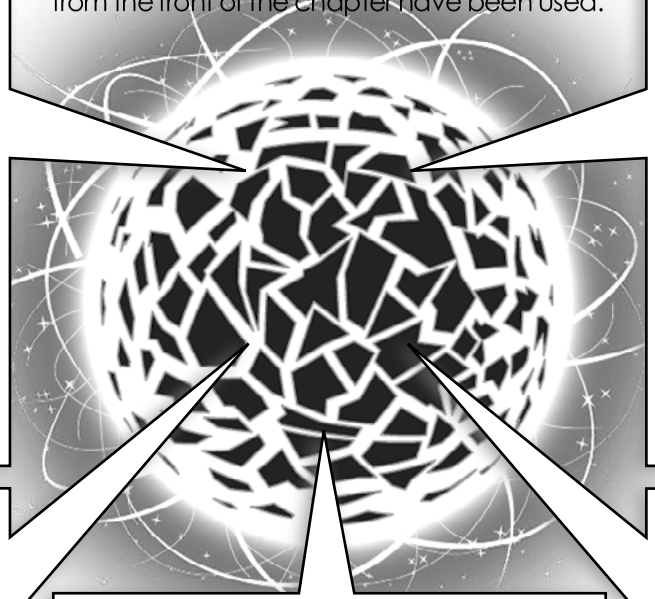
Foundation Chemistry Chapter Review

Use the boxes to write down the key points from this chapter. Ensure that all key words from the front of the chapter have been used.



Atomic Structure

Ionic Bonding and Ionic Compounds

Ion Formation

Writing Chemical Formula

Balancing Equations

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End of Chapter Review Questions

1. Complete the table.

Subatomic particle	Mass	Electrical charge	Location within atom

2. Write the electron arrangement of the following atoms:

(a) Calcium _____ (b) Boron _____

(c) Nitrogen _____ (d) Sulfur _____

3. A chemist found that when potassium was placed in water, a violent reaction took place during which potassium hydroxide and hydrogen gas were produced.

(a) Write the word equation for this reaction.

_____

(b) Write a balanced chemical equation for this reaction.

_____

4. The following question is typical of one that you will find in your exam. The questions (a)-(d) below it are designed to help you work through the steps required to answer it.

NZPQA

1. Magnesium and oxygen atoms both form ions. Magnesium forms an ion with a charge of 2+, whereas oxygen forms an ion with a charge of 2-. Explain why these two atoms form ions with different charges. _____

(a) Define the term '*ion*'. _____

_____

(b) Outline how atoms gain full valence shells of electrons. _____

_____

(c) Magnesium

What group on the Periodic Table is magnesium in? _____

How many electrons does magnesium have in its outer shell? _____

How many electrons does it need to gain to have a full outer shell? _____

How many electrons does it need to lose to have a full outer shell? _____

Is it going to be easier for magnesium to gain or lose electrons? _____

What will be the charge on the magnesium ion? _____

(d) Oxygen

What group on the Periodic Table is oxygen in? _____

How many electrons does oxygen have in its outer shell? _____

How many electrons does it need to gain to have a full outer shell? _____

How many electrons does it need to lose to have a full outer shell? _____

Is it going to be easier for oxygen to gain or lose electrons? _____

What will be the charge on the oxide ion? _____

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5. An atom of sodium has a mass of 23 whereas an atom of magnesium has a mass of 24.

(a) Explain why atoms are electrically **neutral**. In your answer, you should fully describe the atomic structure of sodium and magnesium, and state their electron configurations.

(b) Explain why the ions in sodium hydroxide combine to give the formula NaOH but the ions in magnesium hydroxide combine to give the formula $Mg(OH)_2$.

In your answer, you should:

- **Compare** the charges on the individual ions found in the compounds sodium hydroxide and magnesium hydroxide.
- **Explain** why the ions combine in the ratios the way they do to form the compounds NaOH and $Mg(OH)_2$.

Hints for answering these NCEA style questions

Define an atom and its subatomic particles. Include mass and electrical charge of the sub-atomic particles.

State the atomic structure of Mg.

State Mg's electron configuration.

Make a statement linking its atomic structure to its electrical neutrality.

State the atomic structure of Na.

State Na's electron configuration.

Make a statement linking its atomic structure to its electrical neutrality.

State the charge of the sodium ion.

State the charge of the magnesium ion.

State the charge of the hydroxide ion.

Write a statement about the electrical neutrality of an ionic compound (positive charges must equal negative charges).

Justify the formula of NaOH by discussing the balancing of positive (Na^+) and negative charges (OH^-).

Justify the formula of $Mg(OH)_2$ by discussing the balancing of positive (Mg^{2+}) and negative charges (OH^-).

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RATES OF REACTIONS

By the end of this chapter you should be able to:

	I KNOW THIS ALREADY	I LEARNED THIS	I REVISED THIS
Use both the '*particle theory*' and '*collision theory*' to describe chemical reactions.			
Define the term '*reaction rate*'.			
Describe how reaction rates can be *measured*.			
Explain how *temperature*, *concentration* and *surface area* affect reaction rates.			
Explain the effect of *catalysts* on reaction rates.			
Explain why the *rate* of a chemical reaction changes over time.			
Carry out a number of investigations into the factors that affect reaction rates.			

Key Terms

Activation energy

My Definition: _____

_____

Catalyst

My Definition: _____

_____

Collision theory

My Definition: _____

_____

Concentration

My Definition: _____

_____

Kinetic energy

My Definition: _____

_____

Particle

My Definition: _____

_____

Particle theory

My Definition: _____

_____

Product

My Definition: _____

_____

Reactant

My Definition: _____

_____

Reaction rate

My Definition: _____

_____

Surface area

My Definition: _____

_____

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Introduction to Chemical Reactions

In order to understand chemical reactions, you need to be aware of two simple, but very important, chemical theories.

Particle Theory

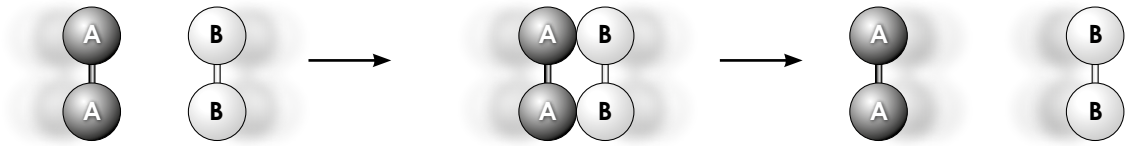
All matter is made up of tiny particles (atoms, ions or molecules) and these particles are in constant motion. Temperature affects the speed of the particles (i.e. when the temperature increases the speed of the particles also increases).

Collision Theory

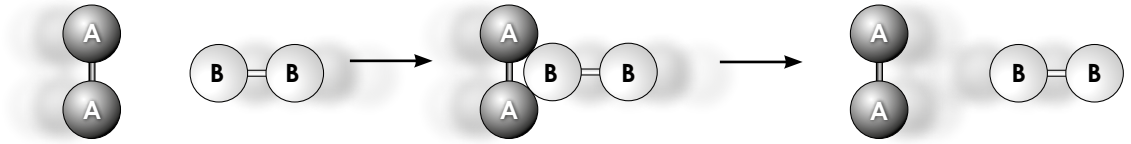
In order for a chemical reaction to occur, two or more reactant particles must collide with sufficient force (energy) and at the correct orientation. The minimum amount of energy required for a chemical reaction to proceed is called the *activation energy*.

Visualising the Collision Theory

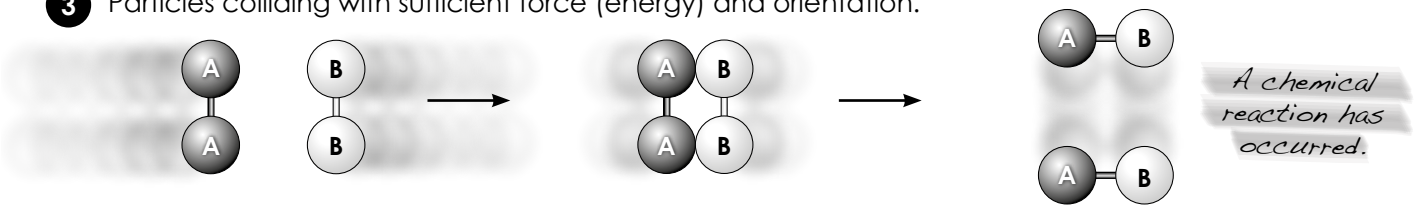
1. Particles colliding with insufficient force (i.e. They are moving too slowly).



2. Particles colliding with sufficient force but the incorrect orientation.



3. Particles colliding with sufficient force (energy) and orientation.



1. Complete the paragraph using the word list below.

react	collision	collide	force	orientation

Reactant particles will only _____ together if they _____ with sufficient _____, and at the correct _____ to break bonds. This is called the _____ theory.

2. Define the term '*activation energy*': _____

_____

3. Identify which of the following scenarios would lead to an increase in the number of collisions between particles.

(a)	Increasing the number of particles in a given volume.	increase/decrease in frequency of collisions
(b)	Decreasing the speed of the particles by cooling them down.	increase/decrease in frequency of collisions
(c)	Decreasing the number of particles in a given volume.	increase/decrease in frequency of collisions
(d)	Increasing the speed of the particles by heating them up.	increase/decrease in frequency of collisions

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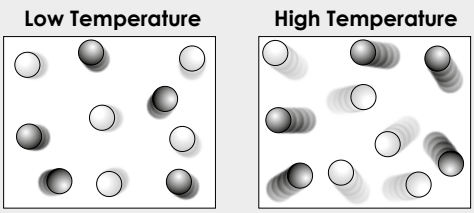
Factors Affecting the Rate of a Reaction

Temperature

The rate of a chemical reaction can be increased by raising the temperature of the reaction.

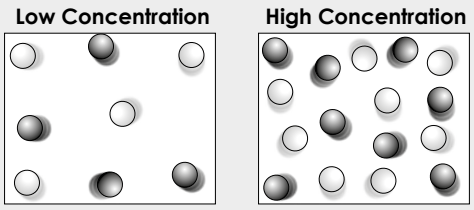
Raising the temperature causes the reactant particles to move more quickly. This means they have more energy (specifically *kinetic energy*). Particles that are moving more quickly, with more energy, have a higher chance of colliding successfully and will collide more often.



Concentration

The rate of a chemical reaction can be increased by increasing the concentration of one or all of the reactants.

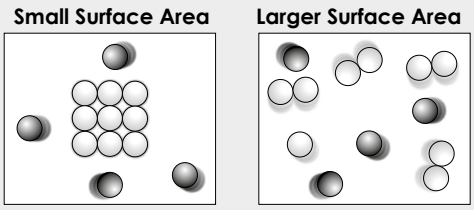
Increasing the concentration means particles are more numerous and closer together, so there is an increased chance of collisions.



Surface area

Increasing the surface area of a reactant leads to an increase in reaction rate.

If a solid reactant is broken into small pieces, or ground into a powder, then its surface area has increased. This means more particles are exposed, meaning more particles are able to collide.



Catalysts

Catalysts are special chemicals that speed up the rate of reaction but are not used up in that reaction. Some catalysts provide a specific site for collisions to occur, while others lower the amount of energy required to start the reaction (known as the *activation energy*).

1. A 2 g strip of magnesium ribbon was added to a 100 mL beaker containing 20 mL of 1.0 mol L^{-1} sulfuric acid. The experiment was conducted at room temperature (25°C). Bubbles of hydrogen gas were produced.

   For each change listed below, outline how the reaction rate will be affected. Use the words *increase*, *decrease* or *stays the same* for your answers.

   Change One

   (a) The experiment was carried out in a *200 mL beaker*.

   Effect: _____

   Change Two

   (b) The temperature of the reaction mixture was increased to *40°C*.

   Effect: _____

   Change Three

   (c) *50 mL of water* was added to the beaker. The same volume of acid and magnesium were then added.

   Effect: _____

   Change Four

   (d) The experiment was repeated using *powdered magnesium* instead of magnesium ribbon.

   Effect: _____

   Change Five

   (e) A *50 mL beaker* was used, instead of a 100 mL beaker.

   Effect: _____

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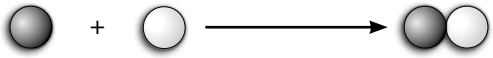
Measuring Reaction Rates

When scientists talk about the "rate of a reaction", they are actually taking about how fast the reaction happens.

If we consider the reaction:

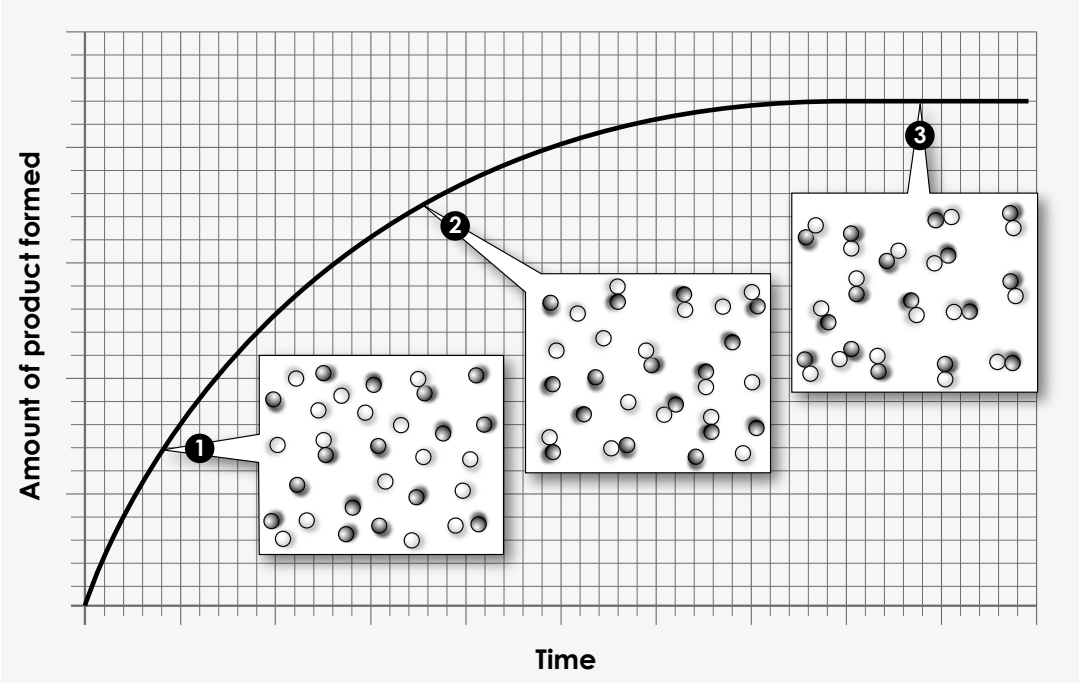


Then there are two possible ways of measuring the rate:

(a) measure how quickly the *products* ( ) are made;

(b) measure how quickly one of the *reactants* (or) disappears.

The graph below shows the results of a reaction rate investigation. The steeper the line, the faster the rate of reaction. Reactions are usually fastest at the beginning, when the concentration of reactants is greatest. When the line becomes horizontal, the reaction has stopped.



1. Outline why:

   (a) Reactions start out at a relatively fast rate: _____

   _____

   (b) Reactions slow down after a period of time: _____

   _____

   (c) Reactions eventually stop: _____

   _____

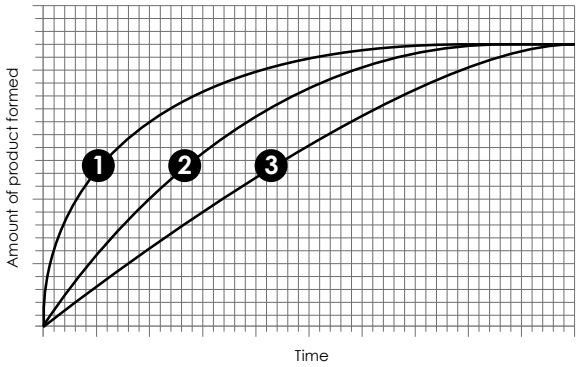
2. The graph below shows the results of three experiments testing the effects of temperature of an acid and rate of reaction with magnesium.

   (a) Which graph (1, 2, or 3) shows the results of the experiment in which the acid had the highest temperature?

   _____

   (b) Which graph (1, 2, or 3) shows the results of the experiment in which the acid had the lowest temperature?

   _____



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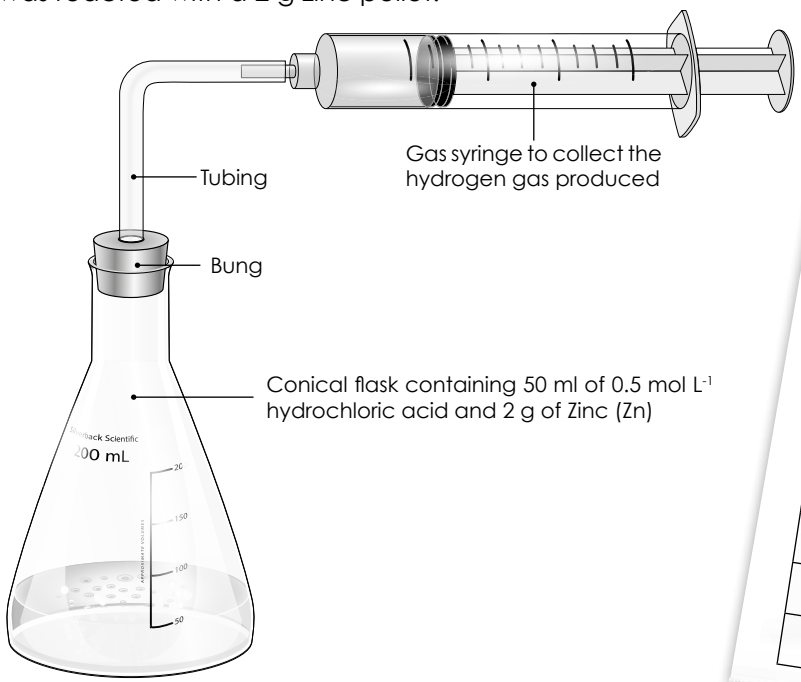
Investigating Reaction Rates

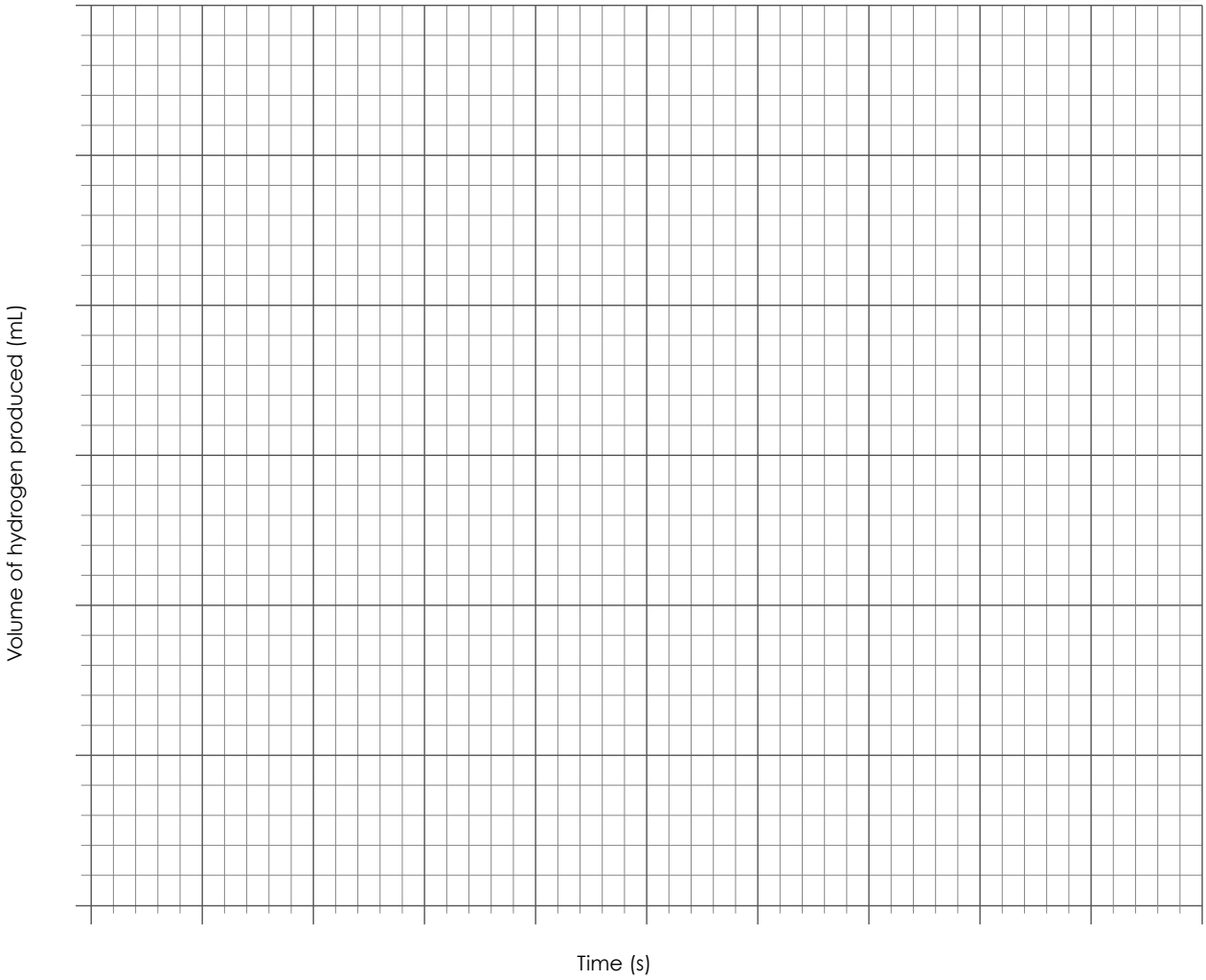
When zinc reacts with hydrochloric acid, hydrogen gas is produced. Using the following equipment, the gas can be collected. By measuring the volume of gas collected at various stages of the reaction, the reaction rate can be calculated.

In the experiment shown below, 50 mL of dilute (0.5 mol L^{-1}) hydrochloric acid (HCl) was used. It was reacted with a 2 g zinc pellet.



Time (s)	Volume of hydrogen (mL)
0	0
10	26
20	37
30	no reading taken
40	48
50	51
60	52
70	54
80	54
90	55
100	55

1. Use the data table to plot a graph of the results.



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2. Put an 'X' on your graph where the reaction is happening the fastest.

3. Use your graph to calculate:

   (a) The volume of hydrogen gas collected in the first 15 seconds.

   _____

   (b) The volume of hydrogen gas collected after 30 seconds.

   _____

4. The students carrying out this experiment wanted to repeat it, but this time at a faster reaction rate. They were told by their teacher they were not allowed to change the volume of acid, or the mass of zinc.

   Outline three ways the students could increase the rate of this reaction and explain how each change leads to a faster reaction.

   Change 1: _____

   Explanation: _____

   _____

   _____

   _____

   _____

   _____

   _____

   _____

   Change 2: _____

   Explanation: _____

   _____

   _____

   _____

   _____

   _____

   _____

   _____

   Change 3: _____

   Explanation: _____

   _____

   _____

   _____

   _____

   _____

   _____

   _____

5. Using the axis on the previous page, sketch the graph you would expect to see if the experiment was repeated using the method you outlined in "Change 1".

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Investigating the Effect of Temperature on Reaction Rate

At a higher temperature, the number of collisions occurring between reactant particles is greater because the particles are moving more quickly. When a collision occurs, there is more chance of a reaction taking place because the kinetic energy in the particles is greater.

At a lower temperature, the number of collisions is lower because the particles are moving more slowly. Also when a collision occurs, there is less chance of a reaction taking place because the kinetic energy in the particles is less.

Changing the temperature of a reactant **changes** how quickly the particles are moving (i.e. it will increase the amount of energy they have, if the temperature is increased).

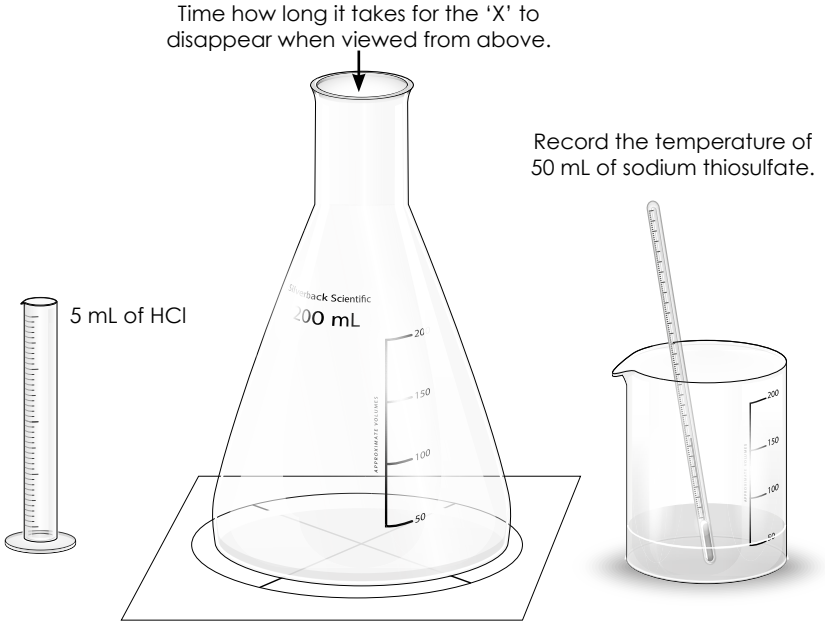
Introduction: In this experiment the effect of temperature on the rate of reaction between sodium thiosulfate and hydrochloric acid (HCl) is investigated.

Equipment: Conical flask, beaker, 5 mL and 50 mL measuring cylinders, stopwatch, black cross on paper, water bath, thermometer, 0.1 mol L^{-1} sodium thiosulfate, 2.0 mol L^{-1} hydrochloric acid (HCl).

Method

1. Put the 'X' paper on the bench mat, and put the conical flask on top of the paper.
2. Measure 50 mL of sodium thiosulfate solution and put it into the beaker.
3. Record the temperature of the sodium thiosulfate.
4. Measure 5 mL of HCl and pour this into the conical flask.
5. Pour the sodium thiosulfate into the conical flask, start the stopwatch and swirl the flask. Time how long it takes for the cross to disappear when viewed from above (i.e. look down the mouth of the conical flask).
6. Wash out the flask thoroughly.
7. Repeat the experiment, using a water bath to heat the sodium thiosulfate to 30°C, then 40°C and finally 50°C. Keep the volume of acid the same each time.

You'll find pages with the 'X's on them at the end of the chapter.



Results: Draw a table for your result here.

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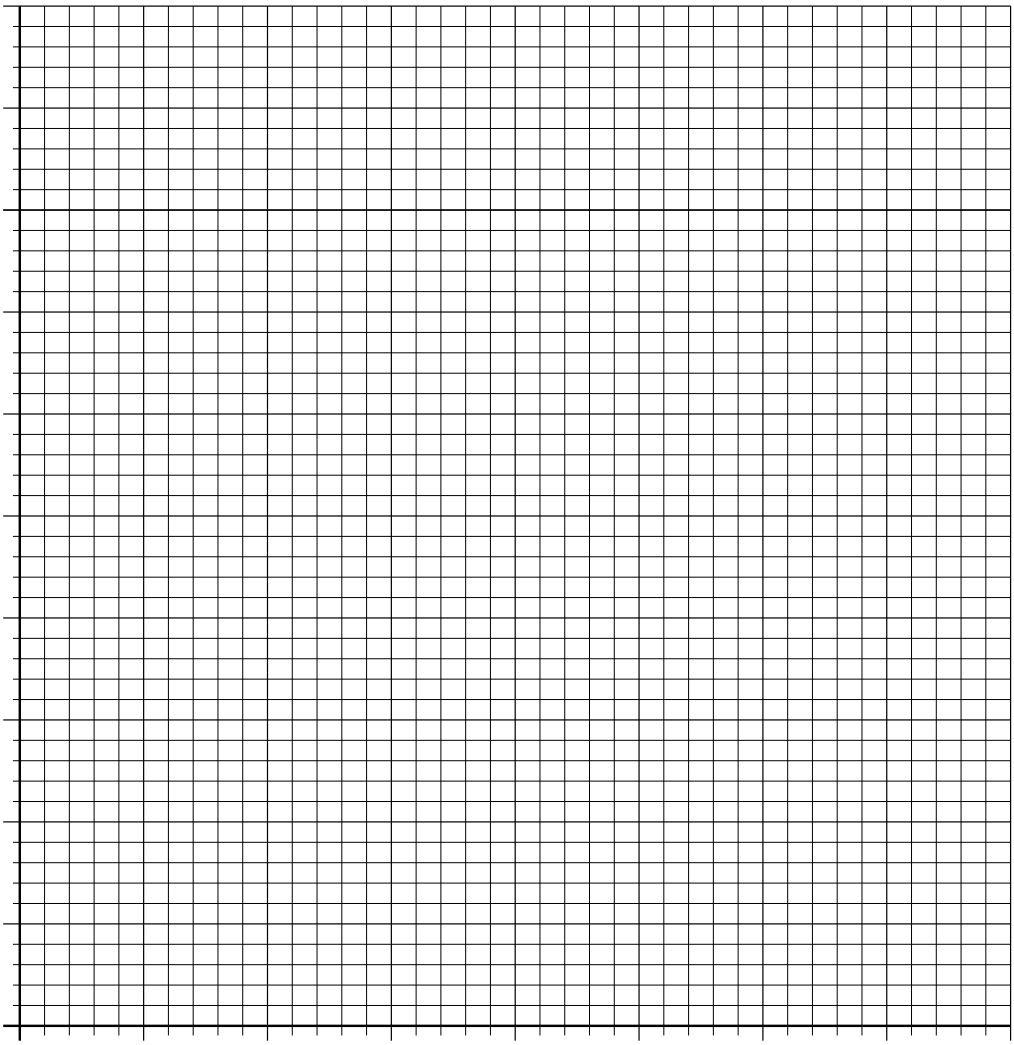
Analysis of results

Plot a graph of time taken for the cross to disappear (vertical axis) against the temperature of sodium thiosulfate used (horizontal axis).



Conclusion: Explain your results. You must include:

- A statement outlining the collision theory.
- A statement linking your results to the collision theory.

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Investigating the Effect of Concentration on Reaction Rate

Concentration is defined as the number of many particles are in a given volume. Concentration is measured in moles per litre (mol L^{-1}).

A *concentrated* acid contains more acid particles and less water particles than a more *dilute* acid.

Increasing the concentration of a solution leads to more collisions (greater frequency of collisions), because the particles are closer together, so the rate of the reaction goes up. In other words, with a more concentrated acid, the number of acid particles is greater, so the number of collisions is greater and the rate of the reaction is higher (faster).

In a less concentrated acid, the number of collisions is lower, so the rate of the reaction is slower.

Changing the concentration of a reactant **does not change** how quickly the particles are moving (i.e. it doesn't increase the amount of kinetic energy they have).

Introduction: In this experiment the effect of concentration on the rate of reaction between sodium thiosulfate and hydrochloric acid is investigated.

Equipment: A conical flask, measuring cylinder, stopwatch, black cross on paper, 0.2 mol L^{-1} sodium thiosulfate, 2.0 mol L^{-1} hydrochloric acid.

Method:

1. Put the 'X' paper on the bench mat, and put the conical flask on top of the paper.
2. Measure 10 mL of sodium thiosulfate solution and put it into the conical flask.
3. Measure 40 mL of water and put it into the conical flask. Swirl the flask to mix the contents.
4. Measure 5 mL of acid. Pour the acid into the flask, start the stopwatch, and swirl the flask. Time how long it takes for the cross to disappear.
5. Wash out the flask thoroughly. Repeat the experiment using the other volumes of sodium thiosulfate and water in the table on the right. Keep the volume of acid the same each time.

Volume of sodium thiosulfate (mL)	Volume of water (mL)
10	40
20	30
30	20
40	10
50	0

Results:

Draw a table for your results here.

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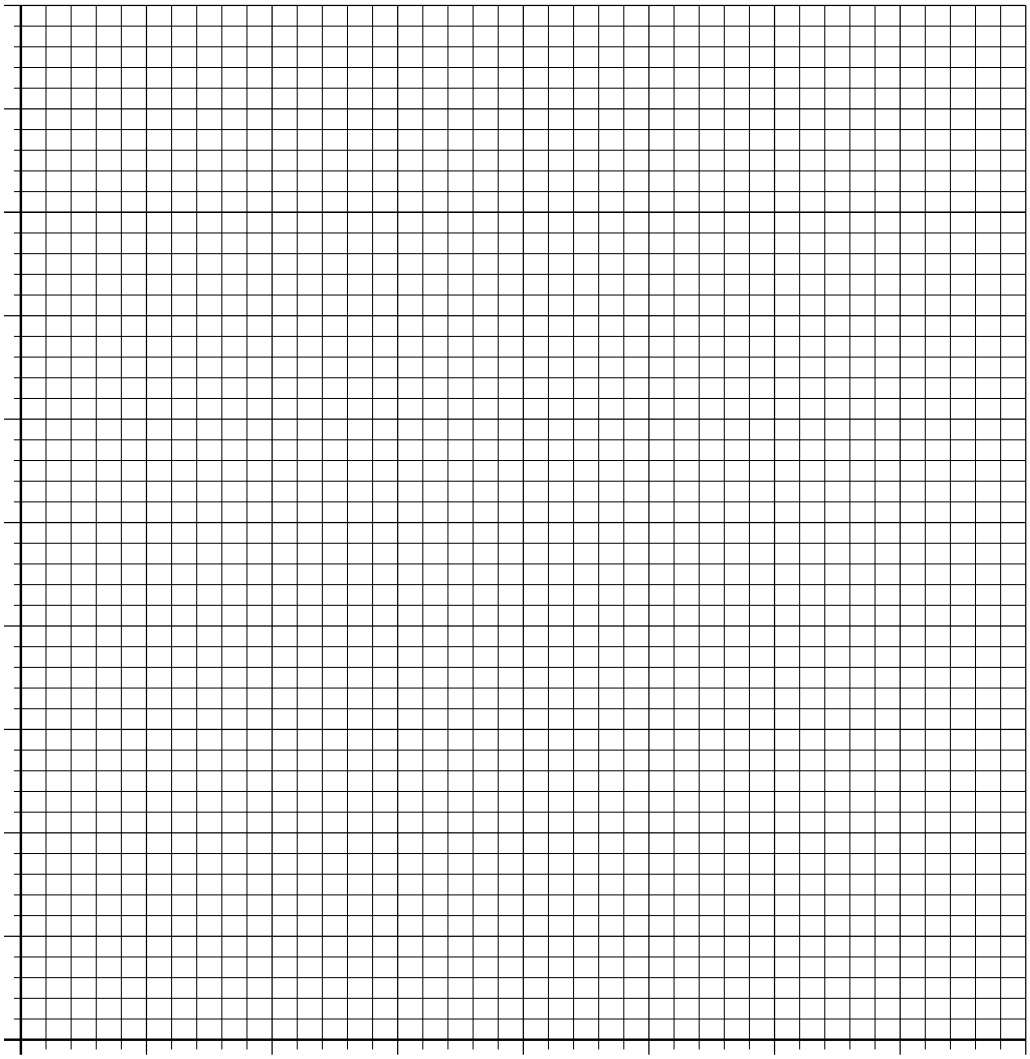
Analysis of results:

Plot a graph of time taken for the cross to disappear (vertical axis) against the volume of sodium thiosulfate used (horizontal axis).



Conclusion: Explain your results. You must include:

- A statement outlining the collision theory.
- A statement linking your results to the collision theory.

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Observing the Effects of Surface Area on Reaction Rate

Solids with a smaller particle size (e.g. powders or small chips) react more quickly than solids with a larger particle size (e.g. large chips).

Reducing the size of particles increases the rate of a reaction because it increases the surface area available for collisions to take place. This increases the number of collisions.

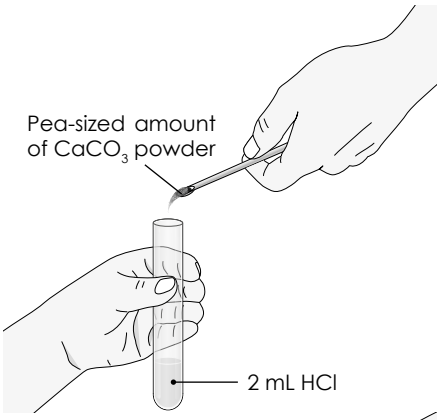
Changing the surface area of a reactant has **no effect** on the energy of the particles.

Aim: To make simple observations during a reaction between calcium carbonate ($CaCO_3$) chips and powder, with hydrochloric acid (HCl).

Equipment: Boiling tube, calcium carbonate chips and powder, 1.0 mol L^{-1} hydrochloric acid (HCl), measuring cylinder, spatula.

Method:

1. Measure 2 mL of hydrochloric acid and pour this into your boiling tube.
2. Holding your boiling tube over a sink or heatproof mat, add a pea-sized amount of calcium carbonate powder to your boiling tube. Record your observations below.



Observations of powdered $CaCO_3$: _____

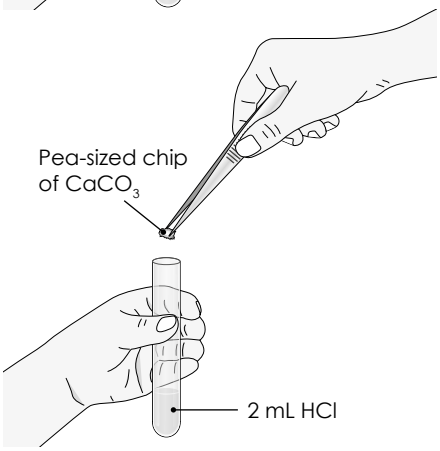
_____

_____

_____

_____

3. Repeat the experiment, but this time use a chip of calcium carbonate that is roughly the same size as the spatula of powder you used previously. Record your observations below.



Observations of $CaCO_3$ chip: _____

_____

_____

_____

_____

Conclusion: Explain your results. You must include:

- A statement outlining the collision theory.
- A statement linking your observations to the collision theory.

_____

_____

_____

_____

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Investigating the Effect of Surface Area on Reaction Rate

It is difficult to qualitatively measure the effect of surface area on reaction rate, especially when it comes to making up at least four evenly spread variables to test by 'crushing up powder'. The amount of reactants must remain the same in order to conduct a fair test. One of the most straight forward chemistry experiments when investigating rates of reaction is to time how long it takes for magnesium ribbon to dissolve in hydrochloric acid. For an investigation into the effect of surface area, we can change the amount of surface area exposed to react by coating various amounts the same sized magnesium ribbon piece with nail polish.

Introduction: In this experiment the effect of surface area on the rate of reaction between magnesium ribbon and hydrochloric acid is investigated.

Equipment: Magnesium ribbon, 1.0 mol L^{-1} hydrochloric acid (HCl), boiling tube, measuring cylinder, stopwatch, nail polish.

% SA exposed	Sides coated in nail polish
25	1.5
50	1.0
75	0.5
100	0
Assume the thickness of the magnesium ribbon is constant.	

Method:

1. Cut magnesium ribbon into 10 mm pieces. You will need 12 pieces in total.
2. Measure 10 mL of hydrochloric acid and pour this into your boiling tube.
3. Place a piece of magnesium ribbon into your boiling tube and time how long the magnesium ribbon takes to disappear. Record your result.
4. Repeat the experiment two more times, using fresh HCl each time.
5. Paint half of one side of a 10 mm piece of magnesium ribbon with nail polish. Wait until it dries. Repeat steps 2 - 4 with the half painted piece of magnesium ribbon.
6. Repeat steps 2 - 4 firstly with magnesium ribbon completely painted on one side, then with magnesium ribbon painted completely on one side AND half of the other.
7. Find the mean of your data collected at each variable tested.

Results:

Draw a table for your results here.

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Analysis of results:

Plot a graph of time taken for the magnesium ribbon to disappear (vertical axis) against the percent of surface area exposed (horizontal axis).

Conclusion: Explain your results. You must include:

- A statement outlining the collision theory.
- A statement linking your observations to the collision theory.

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Catalysts

A catalyst is a substance that speeds up a reaction, but is chemically unchanged at the end of the reaction. When the reaction has finished, you would have exactly the same mass of catalyst as you had at the beginning.

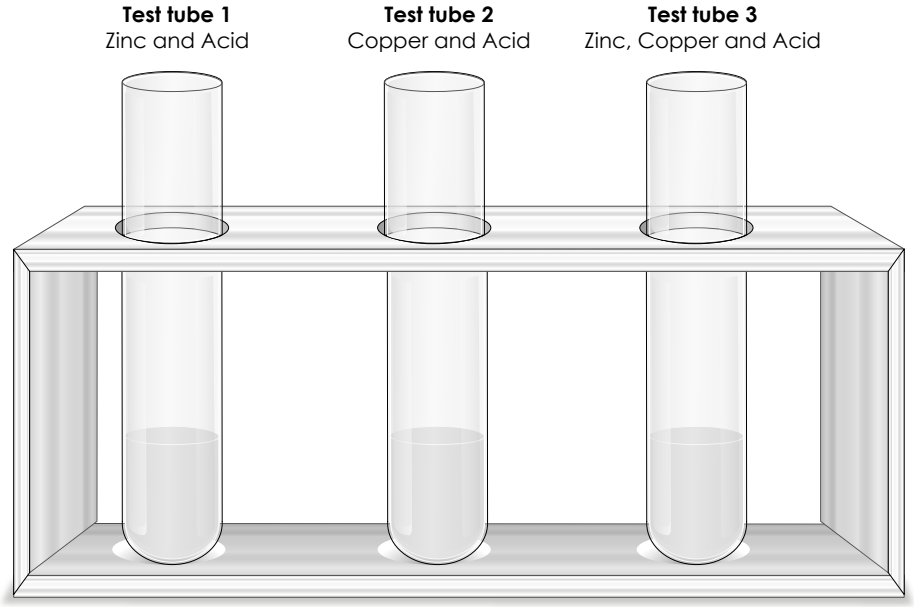
Observing the Effect of a Catalyst on a Chemical Reaction

Aim: To observe the effects of a copper catalyst on the reaction between zinc and sulfuric acid.

Equipment: Three test tubes, test tube rack, 10 mL measuring cylinder, dropping pipette, granulated zinc, copper turnings or powder, dilute sulfuric acid (H_2SO_4).

Method:

1. Add roughly the same mass of zinc to test tubes 1 and 3.
2. Add roughly the same mass of copper to test tubes 2 and 3.
3. Add 5 mL of dilute sulfuric acid to test tube 1. Note the rate of production of gas bubbles.
4. Add 5 mL of the acid to test tube 2. Note the rate of production of gas bubbles.
5. Add 5 mL of the acid to test tube 3. Note the rate of production of gas bubbles.



Observations		
Test tube 1	**Test tube 2**	**Test tube 3**

1. Define the term '*catalyst*': _____

2. Outline the purpose of test tube 2. _____

3. Suggest a method to show that the copper was not used up in the reaction occurring in test tube 3. _____

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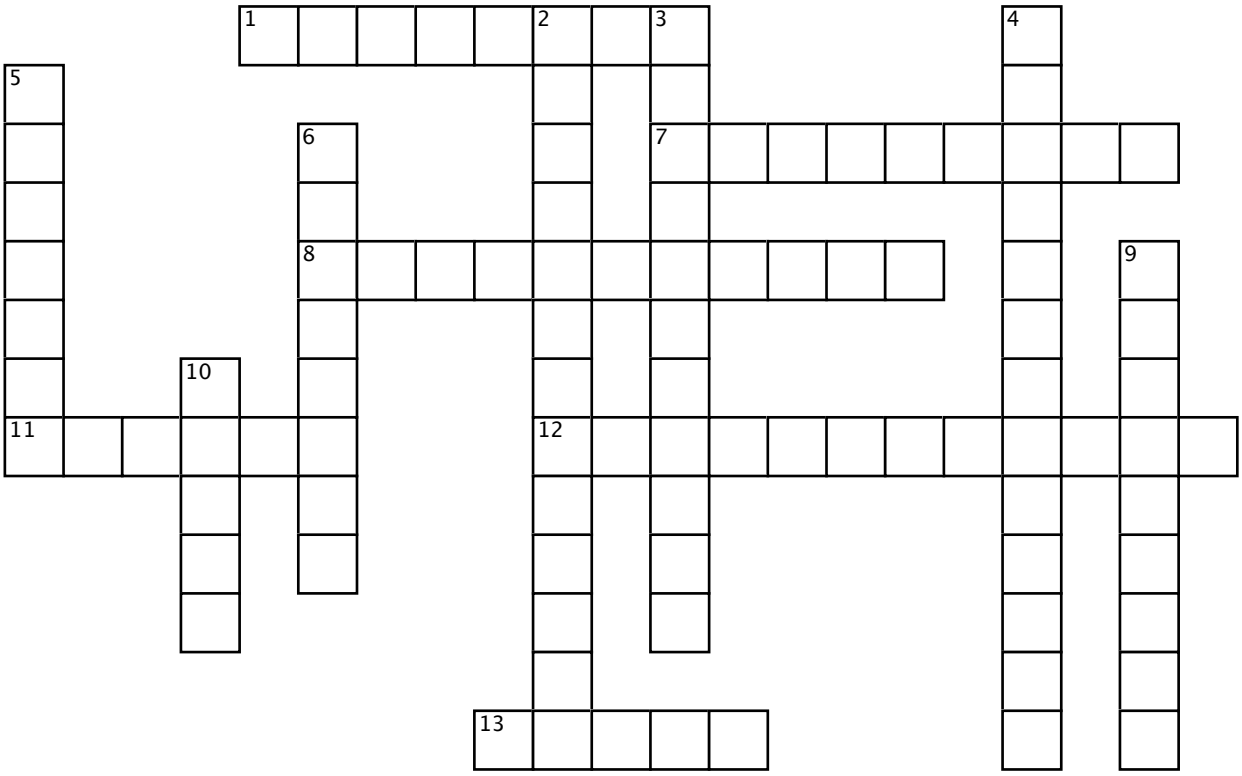
End of Chapter Puzzles

1. Use the clues to solve both the crossword and the word-find.



Across

1. The chemicals that are formed by a chemical reaction.
7. A name for the "ingredients" in a chemical reaction.
8. Increasing this increases the particle's kinetic energy.
11. The faster a particle is moving, the more of this it has.
12. How quickly chemicals form or change in a chemical reaction.
13. In order for a reaction to occur particles must collide with enough energy and at the correct _ _ _ _ _

Down

2. Increasing this means increasing the number of particles in a given volume.
3. Cutting or grinding up a reactant increases this.
4. The amount of particles in a given volume.
5. Particles must do this in order to react.
6. These speed up reactions but are not used up in the reaction.
9. All matter is made of these.
10. Used to symbolise a chemical reaction in an equation.

C	T	I	Z	B	T	C	G	G	G	X	W	M	N	G	R	O	Y	B	L	I	F	N	W	J
X	O	P	O	W	Q	O	O	R	S	U	R	F	A	C	E	A	R	E	A	K	Z	T	R	D
J	R	N	P	B	K	Q	Z	N	C	E	P	C	A	T	A	L	Y	S	T	I	P	Q	E	Z
Y	U	C	C	R	H	P	F	B	C	R	E	A	C	T	I	O	N	R	A	T	E	T	A	A
H	G	M	C	E	O	T	E	M	P	E	R	A	T	U	R	E	E	N	E	R	G	Y	C	A
P	J	C	H	V	N	D	W	U	X	G	N	H	I	X	B	V	Z	B	Q	V	D	T	T	F
A	S	U	S	S	M	T	U	I	A	Z	W	T	Y	Y	X	J	H	S	M	T	D	S	A	O
F	N	W	B	Z	P	O	R	C	B	H	P	A	R	T	I	C	L	E	S	V	I	M	N	F
X	Y	G	L	G	Q	B	W	A	T	S	H	E	Y	A	G	C	O	L	L	I	D	E	T	S
B	O	C	L	P	U	D	Q	M	T	S	L	T	S	K	T	N	Z	T	L	U	Q	U	S	S
Z	D	H	N	E	Y	F	V	G	U	I	P	C	S	K	P	I	F	Z	T	R	C	N	O	G
D	L	Y	Y	H	G	Z	U	P	W	O	O	U	B	V	O	E	O	S	K	R	D	D	A	G
Z	A	R	R	O	W	P	B	K	K	M	B	N	O	S	R	U	B	N	G	X	U	X	C	I

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Rates of Reactions Chapter Review

Use the boxes to write down the key points from this chapter. Ensure that all key words from the front of the chapter have been used.

Particle Theory and Collision Theory

Effect of Concentration on Reaction Rates

Effect of Temperature on Reaction Rates

Effect of Catalysts on Reaction Rates

Effect of Surface Area on Reaction Rates

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End of Chapter Review Questions

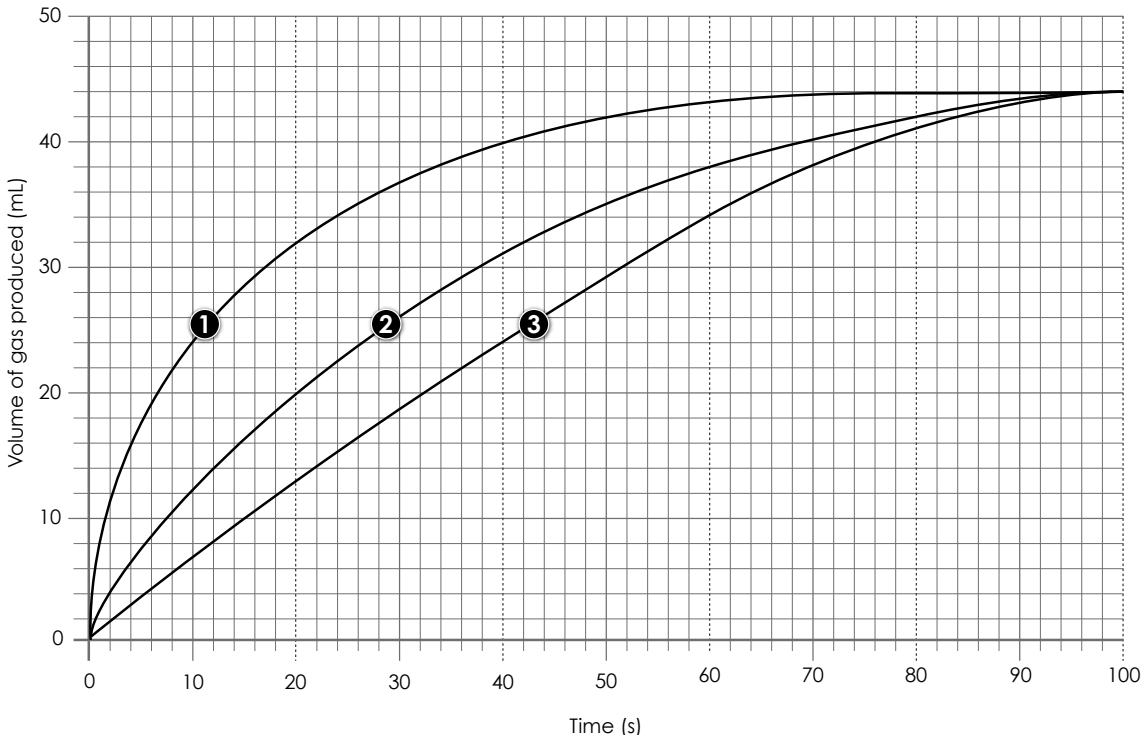
1. Choose the statement that best describes the collision theory.
   (a) When two or more particles collide there is often a reaction.
   (b) Random collisions between particles result in random reactions.
   (c) Particles need to collide with enough energy and at the correct angle to react.
   (d) Reactions occur because particles are moving.

2. There are four factors that may affect the rate of a chemical reaction. Complete the table by writing in the factor that is being described.

Factor	Description
	There are more particles to collide.
	Particles are moving faster so there are more collisions and these collisions occur with more energy.
	The reaction requires less energy to start.
	There are more particles exposed for other reactant particles to collide with.

3. In terms of rates of reaction, outline why:
   (a) Food lasts longer if it is stored in the freezer. _____
   _____
   _____
   (b) Wood burns easier if it is split into kindling. _____
   _____
   _____

4. The graph below shows the results of an investigation into the effects of surface area on reaction rate. The student used three different sizes of calcium carbonate - 4 mm chips, 2 mm chips and powdered. The calcium carbonate was reacted with hydrochloric acid. The rate at which carbon dioxide gas was produced was recorded and graphed.



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(a) Write an aim for this investigation. _____

_____

(b) Outline which variables would need to be controlled (kept the same) during this investigation.

_____

_____

_____

(c) Complete the chemical equation for this reaction by adding in the formula of the missing compounds and then balancing the overall equation.

_____ + HCl ⟶ $CaCl_2$ + H_2O + _____

(d) Which line on the graph represents the powdered calcium carbonate? _____

(e) Justify your answer to (d). _____

_____

_____

(f) Calculate the volume of CO_2 produced at the following stages of the investigation.

Experiment Number	Time				
	20 Seconds	40 Seconds	60 Seconds	80 Seconds	100 Seconds
1					
2					
3					

(g) Explain why the final volume of CO_2 produced was the same for all three experiments.

_____

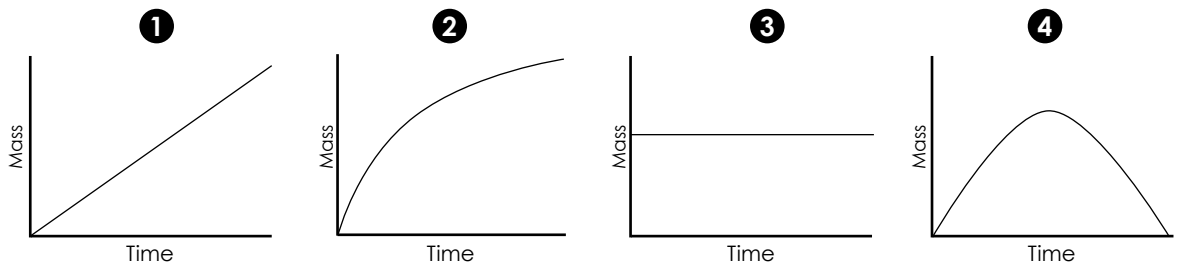
_____

_____

5. Hydrogen peroxide is a poisonous compound which gradually decomposes (breaks down) into water and oxygen gas. The rate of this reaction can be increased if some manganese dioxide is added.

(a) What is the role of manganese dioxide? _____

(b) Which of the graphs below represent what happens to the mass of the manganese dioxide as the reaction proceeds? Give a reason for your answer.



Graph number: _____

Reason for your choice: _____

_____

_____

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6. A 3 mm diameter pellet of zinc was added to a 100 mL beaker containing 50 mL of 2.0 mol L^{-1} hydrochloric acid. The experiment was conducted at 40°C.

For each change listed below, outline how the reaction rate will be affected. Use the words *increase*, *decrease* or *stays the same* for your answers.

Change One

(a) The experiment was conducted at 20°C.

Effect: _____

Change Two

(b) The experiment was carried out in a 200 mL conical flask.

Effect: _____

Change Three

(c) The experiment was repeated using three smaller zinc pellets that together had the same mass as the original 3 mm pellet.

Effect: _____

Change Four

(d) The experiment was repeated using 3.0 mol L^{-1} hydrochloric acid.

Effect: _____

Change Five

(e) 20 mL of water was added to the beaker before the experiment was repeated.

Effect: _____

Change Six

(f) The experiment was conducted at 60°C.

Effect: _____

7. Explain the effect on the reaction rate change for "Change One" and "Change Three" from the previous question. You should use the word "particles" and "collisions" in your answer.

(a) Explanation for Change One: _____

(b) Explanation for Change Three: _____

Hints for answering these NCEA style questions

The temperature has *decreased*.

The size of the flask has increased.

The surface area has *increased*.

The concentration of the acid has *increased*.

The concentration of the acid has *decreased*.

The temperature has *increased*.

State the collision theory.

Outline the effect of *decreasing* the temperature on particle collisions, and then on reaction rate.

State the collision theory.

Outline the effect of *increasing* the surface area on particle collisions, and then on reaction rate.

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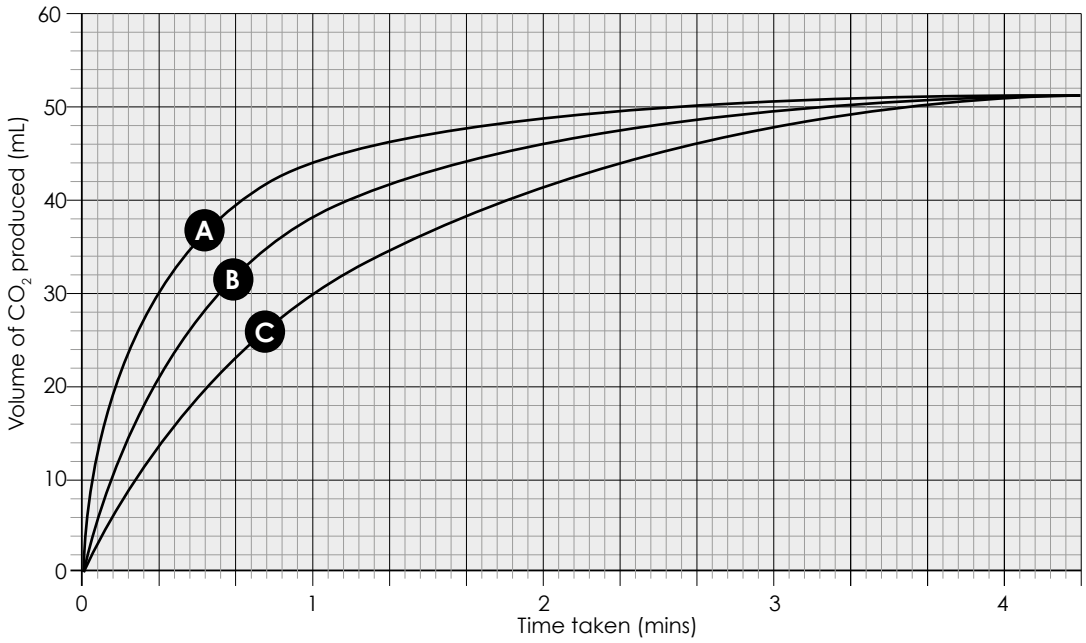
8. Calcium carbonate reacts with dilute hydrochloric acid as shown in the equation:

$$CaCO_{3(s)} + 2HCl_{(aq)} \longrightarrow CaCl_{2(aq)} + H_2O_{(l)} + CO_{2(g)}$$

The rate at which this reaction takes place can be studied by measuring the amount of carbon dioxide gas produced. The graphs below show the results of three experiments, A, B and C. In each experiment the amount of calcium carbonate, the volume of acid and the concentration of the acid were kept the same but the temperature of the acid was changed each time. The calcium carbonate was in the form of small, 4 mm chips.

Volume of CO_2 produced when $CaCO_3$ reacts with hydrochloric acid at three different temperatures



(a) Which line, A, B or C, shows the results of the experiment in which the acid had the highest temperature?

Experiment: _____

Explain your answer. _____

(b) (i) In experiment B, how did the rate of reaction change after one minute compared with the rate of reaction after two minutes? _____

(ii) Explain why the reaction rate changes during experiment B. _____

Hints for answering these NCEA style questions

State the collision theory.

Outline the effect of increasing the temperature on particle collisions, and then on reaction rate.

Use the data (i.e. numbers) from the graph in your answer.

State the collision theory.

Use the words "particles", "reactants", and "product" in your answer

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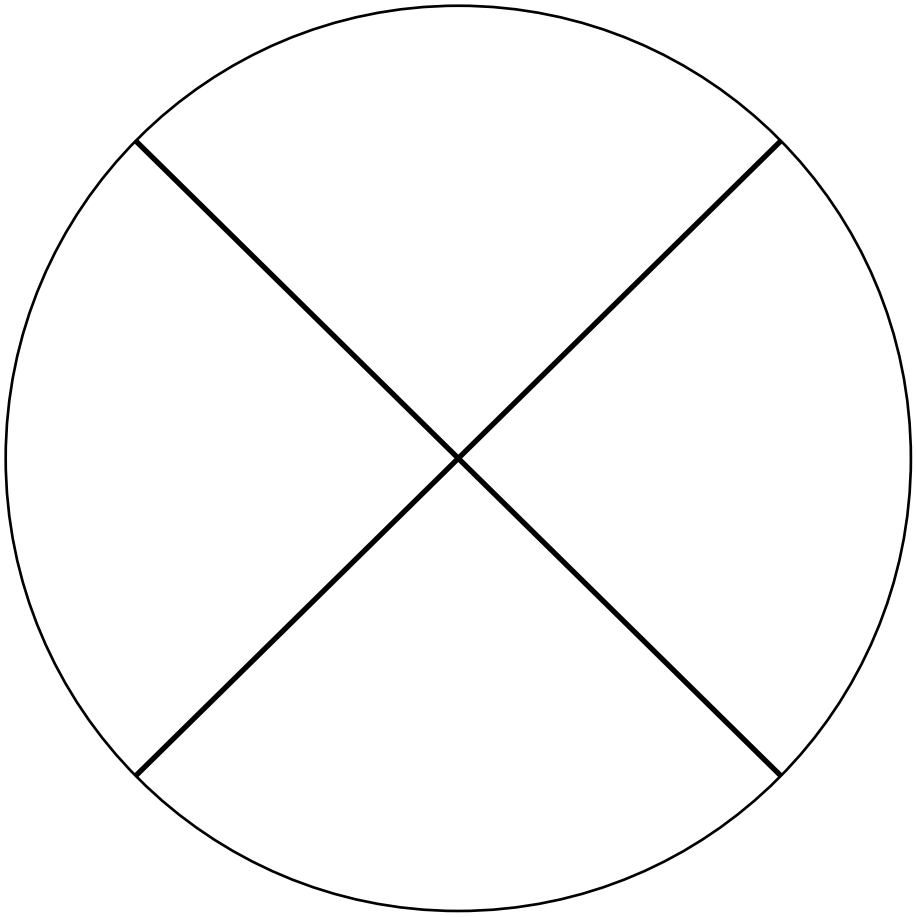
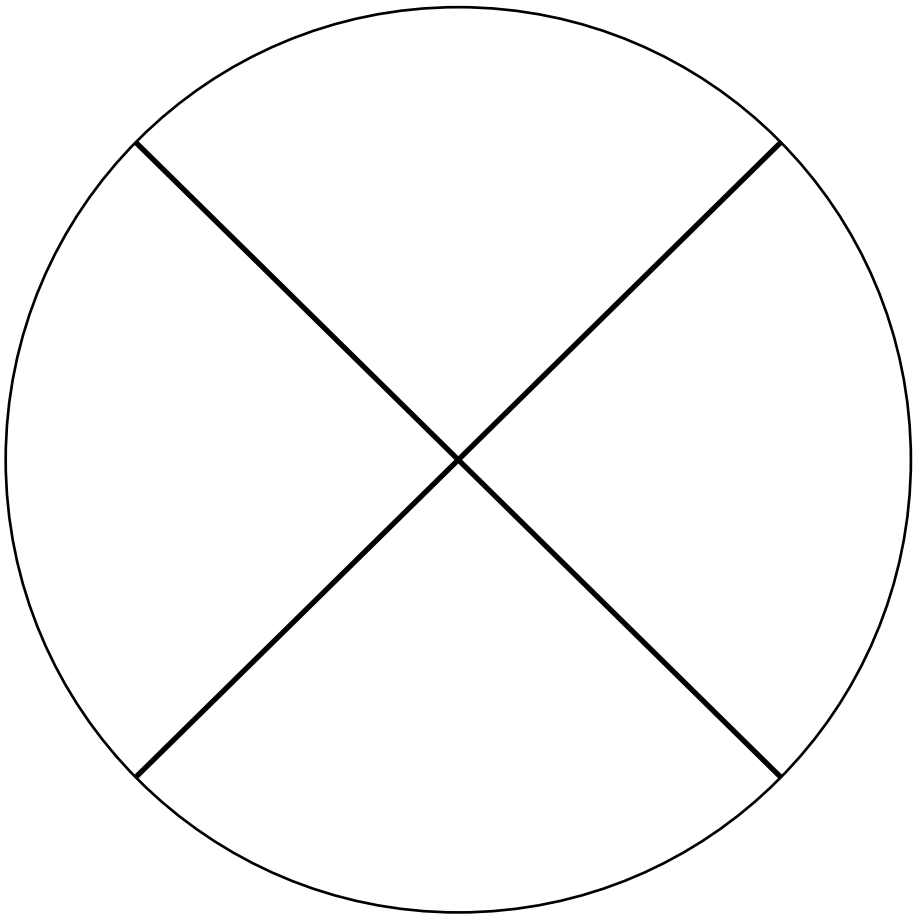
Crosses for Reaction Rate Experiments





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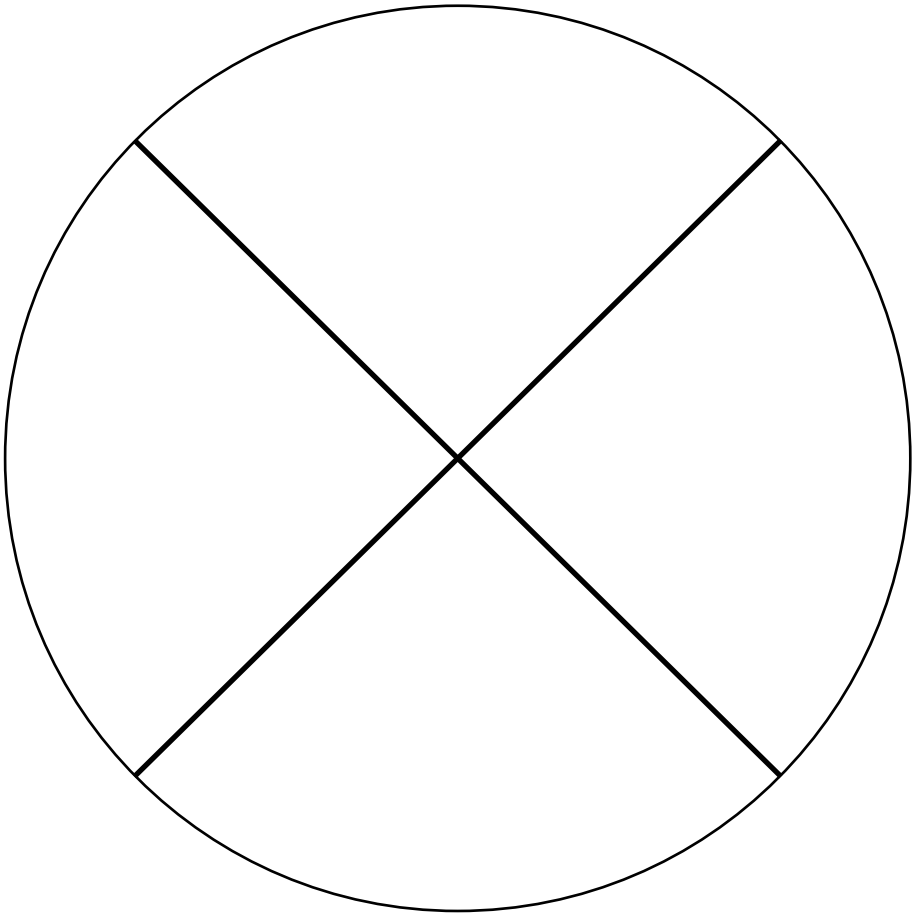
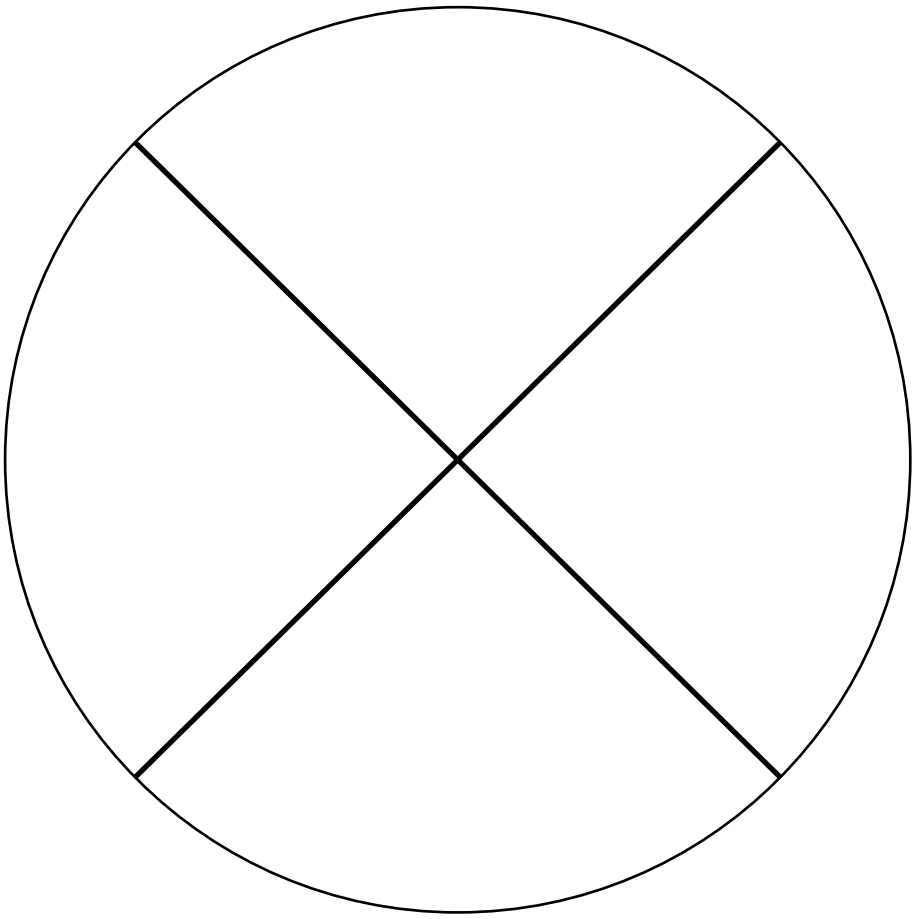
Crosses for Reaction Rate Experiments





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ACIDS AND BASES

By the end of this chapter you should be able to:

	I KNOW THIS ALREADY	I LEARNED THIS	I REVISED THIS
Define the terms '*acid*', '*base*' and '*alkali*'.			
Name and write the *formulae* of three common laboratory acids.			
Use a range of *indicators* to classify substances as acid, alkali or neutral.			
Classify *acids* and *alkalis* as chemicals with distinct properties and uses.			
Use the *pH scale* to compare the acidity and alkalinity of different solutions.			
Name and write the formulae for various *metal oxides*, *metal hydroxides*, *metal carbonates* and *hydrogen carbonates*.			
Describe *neutralisation* reactions.			
Identify the products of *neutralisation* reactions.			
Write *word* and *symbol* equations for a range of reactions involving acids and bases.			
Describe some *everyday uses* of acids, alkali and neutralisation.			

Key Terms

Acid

My Definition: _____

_____

Base

My Definition: _____

_____

Alkali

My Definition: _____

_____

Concentrated

My Definition: _____

_____

Dilute

My Definition: _____

_____

Neutralisation

My Definition: _____

_____

Salt

My Definition: _____

_____

Dissociation

My Definition: _____

_____

pH Scale

My Definition: _____

_____

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Acids

Acids are substances composed of one or more hydrogen atoms chemically bonded to one, or a group of, non-metal atoms. For example, sulfuric acid (H_2SO_4) is composed of two hydrogen atoms (H) bonded to a sulfate group (SO_4^{2-}).

When an acid molecule is added to water, it will *dissociate* (break apart) into its ions. For example, hydrochloric acid is a solution of hydrogen chloride (HCl) in water. The HCl molecule dissociates into hydrogen ions (H^+) and chloride ions (Cl^-).

Strong acids completely dissociate, releasing all of their hydrogen ions when they come into contact with water. The common laboratory acids (hydrochloric, sulfuric and nitric acids) are all strong acids. *Weak acids*, on the other hand, do not completely dissociate and only release some of their hydrogen ions when they come into contact with water. Organic acids (acetic, citric and other carboxylic acids) are weak acids.

1. Acids share a number of common properties. Identify these properties by crossing out the incorrect terms from the following list.

   (a) Food acids have a *sweet* / *sour* taste.

   (b) Acids are *corrosive* / *flammable*.

Remember an 'ion' is a charged particle because it has lost or gained electrons.

2. Define the term '*dissociate*'. _____

3. (a) Name the three common laboratory acids.

   (i) _____

   (ii) _____

   (iii) _____

   (b) State the ions formed when the acids named above dissociate.

   (i) _____

   (ii) _____

   (iii) _____

4. Name the *ion* common to all acids. _____

5. Compare and contrast the terms *strong acid* and *weak acid*. _____

6. Identify which acid in each pair is the *strongest*.

   (a) Acetic acid or nitric acid _____

   (b) Sulfuric acid or a carboxylic acid _____

   (c) Citric acid or hydrochloric acid _____

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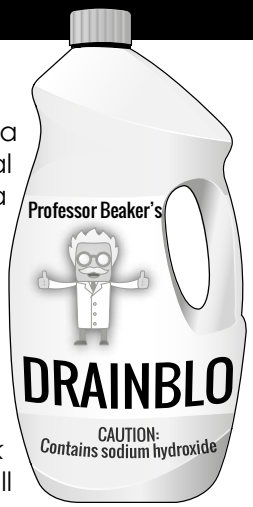
Bases



Bases can be described as '*acid opposites*'. They will remove hydrogen ions from a solution. They are usually metal oxides, metal hydroxides, metal carbonates or metal hydrogen carbonates. Many bases are *insoluble* - they do not dissolve in water. If a base does dissolve in water we call it an *alkali*. For example, copper oxide is a base because it will react with acids, but it is not an alkali because it does not dissolve in water. However, sodium hydroxide is a base because it will react with acids and it is also an alkali because it dissolves in water.

Alkalis *dissociate* when placed into water and create hydroxide (OH^-) ions.

Strong alkalis completely dissociate when they come into contact with water. Hydroxides of any of the group 1 metals (Li, Na, K, etc.) are strong alkalis. *Weak alkalis,* on the other hand, do not completely dissociate and only release a small number of hydroxide ions.

1. Describe the difference between a *base* and an *alkali*. _____

2. Alkalis share a number of common properties. Identify these properties by crossing out the incorrect terms from the following list.
   (a) Alkalis have a *bitter* / *salty* taste.
   (b) Alkalis feel *soapy* / *prickly* on the skin.

3. (a) Describe the difference between a *strong alkali* and a *weak alkali*. _____
   (b) Name three strong alkalis found in the laboratory.
      (i) _____
      (ii) _____
      (iii) _____
   (c) State the ions released when the alkalis named above dissociate.
      (i) _____
      (ii) _____
      (iii) _____

4. Name the *ion* common to all solutions of alkalis. _____

5. Name a product that would be formed if an alkaline solution containing hydroxide ions (OH^-) was added to a solution containing hydrogen ions (H^+) ions. _____

6. Suggest why the following household items are usually alkaline.
   (a) Oven cleaner. _____
   (b) Indigestion tablets. _____

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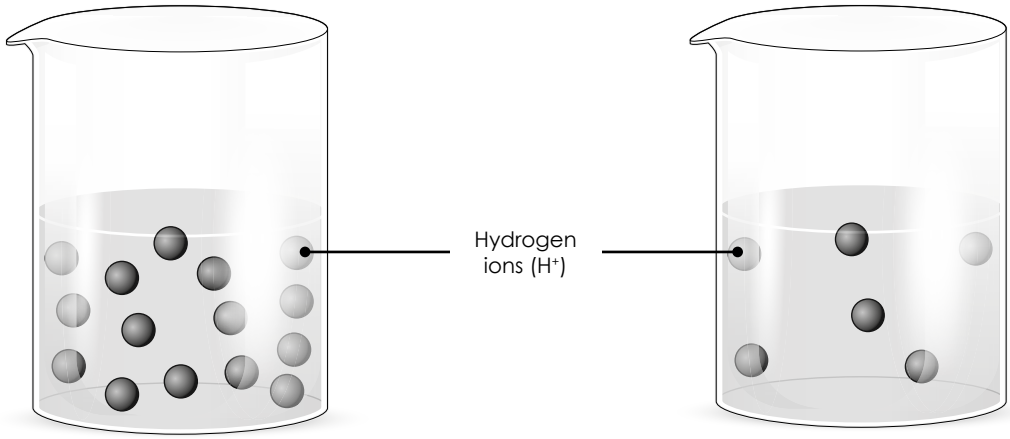
Concentrated and Dilute

The strength of an acid or an alkali does not change depending on concentration. Concentration is a measure of *how many* acid/alkali particles there are per unit volume of water. Students often confuse the terms concentrated with strong and dilute with weak when discussing acids and alkalis. The terms '*concentrated*' and '*dilute*' refer to how much of an acid or an alkali has been added to water.

The reactivity of an acid/alkali is determined by the concentration of ions in the solution. Therefore, concentrated acids/alkalis solutions are more reactive than dilute acids/alkalis of the same type.

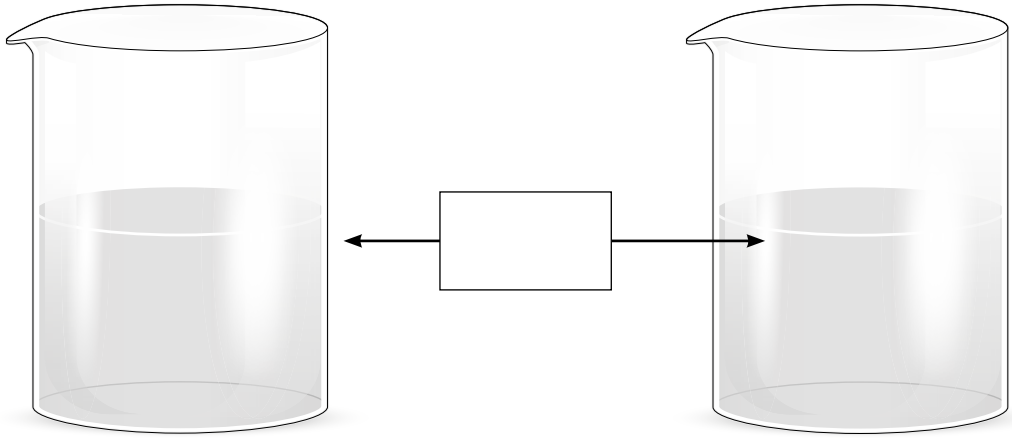


Concentrated Acid

A large amount of hydrogen ions in a volume of water.

Dilute Acid

A small amount of hydrogen ions in a volume of water.



Concentrated Alkali

_____

_____

_____

Dilute Alkali

_____

_____

_____

1. Complete the diagram of the concentrated and dilute alkalis.
2. Is it possible to have a *dilute* solution of a *strong* acid? Explain your answer. _____

_____

_____

_____

_____

_____

_____

_____

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The pH Scale

The pH scale is used to represent the concentration of acids and bases. pH values have no units and generally range from 0 to 14. A pH of 7 is given to neutral solutions. Solutions with a pH *less* than 7 are acids, whereas solutions with a pH greater than 7 are alkaline.

pH is a measure of the concentration of hydrogen ions in a solution. The more hydrogen ions present, the more acidic is the solution.

The pH scale is logarithmic. Each unit on the pH scale represents a tenfold change in acidity. For example, a solution with a pH of 4 is ten times more acidic than a solution with a pH of 5, and 100 times more acidic than a solution with a pH of 6.

1. Complete the following paragraph about the pH scale.

   The _____ scale is used to _____ how acidic or basic a solution is. A very strong acid can have a pH of _____ and a strong base will have a pH of _____. Solutions such as pure water have a pH of 7, meaning they are _____.

2. Match the correct description to each pH number.

pH 1 •	• slightly basic/alkaline
pH 5 •	• neutral
pH 7 •	• strongly basic/alkaline
pH 9 •	• slightly acidic
pH 14 •	• strongly acidic

Indicators

Chemists use indicators to show visually whether a solution is acidic, neutral or alkali. A number of natural dyes change colour, depending on whether they are placed in an acid or base.

Litmus Indicator - Litmus indicator solution turns red in acidic solutions and blue in alkaline solutions. Litmus also comes in a paper form. Blue litmus paper will turn red in an acidic solution and remain blue when added to an alkali solution. Litmus does not tell you how strong the acid or alkali is.

Universal Indicator - Universal indicator shows us how strongly acidic or alkaline a solution is. This is measured using the pH scale. Universal indicator has many different colour changes, from red for strong acids to dark purple for strong bases. In the middle, neutral is indicated by green.

1. Outline the purpose of an '*indicator*'. _____

   _____

2. A student tested a number of solutions with indicators. Write down what the tests suggest about the acidity or alkalinity of the various solutions.

   (a) Solution 1 tested with blue litmus paper and the paper remained blue. _____

   _____

   (b) Solution 2 tested with blue litmus paper and the paper turned red. _____

   _____

   (c) Solution 3 tested with universal indicator. It went dark purple. _____

   _____

   (d) Solution 4 tested with universal indicator, it remained green. _____

   _____

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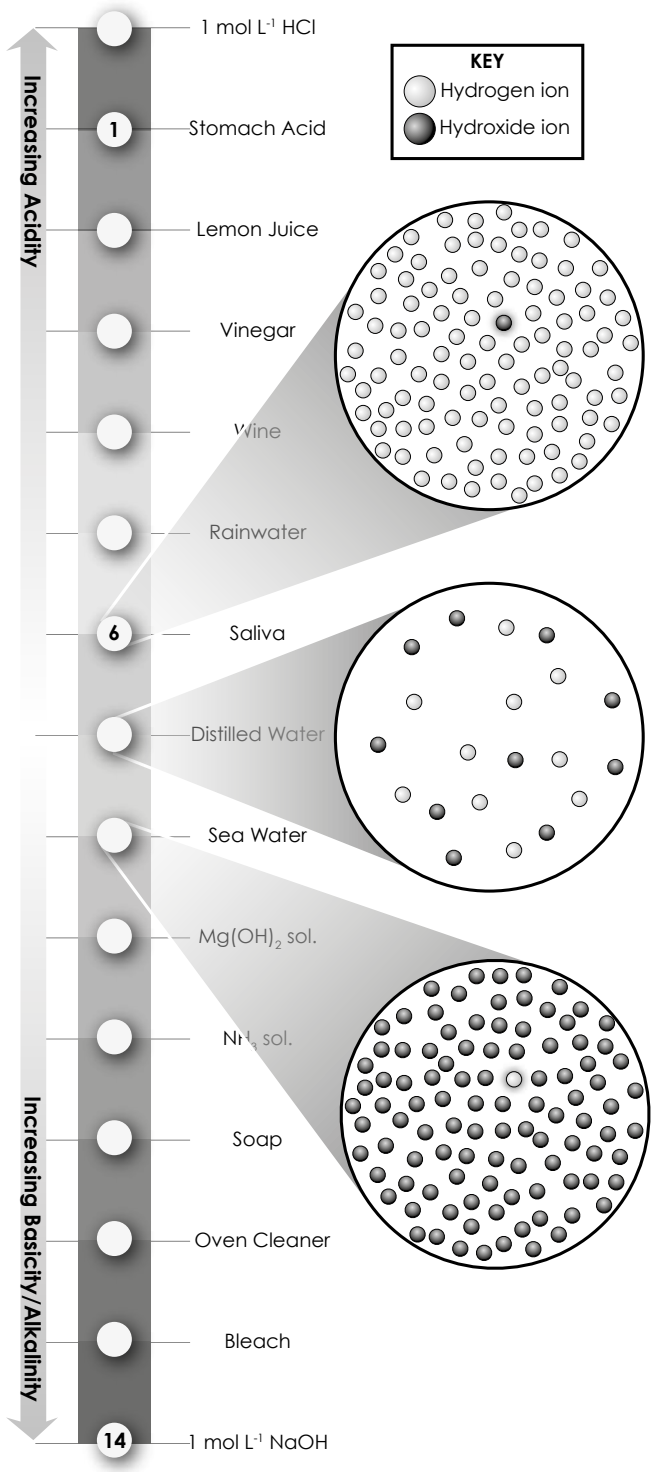
pH and Indicators Summary

1. Complete the diagram below by:
   (a) Using the numbers 0 - 14 to complete the pH range.
   (b) Calculating the H^+ concentration relative to pH 7.
   (c) Colouring in or naming the colours of each pH in universal indicator.
   (d) Colouring in or naming the colours of each pH in litmus.

Colour in Litmus	Colour in U.I.	H^+ concentration relative to pH 7	pH range	Examples
_____	_____	_____		1 mol L^{-1} HCl
_____	_____	_____	1	Stomach Acid
_____	_____	_____		Lemon Juice
_____	_____	_____		Vinegar
_____	_____	_____		Wine
_____	_____	_____		Rainwater
_____	_____	10	6	Saliva
_____	_____	1		Distilled Water
_____	_____	1/10		Sea Water
_____	_____	1/100		$Mg(OH)_2$ sol.
_____	_____	1/1 000		NH_3 sol.
_____	_____	1/10 000		Soap
_____	_____	1/100 000		Oven Cleaner
_____	_____	1/1 000 000		Bleach
_____	_____	1/10 000 000	14	1 mol L^{-1} NaOH



2. Cross out the incorrect terms from the following sentences.
   (a) Acids have a *high* / *low* pH and turn *red*/*blue* in universal indicator.
   (b) The higher the pH, the *more* / *less* hydrogen ions there are in solution.
   (c) Alkalis turn red litmus *blue* / *red*.

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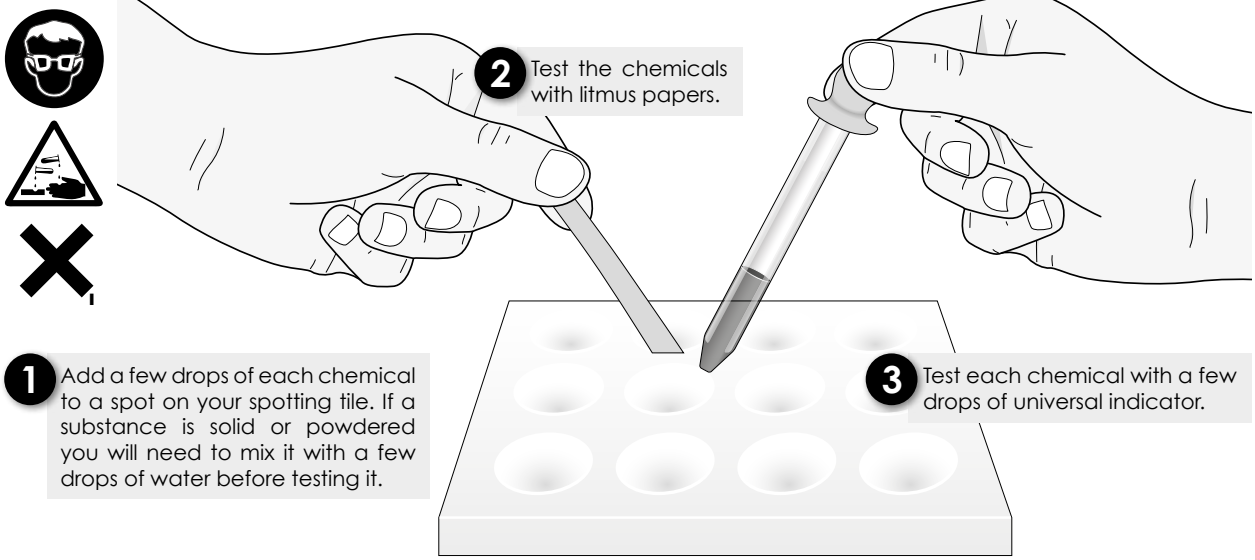
Testing pH

Aim: To test the pH of a range of household chemicals.

Equipment: A variety of household chemicals, spotting tile, red litmus paper, blue litmus paper, universal indicator solution, safety glasses.

Method:



Results:

Chemical being tested	Colour in blue litmus	Colour in red litmus	Colour in universal indicator

Conclusion:

Chemical being tested	Acid or base?	Evidence from investigation

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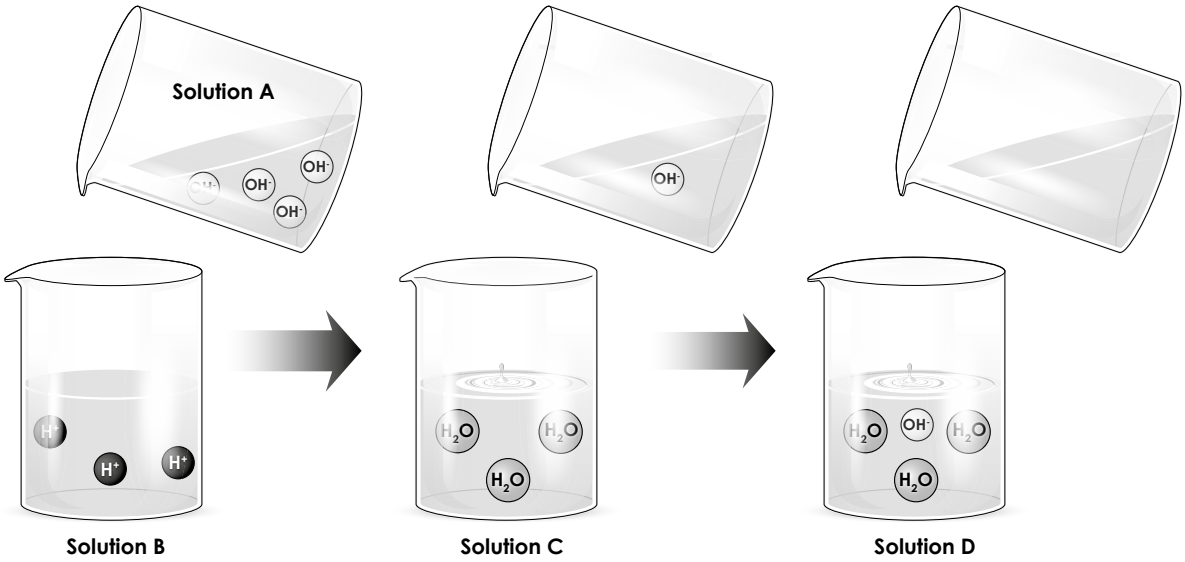
Neutralisation

A chemical reaction occurs when you mix together an acid and a base. The base cancels out the effects of the acid. The reaction is called a '*neutralisation*' reaction because a neutral (pH 7) solution is made if you add just the right amount of acid and base together.

As previous discussed, when an alkali dissociates in water it releases hydroxide (OH^-) ions and when an acid dissociates it produces hydrogen (H^+) ions. When hydroxide ions collide with hydrogen ions, water is produced.



1. With reference to "Solution A", state:
   (a) The ions present. _____
   (b) The possible pH range of the solution. _____
   (c) Whether it is an acid, alkali or neutral? _____
2. With reference to "Solution B", state:
   (a) The ions present. _____
   (b) The possible pH range of the solution. _____
   (c) Whether it is an acid, alkali or neutral? _____
3. With reference to "Solution C", state:
   (a) The ions present. _____
   (b) The possible pH range of the solution. _____
   (c) Whether it is an acid, alkali or neutral? _____
   (d) Justify your answer to (c). You should describe the reaction that has occurred and use the term 'ions' in your answer. _____
4. In terms of the pH and ions present in solution, explain what has happened to create "Solution D" from "Solution B". _____

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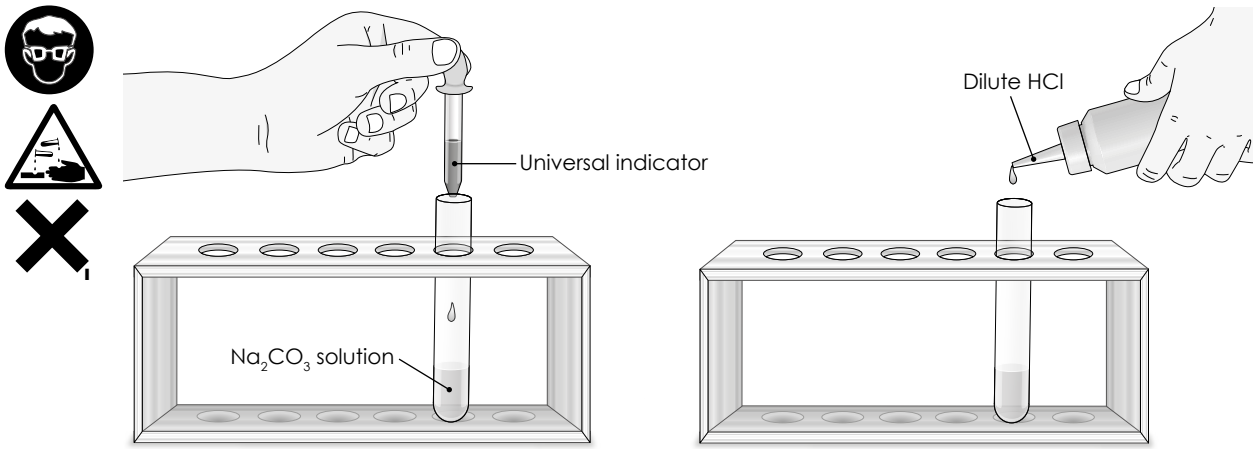
Observing Neutralisation

Aim: To observe a neutralisation reaction.

Equipment: A test tube, test tube rack, 1 mol L^{-1} Na_2CO_3 (sodium carbonate), 1 mol L^{-1} HCl (hydrochloric acid), dropper or dropper bottle, universal indicator solution.

Method:



1. Add approximately 1-2 mL of Na_2CO_3 and place the test tube into the test tube rack. Add 3-5 drops of universal indicator solution.
2. Using a dropper bottle, add HCl drop by drop. Be careful because adding even a small amount of extra acid can mean you'll miss the neutralisation point.

Observations: _____

_____

_____

_____

_____

_____

1. What colour is universal indicator solution in Na_2CO_3 solution? _____
2. Is Na_2CO_3 an acid or an alkali? _____
3. The products of this reaction are sodium chloride, carbon dioxide and water. Write a word equation for this reaction.

   _____
4. Using your observations, what evidence was there to indicate that carbon dioxide was produced? _____
5. How did you know when complete neutralisation had occurred? _____

   _____
6. Describe what you would observe if too much acid was added during step 2. _____

   _____
7. You enter the laboratory to find a large puddle of an unknown liquid on your workbench. You suspect it is an acid spill. Describe how you could test to determine if it is an acid and outline how it could be made safe before wiping it up. _____

   _____

   _____

   _____

   _____

   _____

   _____

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Salts

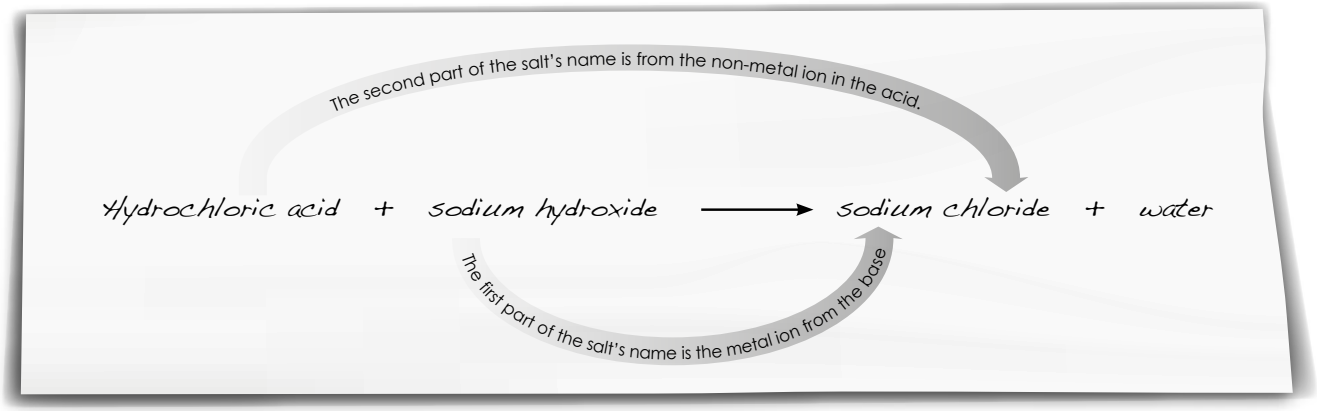
Salts are formed when acids reacts with metals, bases or carbonates. Salts are ionic substances composed of a positively charged metal ion and a negatively charged non-metal ion. Salts have relatively high melting points and many are soluble in water.

One of the most common salts is sodium chloride (NaCl), otherwise known as "table salt".

A salt is always made when an acid is neutralised by a base. The general equation for most neutralisation reactions is:

Acid + Base ⟶ Salt + Water

The exact salt made depends upon which acid and base were used. For example, sodium chloride (NaCl) is produced during the neutralisation reaction between hydrochloric acid and sodium hydroxide.



There are three common laboratory acids, so figuring out the second part of any salt produced by these acids is easier if you learn the following table.

Acid	Acid Formula	Salt Produced	Anion Formula
Hydrochloric acid	HCl	Chlorides	Cl^-
Sulfuric acid	H_2SO_4	Sulfates	SO_4^{2-}
Nitric acid	HNO_3	Nitrates	NO_3^-

Memorise this!

1. Complete the following questions by writing in the name of the salt produced.

(a) Nitric acid + sodium hydroxide — Sodium nitrate

(b) Nitric acid + magnesium hydroxide _____

(c) Sulfuric acid + iron(III) hydroxide _____

(d) Sulfuric acid + zinc hydroxide _____

(e) Hydrochloric acid + sodium hydroxide _____

(f) Hydrochloric acid + lead hydroxide _____

(g) Sulfuric acid + calcium hydroxide _____

(h) Nitric acid + nickel hydroxide _____

(i) Hydrochloric acid + copper(II) hydroxide _____

2. Complete the following by writing the name of the acid used to produce the following salts.

(a) Potassium chloride — Hydrochloric acid

(b) Calcium sulfate _____

(c) Iron nitrate _____

(d) Zinc chloride _____

(e) Lithium sulfate _____

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Producing Salts

Many salts have a wide range of uses, however, some of them are not found in nature and need to be made in the laboratory. Salts can be made by many different methods, but two methods in particular are useful in making *soluble* salts.

How to Make a Salt using Metals, Insoluble Bases or Insoluble Carbonates

Aim: To produce copper sulfate salts by reacting copper oxide with an acid.

Equipment: Copper oxide powder, dilute (0.5 mol L^{-1}) sulfuric acid, 50 mL measuring cylinder, 100 mL beaker, 250 mL beaker, conical flask, Bunsen burner, tripod, gauze mat, funnel, filter paper, thermometer, spatula, evaporating basin, stirring rod.

Method:

1. Add 20 mL of sulfuric acid to a 100 mL beaker. Heat the acid until it reaches 70°C. Turn off your Bunsen burner. Do not boil the acid.
2. Once heated, use a spatula to add pea-sized portions of copper oxide to the beaker. Stir the mixture for 30 seconds.

3. Repeat step 2 until no more will dissolve. Allow the beaker to cool.
4. Fold the filter paper and place it in the funnel. Place the filter funnel into the conical flask.

5. Make sure the beaker is cool enough to hold at the top. The contents should still be hot. You may need your teacher to complete this step.

Copper compounds are poisonous

6. Gently swirl the contents of the beaker to mix, and then pour into the filter paper in the funnel. Allow to filter through.
7. Place the 250 mL beaker on top of your tripod filled with 100 mL of water.

8. Place the evaporating basin on top of the 250 mL beaker and carefully pour some of the solution from the conical flask into the evaporating basin.
9. Gently heat the beaker until the solution in the evaporating basin has reduced by half.
10. Leave the evaporating basin to cool. Once cool, move the evaporating basin to a warm place where it will not be disturbed (e.g. a window-sill) and observe over the next few days.

Observations: _____

_____

_____

_____

_____

_____

_____

1. Complete the word equation for this reaction.

   Copper oxide + sulfuric acid → _____ + _____

2. State the name given to this type of reaction. _____

3. Describe how you could you tell that all of the acid has been neutralised during this investigation. _____

_____

_____

_____

_____

_____

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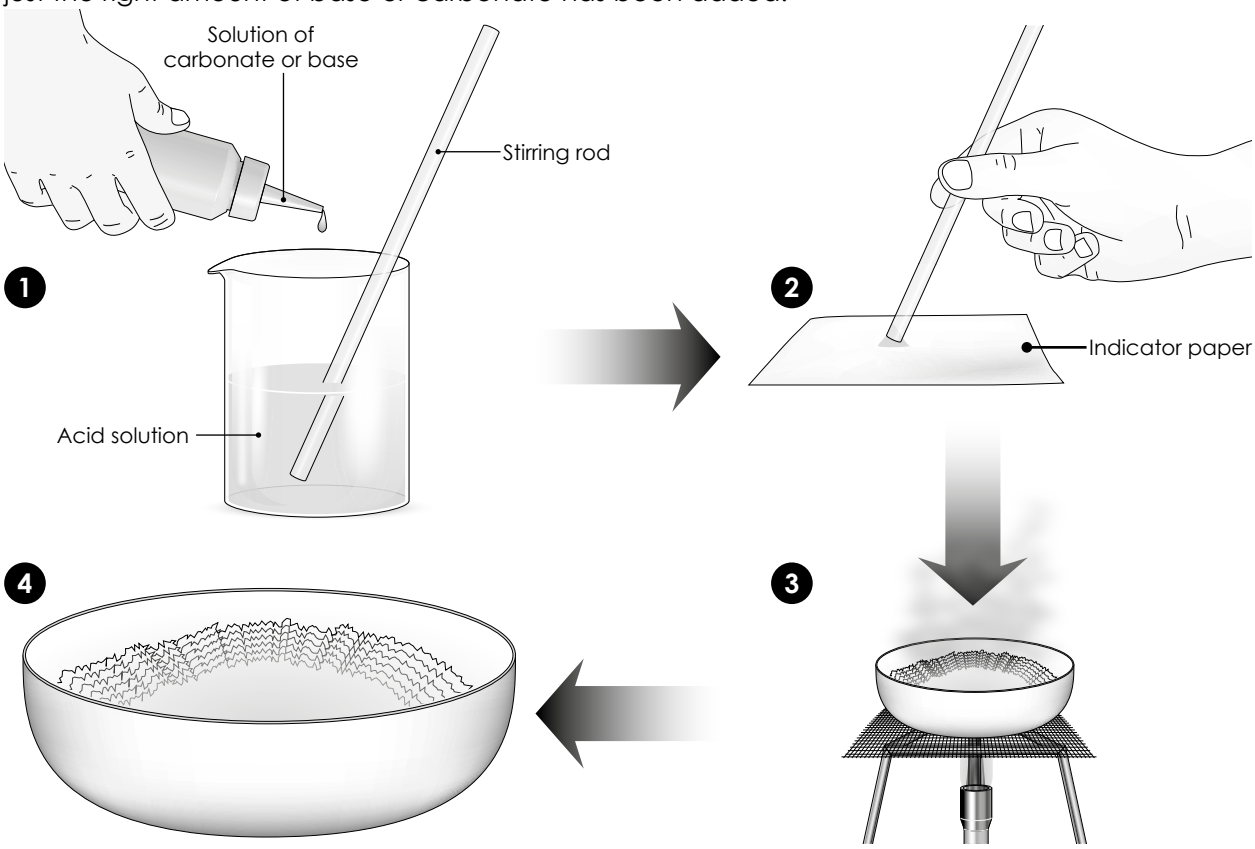
Making a Salt using Soluble Bases or Soluble Carbonates

If the base or carbonate being used to prepare a salt is soluble, you cannot tell if the acid has been used up because excess solids will dissolve even after the acid has been neutralised. Or if a colourless liquid base or carbonate is used, it will just form a colourless solution with the acid. Therefore, an indicator must be used to determine when neutralisation has been achieved and just the right amount of base or carbonate has been added.



1. Use the diagrams to outline how you could use potassium hydroxide and hydrochloric acid to produce a dry sample of potassium chloride. _____

2. Explain how litmus paper could be used during the process shown above to show the salt solution being produced is neutral. _____

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Writing Chemical Equations - Acid + Metal Hydroxide

1. Complete the general equation for the reaction between an acid and a metal hydroxide.

Acid + Metal hydroxide ⟶ _____ + _____

2. Write word equations for the following neutralisation reactions:

(a) Hydrochloric acid and calcium hydroxide.

Hydrochloric acid + calcium hydroxide → calcium chloride + water

(b) Sulfuric acid and sodium hydroxide.

_____

(c) Sulfuric acid and lithium hydroxide.

_____

(d) Nitric acid and magnesium hydroxide.

_____

(e) Hydrochloric acid and iron(II) hydroxide.

_____

(f) Barium hydroxide and nitric acid.

_____

3. Write word equations for the reaction that would produce the following salts.

(a) Sodium chloride.

Sodium hydroxide + hydrochloric acid → Sodium chloride + water

(b) Lithium sulfate.

_____

(c) Zinc nitrate.

_____

(d) Aluminium sulfate.

_____

(e) Potassium nitrate.

_____

(f) Nickel sulfate.

_____

4. Write balanced symbol equations for the following reactions.

(a) Sodium hydroxide and hydrochloric acid

$NaOH + HCl \rightarrow NaCl + H_2O$

(b) Potassium hydroxide and hydrochloric acid.

_____

(c) Sodium hydroxide and sulfuric acid.

_____

(d) Calcium hydroxide and hydrochloric acid.

_____

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Writing Chemical Equations - Acid + Metal Oxide

1. Complete the general equation for the reaction between an acid and a metal oxide.

Acid + Metal oxide ⟶ _____ + _____

2. Write word equations for the following neutralisation reactions.

(a) Sulfuric acid and potassium oxide.

Sulfuric acid + potassium oxide → potassium sulfate + water

(b) Hydrochloric acid and sodium oxide.

_____

(c) Nitric acid and calcium oxide.

_____

(d) Sulfuric acid and lithium oxide.

_____

(e) Hydrochloric acid and barium oxide.

_____

(f) Copper(II) oxide and sulfuric acid.

_____

3. Write balanced symbol equations for the reactions from question 2.

(a) _____

(b) _____

(c) _____

(d) _____

(e) _____

(f) _____

4. A student decided to make potassium chloride using powdered potassium oxide as a reactant.

(a) Name the other reactant the student should use. _____

(b) Write a word and balanced symbol equation for this reaction.

_____

_____

(c) Explain how litmus paper could be used during the process described to show the salt solution being produced is neutral. _____

_____

_____

_____

_____

_____

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Carbonates and Acids

There are two main types of carbonates:

- *Metal carbonates* are made of a metal ion and a carbonate ion (CO_3^{2-}). Common examples include sodium carbonate (Na_2CO_3), calcium carbonate ($CaCO_3$) and magnesium carbonate ($MgCO_3$).
- *Metal hydrogen carbonates* are made of a metal ion and a hydrogen carbonate ion (HCO_3^-). A common example is sodium hydrogen carbonate ($NaHCO_3$), more commonly known as baking soda.

When a carbonate reacts with acid it will form a salt, carbon dioxide and water. Carbon dioxide is a gas and can be seen as bubbles as the reaction proceeds.

Carbonate + Acid ⟶ Salt + Carbon dioxide + Water

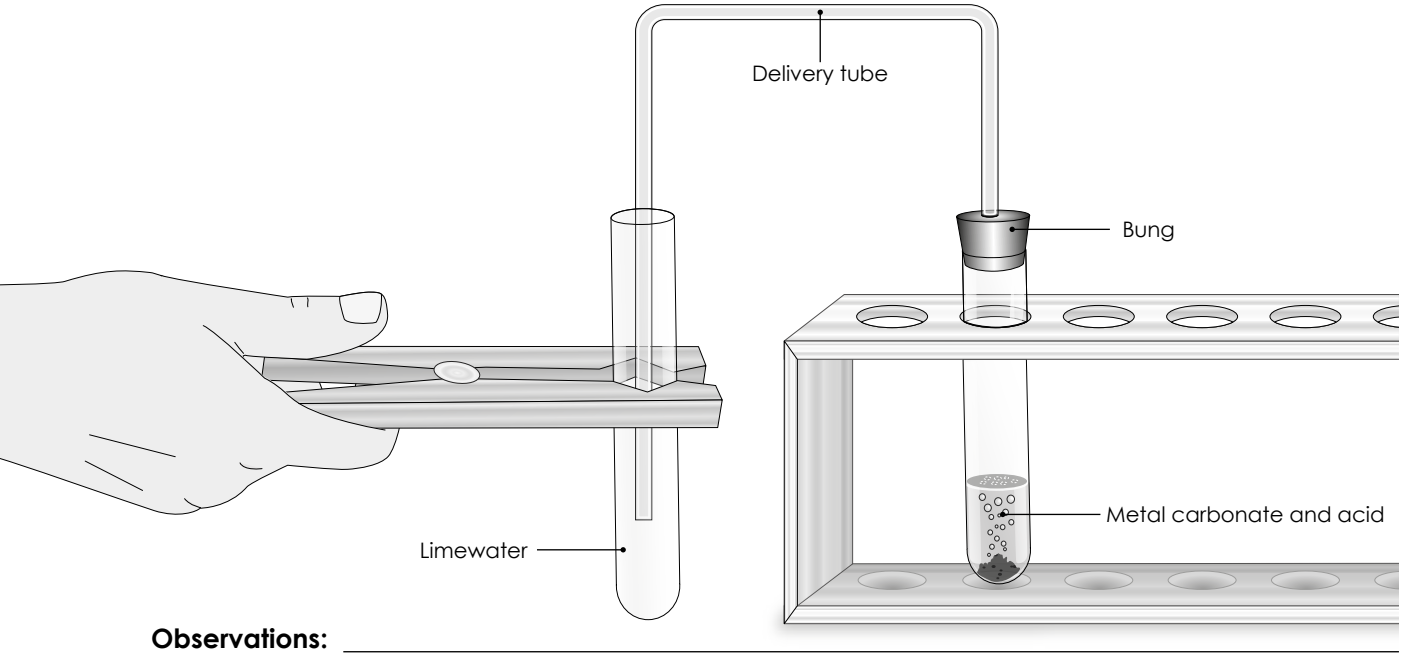
Testing for Carbon Dioxide Gas

Aim: To show that carbon dioxide gas is produced when calcium carbonate reacts with hydrochloric acid.

Equipment: Two boiling tubes, delivery tube and bung, test tube rack, a bottle of dilute hydrochloric acid, small amount of calcium carbonate, test tube tongs, safety glasses, limewater (saturated calcium hydroxide ($Ca(OH)_2$) solution.

Method:

1. Add a 'pea-sized' amount of the metal carbonate into one of the boiling tubes.
2. Add 5 mL of limewater to the other test tube.
3. Place this boiling tube into a test tube rack. Ensure you have the bung and delivery tube ready.
4. Add approximately 2 mL of acid to the metal carbonate and quickly insert the bung and delivery tube into the mouth of the boiling tube.
5. Holding the other boiling tube with your tongs, bubble the gas produced through limewater as shown in the diagram below.



Observations: _____

_____

_____

1. Name the three products of the reaction between calcium carbonate and the acid.

_____

_____

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Writing Chemical Equations - Acid + Carbonate

When a carbonate reacts with an acid, a salt, water and carbon dioxide gas is produced.

1. Complete the following word equations.

Magnesium carbonate + Hydrochloric acid ⟶ _____ + Carbon dioxide + Water

Sodium carbonate + Hydrochloric acid ⟶ _____ + Carbon dioxide + Water

Calcium carbonate + Hydrochloric acid ⟶ _____ + Carbon dioxide + Water

Silver carbonate + Sulfuric acid ⟶ _____ + Carbon dioxide + Water

Zinc carbonate + Sulfuric acid ⟶ _____ + Carbon dioxide + Water

Copper(II) carbonate + Sulfuric acid ⟶ _____ + Carbon dioxide + Water

Aluminium carbonate + Nitric acid ⟶ _____ + Carbon dioxide + Water

Iron(II) carbonate + Nitric acid ⟶ _____ + Carbon dioxide + Water

Barium carbonate + Nitric acid ⟶ _____ + Carbon dioxide + Water

Sodium hydrogen carbonate + Sulfuric acid ⟶ _____ + Carbon dioxide + Water

Magnesium hydrogen carbonate + Hydrochloric acid ⟶ _____ + Carbon dioxide + Water

2. Identify the metal carbonate and the acid in the following equations.

_____ + _____ ⟶ Lead chloride + CO_2 + H_2O

_____ + _____ ⟶ Copper nitrate + CO_2 + H_2O

_____ + _____ ⟶ Lithium sulfate + CO_2 + H_2O

_____ + _____ ⟶ Nickel chloride + CO_2 + H_2O

_____ + _____ ⟶ Iron sulfate + CO_2 + H_2O

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Writing Symbol Equations - Acid + Carbonate

1. Write balanced chemical equations for the following reactions.

(a) Nitric acid reacts with sodium carbonate to produce sodium nitrate, carbon dioxide and water.

_____

(b) Magnesium carbonate reacts with hydrochloric acid to produce magnesium chloride, carbon dioxide and water.

_____

(c) Iron(II) carbonate reacts with sulfuric acid to produce iron(II) sulfate, carbon dioxide and water.

_____

(d) The reaction between copper(II) carbonate and hydrochloric acid produces carbon dioxide, water and green copper(II) chloride.

_____

(e) Water, carbon dioxide and zinc sulfate are produced during a reaction between zinc carbonate and sulfuric acid.

_____

(f) Sulfuric acid and sodium carbonate produce sodium sulfate, carbon dioxide and water.

_____

! Only for experts!

(g) Iron(III) carbonate reacts with nitric acid and produces the salt, iron(III) nitrate, as well as carbon dioxide and water.

_____

2. Write balanced chemical equations for the reaction between the following compounds.

(a) Sulfuric acid and potassium carbonate.

_____

(b) Nitric acid and lithium carbonate.

_____

(c) Hydrochloric acid and calcium carbonate.

_____

(d) Sulfuric acid and barium carbonate.

_____

(e) Hydrochloric acid and zinc carbonate.

_____

(f) Nitric acid and calcium carbonate.

_____

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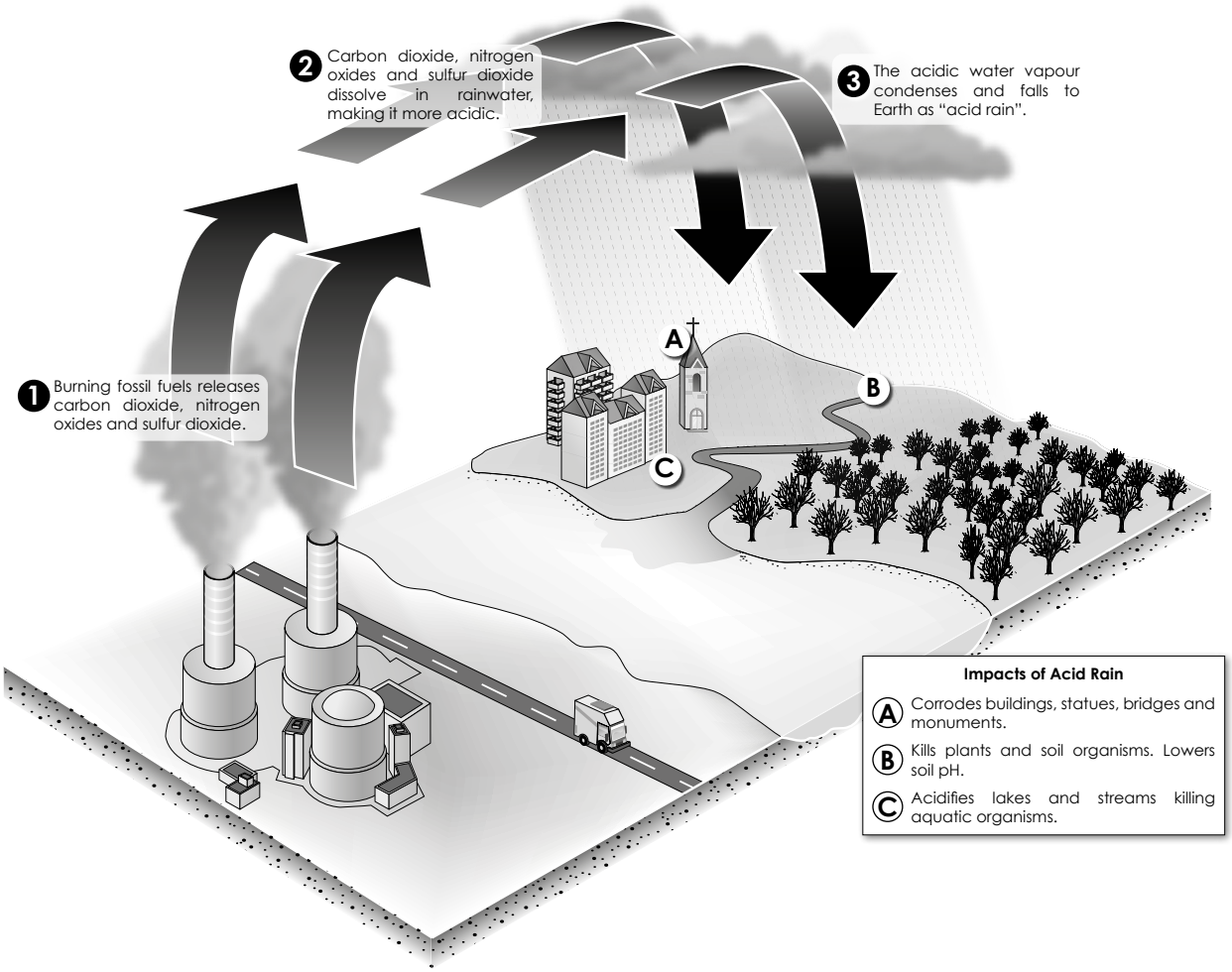
Acid Rain

When fossil fuels such as coal, oil and natural gas are burned, carbon dioxide, nitrogen oxides and sulfur dioxide escape into the air. These molecules dissolve in the water in clouds and make rainwater more acidic than normal. When this happens it is called *acid rain.*

Oamaru Stone is one of New Zealand's most important building materials and is a very pure limestone (calcium carbonate). It is soft enough to be readily sawn and worked. Unfortunately, it is very susceptible to the effects of acid rain.



1. Rainwater is naturally a weak acid with a pH of between 5-6. If you added universal indicator to rainwater what colour would you expect it to turn? _____

2. Would you expect the pH of acid rain to be higher or lower than the pH of normal rain?

   _____

3. What is the chemical formula of limestone? _____

4. One of the acids that contributes to acid rain is nitric acid. What is the formula of nitric acid? _____

5. Write a word equation for the reaction between limestone and nitric acid.

6. Write a balanced chemical equation for the reaction between limestone and nitric acid.

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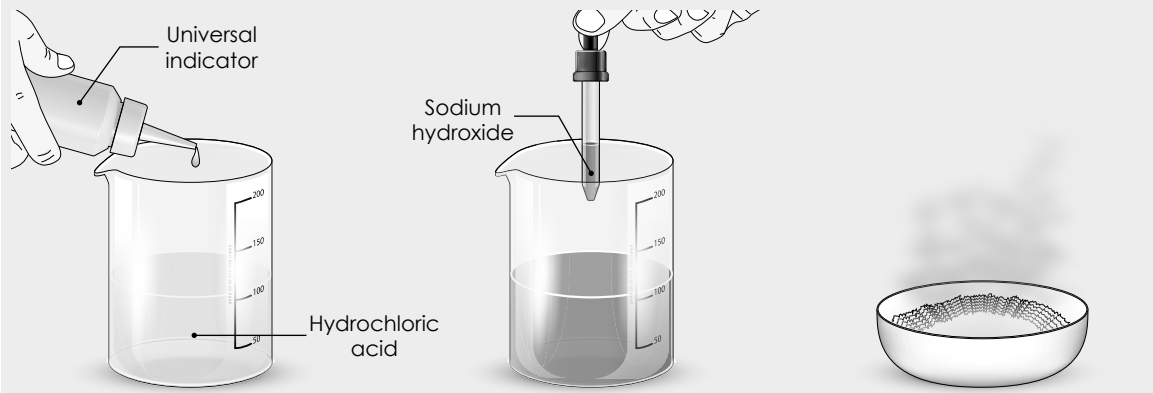
Investigating Reactions

1. A student carried out an experiment in the lab using the following method:



❶ Universal indicator was added to a solution of hydrochloric acid in a beaker.

❷ Sodium hydroxide was added slowly until the solution turned green.

❸ The contents of the beaker were poured into an evaporating dish and left in a warm place for several days.

(a) Write a scientific aim for this experiment. _____

_____

_____

(b) Write a word equation and balanced symbol equation for this reaction.

Word Equation:

Symbol Equation:

(c) Explain the purpose of each step in the method and how the equipment and chemicals used achieve that purpose.

Step ❶

Purpose: _____

_____

Explanation: _____

_____

_____

_____

Step ❷

Purpose: _____

_____

Explanation: _____

_____

_____

_____

Step ❸

Purpose: _____

_____

Explanation: _____

_____

_____

_____

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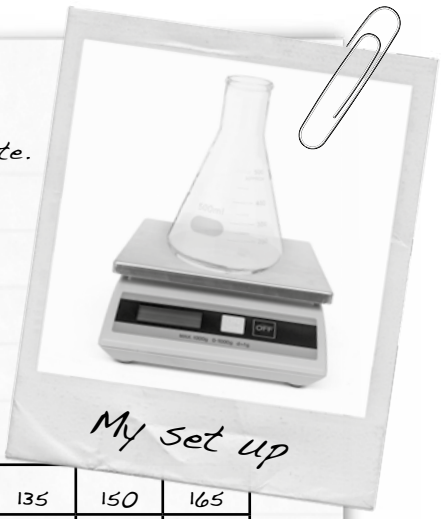
2. The page below was taken from a student's lab manual. Complete the write-up of their investigation.



Aim:

To investigate the reaction between hydrochloric acid and sodium carbonate.

Method:

1. Place a conical flask on the digital balance. Zero the balance.
2. Add 40 mL of hydrochloric acid to a conical flask.
3. Record the mass.
4. Add 5g of solid sodium carbonate to the beaker.
5. Record the change of mass shown on the balance until there is no further change in mass.

Results:

Time (s)	0	15	30	45	60	75	90	105	120	135	150	165
Mass (g)	45	44.7	44.6	44.4	44.2	44.0	43.9	43.8	43.7	43.6	43.4	43.4

Explanation:

Explain why the mass of the beaker and contents would decrease over time.
In your answer you should:

- State any other observations that would be made as hydrochloric acid reacts with the sodium carbonate.
- Explain how the products formed by the reaction lead to the decrease in mass of the beaker and contents.
- Write a word equation AND a balanced symbol equation for the reaction.

Word Equation

Symbol Equation

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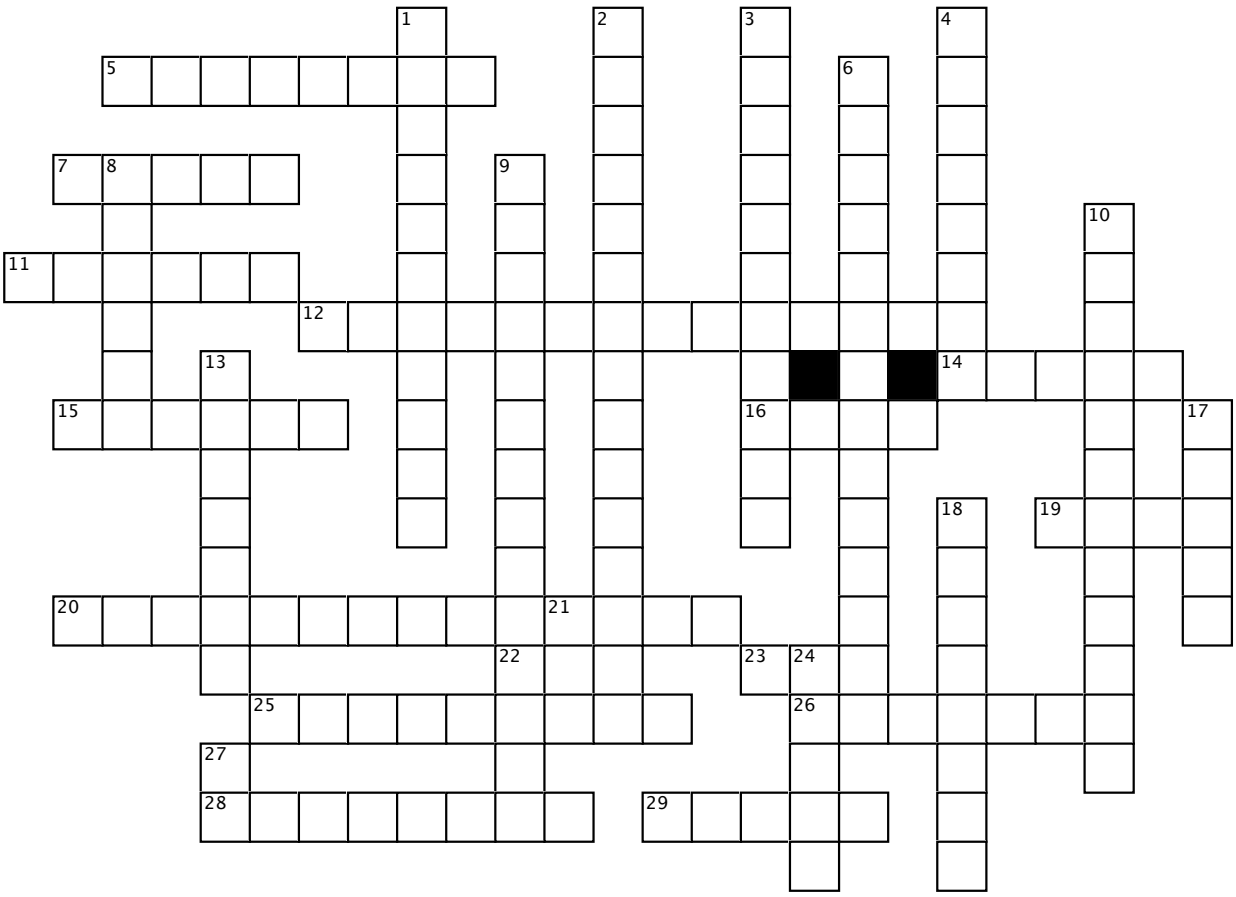
Acids and Bases - End of Chapter Puzzles

1. Use the clues to solve both the crossword and the word-find.



Across

5. Acids release this ion when they dissolve in water.
7. Neutralisation reactions produce a salt and this compound.
11. Will turn red litmus paper blue.
12. Salt formed when sulfuric acid reacts with lithium hydroxide.
14. pH of a solution at the end of neutralisation reactions.
15. The type of acid found in oranges.
16. These chemicals have a sour or sharp taste.
19. Colour of a strong base in universal indicator.
20. Chemical name for "Table Salt".
22. Colour of a strong acid in universal indicator.
23. Number of hydrogen atoms in a water molecule.
25. Type of salts formed by hydrochloric acid.
26. General name for medicine used to neutralise stomach acid.
28. The element that all acids contain.
29. Colour of a neutral solution in universal indicator.

Down

1. Salt formed when nitric acid reacts with lead hydroxide.
2. Salt formed when hydrochloric acid reacts with calcium hydroxide.
3. Salt formed when sulfuric acid reacts with zinc hydroxide.
4. Type of salts formed by nitric acid.
6. Name for a reaction between an acid and a base.
8. A base which is dissolved in water.
9. Salt formed when hydrochloric acid reacts with sodium hydroxide.
10. School laboratory acids belong to this group of acids.
13. Acids found in foods belong to this group of acids.
17. Colour of universal indicator solution at the end of a neutralisation reaction.
18. Type of salts formed by sulfuric acid.
21. Colour of strong acids in universal indicator.
24. One of the two products of a neutralisation reaction.
27. Scale used to measure the concentration of hydrogen ions in a solution.

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A	H	Q	T	A	Z	Z	A	Y	L	D	U	W	M	E	B	M	I	X	U	Y	P	U	I	H
L	B	N	H	N	I	S	V	P	J	W	Z	F	X	K	X	G	X	G	N	Z	H	M	S	Y
K	C	J	A	V	N	B	R	S	Q	G	T	Q	W	C	I	R	P	W	Z	U	J	S	E	D
A	W	N	D	Y	C	N	V	T	N	T	Z	X	X	A	T	E	W	D	K	T	H	F	T	R
L	A	K	Q	K	S	S	S	X	E	F	T	D	Y	L	K	E	J	X	J	K	M	Z	B	O
I	P	I	W	F	U	O	O	R	U	C	Q	D	W	C	J	N	X	Y	F	T	F	Z	L	G
C	H	U	D	X	L	D	D	Q	T	O	N	X	A	I	C	Q	Q	V	W	C	G	N	E	E
B	I	C	N	M	F	I	I	C	R	U	R	P	T	U	A	L	F	L	O	B	O	P	S	N
S	L	T	Z	E	A	U	U	N	A	C	Q	D	E	M	G	O	B	W	D	D	L	M	A	D
U	D	Y	R	E	T	M	M	E	L	H	A	N	R	C	Y	U	T	C	G	W	P	U	J	R
L	R	Y	I	I	E	C	C	R	I	L	L	I	T	H	I	U	M	S	U	L	F	A	T	E
F	U	J	G	I	C	H	H	R	S	O	L	F	D	L	W	E	A	W	L	E	L	O	B	B
A	O	B	R	L	U	L	L	E	A	R	I	Z	L	O	Z	J	M	C	R	H	I	U	Z	W
T	W	A	T	E	R	O	O	D	T	I	X	F	Y	R	N	J	L	X	P	J	Y	C	L	K
E	O	I	D	Y	T	R	R	O	I	D	J	N	B	I	S	E	V	E	N	A	A	O	H	A
S	C	F	L	K	D	I	I	L	O	E	A	D	M	D	A	N	T	A	C	I	D	S	S	L
D	Y	U	K	D	D	D	D	M	N	S	H	E	I	E	L	O	T	U	P	N	Z	E	O	I
Q	I	V	M	I	Z	E	E	M	L	D	G	M	Z	N	W	P	I	N	I	H	Q	U	Z	B
C	W	P	C	N	B	L	U	E	K	N	I	T	R	A	T	E	S	B	B	A	C	E	A	U
L	E	A	D	N	I	T	R	A	T	E	X	R	Z	V	F	W	R	X	D	X	B	S	U	F

2. A scientific statement has been cut up into blocks. Each block contains part of a word for that statement. Rearrange the blocks to remake the statement. Some of them have been done for you.

N - A | N - A | DED | E - A | A L I | I O N | - O C | S.

- I S | - A D | - A - | - N E | S A T | A C T | C U R

WHE			CID				-TO		BAS	
	UTR				- R E		ION			

3. There are 14 misspelt words in the following paragraph. Circle the incorrect words and write them correctly in the space provided below.

Acids, bases and alkillis are found in the laboratery and at home. They can be irritent or corrosive and must be handled carefully. How acid or alkalie a chemical is can be meazured on the pH schale, using indicatorz like litmus and universil indicator. Acids and bases react together to form salts and other producks too. Laboratory acids are far too dangeris to taste, but you will have swallowed some diloot, weak acids. Acids have a sour taste, like vingar and lemon - both of witch contain acids. These are safe to use in food, but they can still hurt if they get into a cut or into your eyez.

(a)_____ (h)_____

(b)_____ (i)_____

(c)_____ (j)_____

(d)_____ (k)_____

(e)_____ (l)_____

(f)_____ (m)_____

(g)_____ (n)_____

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Science Scramble - Acids and Bases

Using 3 or more of the letters below, create as many words as you can. Write the word and the point value into the appropriate box below. The winner is the one with the highest score. The scrambled word is a science term and is worth 20 points if you solve it.

3 letter words	4 letter words

5 letter words	6 letter words

7 or more letter words

Unscrambled Science word

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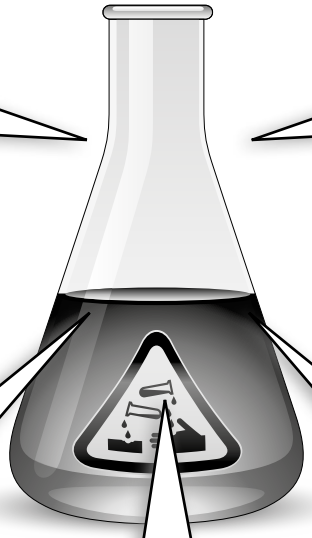
Acids and Bases Chapter Review

Use the boxes to write down the key points from this chapter. Ensure that all key words from the front of the chapter have been used.



Acids and Bases

pH Scale

Concentrated vs Dilute

Indicators

Neutralisation

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End of Chapter Review Questions

1. What is the pH scale used to measure? _____

_____

2. Which group of pH numbers would ALL indicate the presence of acids?

(a) 1 3 5 (b) 1 5 7 (c) 7 9 11 (d) 9 11 13

3. The list below has the wrong descriptions matched up with the pH numbers. Match the correct description to each pH number.

pH 1 •	• weak alkali
pH 5 •	• neutral
pH 7 •	• strong alkali
pH 9 •	• weak acid
pH 14 •	• strong acid

4. Use the word list to complete the table below:

neutral pH 1 strong alkali light green weak acid pH 9 purple

Solution	Type	pH number	Colour in Universal Indicator solution
Hydrochloric acid	strong acid		red
Citric acid		pH 5	yellow
Sodium hydroxide		pH 14	
Sodium bicarbonate	weak alkali		blue green
Distilled water		pH 7	

5. The statements below are all incorrect. Rewrite each statement, changing a single word or number to make the statement correct.

(a) All acids have a pH number greater than 7.

_____

(b) Strong alkalis have a low pH.

_____

(c) Acids turn blue litmus paper blue.

_____

(d) A solution with a pH of 5 is neutral.

_____

(e) A concentrated acid contains a large number of hydroxide ions.

_____

6. (a) Name the ion released by acids when they are placed into water. _____

(b) Name the ion released by alkalis when they are placed into water. _____

(c) What is the name of the process whereby an acid or an alkali breaks up into its ions? _____

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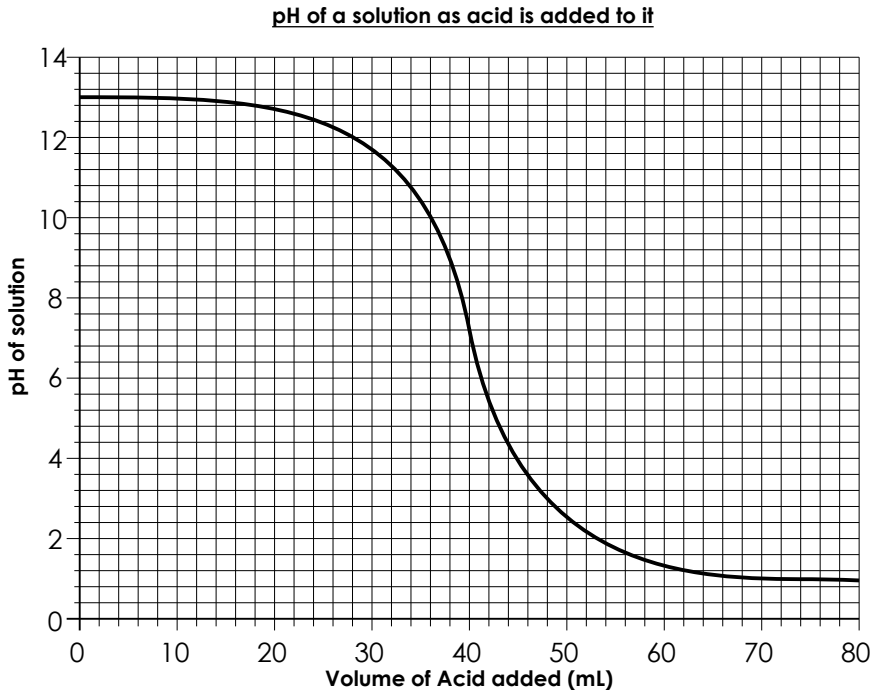
7. Use the word list provided to complete the following paragraph.

nitrate	**acid**	**carbonates**	**neutralisation**	**salt**	**second**	**metal**
hydroxides	**sulfate**	**hydrochloric**	**base**	**salts**	**oxides**	**soluble**

When an acid reacts with a _____ a salt and water are formed. This type of reaction is known as _____. The _____ formed has two parts to its name. The first part is from the _____ ion and the _____ part of the name is taken from the particular acid used in the neutralisation reaction. For example, sulfuric acid forms _____ salts, _____ acid forms chloride salts and nitric acid forms _____ _____.

A base is a substance which will react with an _____ to form a salt and water. Bases are metal _____ , metal _____, and metal _____. If the base is _____ in water it is known as an alkali.

8. The graph below shows the pH of a solution as increasing amounts of acid are added to it.



(a) Is the solution at the start of the investigation acid or alkali? _____

(b) What evidence did you use to answer question (a)? _____

_____

(c) How much acid was added before the solution became neutral? _____

(d) What was the pH of the acid that was added to the solution? _____

(e) What evidence did you use to answer question (d)? _____

_____

9. Write symbol equations for the following reactions:

(a) Sodium hydroxide reacting with sulfuric acid to produce sodium sulfate and water.

_____

(b) Sodium chloride and water form when sodium oxide reacts with hydrochloric acid.

_____

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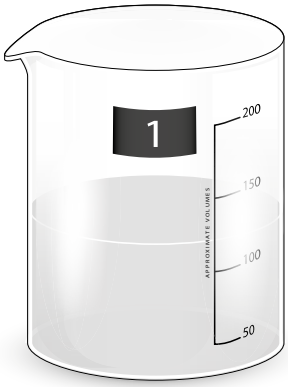
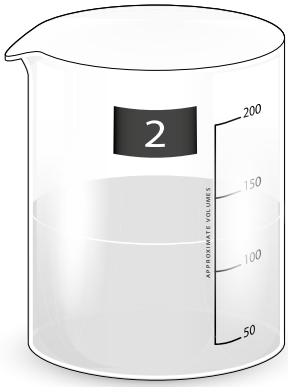
10. Two beakers are shown below. Beaker one contains sulfuric acid solution and 5 drops of universal indicator. Beaker two contains pure water and 5 drops of universal indicator. Sodium hydroxide solution was added to both beakers until no more changes were observed.



Beaker 1

Sulfuric acid + 5 drops of universal indicator



Beaker 2

Pure water + 5 drops of universal indicator

(a) Write a word equation AND a balanced symbol equation for the reaction between sulfuric acid and sodium hydroxide.

Word equation

Symbol equation

(b) What is the colour of universal indicator in each solution at the start?

Beaker 1 (acid): _____

Beaker 2 (water): _____

(c) Describe the **colour** changes as sodium hydroxide solution is added to each beaker, AND explain what this tells you about the changing **pH** of each solution.

Beaker one: _____

Beaker two: _____

Hints for answering these NCEA style questions

"No more changes" is a key phrase in the question.

It may help you to write on the beakers the relative pH, and colour of the solutions at the start of the investigation.

Use the general equation: *Acid + Base → Salt + Water* to assist you. Remember the name of the salt comes from the metal ion in the base and the negative ion from the acid.

Don't forget to balance the equation.

Universal indicator is red in acids, green in neutral solutions and blue/purple in alkaline solutions.

The pH will *increase* as NaOH is added.

Break down the colour changes into at least five stages, starting with red and ending with purple.

The pH will *increase* as NaOH is added.

Because it contains distilled water the initial solution will be green in U.I.

Break down the colour changes into at least three stages, starting with green and ending with purple.

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11. A student wanted to make a dry sample of neutral salt, copper(II) sulfate ($CuSO_4$).

(a) Explain how to make copper sulfate by mixing copper carbonate and sulfuric acid solutions using school laboratory equipment (your explanation may use notes and diagrams). _____

(b) Explain how litmus paper could be used during the process described to show the salt being produced is neutral. _____

(c) Write a word equation AND a balanced symbol equation for the reaction between copper carbonate and sulfuric acid.

Word equation

Symbol equation

Hints for answering these NCEA style questions

It may help to use a step-wise method.

You should be using an evaporating dish, a Bunsen burner and an indicator.

Ensure your diagram is labeled.

Red litmus paper will remain red in either an acidic or a neutral solution.

Blue litmus will remain blue in an alkaline or a neutral solution.

By using both red and blue litmus, neutrality can be determined.

Use the general equation: *Acid + Metal carbonate → Salt + Carbon dioxide + Water* to assist you. Remember the name of the salt comes from the metal ion in the base and the negative ion from the acid.

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Acids and Bases (90944) Practice Exam

NZPQA

NEW ZEALAND **PRETEND** QUALIFICATION AUTHORITY

Level 1 Science

90944 (1.5): Demonstrate understanding of aspects of acids and bases

+1	+2	+3	−3	−2	−1
H^+	Ca^{2+}	Al^{3+}	P^{3-}	O^{2-}	F^-
Na^+	Mg^{2+}	Fe^{3+}	PO_4^{3-}	S^{2-}	Cl^-
Li^+	Cu^{2+}			CO_3^{2-}	Br^-
K^+	Pb^{2+}			SO_4^{2-}	I^-
NH_4^+	Fe^{2+}				OH^-
Ag^+	Be^{2+}				HCO_3^-
	Zn^{2+}				NO_3^-
	Ba^{2+}				

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe

For Assessor's use only	**Achievement Criteria**	
Achievement	**Achievement with Merit**	**Achievement with Excellence**
Demonstrate understanding of aspects of acids and bases. ☐	Demonstrate an in-depth understanding of aspects of acids and bases. ☐	Demonstrate comprehensive understanding of aspects of acids and bases. ☐
Overall Level of Performance ☐		

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QUESTION ONE

(a) Complete the following table.

Name	Symbol	No. of electrons	Electron arrangement
Lithium		3	
			2,6
	Ne		
		17	

(b) Sodium atoms form an ion with a charge of +1, whereas chlorine atoms form an ion with a charge of -1.

Explain why sodium and chlorine atoms form ions with different charges. In your answer, you should:

- Define an ion.
- Explain why atoms form ions.
- Identify the group on the Periodic Table where each atom is found.
- Explain why sodium forms ions with a charge of +1 and chlorine forms ions with a charge of -1.

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QUESTION TWO

(a) A scientist claimed to have discovered a new element which he named silverbackium (Sv). He stated that silverbackium belongs in Group 1 of the Periodic Table.

You have been asked to predict other properties of Silverbackium.

In your answer you should:

- Predict how many outer shell electrons an atom of silverbackium has.
- Predict the charge on the silverbackium ion and explain why it has this charge.
- Write the formula of silverbackium hydroxide and silverbackium carbonate.

(b) Silverbackium carbonate is a white solid. When added to hydrochloric acid a reaction takes place and a gas is given off.

(i) Name the gas given off by this reaction. _____

(ii) Describe a test to identify this gas, with the result you would expect.

Test: _____

Result: _____

(iii) Name the substance remaining in solution after the reaction between silverbackium carbonate and hydrochloric acid is complete. _____

(c) Silverbackium sulfate is a green salt and can be prepared in the laboratory using silverbackium oxide and an acid.

Name the acid you would use to prepare silverbackium sulfate. Justify your choice.

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QUESTION THREE

A student is investigating the reaction between sulfuric acid and sodium hydroxide. She puts 10 mL of dilute sulfuric acid into a beaker and then adds 5 drops of universal indicator solution to the acid. She then takes a solution of sodium hydroxide (at the same concentration as the acid) and, drop by drop, adds it to the acid. She keeps adding the sodium hydroxide until the solution in the beaker stops changing colour.

(a) Describe the colour of the universal indicator solution:

(i) In the sulfuric acid before any sodium hydroxide was added.

_____

(ii) At the end of the investigation.

_____

(b) At one stage during the investigation, the acid in the beaker was completely neutralised by the sodium hydroxide.

Describe the colour of the solution at this point.

_____

(c) Explain the relationship between the pH of the solutions and the ions in the solutions:

(i) In the sulfuric acid before any sodium hydroxide was added. _____

_____

_____

_____

_____

_____

(ii) When the solution was neutral. _____

_____

_____

_____

_____

_____

(iii) At the end of the investigation. _____

_____

_____

_____

_____

_____

(d) Write a word equation for this reaction.

(e) Write a balanced symbol equation for the reaction.

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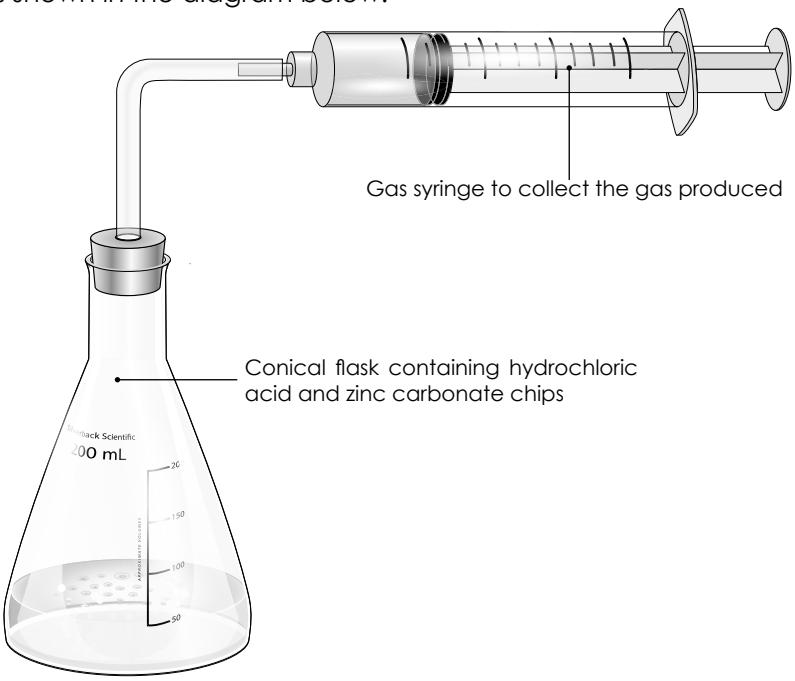
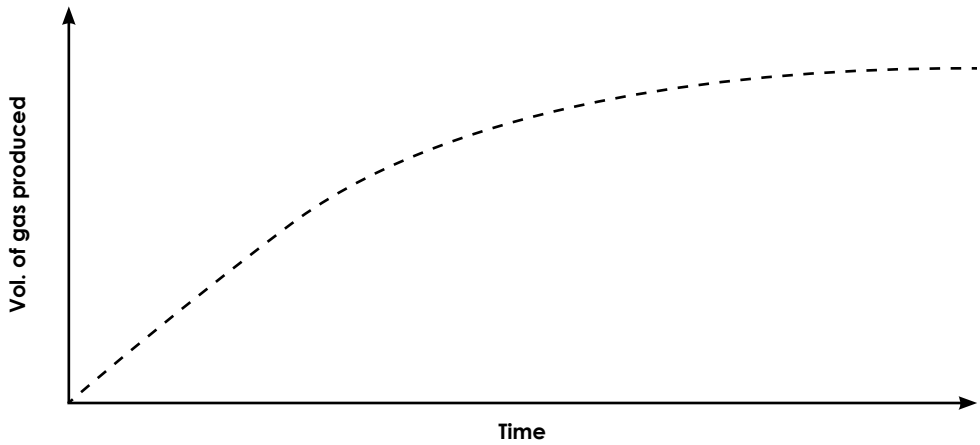
QUESTION FOUR

Zinc carbonate chips are added to dilute hydrochloric acid in a conical flask. The flask is connected to a gas syringe, as shown in the diagram below.



The volume of gas produced is measured over a few minutes, and the results used to sketch a graph.



(a) The slope of the graph is steep at the beginning and then levels off over time. Explain what is happening, in terms of particles and collisions, during this reaction.

(b) The experiment is repeated but this time the same mass of zinc carbonate chips is crushed into a powder before it is added to the same volume and concentration of acid.

Add another line to the graph to show the expected results of this new investigation.

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(c) Discuss the effect on the reaction rate of using powdered zinc carbonate with hydrochloric acid compared with using zinc carbonate chips. You should:

- Compare the rates of reaction.
- Explain the differences in the reaction rate by discussing how crushing the zinc carbonate affects the number of successful particle collisions.
- Include a word equation and a balanced chemical equation for the reaction.

Word Equation

Chemical Equation

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AS 90948 UNDERSTANDING OF

Genetic Variation

SCIENCE 1.9

Science 1.9 Demonstrate understanding of biological ideas relating to genetic variation

Level: 1 **Credits: 4** **Assessment: External**

Achievement	Achievement with Merit	Achievement with Excellence
Demonstrate understanding of biological ideas relating to genetic variation.	Demonstrate in-depth understanding of biological ideas relating to genetic variation.	Demonstrate comprehensive understanding of biological ideas relating to genetic variation.

Explanatory Notes

1 Demonstrate understanding involves recognising, naming, drawing and giving characteristics of, or an account of, genetic variation.

2 Demonstrate in-depth understanding involves explaining how or why genetic variation occurs.

3 Demonstrate comprehensive understanding involves linking biological ideas about genetic variation. It may involve explaining, elaborating, applying, justifying, relating, evaluating, comparing and contrasting, or analysing.

4 Biological ideas relating to genetic variation are limited to concepts and processes connected with:

- The continuity of life based on the inheritable nature of DNA.
- Links between DNA and variation in phenotypes.
- Variation in phenotypes as adaptive features.

5 Biological concepts and processes relating to the inheritable nature of DNA will be selected from:

- The roles of DNA in both carrying instructions to the next generation and determining phenotype.
- The relationship between DNA, alleles, genes and chromosomes.
- The way in which genotype determines phenotype.
- The way chromosomes exist as pairs so that individuals inherit two copies of each gene.

6 Biological concepts and processes relating to variation in phenotypes will be selected from:

- The significance of an allele as an alternative version of a gene.
- The role of mutations in forming new alleles.
- The role of meiosis in generating gametes (students are not required to provide the names of the stages of meiosis).
- The significance of sexual reproduction (in producing a new mix of alleles).
- The patterns of inheritance involving simple monohybrid inheritance showing complete dominance, sex determination, possible genotypes and phenotype ratios.

7 Biological concepts and processes relating to variation in phenotypes as adaptive features will be selected from:

- Inheritable and non-inheritable variations that exist within a group of living organisms.
- Differing rates of survival by various members of a group may depend on their phenotype.
- The importance of variation within populations (population and species survival) in a changing environment such as pest infestation, disease, drought or flood.
- The advantages and disadvantages of sexual reproduction.

8 The student must be familiar with the following genetic language and conventions: gene, allele, mutation, genotype, phenotype, gamete, zygote, dominant, recessive, homozygous, heterozygous, pure breeding, Punnett square and pedigree chart.

THE GENETIC CODE

By the end of this chapter you should be able to:

	I KNOW THIS ALREADY	I LEARNED THIS	I REVISED THIS
Explain the relationship between cells, nuclei, chromosomes and DNA.			
Describe the relationship between DNA, alleles, genes and chromosomes.			
Outline the role DNA plays in carrying genes to the next generation and in determining phenotype.			
Draw a labelled diagram of a DNA molecule using the terms nucleotide, triplet, sugar, phosphate and base.			
Use the '*complementary base-pairing rule*' to help explain the process of DNA replication.			
Explain that DNA contains the genetic code for making proteins, and proteins are the 'building blocks' for most of your body.			

Key Terms

Nucleus

My Definition: _____

_____

Deoxyribonucleic acid

My Definition: _____

_____

Chromosome

My Definition: _____

_____

Homologous

My Definition: _____

_____

Gene

My Definition: _____

_____

Allele

My Definition: _____

_____

Nucleotide

My Definition: _____

_____

Base

My Definition: _____

_____

Amino Acid

My Definition: _____

_____

Protein

My Definition: _____

_____

Trait

My Definition: _____

_____

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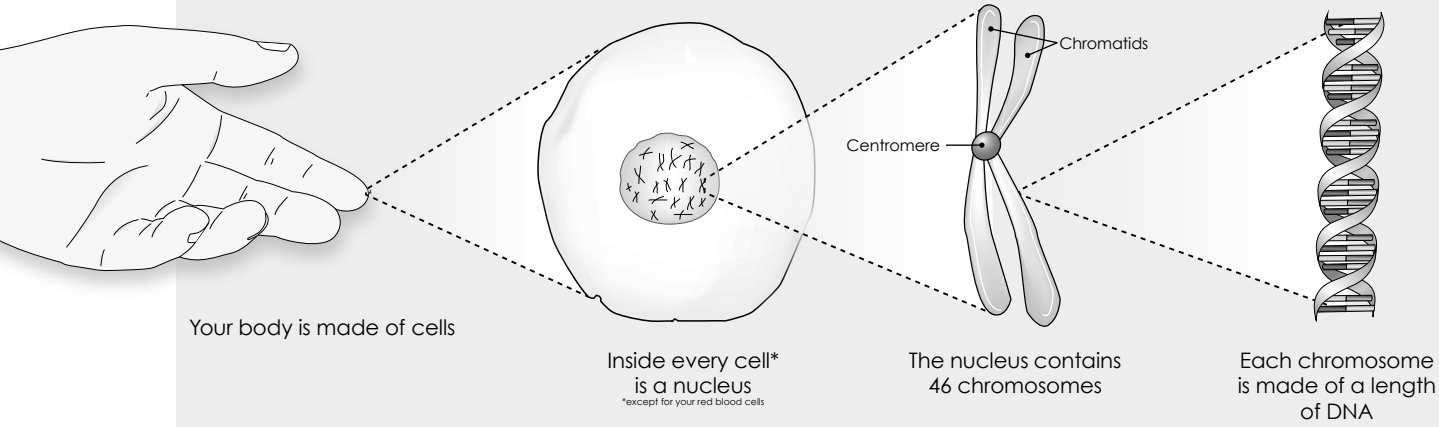
Cell and Chromosomes

Immediately after fertilisation (when a sperm cell joins an ovum) most organisms consist of a single cell. That single cell contains all the necessary instructions to grow into a multicellular organism, how well that organism will carry out its life functions and even whether it will get certain diseases. The development of an organism from a single fertilised egg cell is very complicated and all of the instructions on how to do so were, at one point, contained in that single fertilised egg.

These instructions are called the '*genetic code*'. The genetic code is found within the *DNA*. DNA occurs as *chromosomes* contained within the *nucleus* of each cell.



Each species has its own unique number of chromosomes. Humans have 46 chromosomes. These chromosomes occur in pairs called *homologous pairs* ('homos' is Greek for 'the same'). One chromosome of the pair comes from your mother, the other chromosome comes from your father. Homologous chromosomes are identical in size and shape.

1. Place the following terms in order from biggest to smallest.

DNA **Nucleus** **Chromosome** **Cell** **Organism**

_____ _____ _____ _____ _____

2. From a single cell (i.e. a fertilised egg), an average human grows to contain an estimated 50 - 100 trillion cells.
   (a) Describe where the single cell gets the information to ultimately produce an adult human? _____
   (b) Outline where this information is stored. _____

3. Most cells in the human body contain 46 chromosomes, arranged as 23 pairs.
   (a) How does the term '*chromosome*' relate to '*DNA*'. _____
   (b) Outline the role of the *nucleus*. _____
   (c) Define the term '*homologous pair*'. _____
   (d) Predict how many of these chromosomes come from:
      (i) the person's mother? _____
      (ii) the person's father? _____

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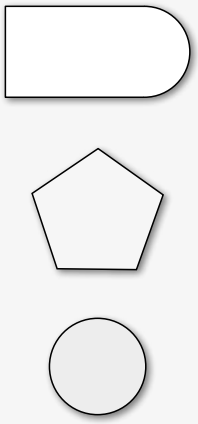
My DNA Model

KEY



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The Genetic Code

Each species has its own unique set of genes that make that particular species function in its own unique way. The information stored in genes is written in a code, using a language that is the same for all living things. DNA uses only four chemicals (called '*bases*') that act as the code letters. Cells are able to follow a genes instructions by reading this four-letter code. There are four different bases found in all DNA molecules, *adenine* (A), *thymine* (T), *cytosine* (C) and *guanine* (G). The different chemical make-up these bases means that adenine always bonds with thymine, and cytosine always bonds with guanine. This specific pairing of bases is called the "*complementary base-pairing rule*". The difference between one gene an another is the order of these bases.

1. Describe the "*complementary base-pairing rule*". _____

_____

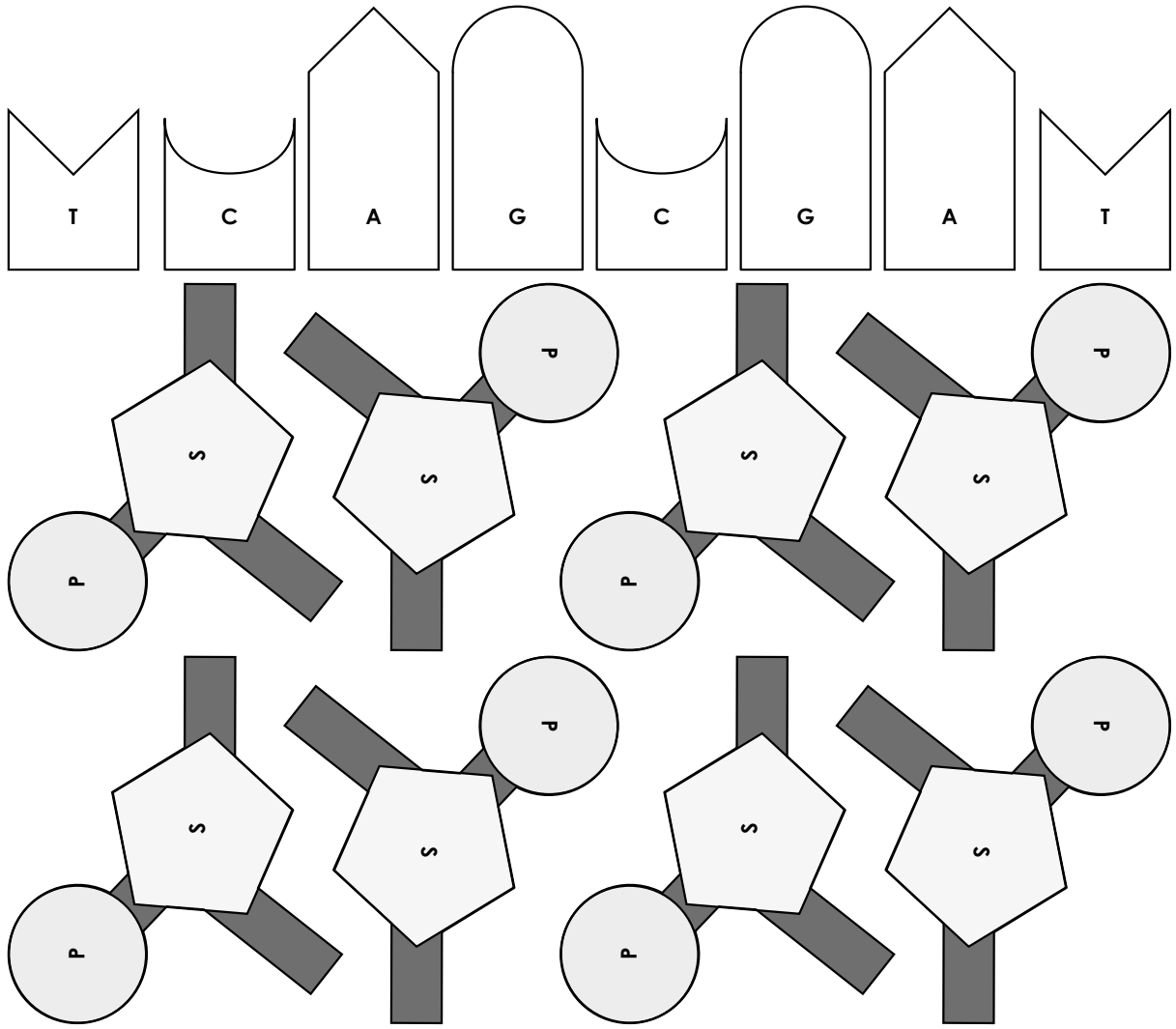
_____

2. Use the complementary base-pairing rule to complete the DNA molecule.

G	C	C	T	C	A	G	C	A	T	T	C	G	C	G	T	A	T	A	A	C	G	G

Making a DNA Molecule

1. Cut out the pieces of the DNA molecule below.
2. Colour in the pieces, using the same colour for pieces that have the same letter or name.
3. Read and complete the following page on "*Nucleotides*".
4. Assemble the model on the previous page by gluing the bases next to a sugar and linking the phosphates.
5. Construct a key to identify the different parts of the molecule represented by the letters.



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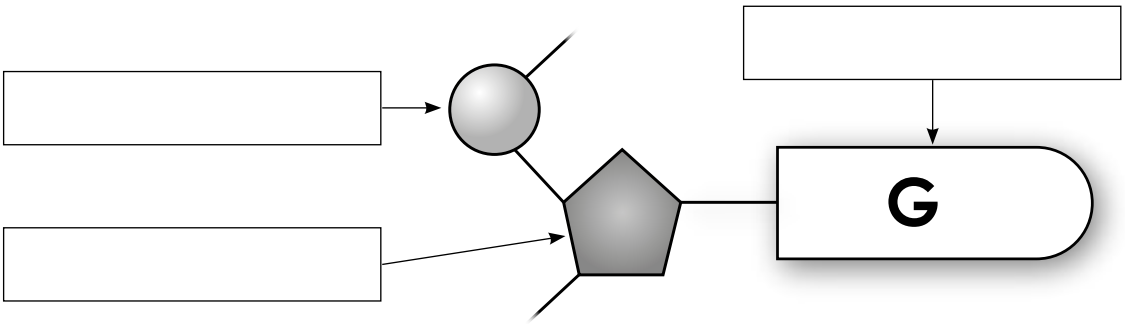
Nucleotides

The structure of deoxyribonucleic acid (DNA) is the same in all living things. It looks like a twisted ladder, known as a *double helix*. DNA is made up of simple repeating units called *nucleotides*. A nucleotide is comprised of a *sugar*, a *phosphate* and a *base*. The sides of DNA are made up of the sugar and the phosphate. These sides are held together by bonding between the *bases*.

1. Label the diagram of the nucleotide shown below.



2. State the base that bonds with:

   (a) Guanine _____

   (b) Adenine _____

THIS SECTION HAS BEEN DELIBERATELY LEFT BLANK

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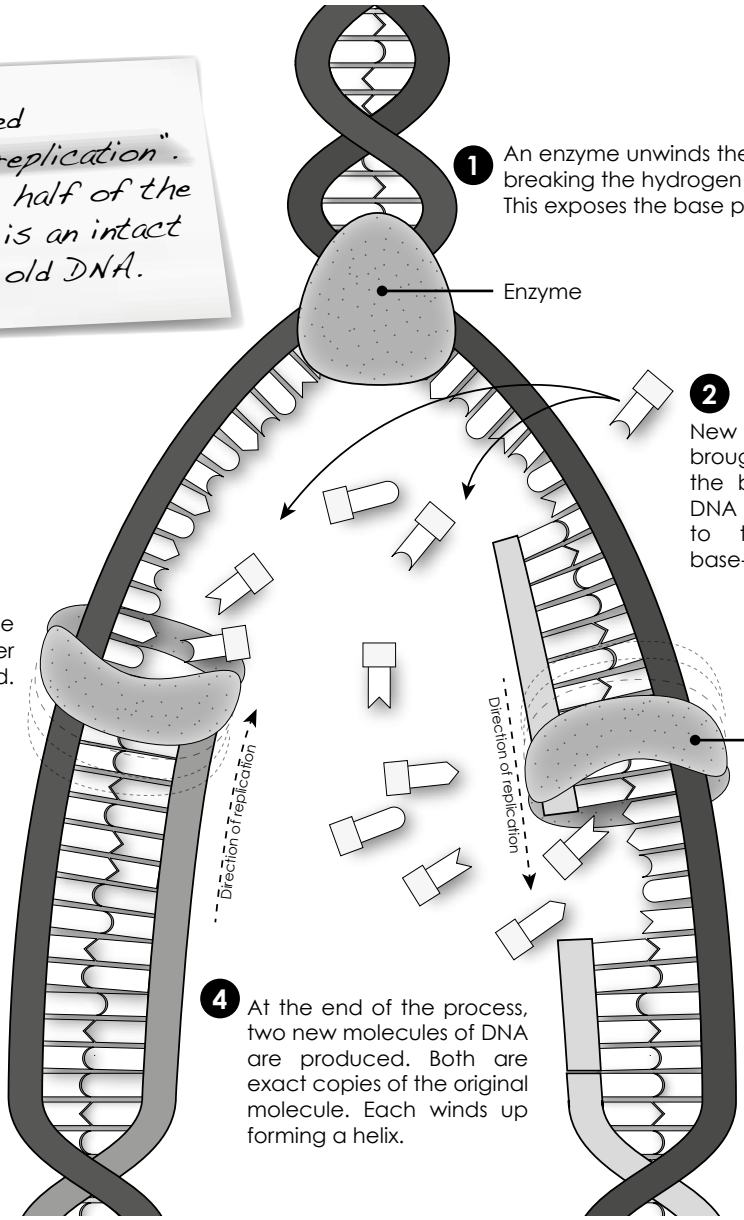
DNA Replication

In order to ensure that every new cell has its own complete copy of the genetic code, DNA must be copied (replicated) before a cell divides.

It is called "semi-conservative replication". This is because one half of the new DNA molecule is an intact strand from the old DNA.



1. Does DNA replication occur before, during or after cell division? _____

2. Describe the purpose of DNA replication. _____

3. Summarise the key processes involved in DNA replication. _____

4. Explain why DNA replication is known as '*semi-conservative replication*'. _____

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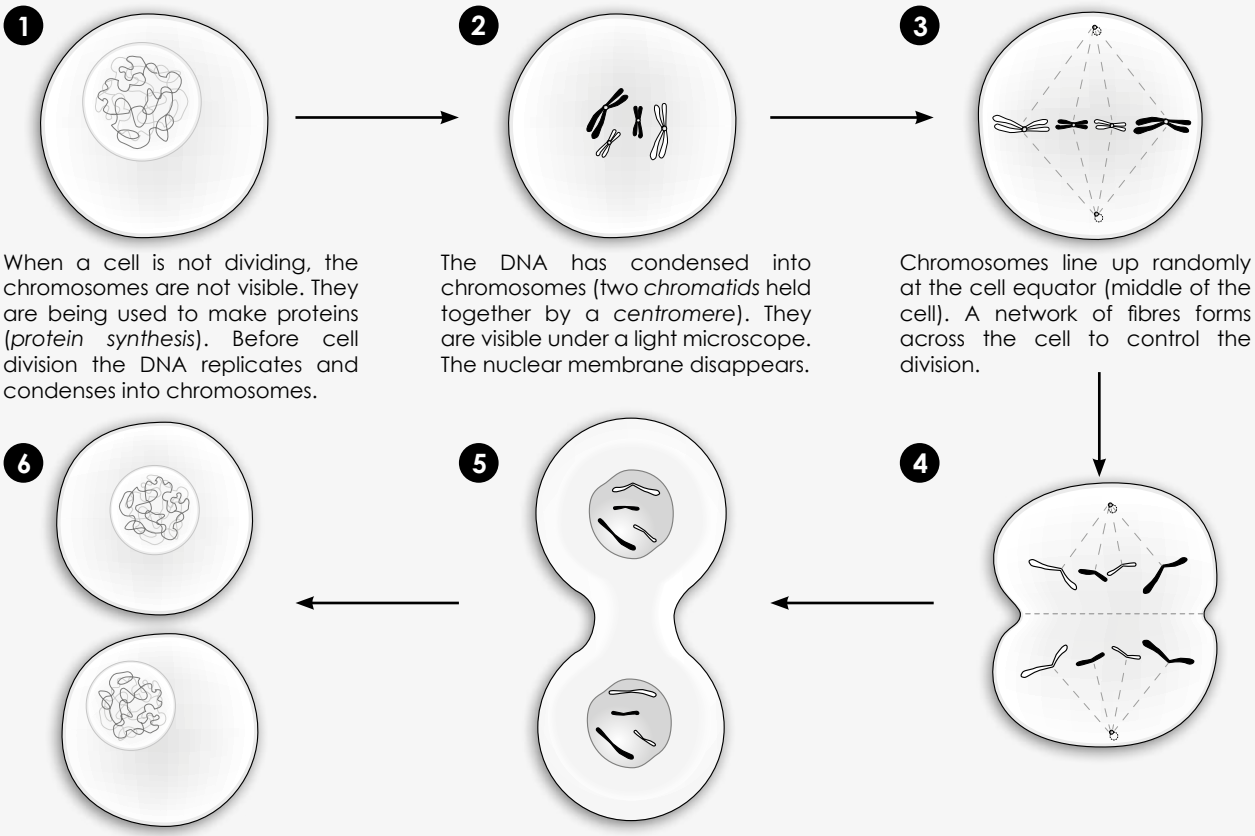
Mitosis

Mitosis is a process that a cell goes through when it divides to form two new cells. The primary purpose of mitosis is growth, as it is through mitosis that an organism goes from a single cell (i.e. a fertilised ovum) to an adult containing trillions of cells. Mitosis also serves the role of providing new cells when damaged cells need replacing.

Mitosis occurs in every cell in your body (except for the *gametes* - sperm and ova). Prior to mitosis, a copy of every chromosome is created so that, after mitosis, each new cell has a complete set of chromosomes. Therefore, apart from mutations, each new cell will have the same genetic code as its parent. This seems obvious when you consider that damaged skin cells, for example, must be replaced with cells identical in function to the original cell.

Key stages of mitosis in a cell with only four chromosomes



1. When a cell is not dividing, the chromosomes are not visible. They are being used to make proteins (*protein synthesis*). Before cell division the DNA replicates and condenses into chromosomes.
2. The DNA has condensed into chromosomes (two *chromatids* held together by a *centromere*). They are visible under a light microscope. The nuclear membrane disappears.
3. Chromosomes line up randomly at the cell equator (middle of the cell). A network of fibres forms across the cell to control the division.
4. *Chromatids* of each chromosome get separated by the network of fibres and are moved towards the poles.
5. The fibre network retracts and a nuclear membrane forms around each set of chromosomes. The chromosomes start to uncoil and disappear from view.
6. Two identical daughter cells are produced, each with a copy of the original chromosomes.

1. Outline the primary purpose of mitosis. _____

_____

_____

2. Name two places where mitosis occurs: (a) _____

(b) _____

3. (a) Name two types of cells where mitosis does not occur.

(i) _____

(ii) _____

(b) What is the general name given to these two types of cells. _____

4. How many *daughter cells* are formed by mitosis? _____

5. How many chromosomes are found in (a) a normal human body cell? _____

(b) daughter cells produced by mitosis? _____

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DNA to Protein

DNA contains the genetic code for making proteins. Proteins play a significant structural and biochemical role in organisms. Proteins are the building blocks for most of your body. In the same way that a wall is made mostly of bricks, your body is made mostly of protein. In our cells, proteins (in the form of enzymes) do most of the work. For example, proteins help break down food to release energy, and they help to organise the transport of useful chemicals between cells.

The bases that make a gene are arranged in groups of three - called a *triplet*. Each triplet carries the code for a specific amino acid. A protein is simply a long chain of amino acids folded into a specific shape.

Some Important Proteins

Keratin (skin, hair, nails, etc.).

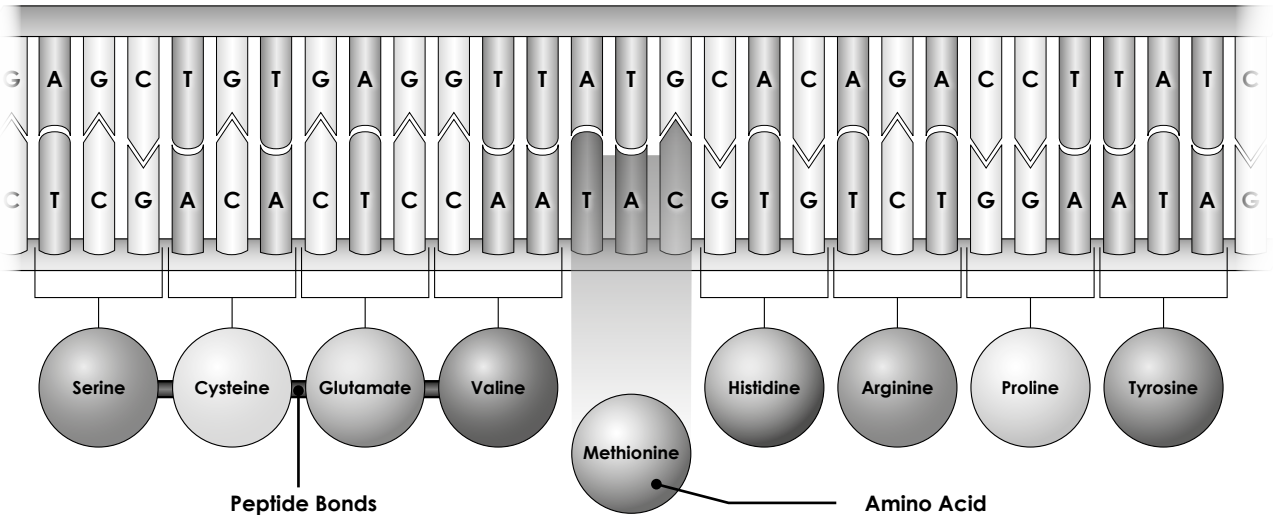
Collagen (ligaments, tendons, muscles and bones).

Elastin (ensures your body resumes its shape after moving).

Haemoglobin (transports oxygen in your blood).

Numerous hormones and antibodies.

This diagram is a simplification. There are a number of processes that occur between reading DNA and producing a protein.



These amino acids join together by *peptide bonds* and form a long chain of amino acids (known as a '*polypeptide chain*'. This polypeptide then folds into a specific shape known as a *protein*.

Each three-letter code (triplet) carries the code for an amino acid. In this case "T-A-C" codes for *methionine*.

1. Outline why proteins are considered to be '*important biological molecules*'. _____

_____

_____

2. Describe the relationship between:

   (a) A *triplet* and an *amino acid*. _____

   _____

   _____

   (b) An *amino acid* and a *protein*. _____

   _____

   _____

3. Use the word list to complete the paragraph below.

functions	amino acids	base sequence	proteins	triplets	building blocks

DNA contains the instructions for linking _____. These amino acids fold together to make _____. Proteins are important because they are the _____ _____ of our body and carry out many important _____ within the body. The _____ _____ of DNA can be broken down into _____ (three-base sequences). Each triplet carries the code for a specific amino acid.

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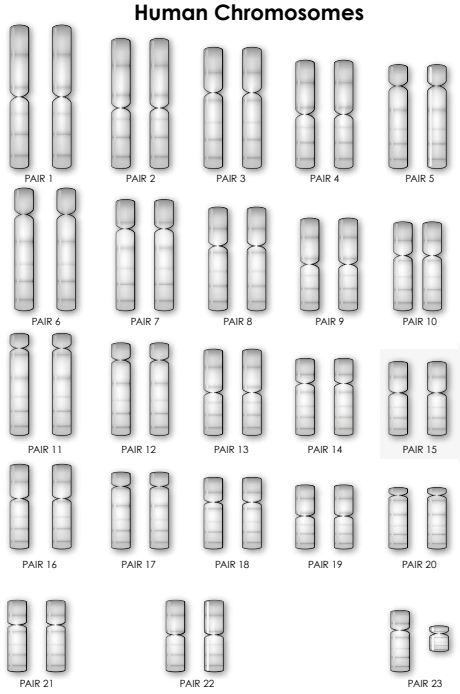
Genes and Alleles

The base sequence of DNA carries the instructions that make proteins. Proteins are the 'building blocks' for all organisms and carry out a number of important biochemical functions. A section of DNA that carries the code for making a specific protein is called a *gene*. A single gene may be thousands of base pairs long.

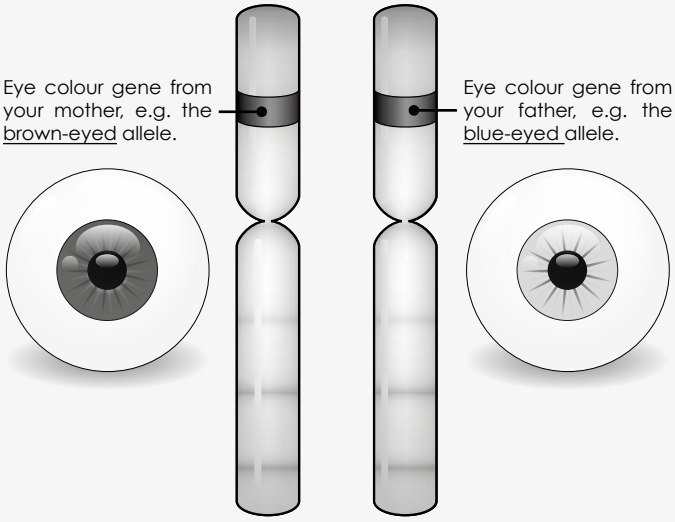
Each pair of homologous chromosomes carries the same, but not necessarily identical, genes. For example, both chromosomes of a particular homologous pair might contain the gene for eye colour, but one can be a "brown-eyed" version of the gene and the other can be "blue-eyed". Alternative versions of genes are called '*alleles*' (pronounced 'al-eels').

A Representation of the 46 Human Chromosomes



Homologous Pair 15

Because you inherit half of your genetic information from your mother, and the other half from your father, you may have different forms of a gene (called *alleles*).



Alleles have a slightly different order of bases so the protein, and therefore the *trait* (characteristic) they produce is different.

1. Distinguish between:

   (a) *DNA* and a *gene*. _____

   (b) A *gene* and an *allele*. _____

2. Describe why:

   (a) Alleles occur in pairs. _____

   (b) Someone could have two different alleles for the same gene. _____

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Science Scramble - Genetic Code

Using 3 or more of the letters below, create as many words as you can. Write the word and the point value in the appropriate box below. The winner is the one with the highest score. The scrambled word is a science term and is worth 20 points if you solve it.

3 letter words	4 letter words

5 letter words	6 letter words

7 or more letter words

Unscrambled Science word

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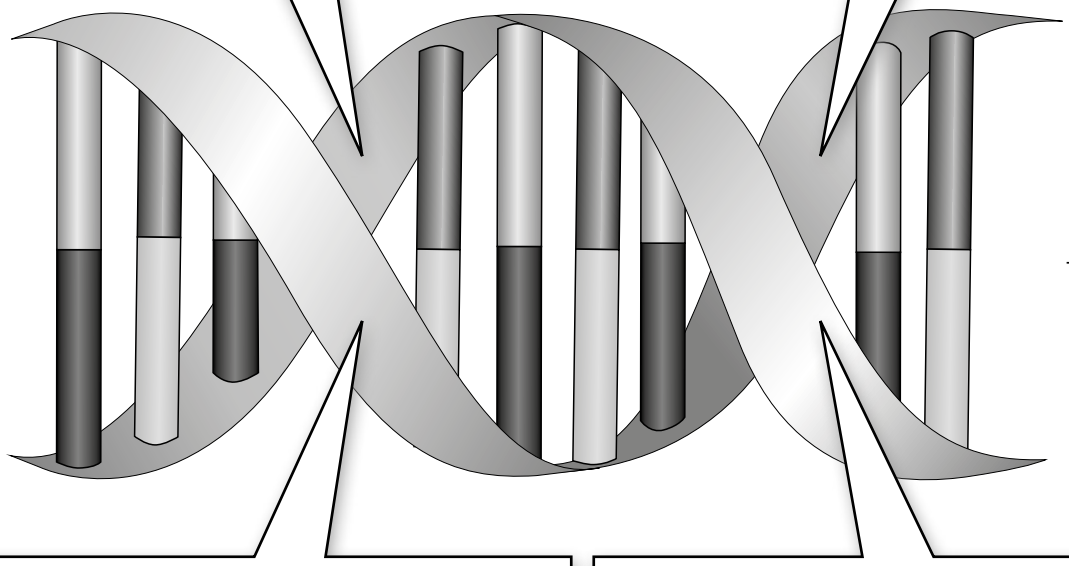
The Genetic Code Chapter Review

Use the boxes to write down the key points from this chapter. Ensure that all key words from the front of the chapter have been used.



The Structure of DNA

DNA Replication

Making Proteins and their Importance

Genes and Alleles

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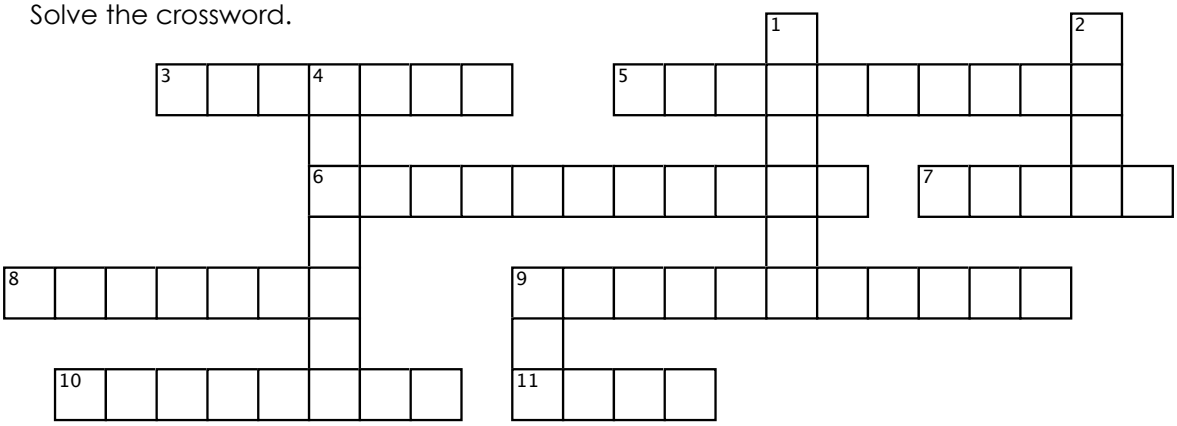
End of Chapter Review Questions

1. Solve the crossword.



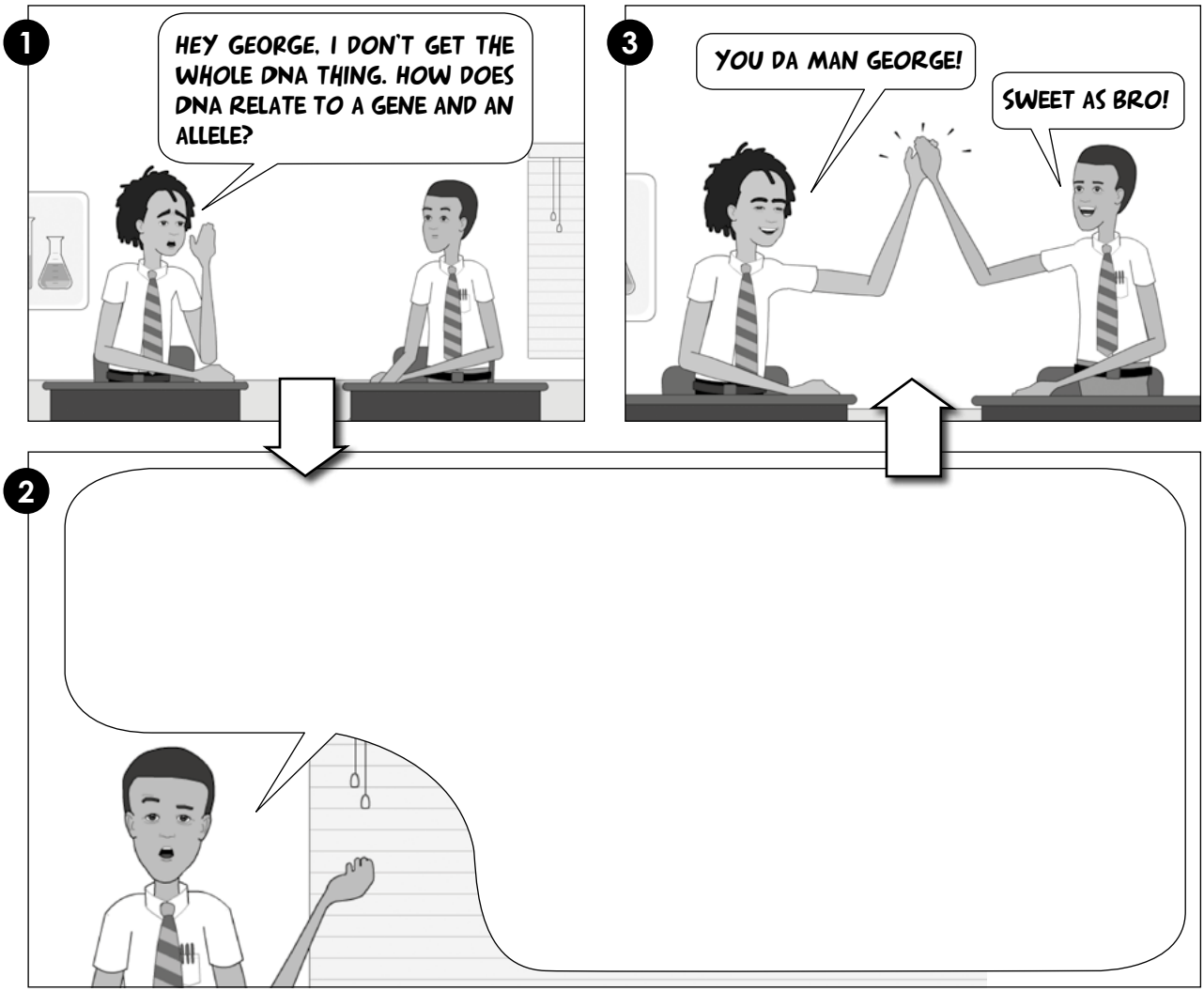
Across

3. Cytosine always bonds with this base.
5. Made of a sugar molecule, a phosphate and a base.
6. You have 46 of these in almost every cell in your body.
7. A triplet is made of this many bases.
8. Adenine always bonds with this base.
9. Term used to describe the shape of a DNA molecule.
10. Number of chromosomes found in a normal human cell.
11. The 'A' in DNA.

Down

1. An alternative form of a gene.
2. A length of DNA that holds the instructions for a certain characteristic.
4. Chromosomes are found in this part of a cell.
9. Abbreviation for deoxyribonucleic acid.

2. Complete the cartoon by writing in an answer to Hemi's question.



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3. Mix and match the following terms and definitions.

Allele •	• A section of DNA that codes for a specific trait or characteristic.
Gene •	• A long chain molecule made up of many repeating units called monomers.
Nucleotide •	• An acid that carries the genetic information in the cell and is capable of self-replication.
DNA •	• The building blocks of your body. Made up of long chains of amino acids.
Protein •	• An alternative form of a gene.
Polymer •	• The repeating unit of a DNA molecule. Made up of a sugar, a phosphate and a base.

4. Draw a labelled diagram in the box to show the relationship between a *gene*, an *allele* and the structure of a *DNA* molecule.

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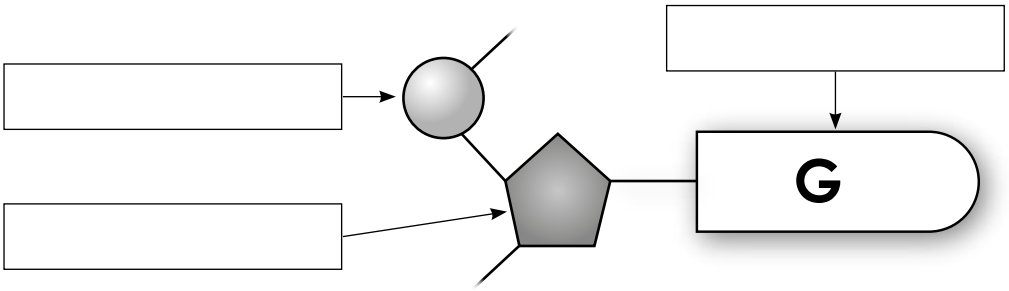
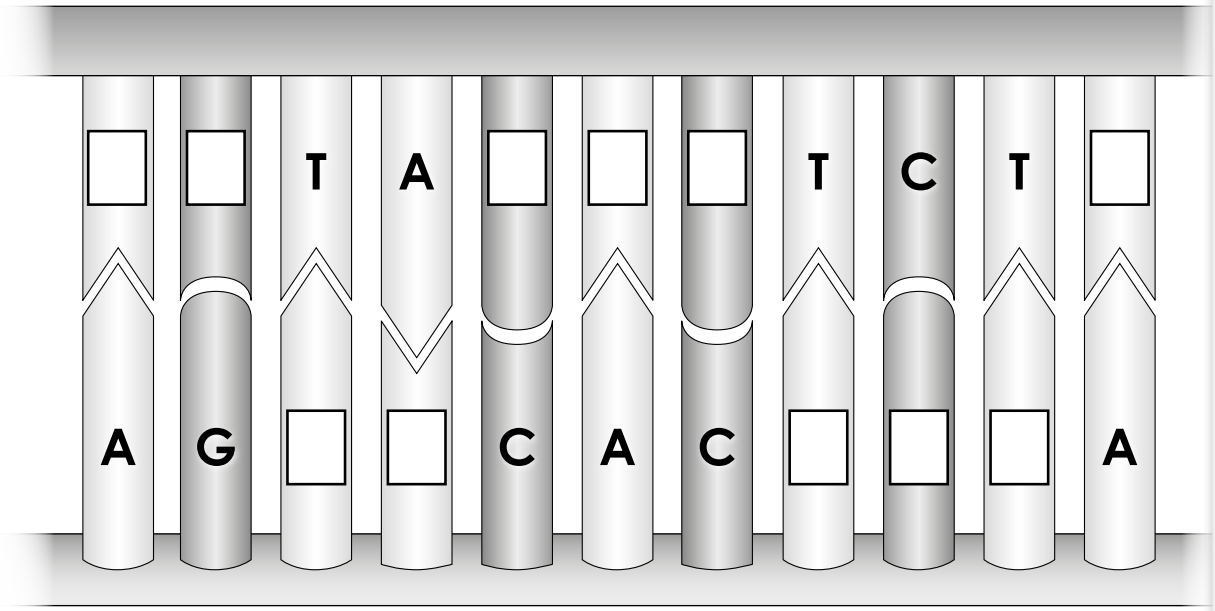
5. DNA is made up of repeating units called nucleotides.

(a) Label the nucleotide shown below.



(b) The bases within a DNA molecule pair up according to their different chemical makeup. Scientists call this the "complementary base-pairing rule".

Use the base-pairing rule to complete the DNA strand shown below.



6. Read the following sentence and answer the questions that follow.

"The ability to roll your tongue may be controlled by a gene. People who can roll their tongue have the allele 'R' while those that cannot roll their tongue do not."

(a) What '*trait*' is the text referring to? _____

_____

_____

(b) Explain how someone could have two different alleles for the same gene.

_____

_____

_____

_____

_____

_____

Hints for answering these NCEA style questions

Nucleotides are made of a phosphate, a sugar and a base.

There are four bases (A, T, C, G). The 'straight' letters go together and 'curved' letters go together.

Use '*genetically determined*' in your answer

Discuss where your chromosomes come from (i.e. half from your father and the other half from your mother). Use this to explain the answer.

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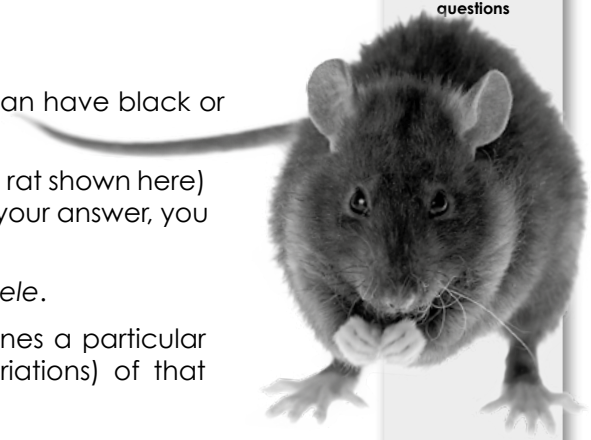
7. Genes determine many of the features of organisms, such as the colour of the fur on rats.

A gene is a part of a DNA molecule.

The type of rat shown in the photograph on the right can have black or white fur.



Discuss how information in DNA gives organisms (like the rat shown here) their individual features, such as black and white fur. In your answer, you should:

- Explain the difference between a *gene* and an *allele*.
- Explain how the base sequence on DNA determines a particular feature (e.g. fur colour) and different forms (variations) of that feature (e.g. black and white fur).

Hints for answering these NCEA style questions

Explain the difference between a gene and an allele in terms of how they impact on traits.

Describe how a gene codes for a protein which then determines a trait.

Explain that the base sequence on a gene determines the appearance of a particular feature (in this case the rat's fur colour).

You might like to show the relationship between a *gene* and an *allele* in a diagram of a chromosome.

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PREDICTING INHERITANCE

By the end of this chapter you should be able to:

	I KNOW THIS ALREADY	I LEARNED THIS	I REVISED THIS
Carry out simple genetic crosses to determine the expected sex of offspring.			
Distinguish between the terms '*genotype*' and '*phenotype*'.			
Define the terms '*homozygous*' and '*heterozygous*'.			
Correctly use the terms '*dominant*' and '*recessive*' when referring to alleles.			
Carry out genetic crosses using Punnett squares.			
Determine genotypic and phenotypic ratios.			
Use pedigree charts to determine genotype and phenotype.			
Explain the importance of a '*test cross*'.			

Key Terms

Allele
My Definition: _____

Dominant
My Definition: _____

Recessive
My Definition: _____

Trait
My Definition: _____

Genotype
My Definition: _____

Phenotype
My Definition: _____

Pure-bred
My Definition: _____

Homozygous
My Definition: _____

Heterozygous
My Definition: _____

Pedigree chart
My Definition: _____

Test cross
My Definition: _____

Please note that some of the traits discussed in this chapter are controlled by more than one gene. The inheritance of these traits has been simplified in order to make it easier for you to understand the processes involved.

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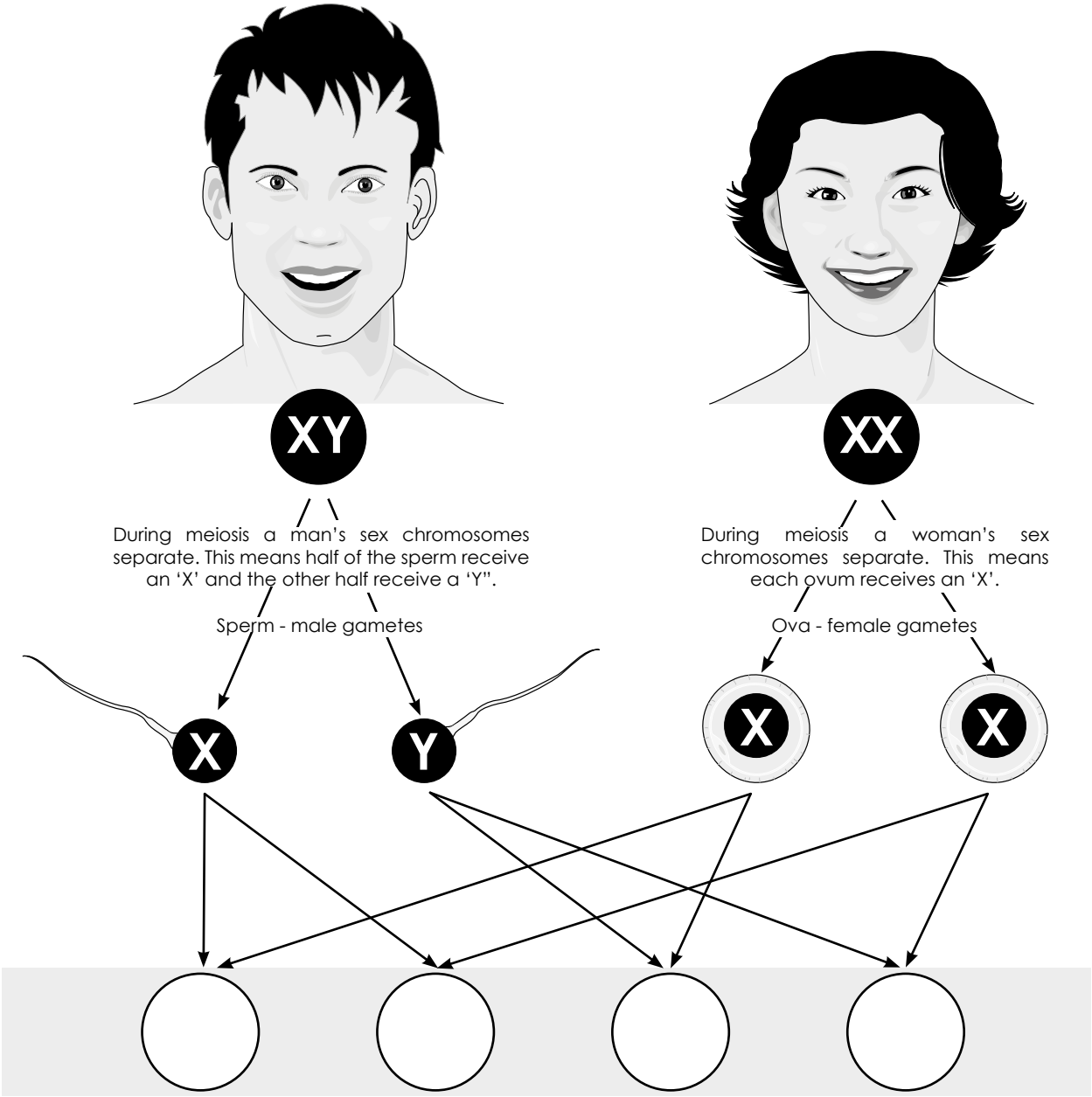
Sex Determination

Human body (*somatic*) cells contain 46 chromosomes. 22 pairs of these are homologous chromosomes and one pair are our sex chromosomes. Females have sex chromosomes scientists label as 'XX', whereas males have sex chromosomes scientists label as 'XY'. The process of meiosis results in *gametes* (sex cells) containing half the original number of chromosomes. If we consider just the sex chromosomes (XX and XY), this means half of all male gametes will contain an 'X' and half will contain a 'Y'. All female gametes will contain an 'X' chromosome.



1. Complete the diagram by showing the possible combinations of sex chromosomes that could form in the fertilised ova.
2. What is the probability that any baby produced would be a boy? _____
3. What is the probability that any baby produced would be a girl? _____
4. If a couple already had 2 children, both of whom were girls, what is the probability that the next baby will be a boy? _____
5. Justify your answer to question 4. _____

_____

_____

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Genotype and Phenotype

An organism's *phenotype* is its observable characteristics. It is a result of the interaction between its genes and its environment. For example, eye colour is observable so it is part of your phenotype.

An organism's *genotype* is the set of genes/alleles that it carries. The phenotype of an organism is an expression of its genes/alleles. Remember that for each gene you will inherit two alleles (one from your mother and one from your father), and these alleles may be different.

If one allele is *dominant* over the other it will always be expressed in the phenotype. Dominant alleles are usually shown with a capital letter. A recessive allele will only be expressed in the phenotype if no dominant alleles are present. Recessive alleles are shown with a lower-case letter.

If both alleles are the same they are called *homozygous* (*homo* means "the same"). If the alleles are different they are called *heterozygous* (*hetero* means "different").

For example, in rats the colour of their fur coat is controlled by a gene. There are two forms (or alleles) of this gene: the allele for black fur (B) is dominant over the allele for white fur (b).

Homozygous dominant	Heterozygous	Homozygous recessive
Genotype: BB **Phenotype:** Black	**Genotype:** Bb **Phenotype:** Black	**Genotype:** bb **Phenotype:** White

1. The length of fur on a rat is also controlled by a gene. The long fur allele is (L) while the short fur allele is (l).

   (a) Which allele is:

   (i) Dominant? _____

   (ii) Recessive? _____

   (b) Describe the phenotype of individuals with the following genotype.

   (i) LL _____

   (ii) ll _____

   (iii) Ll _____

   (c) State the genotype and phenotype of the rat that is:

   (i) Homozygous recessive. _____

   (ii) Heterozygous. _____

   (iii) Homozygous dominant. _____

   (d) Explain why a rat that has long fur can have two possible genotypes.

   _____

   _____

   _____

   (e) Explain why a rat that has short fur can only have one possible genotype.

   _____

   _____

DON'T be tempted to say dominant alleles are 'stronger'.

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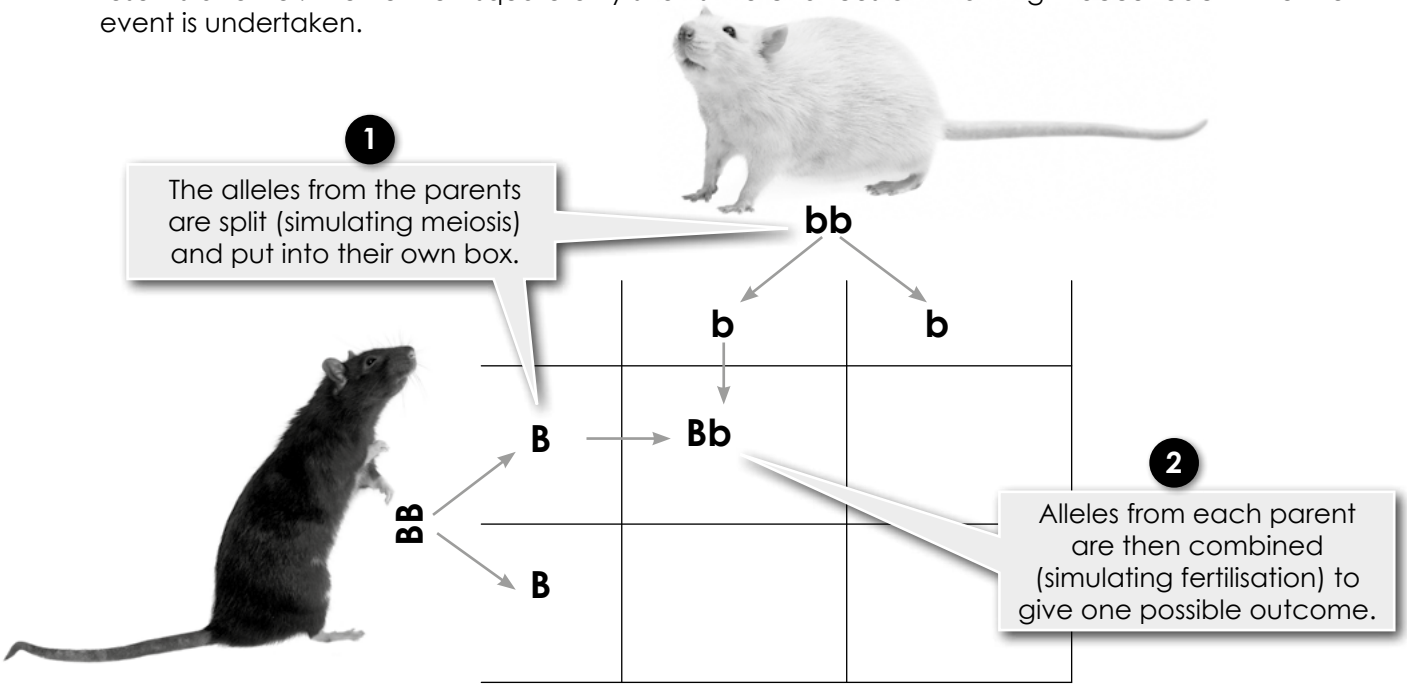
An Introduction to Punnett squares

Scientists use a grid-like tool (called a "Punnett square") to make predictions about how offspring may inherit alleles.

The Punnett square shows only the probability of what might occur and not the actual results. Probability is the chance of something occurring. If you flip a coin 100 times, since there are 2 sides to the coin, you would expect 50 heads and 50 tails. If you flip the coin 100 times, you may actually get 60 heads and 40 tails. Prediction is one thing, and actually getting the predicted result is another. The Punnett square only shows the chances of what might occur each time the event is undertaken.



1. (a) Complete the Punnett square above to show the other three possible outcomes.

   (b) What is the probability (%) that these two rats will produce a white offspring?

   _____

2. (a) Complete the Punnett square below to show the possible results of a cross between two white rats.

White female

Alleles = _____

White male

Alleles = _____

   (b) What is the probability (%) that these two rats will produce a black offspring?

   _____

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Predicting Rat Fur Colour

From the previous exercise recall that the colour of a rat's coat is controlled by a gene. There are two forms of this gene: the allele for black fur colour (B) is dominant over the allele for white fur colour (b).

1. (a) Complete the Punnett square to show the possible results of a cross between a homozygous dominant black male and a heterozygous black female.

Black female

Alleles = _____

Black male

Alleles = _____

(b) What is the probability (%) that an offspring will be:

(i) Black? _____ (ii) White? _____

2. (a) Complete the Punnett square to show the possible results of a cross between a heterozygous black male and a heterozygous black female.

Black female

Alleles = _____

Black male

Alleles = _____

(b) What is the probability (expressed as a fraction) that an offspring will be:

(i) Black? _____ (ii) White? _____

(c) What is the probability (expressed as a fraction) that an offspring will be:

(i) Homozygous dominant? _____

(ii) Homozygous recessive? _____

(iii) Heterozygous? _____

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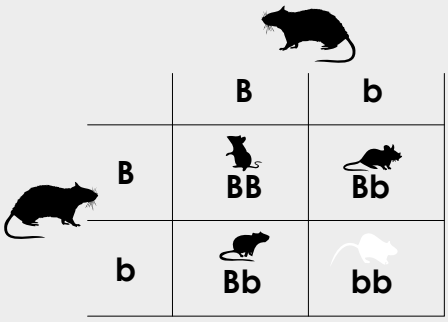
Genotypic and Phenotypic Ratios

The possible results of a genetic cross are usually expressed as a ratio. This may be a genotypic ratio (ratio of the possible allele combinations), or a phenotypic ratio (ratio of the possible phenotypes).



	B	b
B	BB	Bb
b	Bb	bb

A cross between two heterozygous black rats (Bb x Bb).

The genotypic ratio takes into account all the possible genotypes and is written as:

1BB : 2Bb : 1bb

The phenotypic ratio is an expression of the possible phenotypes and is written as:

3 Black : 1 White

1. Using the same alleles from the previous exercise, show the possible phenotypic and genotypic ratios of the following crosses. You should use a Punnett square in your answer.

(a) A homozygous dominant black rat crossed with a homozygous recessive white rat.

Genotypic ratio of the offspring: _____

Phenotypic ratio of the offspring: _____

(b) A homozygous dominant black rat crossed with a heterozygous black rat.

Genotypic ratio of the offspring: _____

Phenotypic ratio of the offspring: _____

(c) A homozygous recessive white rat crossed with a heterozygous black rat.

Genotypic ratio of the offspring: _____

Phenotypic ratio of the offspring: _____

(d) A heterozygous black rat crossed with a heterozygous black rat.

Genotypic ratio of the offspring: _____

Phenotypic ratio of the offspring: _____

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Floppy-Eared Rabbits

In rabbits, a gene controls the orientation of their ears. The allele for upright ears (E) is dominant to the allele for floppy ears (e).

1. State the possible genotype of:

   (a) A rabbit with upright ears. _____

   (b) A rabbit with floppy ears. _____

   (c) A rabbit that is *heterozygous* for upright ears. _____

2. (a) Complete the Punnett square to show the possible offspring produced when a rabbit with floppy ears mates with a rabbit that is heterozygous for upright ears.

   Genotype for floppy-eared parent: _____

   Genotype for upright-eared parent: _____

   (b) State the expected:

   Genotypic ratio of the offspring: _____

   Phenotypic ratio of the offspring: _____

3. Use a Punnett square to show how two rabbits with upright ears could produce offspring with floppy ears. Identify the floppy eared genotype with a circle.

   Genotype for parent 1: _____

   Genotype for parent 2: _____

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The Cabbage Butterfly (*Pieris rapae*)

Pieris rapae (commonly known as the 'white cabbage butterfly') is a common agricultural pest in New Zealand. Two forms of *Pieris rapae* are known. One form has two prominent dark spots on each of its wings and is controlled by a dominant allele 'W'. The other form only has one dark spot on each wing and is controlled by the allele 'w'.

A butterfly with two wing spots is mated with a butterfly with one wing spot. They produce 726 offspring. Of these offspring, 358 have two spots on each wing.

1. Use the information above to predict the genotypes of the parents. Justify your answer.

Genotype of parent with two wing spots: _____

Genotype of parent with single wing spots: _____

2. Explain why the phenotypic ratio *predicted* by your Punnett square does not match the *actual* phenotypic ratio observed in the offspring.

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Pure Breeding

If an organism is '*pure breeding*' it means that it is homozygous for the allele being studied, i.e. all of the offspring produced by either self fertilisation (in plants), or by breeding with others who are identical for this characteristic, show the same phenotype as the parent.

1. A plant geneticist produced two lines of pea plants that were pure breeding for flower colour. One line produced purple flowers; the other, white flowers. The geneticists found that purple flowers (P) were dominant to white flowers (p).

   (a) Define the term '*pure breeding*'. _____

   _____

   _____

   _____

   _____

   (b) Complete the Punnett square below to show the possible genotypic and phenotypic ratios of the offspring produced when two pure-breeding purple-flowering plants are crossed.

   Genotype of parent 1: _____ Genotype of parent 2: _____

   Genotypic ratio of the offspring: _____

   Phenotypic ratio of the offspring: _____

2. Complete the Punnett square below to show the possible genotypic and phenotypic ratios of the offspring produced when a pure-breeding purple-flowering plant is crossed with a pure-breeding white-flowering plant.

   Genotype for purple flowered: _____ Genotype for white flowered: _____

   Genotypic ratio of the offspring: _____

   Phenotypic ratio of the offspring: _____

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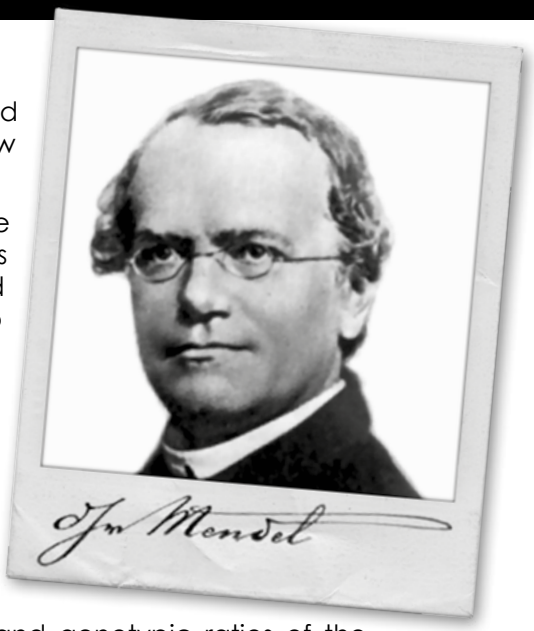
Mendel's Peas



Gregor Johann Mendel (1822 - 1884) was an Austrian monk and scientist who gained posthumous fame as the figurehead of the new science of genetics.

Mendel discovered the principles of heredity by studying the inheritance of various characteristics of pea plants. One of Mendel's most famous studies involved the inheritance of round and wrinkled seeds. He found that the alleles for round seeds were dominant to that of wrinkled seeds.

Homozygous dominant
Genotype: RR
Phenotype: Round

Heterozygous
Genotype: Rr
Phenotype: Round

Homozygous recessive
Genotype: rr
Phenotype: Wrinkled

1. Use a Punnett square to show the expected phenotypic and genotypic ratios of the offspring produced from the following crosses:

   (a) Two homozygous dominant plants.

   Genotype of parent 1: _____ Genotype of parent 2: _____

   Genotypic ratio of the offspring: _____

   Phenotypic ratio of the offspring: _____

   (b) Two heterozygous plants.

   Genotype of parent 1: _____ Genotype of parent 2: _____

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Genotypic ratio of the offspring: _____

Phenotypic ratio of the offspring: _____

(c) Plant one is a pure-breeding plant that produces round seeds. Plant two produces wrinkled seeds.

Genotype of plant 1: _____ Genotype of plant 2: _____

Genotypic ratio of the offspring: _____

Phenotypic ratio of the offspring: _____

2. During one of Mendel's investigations he found that a cross between two plants resulted in 5474 round seeds and 1850 wrinkled seeds.

Use the phenotypic ratio of the seeds produced to determine the probable genotypes of the parent plants. You should:

- Calculate the simplest phenotypic ratio of the offspring.
- Explain how the phenotypic ratio can be used to determine the parent's genotype.
- Use a Punnett square as part of your answer.

_____

_____

_____

_____

_____

_____

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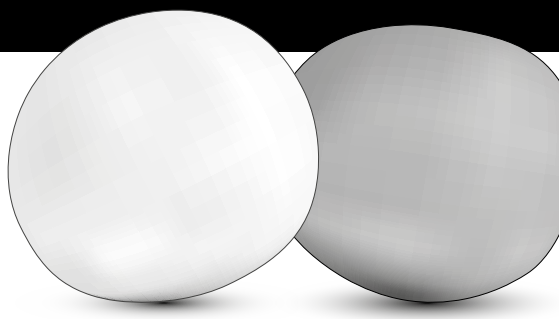
More Peas



As well as flower colour and the shape of peas, Mendel also studied the inheritance of pea colour. The plants he used produced two pea seed colours. Green pea seeds were controlled by the dominant allele (G) and yellow seeds were controlled by the allele (g).

1. State the possible genotypes of:
   - (a) A green seed producing plant: _____
   - (b) A yellow seed producing plant: _____
   - (c) A plant that is pure breeding for green seeds: _____
   - (d) A plant that is homozygous recessive for seed colour: _____
2. (a) Complete the Punnett square to show the possible offspring produced when a plant that is pure-breeding for yellow seeds is crossed with a plant that is pure-breeding for green seeds.

   - (b) What percentage of the offspring would you expect to produce:
     - (i) Green seeds? _____
     - (ii) Yellow seeds? _____
3. Use a Punnett square to help you explain how two pure-breeding green seed plants cannot produce offspring that have yellow seeds. _____

_____

_____

_____

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4. During one of Mendel's investigations he found that a cross between two plants (Plant 'A' and plant 'B') resulted in 8 102 green seeds that grew into plants (plants 'C'). No yellow seeds were produced.

(a) Plant 'A' is a pure-bred green pea plant. State the:

(i) Genotype of plant 'A': _____

(ii) Possible genotypes of plant 'B': _____

(b) Mendel then self-pollinated one of the offspring from the first cross (i.e. plant 'C' x plant 'C'). The offspring from this second cross (plants 'D') resulted in plants that produced a total of 8 023 seeds of which 6 022 seeds were green and 2 001 were yellow.

Use the phenotypic ratio of the seeds produced from plants 'D' to determine the probable genotype of the parent plant 'C'. You should:

- Calculate the simplest phenotypic ratio of the offspring.
- Explain how the phenotypic ratio can be used to determine the parent's genotype.
- Use a Punnett square as part of your answer.

_____

_____

_____

_____

_____

_____

(c) Based on what is now known about plants 'C' and plants 'D', State the probable genotype of plant 'B'. Justify your answer. _____

_____

_____

_____

_____

(d) Explain the likely outcome if the experiment was repeated, but this time plant 'A' and 'B' were *both* yellow seed producing plants. _____

_____

_____

_____

_____

Mendel was able to produce actual ratios that were very close to the expected ratios because of the large number of offspring produced by his pea plants.

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Hairless Guinea Pigs

A rare genetic condition causes some guinea pigs to be born without the ability to produce hair. The allele carried by most guinea pigs is an (H) which results in normal hair growth. Affected guinea pigs carry the alleles (hh).

A normal guinea pig

A hairless guinea pig

1. State the possible genotypes of:

   (a) A guinea pig with normal hair. _____

   (b) A hairless guinea pig. _____

   (c) A guinea pig who is pure breeding for normal hair. _____

2. (a) Is hairlessness the dominant condition? _____

   (b) Explain your answer to (a). _____

   _____

   _____

3. (a) Complete the Punnett square to show the possible offspring produced when a pure-breeding guinea pig with normal hair mates with a pure-breeding guinea pig without hair.

   Parents' genotypes: _____ and _____

   (b) What percentage of the offspring would you expect to have normal hair?

   _____

   (c) What percentage of the offspring would you expect to be hairless?

   _____

   (d) What is the expected genotypic ratio of the offspring? _____

   (e) What is the expected phenotypic ratio of the offspring? _____

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4. A guinea pig is hairless, but both of its parents have normal hair. Complete the Punnett square to show how this is possible.

Parents' genotypes: _____ and _____

Genotypic ratio of the offspring:

_____

Phenotypic ratio of the offspring:

_____

5. Use a Punnett square to show how two hairless guinea pigs cannot produce a normal haired offspring.

Parents' genotypes: _____ and _____

Genotypic ratio of the offspring:

_____

Phenotypic ratio of the offspring:

_____

6. Use a Punnett square to show how two pure-bred normal-haired parents cannot produce hairless offspring.

Parents' genotypes: _____ and _____

Genotypic ratio of the offspring:

_____

Phenotypic ratio of the offspring:

_____

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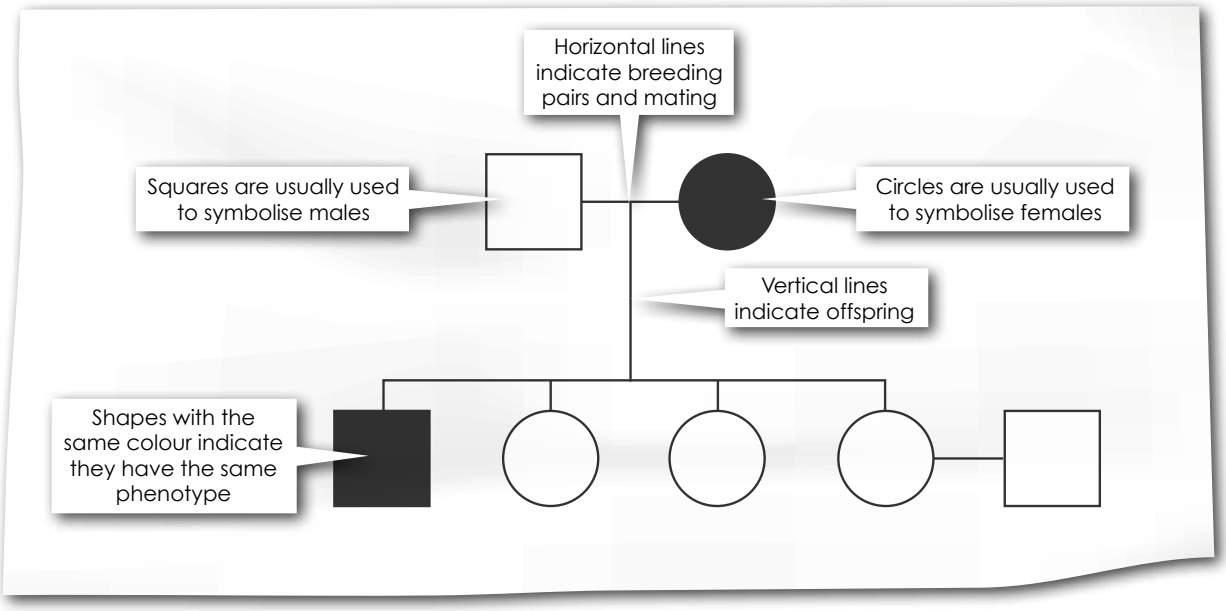
Pedigree Charts

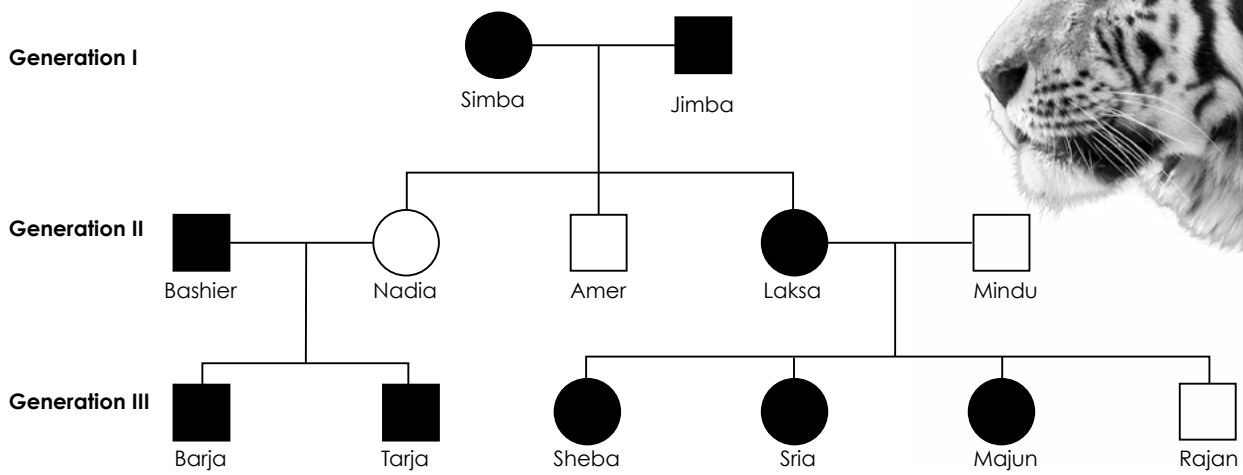
A pedigree chart is like a family tree that shows the genetic relationships between members of the same family. They can show many generations and are used to track genetic conditions.



Tigers' Fur

Tigers with white fur are extremely rare in the wild. However, two orange-brown tigers in captivity in the United States, called "Simba" and "Jimba", are known to produce white offspring. Orange-brown fur is coded by the dominant allele (T). An orange-brown tiger can have the genotype 'Tt' or 'TT'. A tiger with the genotype 'tt' will have white fur.

The pedigree diagram below shows three generations of tigers. The black shapes indicate tigers with orange-brown fur. The white shapes indicate tigers with white fur. Male tigers are shown by squares, females by circles.



1. (a) How many offspring did the tigers named "Simba" and "Jimba" have?

   _____

   (b) How many of these offspring were female?

   _____

   (c) How many of their offspring had orange-brown fur?

   _____

2. What is the name of:

   (a) The tiger "Nadia" mated with? _____

   (b) The male tiger of the second generation? _____

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3. Describe the gender and fur colour in the second generation of tigers. _____

4. Explain how both of the original tigers had orange-brown fur, but some of their cubs have white fur. You should use a Punnett square to help you explain your answer.

5. Determine the genotype of "Laksa". Support your answer with:

- Reference to specific tigers from the pedigree chart.
- A Punnett square.

6. Outline why it is difficult to determine the genotype of "Bashier".

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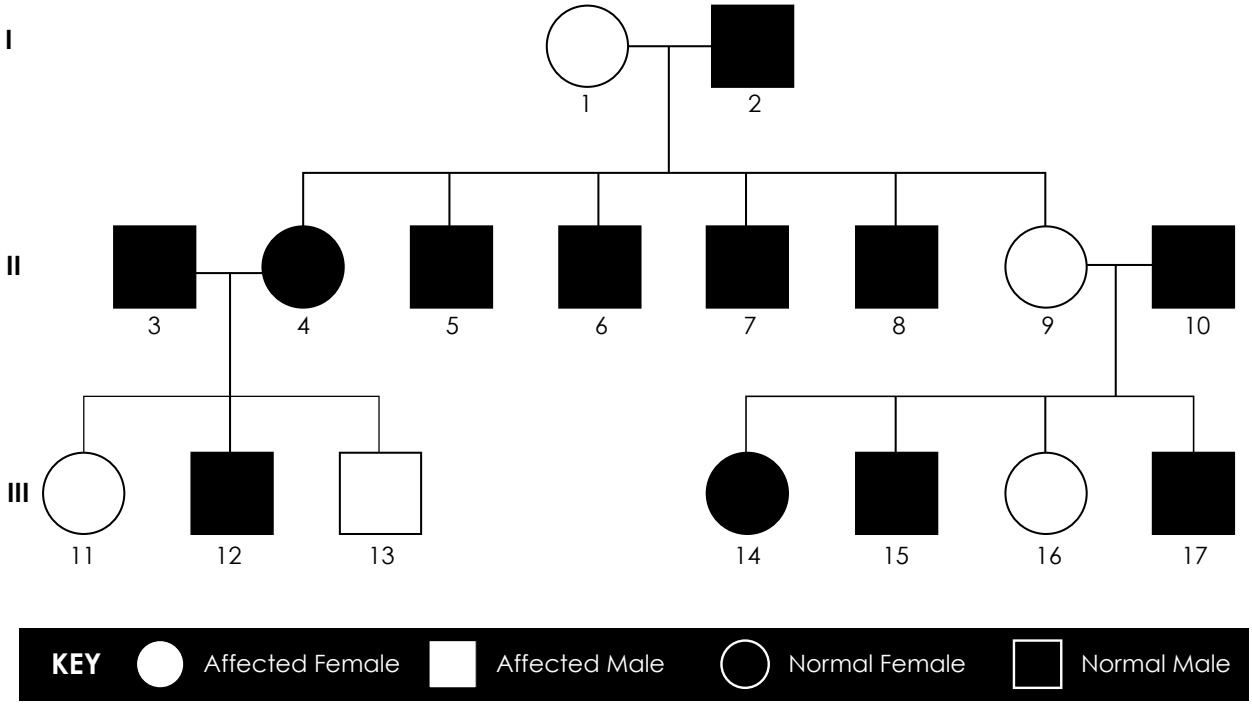
Cystic Fibrosis

Cystic fibrosis is a genetic disorder which results in the lungs becoming filled with a thick mucus. This frequently-occurring disorder often leads to pneumonia and death during childhood.

The pedigree chart below shows the inheritance of the disease through three generations of a family.



1. State whether cystic fibrosis is a dominant or recessive condition?

2. Explain the reason for your answer to 1. Support your answer with:
   - Reference to specific individuals from the pedigree chart.
   - A Punnett square.

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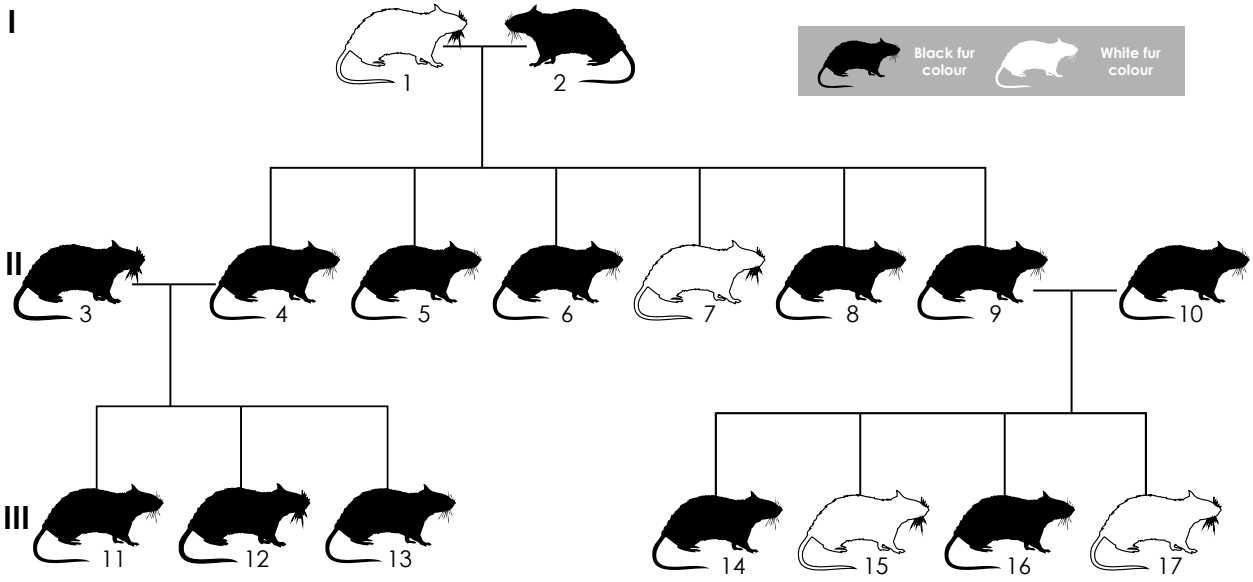
Pedigree Rats

In common rats, fur colour is controlled by a gene. Fur colour can either be black or white. The pedigree diagram below shows the inheritance of fur colour through three generations of rats.



1. Using evidence from the pedigree chart, determine the genotype of 'Rat 9' and 'Rat 10'. In your answer you must:
   - Explain whether the white-furred phenotype is dominant or recessive.
   - Refer to specific rats from the pedigree chart.
   - Support your answer with Punnett squares.

2. A rat breeder suspects that 'Rat 4' maybe be a pure breeding (*homozygous*) black rat. Using evidence from the pedigree chart, explain how 'Rat 4' CANNOT possibly be homozygous. Support your answer by:
   - Referring to specific rats from the pedigree chart.
   - Using Punnett squares.

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A Test Cross

Animal and plant breeders often want pure-bred stock. This is because the pure-bred organism has no hidden genetic characteristics that may be undesirable. When pure breeding individuals cross, they will always produce offspring with the same phenotype as the parents.

If we consider the rats from the previous exercises (i.e. B = black and b = white), just because a rat displays the dominant phenotype (black fur), it doesn't necessarily mean it is a pure bred (homozygous). A black rat could be heterozygous (Bb) or homozygous (BB).

In order to determine if an animal is pure bred, a breeding test, called a *test cross*, is carried out. A test cross involves mating the organism in question with an individual that is *homozygous recessive* for that condition. If the recessive phenotype appears in the offspring then the organism in question must be heterozygous.

1. Define the term '*pure bred*': _____

_____

_____

2. Outline why an animal or plant breeder may only want stock that is pure bred? _____

_____

3. In guinea pigs, long hair (L) is dominant to short hair (l). A guinea pig breeder suspects that one of her long-haired guinea pigs is not pure-bred. Outline how the breeder could determine whether the guinea pig in question is pure-bred or not. You should use a Punnett square to support your answer.

_____

_____

_____

_____

_____

_____

4. A plant breeder carried out a test cross on some of his flowers. He knew that the allele for red flowers (R) is dominant to the allele for white flowers (r). He crossed one of his red roses with a white rose. 200 seeds were produced from the cross. When planted, 106 of these seeds grew into a plant that produced red flowers. 94 of the seeds grew into plants that produced white flowers.

   (a) Was the original red parent plant pure-bred? _____

   (b) Justify your answer to (a). _____

   _____

   (c) Based on the observed phenotypic ratio (i.e. 106 red : 94 white), what are the likely genotypes of the parent plants? _____

   _____

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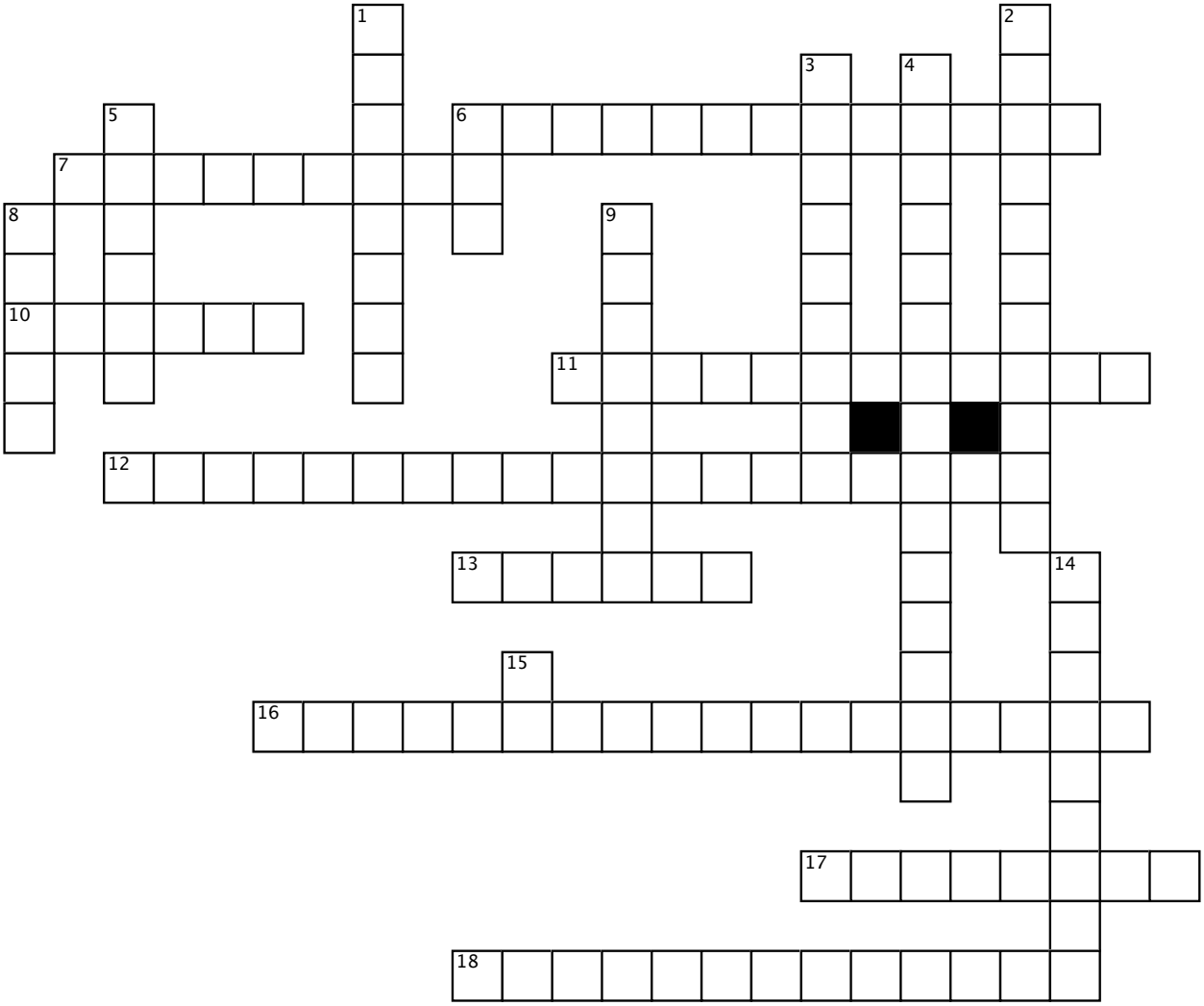
Predicting Inheritance Crossword



Across

6. A chart that shows the genetic relationships between members of the same family.
7. This allele is only expressed in the phenotype if two of them are present.
10. An alternative form of a gene.
11. If an organism has two alleles that are different, they are described as this.
12. If an organism has two alleles that are the same and recessive, they are described as this.
13. Considered to be the 'father' of modern genetics.
16. If an organism has two alleles that are the same and dominant, they are described as this.
17. Name for the set of alleles carried by an organism.
18. A grid-like diagram used to make predictions about inheritance.

Down

1. This allele is always expressed in the phenotype even if only one of them is present.
2. 46 of these in a somatic cell.
3. The name for a breeding test performed in order to determine if an animal is pure bred.
4. Name for a ratio showing the expected appearance of the offspring.
5. If you were 'XX' for chromosome pair 23 you would be one of these.
6. Plants used by Mendel to study genetics.
8. Another word for a genetic characteristic.
9. A term used to describe an individual who is homozygous for a trait.
14. The physical appearance of an organism.
15. Description of chromosome pair 23 in a human male.

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Predicting Inheritance Word Search

The answers to the crossword are all hidden in this word find.

O	V	U	U	F	E	M	A	L	E	E	V	M	M	A	I	C	F	D	J	S	A	Z	H	Z
U	X	S	O	X	E	L	N	T	E	S	T	C	R	O	S	S	K	Q	P	C	N	C	O	P
Q	H	Y	X	C	H	R	O	M	O	S	O	M	E	S	I	U	I	B	C	F	V	T	M	U
T	V	V	J	W	R	E	C	E	S	S	I	V	E	Z	D	D	Q	T	V	Q	Q	O	O	N
J	W	Y	L	N	P	R	K	N	X	K	E	J	X	F	W	O	I	F	W	T	V	L	Z	N
P	P	X	V	P	Z	E	Q	K	L	B	E	E	Z	S	P	F	M	S	F	J	E	O	Y	E
R	E	W	V	T	H	G	P	M	J	N	N	N	V	M	N	W	Q	I	Y	D	Z	X	G	T
P	I	D	A	M	Y	E	Q	Z	Y	P	I	O	X	D	I	E	Q	M	N	U	O	W	O	T
B	U	Y	I	G	D	X	N	Y	L	Z	V	V	F	H	R	L	B	E	Q	A	C	P	U	S
M	U	P	I	G	H	O	M	O	Z	Y	G	O	U	S	D	O	M	I	N	A	N	T	S	Q
C	L	O	F	V	R	A	X	Z	T	Q	Y	H	P	X	H	H	Y	V	K	M	T	T	R	U
W	A	W	T	J	W	E	M	O	P	Y	I	H	F	O	H	X	W	P	I	U	Y	E	E	A
T	A	J	C	Y	J	C	E	P	J	H	P	U	M	N	P	H	M	M	A	Z	P	D	C	R
W	E	Y	N	Q	J	Q	V	C	U	X	E	I	R	F	W	O	Y	M	O	T	M	T	E	E
J	H	O	R	W	E	P	G	A	H	R	P	N	C	G	E	N	O	T	Y	P	E	R	S	U
P	T	B	G	L	M	K	L	Y	B	A	E	A	O	R	A	Z	S	E	L	D	S	A	S	H
O	P	X	Q	M	C	T	T	I	F	Q	R	B	W	T	A	B	X	F	P	Y	X	I	I	H
T	B	T	S	Y	M	H	Y	L	D	Q	L	T	R	V	Y	T	H	Y	W	G	K	T	V	M
N	T	H	E	T	E	R	O	Z	Y	G	O	U	S	E	M	P	I	A	L	L	E	L	E	W
G	E	K	P	F	T	T	P	P	E	A	T	W	P	K	D	A	E	O	K	Y	H	S	S	Z

Predicting Inheritance - Word Scramble

Unscramble the letters and write the correct word in the space provided.

homecmroos _____ nege _____

nepttun _____ mozgohoyus _____

elllea _____ airtt _____

giepdree _____ sezhygoutero _____

tranceheini _____ yhenppote _____

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Predicting Inheritance Chapter Review

Use the boxes to write down the key points from this chapter. Ensure that all key words from the front of the chapter have been used.

Genotypes and Phenotypes

Pedigree Charts

Punnett squares

Sex Determination

Test Cross

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End of Chapter Review Questions

1. Trenrose Peonies in Central Hawke's Bay grow peony flowers. They have carried out a number of breeding experiments on their flowers and have found that red colour (R) is dominant to white (r) colour in peonies.

   (a) Describe what is meant by the terms dominant and recessive.

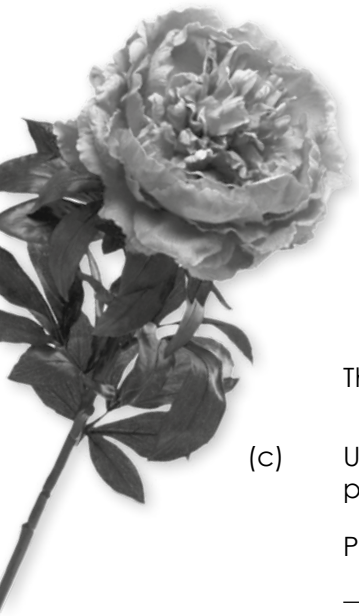
   (i) Dominant: _____

   _____

   (ii) Recessive: _____

   _____

   (b) After a cross between two peony plants it was found that 50% of the offspring produced red flowers and 50% of the offspring produced white flowers. Use a Punnett square to show the likely genotypes of the parent plants.



The genotypes of the parents are _____ and _____.

   (c) Use the example of peony flower colour to describe the difference between phenotype and genotype.

   Phenotype is: _____

   _____

   _____

   Genotype is: _____

   _____

   _____

2. In the kiwi, sex is determined by two chromosomes. Unlike mammals such as humans, it is the male kiwi that has two of the same type of sex chromosome. Male birds have two Z chromosomes and female birds have a Z and a W chromosome.

   Complete the Punnett square below to show the possible combinations of sex chromosomes that could form in a fertilised egg.

Male gametes

Female gametes

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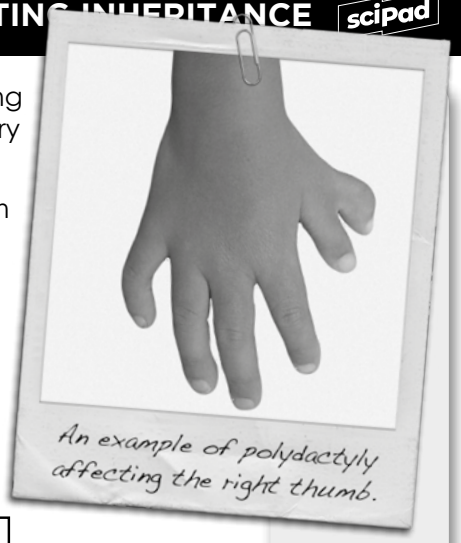
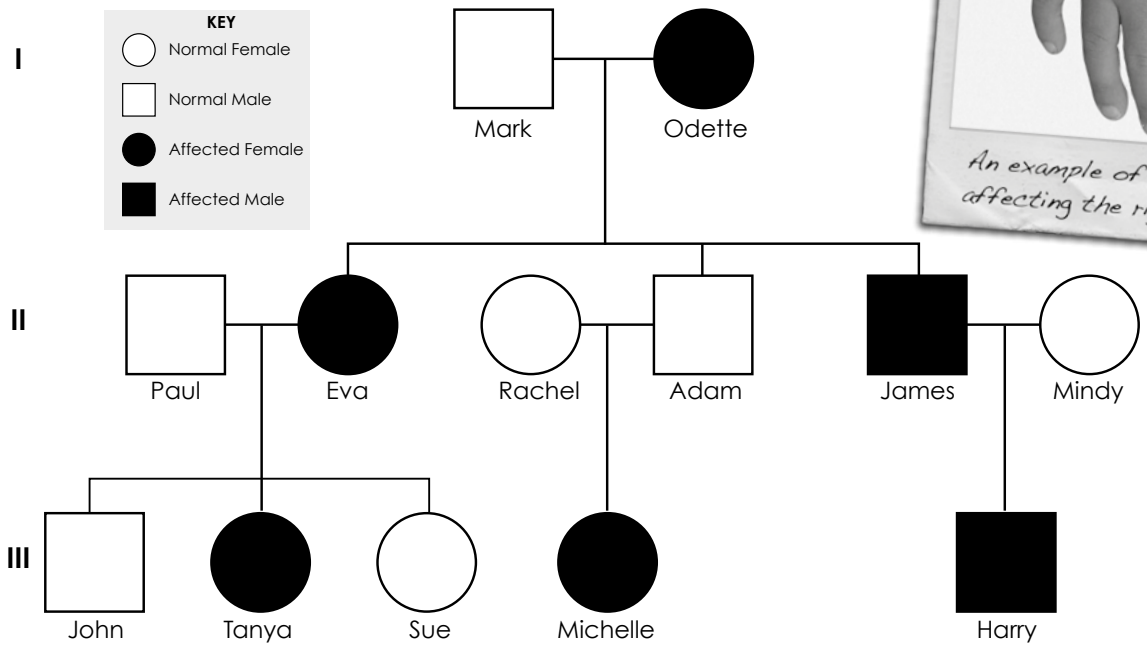
3. Polydactylism is a genetic disorder that results in a person being born with extra fingers or toes. It occurs in approximately 1 in every 500 live births in New Zealand.

The pedigree chart below shows the inheritance of polydactylism through three generations of one family.





Using evidence from the pedigree chart, determine the genotype of 'Odette'. In your answer you must:

- Explain whether the polydactylism allele is *dominant* or *recessive*.
- Refer to specific individuals from the pedigree chart.
- Support your answer with Punnett squares.

Hints for answering these NCEA style questions

If the examiner hasn't given you the alleles - make up your own. Don't forget to include a key somewhere in your answer so the marker knows which allele codes for which trait.

Look for parents who don't show the trait, but produce children who do.

Write suspected genotypes on the pedigree chart.

Test suspected genotypes with Punnett squares on scrap paper.

One of the easiest ways to refer to individuals from the pedigree chart is to name the genotypes on your Punnett square.

For example, in your answer you could have a Punnett square involving Odette and Mark. In this case you would name the genotypes that correspond to the phenotypes of Eva, Adam and James.

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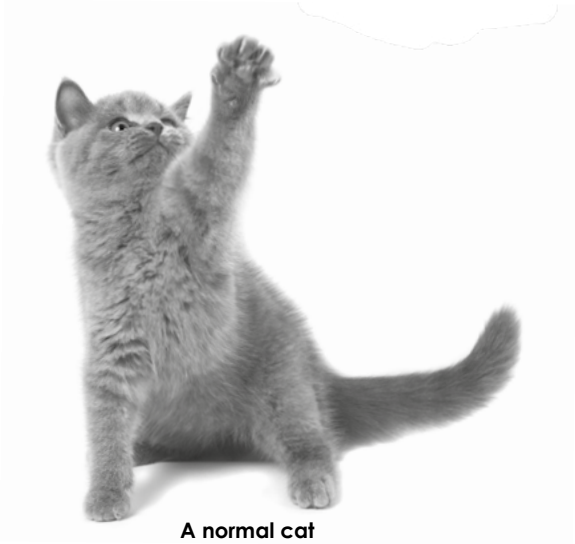
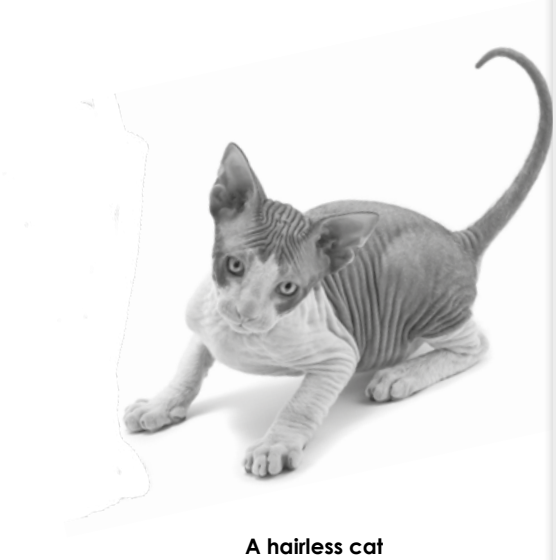
4. A rare genetic condition causes some cats to be born without the ability to produce hair. Normal hair is produced by a dominant allele (H), while hairlessness is caused by the recessive allele (h).



A normal cat



A hairless cat

(a) Describe what is meant by the terms **dominant** and **recessive**.

_____

_____

_____

_____

(b) After a cross between two cats it was found that half (50%) of the offspring had normal hair and half (50%) of the offspring were hairless.

Describe the genotype and phenotype of the parents. In your answer you must:

- Define the terms "*phenotype*" and "*genotype*".
- Use a Punnett square to support your answer.

_____

_____

_____

_____

_____

_____

_____

_____

Parent 1: Genotype _____ Phenotype _____

Parent 2: Genotype _____ Phenotype _____

Hints for answering these NCEA style questions

Use two separate sentences to define the terms ensuring you use the word "allele" in your answers.

Define '*genotype*' ensuring you use the word '*alleles*'.

Define '*phenotype*' ensuring you use the phenotypes given in the question as examples.

You will need to deduce the genotypes of the parents. Try various genotypes in Punnett squares on some scrap paper to see which cross would result in 50% normal, 50% hairless.

Once you have your answer, write it neatly in the Punnett square provided.

State the parents' genotype and phenotype. Be careful you don't mix them up.

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(c) The sex of the cats is controlled by two chromosomes. Female cats have the chromosomes ZZ, whereas male cats have the chromosomes ZY.

Two cats already have *4 male* offspring.

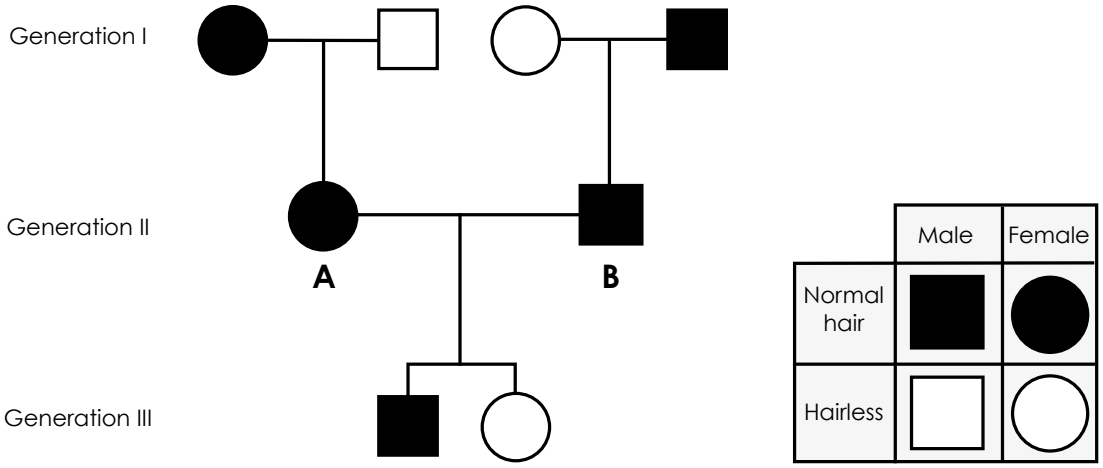
Discuss the likelihood of their next offspring being female. In your answer you should:

- Complete a Punnett square to support your answer.
- Explain the relevance of the pair already having offspring.

Male gametes

Female gametes

(d) The pedigree chart below shows the inheritance of hairlessness through three generations of cats.



Explain why the genotype of female A in generation II of the pedigree diagram shown above must have the genotype Hh.

Hints for answering these NCEA style questions

Remember the sex of new offspring is not affected by the sex of previous offspring.

State the expected probability as either a fraction or a percentage.

Ensure you put the correct chromosomes into the correct spaces on the Punnett square (i.e. ZY is male and ZZ is female).

Look at the parents of female 'A'. her father was hairless (hh) while her mother was normal (HH or Hh). Because female 'A' has normal hair she must have one normal hair allele. Because her father was hairless, he would have contributed an 'h' to her genotype.

You could draw a Punnett square to support your answer.

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UNDERSTANDING VARIATION

By the end of this chapter you should be able to:

	I KNOW THIS ALREADY	I LEARNED THIS	I REVISED THIS
Define variation in terms of being *continuous* or *discontinuous*.			
Discuss the advantages and disadvantages of *asexual reproduction* in terms of producing offspring that are genetically identical (*clones*).			
Describe the process of *meiosis* and explain why it is important in generating variation in the gametes.			
Explain how *sexual reproduction* produces new combinations of alleles.			
Discuss the advantages and disadvantages of sexual reproduction.			
Explain the importance of *mutations* in forming new alleles.			
Discuss why individuals in a population may have differing probabilities of survival based on their *phenotype*.			
Explain the importance of *variation* within a population during a change in their environment such as pest infestation, disease, drought or flood.			

Key Terms

Genetic variation

My Definition: _____

_____

Meiosis

My Definition: _____

_____

Gamete

My Definition: _____

_____

Zygote

My Definition: _____

_____

Asexual Reproduction

My Definition: _____

_____

Sexual Reproduction

My Definition: _____

_____

Mutation

My Definition: _____

_____

Crossing over

My Definition: _____

_____

Independent assortment

My Definition: _____

_____

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What is Variation?

The term '*species*' is used by scientists to classify organisms of the same type. Organisms of the same species are able to reproduce to make more of that species.

All humans belong to the same species - *Homo sapiens*. Although the people in your class are all the same species, they are all slightly different. Scientists call this difference '*variation*'. The variation between members of the same species (i.e. your classmates) will always be less than the variation between two individuals of different species (i.e. you and a seagull).

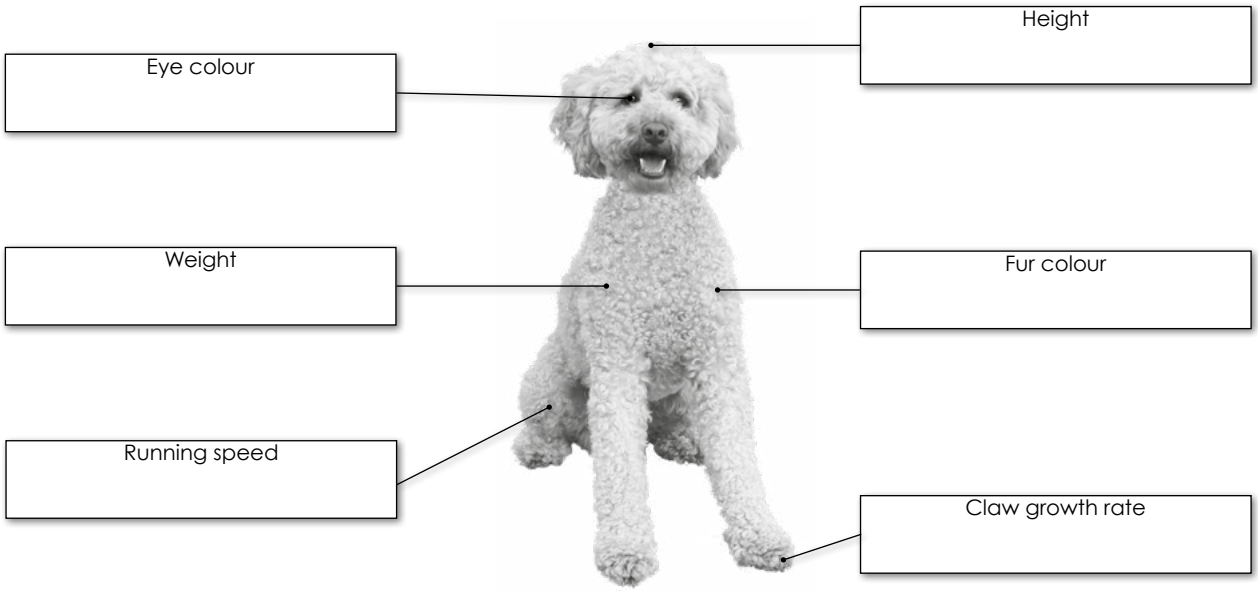
Types of Variation

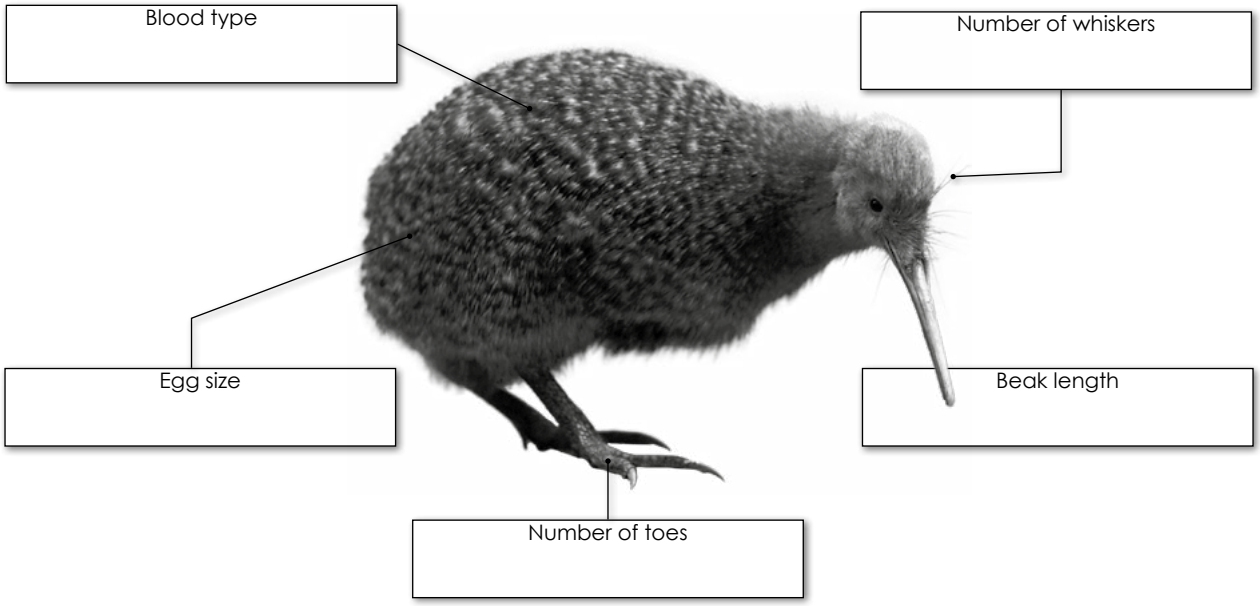
Variation can be *continuous* or *discontinuous*.

In continuous variation there is a complete range of measurements from one extreme to the other. For example, human height ranges from the shortest person in the world to the tallest person. Humans could be any height in between these values.

Discontinuous variation occurs when characteristics fall into a number of distinct classes or categories. For example, your ear lobes can either be "fixed" to the side of your head, or "free" to dangle. There is no in-between.

1. Label the photographs below by stating whether the examples show continuous or discontinuous variation.





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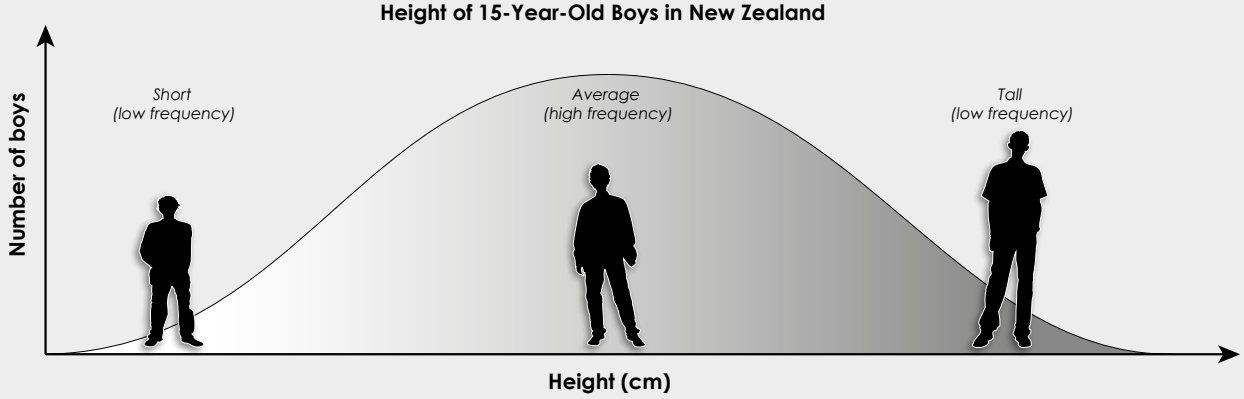
Variation and Normal Distribution

The study of a measurable *trait* (such as height) in a large population usually reveals that very few individuals possess extreme characteristics (i.e. very tall or very short) and that more individuals are found nearer the average value for that population. This type of distribution is called a "normal *distribution*" and is characterised by a bell-shaped graph as shown below.

Height of 15-Year-Old Boys in New Zealand



Measuring Height

Method: 1. Your teacher will set up a measuring station for you to measure your height.

Results: My height _____cm

Collate the class's results on the board so you can get data for the entire class. Record the class results in the table below and draw a line graph of your data.

Height (cm)	< 140	140 -145	146 -150	151 -155	156 -160	161 -165	166 -170	171 -175	176 -180	> 180
Tally										

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Discussion:

1. Discuss how your results show *variation*. _____

2. Is height an example of *continuous* or *discontinuous* variation? Justify your answer. _____

3. Explain why the results from your class do not show a *smooth* normal distribution curve.

4. State whether the following characteristics show *continuous* or *discontinuous* variation.

   (a) Weight. _____

   (b) Eye colour. _____

   (c) Blood type. _____

   (d) Hair colour. _____

   (e) Fingernail growth rate. _____

   (f) The ability to roll your tongue. _____

   (g) Foot length. _____

   (h) Gender. _____

5. The fur colour in rabbits is an example of continuous variation.

   (a) Sketch a labelled graph for the distribution of fur colour within a large population of wild rabbits.

   (b) Suggest a reason why only a relatively small number of rabbits have either light or dark fur. _____

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Sources of Variation - An Overview

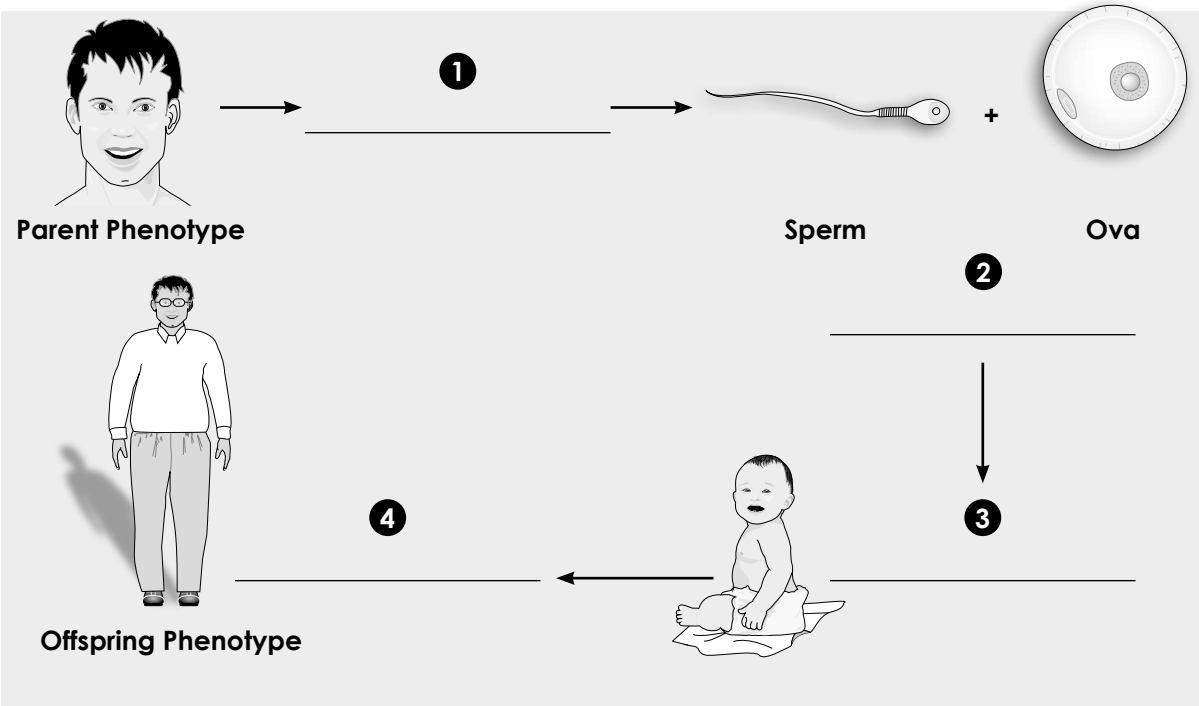
Without genetic variation some of the basic mechanisms of evolutionary change cannot operate.

The table and diagram below shows some of the primary sources of genetic variation, which will be covered in more detail in this chapter.

1. Match the '*Source of Variation*' with its '*Definition*'.

Source of Variation	Definition
Mutation •	• The unique combination of alleles in sperm and ova and the random chance of them meeting mean that an individual is born with a completely unique *genotype* (combination of alleles) and *phenotype* (appearance).
Sexual Reproduction •	• Changes in the base sequence of DNA that may result in new alleles.
Fertilisation •	• Can act to alter the expression of the genotype. For example, food and nutrient availability, competition, light intensity (plants), and disease, etc. may all result in modification of the expected phenotype.
Environment •	• The process of *meiosis* (cell division for production of gametes - sperm and ova) and *mate selection* result in unique combinations of alleles.

2. Use the terms from the 'Source of Variation' column to label the diagram below.



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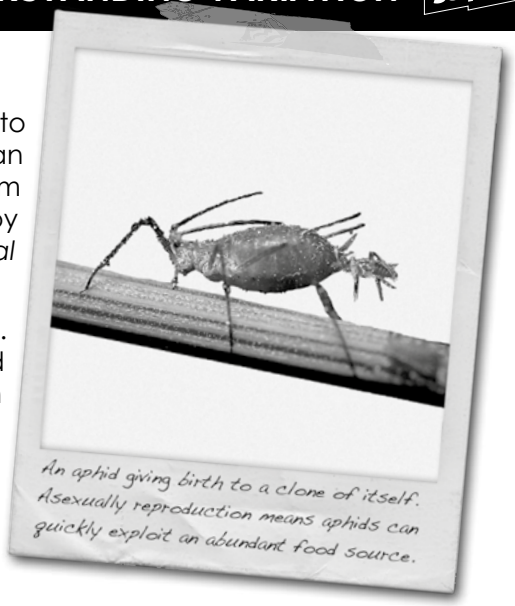
Asexual Reproduction


An aphid giving birth to a clone of itself. Asexually reproduction means aphids can quickly exploit an abundant food source.

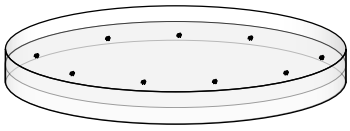
All living things need to reproduce (produce offspring) in order to ensure the continued survival of their species. Reproduction can be defined as the creation of a new individual or individuals from previously existing individuals. There are two main methods by which organisms reproduce: *asexual* reproduction and *sexual* reproduction.

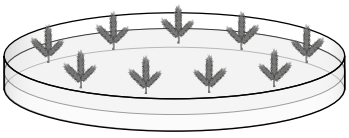
Asexual reproduction needs only one parent (usually a female). The offspring are identical to the parent and to each other and are known as *clones*. Asexual reproduction is more common in plants than in animals, although there are some animals that can reproduce this way. Potatoes and strawberries can both reproduce asexually. The main advantage of asexual reproduction is that it is an efficient method of reproducing (no time or energy is spent looking for a mate) which means the individual can exploit favourable conditions (lots of food and space, etc.) very quickly. However, because the clones are all identical and there is no genetic variation, if the environment changes or they are exposed to a new disease they may have little chance of survival.

1. Define the term *asexual reproduction*. _____

2. Outline why asexual reproduction *doesn't* lead to variation in the offspring. _____

3. In New Zealand, most of our commercial pine forests are grown from clones.





1. Cuttings are taken from carefully selected trees. Small sections of tissue are removed from the cutting.
2. The sections of tissue are grown in a nutrient mix that contains hormones to promote root growth.
3. The sections of tissue grow into new trees, all being genetic clones of each other.

(a) Name the type of cell division occurring between stages 2 and 3 in the diagram above. _____

(b) Discuss the genetic advantage of using clones rather than seeds. _____

(c) Discuss the major disadvantages of relying on pine trees that are all genetically identical (clones). _____

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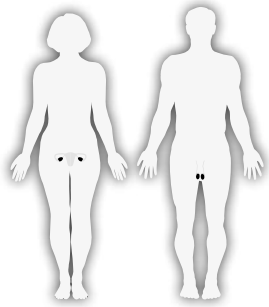
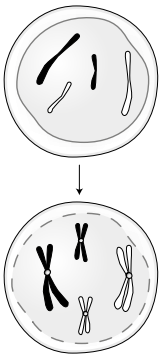
Cell Division - Meiosis

Meiosis (from the Greek, meaning "*to make smaller*") is a special type of cell division that produces male and female *gametes*. A gamete is a sex cell (sperm in males and ova in females). A human body cell contains 46 chromosomes. Gametes only contain half as many chromosomes (23). During meiosis genes get shuffled, and this leads to variation within a population. Meiosis is the reason you look similar, but not identical, to your parents and siblings. The diagram below is simplified and only shows a cell containing 4 chromosomes.



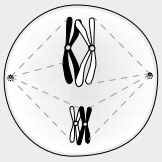
Meiosis only occurs in the testes of men or the ovaries of women.



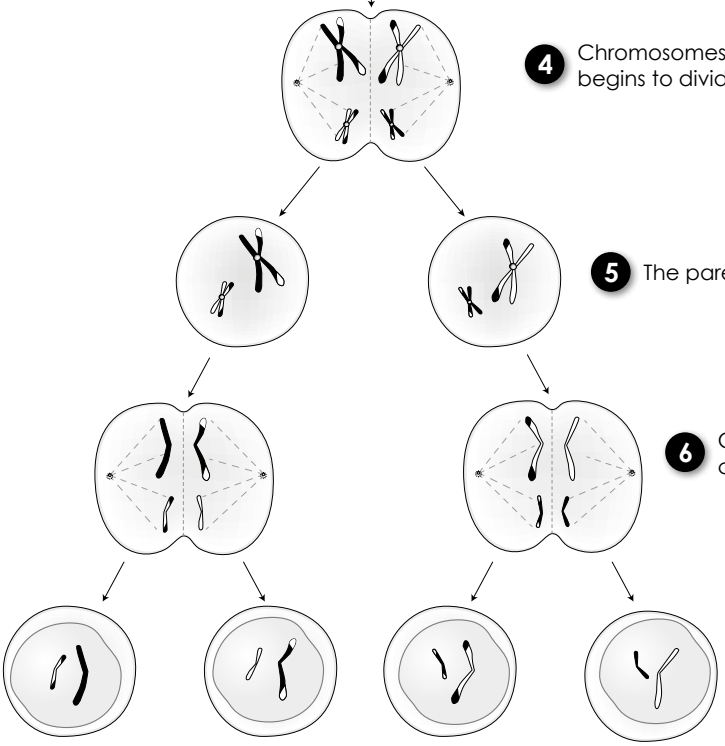
1. When the cell is not dividing, the chromosomes are not visible. They are unwound and are being used to make proteins (*protein synthesis*). They are shown here as discrete chromosomes so you can track the differences between the parent cell and the daughter cells.

2. Chromosome replicate. The nuclear membrane disappears.

Crossing Over
This process is very important. It ensures that there will be *variation* among the offspring.



3. Homologous pairs of chromosomes exchange sections of DNA (and therefore genes) by a process called *"crossing over"*. They then line up at the cell equator (the middle of the cell) in random order.



4. Chromosomes get pulled apart and the parent cell begins to divide.

5. The parent cell splits in two.

6. Chromosomes line up in single file at the cell equator and get pulled apart.

7. Four daughter cells (or *gametes*) are produced, each with half of the original number of chromosomes.

1. Outline the primary purpose of meiosis. _____

_____

2. Name two places where meiosis occurs: (a) _____

(b) _____

3. How many daughter cells are formed by meiosis? _____

4. How many chromosomes are found in (a) a normal human body cell? _____

(b) daughter cells produced by meiosis? _____

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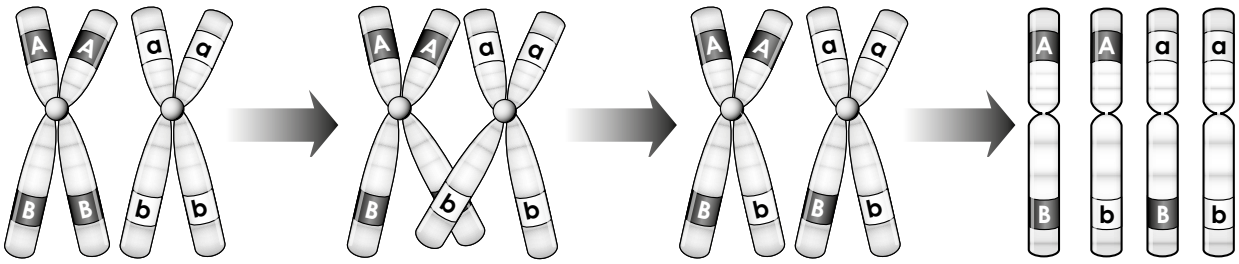
Meiosis as a Cause of Variation

Meiosis produces genetic variation - it's the reason why you don't look identical to other members of your family. There are two important steps occurring during meiosis that cause this *variation*.

Crossing Over

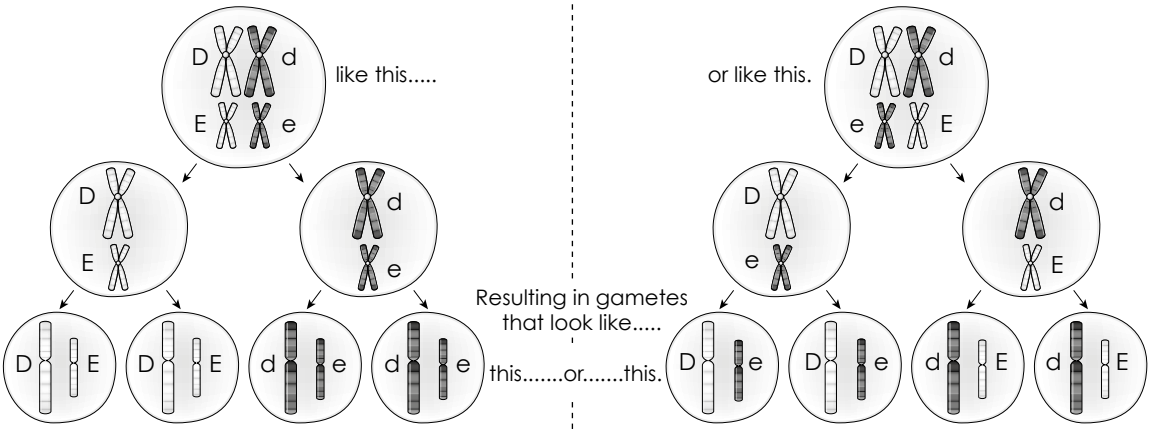


Homologous chromosomes pair up. | Parts of neighbouring chromosomes cross over. | Crossed over sections of chromosomes (and therefore alleles) are exchanged. | Each gamete produced may have different combinations of alleles.

Independent Assortment

When homologous pairs of chromosomes line up during meiosis, they do so randomly (i.e. in no particular order). This means it is completely random which combination of alleles end up in a particular gamete. In humans, independent assortment of our 23 pairs of chromosomes means there are over 8 million possible combinations!

The same four chromosomes line up randomly.....



1. Explain how cell division by meiosis leads to genetic variation. _____

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Sexual Reproduction

Sexual reproduction requires two parents. The offspring produced by sexual reproduction are similar, but not identical, to the parents. The offspring are a combination of the characteristics of the parents. The main advantage of sexual reproduction is that it produces *variation*. This means a few of the offspring may be better suited to survive in the habitat, meaning the species can become more successful over time. Many organisms reproduce sexually. The benefits of producing offspring that show variation far outweigh the costs of finding a mate, breeding and producing offspring.

1. Define the following terms:

   (a) *Variation.* _____

   _____

   _____

   (b) *Sexual reproduction.* _____

   _____

   _____

2. Complete the table to show the key differences between asexual and sexual reproduction.

	Asexual reproduction	**Sexual reproduction**
Number of parents required		
Relative time required to produce offspring	*Fast / Slow*	*Fast / Slow*
Variation between parent and offspring	*Yes / No*	*Yes / No*
Examples of organisms that use this method		

3. Use the data from the table and the page on "Asexual Reproduction" to compare and contrast the advantages and disadvantages of sexual and asexual reproduction.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

An examiner's report stated very few candidates were able to discuss the disadvantages of sexual reproduction.

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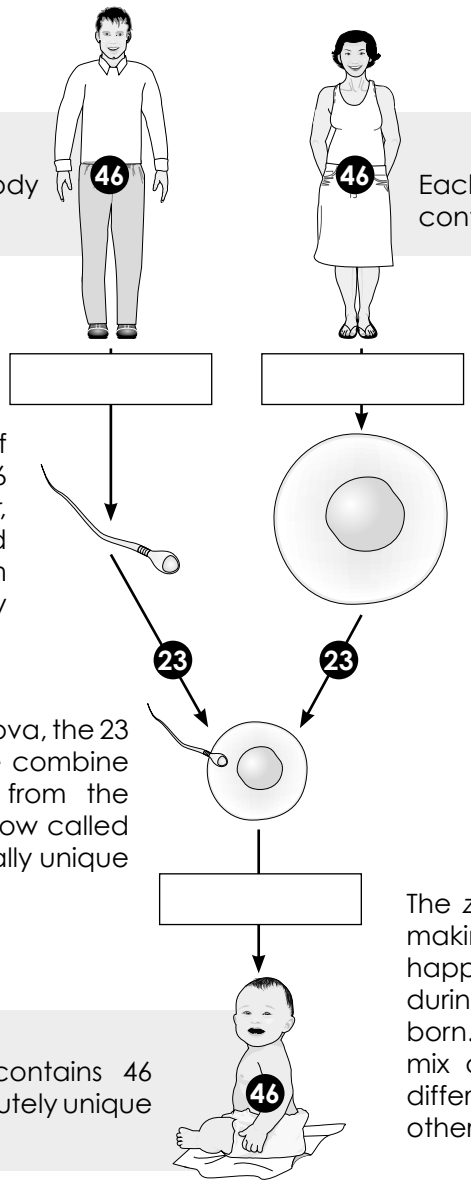
Making Babies



Your Dad
Each cell in the male body contains 46 chromosomes.

Your Mum
Each cell in the female body contains 46 chromosomes.

Sperm
During the production of sperm cells, the male's 46 chromosomes cross over, independently assort and separate, so each sperm cell receives 23 genetically unique chromosomes.

Ova
During the production of an ova, the female's 46 chromosomes cross over, independently assort and separate, so each ova receives 23 genetically unique chromosomes.

Fertilisation
When the sperm reaches the ova, the 23 chromosomes from the male combine with the 23 chromosomes from the female. The fertilised ova is now called a *zygote* and has 46 genetically unique chromosomes.

Birth
The *zygote* then grows and divides making new cells. This process happens many thousands of times during the 9 months until you are born. Because you have a unique mix of alleles you are genetically different to your parents, and every other human being!

You
Each cell in your body contains 46 chromosomes, with an absolutely unique arrangement of alleles.

1. Complete the diagram by writing in the white boxes the type of cell division occurring at that stage.

2. Define the term '*zygote*'. _____

3. Discuss why it is important that gametes contain half the number of chromosomes found in the parent._____

4. State the two processes that occur during the production of gametes that leads to genetic variation in the offspring. (a) _____
   (b) _____

5. Identify which of the following statements is *incorrect*.
   Fertilisation leads to genetic variation because:
   (a) Two genetically unique gametes randomly combine forming unique offspring.
   (b) The resulting offspring has a mix of the genetic material of the parents.
   (c) Male gametes are genetically more diverse than female gametes.

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Mutation as a Cause of Variation

Previously you have seen that meiosis and sexual reproduction bring about new combinations of genes in individuals within a population. However, neither meiosis nor sexual reproduction can create new genes or alleles.

In order to create a new gene or allele the base sequence of a section of DNA needs to change. When a permanent change occurs in the base sequence of DNA, scientists call it a *mutation*.

Despite what you may have seen on TV or in the movies, mutations do not turn turtles into ninjas, or cause blades of metal to come shooting out of your fists when you're angry!

Most organisms are 'carrying' mutations – including yourself. In fact it is suggested that each of us has up to 30 mutations in our bodies at any one time.

Mutations can occur naturally during DNA replication. The rate of mutation can be increased by exposure to *mutagens*. Common mutagens include some chemicals (such as those found in cigarettes and fatty foods), ultraviolet light (from the Sun), and radiation (from x-rays, or radioactive materials, etc.).

'Mutation' sounds like a word that means only bad things. However, mutations can be *neutral* or *silent* (i.e. they have no observable effect on an organism). Some mutations may be harmful and may affect the survival of the organism.

One of the most common harmful effects of mutations in humans is cancer. Cancer is caused by a mutation which makes cells divide and grow at an abnormally fast rate. As the cancerous cells continue to grow and divide they produce a mass of tissue called a *tumour*.

Occasionally, a *beneficial mutation* will give the organism a survival advantage over other members of its species, and it may live on in conditions where others die (e.g. there are examples of insects that, due to a mutation, are resistant to most common insecticides).

1. State the three causes of variation within a population. _____

2. Define the term '*mutation*'. _____

3. (a) Define the term '*mutagen*'. _____

   (b) Give three examples of mutagens (i) _____
   (ii) _____
   (iii) _____

   (c) Exposure to mutagens may lead to a particular disease in humans. Name this disease. _____

4. Outline the differences between a *silent* mutation, a *beneficial* mutation and a *harmful* mutation. _____

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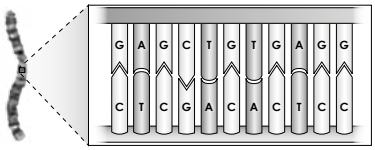
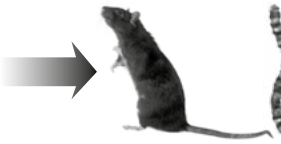
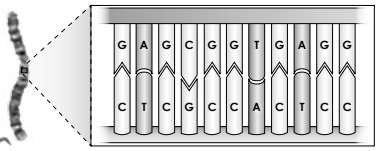
Mutations can change an allele or create a new one. This may cause an increase in the variation within a population.





The normal base sequence from a gene results in a **protein** that leads to a dark-coloured phenotype.



A single mutation in the gene for coat colour has resulted in a different **protein** being produced. This results in a white-coloured phenotype.

Mutations that occur in body cells (somatic cells) are not passed on to the offspring (i.e. they are not inherited). Only mutations that occur in gametes can be passed onto the offspring.

5. Draw a circle to identify where the mutation has occurred in the diagram above.

6. Albinism is a mutation that causes an organism to be born without any pigmentation in its skin. Albinism affects a number of animals, including humans. Albino rabbits are very common in captivity but are almost never seen in the wild.

   Give reasons why albino animals are very rarely found in natural environments, but are quite common in captivity. _____

   _____

   _____

   _____

7. A common example of a mutation leading to increased variation is seen among bacteria. Use the numbers 1-6 to arrange the following statements in order, explaining how bacteria are evolving to become resistant to antibiotics.

	After visiting the doctor they are prescribed antibiotics to kill the bacteria.
	Within the population of bacteria, a few individuals have a mutation that gives them some resistance to the antibiotics.
	The bacteria that contain the mutation are only partially damaged. Completing the full course of pills could have killed all the bacteria.
	Prescribed antibiotics begin to kill the most of the bacteria. The patient feels better so stops taking the antibiotics.
	A person suffers from a throat infection caused by bacteria.
	The resistant bacteria now multiply and create a population of bacteria that are now resistant to the antibiotic. The infection is potentially untreatable.

8. Mutations that occur in somatic cells of humans (i.e. in the skin) are not inherited.

   (a) What is a *somatic* cell? _____

   (b) Outline how a mutation in a parent's cell can be passed on to their offspring. ____

   _____

   _____

   _____

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The Importance of Variation

Variation contributes to the survival of a species. Without variation, evolutionary changes cannot occur. If the climate changes, a new disease appears, the food supply changes or a new predator appears, those individuals that are best suited to the change will survive and reproduce. Those that are not well suited tend to die off before they are able to reproduce and pass on their genes to future generations.

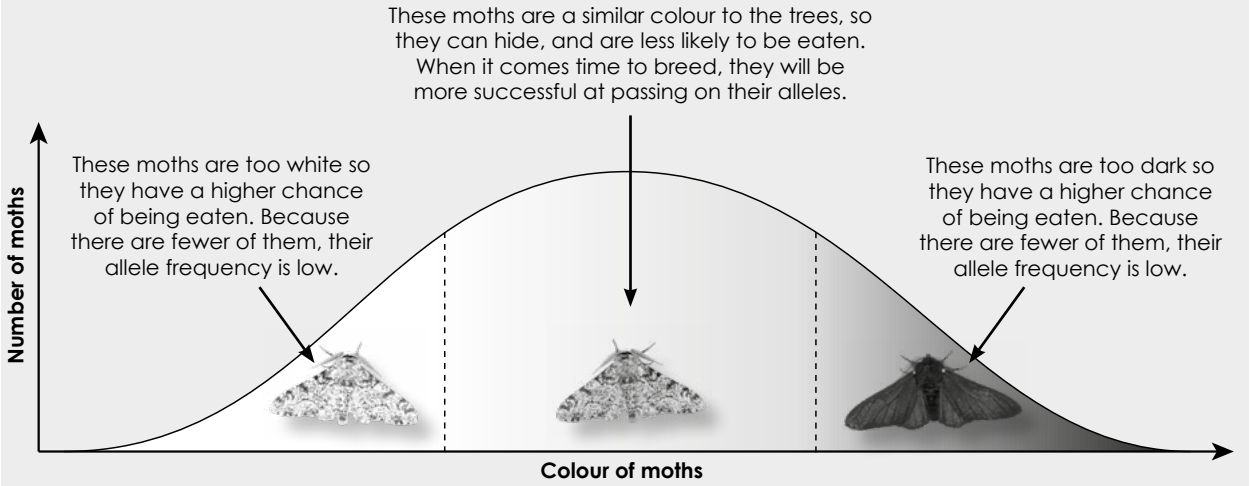
Scientists call this process "*natural selection*". The environment 'selects' the best individuals, and as a result, the species changes (evolves).

Because favourable phenotypes will always be more numerous within a population (unfavourable phenotypes will be selected against and therefore less numerous) when a graph of phenotypic frequency is plotted, it will typically be normally distributed.

An Example of Selection in Peppered Moths

The Peppered Moth (*Biston betularia*) is common throughout England. The moths have two main colour variations. Most of the moths are grey in colour with small black speckled spots. The grey moths are able to blend in with the light-coloured lichens and tree bark. The less common dark-coloured moths are more likely to be eaten by birds.

Scientists collected moths and recorded their colour. Like most genetics characteristics, their colour showed variation. A few were very white, most were grey, and a few were black.



1. Suggest two possible causes of the variation within the moth population

   (a) _____

   (b) _____

2. Explain why the grey-coloured moth has the most favourable appearance (*phenotype*).

   _____

   _____

   _____

   _____

During the Industrial Revolution, the countryside between London and Manchester was blanketed with soot from the new coal-burning factories. Many of the light-bodied lichens died from sulfur dioxide emissions, and the trees became covered with soot.

3. (a) State the moth colour that would now be favoured. _____

   (b) Justify your answer. _____

   _____

   _____

   _____

   _____

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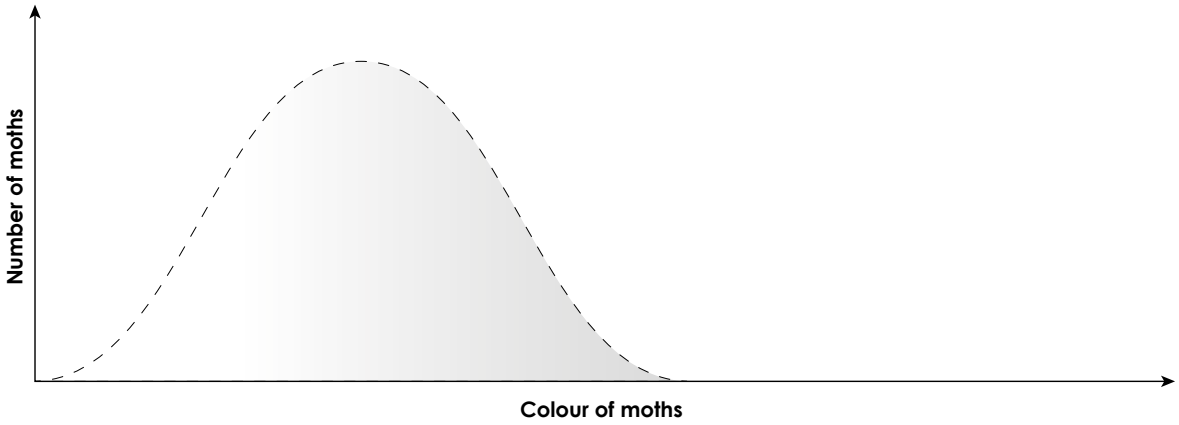
4. Sketch a labelled graph to show the relative frequency of moth colour during the Industrial Revolution. The frequency of moth colours before the Industrial Revolution has been plotted for you.



5. Put the following statements in order to demonstrate how the frequency of the grey-coloured Peppered Moth changes. The first one has been done for you.

Order of statement	Statement
1	Individuals within the moth population show variation.
	Individuals that were better adapted survived better and had more offspring.
	Over many generations, successful alleles became more common and unsuccessful ones became rarer or were removed.
	Survivors pass on their genes to the next generation.
	Some colour variants in the population have an advantage since they are better camouflaged.
	Some individuals are eaten by predators every day.

In 1956 the British Government passed the "Clean Air Act" that banned factories from burning coal and producing lots of soot near towns and cities.

6. Explain the likely impact of the "Clean Air Act" on the frequency of grey-coloured and dark-coloured Peppered Moths. _____

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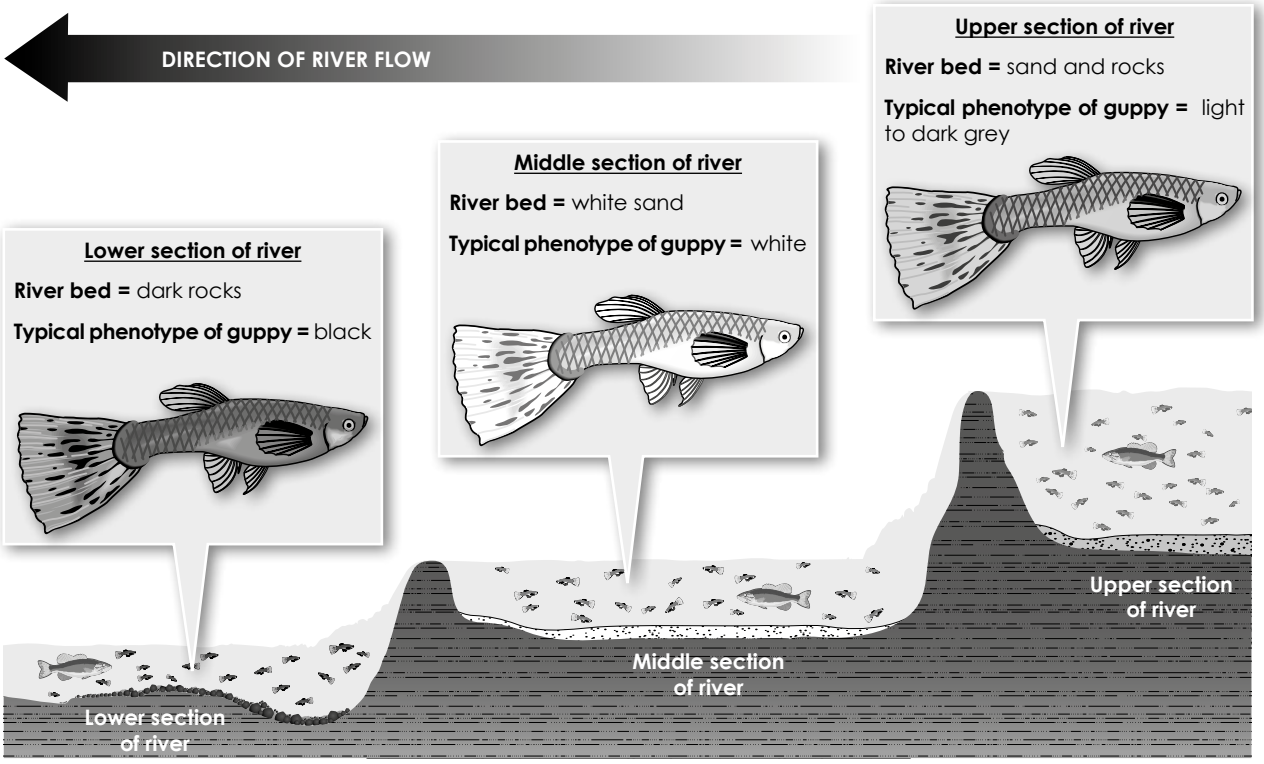
Variation in Guppies - An Example of Natural Selection

Three different populations of guppies (a type of small fish) are found in the same river. The river bed of the upper section of the river is covered with sand and rocks. In the middle section it is mainly covered in a fine white sand. The bed in the lower section of the river is covered in dark pebbles and bedrock. The three sections of river are divided by waterfalls that act as barriers, preventing fish from lower sections reaching the section above them. A predatory fish called a cichlid (pronounced "sick-lid") eats guppies. They are present in all sections of the river.



1. Name the main predator of the guppies in this river. _____

2. Guppies cannot out-swim a predator. Suggest how guppies might avoid being eaten.

_____

3. Using the information from the top of the page and your answers to questions 1 and 2, write a reasonable explanation that accounts for the colour differences in the three guppy populations. Ensure you mention the words variation (in colour) and selection (by predators) in your answer. _____

_____

_____

_____

_____

_____

_____

_____

_____

4. Female guppies prefer to mate with males with the biggest tail. Suggest why male guppies have not evolved very large tails to exploit this advantage? _____

_____

_____

_____

_____

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Variation in Rodents - An Example of Natural Selection

SILVERBACK TIMES

BRINGING YOU THE LATEST NEWS FROM AROUND NEW ZEALAND

MUTANT MICE GET FAT ON POISON

Mice have found ways of outwitting humans in the matter of survival - by evolving resistance to a common poison.

New research by Michael Kohn and colleagues at Rice University suggests a genetic mutation has given the ordinary house mouse this extraordinary ability.

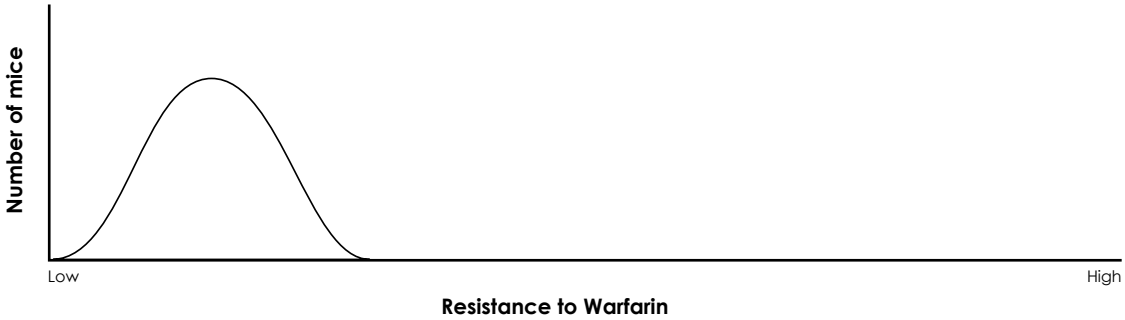
Warfarin is a chemical used to kill rodents. It works by thinning their blood and preventing it from clotting. Given in sufficient amounts, warfarin will cause animals to bleed to death internally.

When warfarin is used it has been found that some mice were resistant to its effects. The more warfarin was used the more common resistant mice became.

Kohn, associate professor of ecology and evolutionary biology at Rice, said the mice evolved to become poison resistant due to a previously silent mutation. Because the reproductive generation time in mice is so quick, this mutation was able to spread quickly. "A key element of this study is that we've caught evolution in the act," he said.

The use of warfarin as a rodent poison is now declining because many mouse populations have developed complete resistance to it.

1. The graph below shows the frequency of warfarin resistance in an initial population. Show the change in the frequency of resistance in the future generations of mice as they are poisoned by warfarin.



2. Arrange the following statements in order to show how natural selection has caused some mice populations to become resistant to warfarin.

	The mutated gene is passed on to offspring.
	A mutation in a sex cell of a mouse makes its offspring resistant to warfarin.
	The number of resistant mice increases with each generation.
	Warfarin kills most mice.
	Mutations may happen when DNA is copied in the cell.
	The resistant mice have a better chance of surviving and reproducing.
	People use warfarin to kill mice.
	Mutations are a change in the genetic code.
	Mutations can be caused by some chemicals or ionizing radiation.

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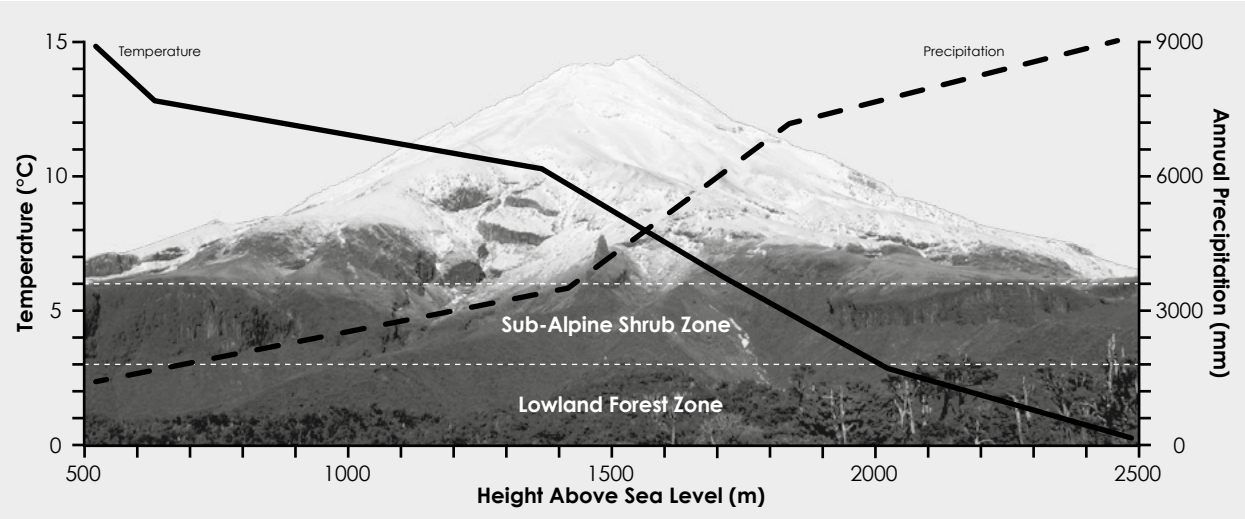
The Effect of the Environment on Phenotype

The phenotype of an organism (i.e. its observable characteristics) results from the interaction between its genotype and the environment.

GENOTYPE + ENVIRONMENT = PHENOTYPE

Mutations can potentially change the phenotype of an individual by altering the genotype. However, other environmental factors can change the phenotype without altering the genotype. For example, a person may have the genes which if expressed to their potential would result in above average height. However, if that person grows up in an environment where their diet is inadequate, they may actual never reach their genetic potential.



1. The diagram above shows the changes in temperature and precipitation with altitude on Mount Taranaki.

   (a) Rimu trees growing in the 'lowland forest zone' are tall and erect, whereas the same species growing in the 'sub-alpine shrub zone' are much smaller in appearance. Use the diagram to suggest reasons for the difference in growth forms. _____

   _____

   _____

   _____

   _____

   (b) A cutting from a Rimu tree growing in the sub-alpine zone was taken to a greenhouse and grown under ideal conditions. Identify the cause of the original tree's phenotype (genotype or environment?) with justification if:

   (i) the cutting grew into a tree with a phenotype similar to its original form.

   _____

   _____

   _____

   _____

   _____

   (ii) the cutting grew into a tree that was tall and erect.

   _____

   _____

   _____

   _____

   _____

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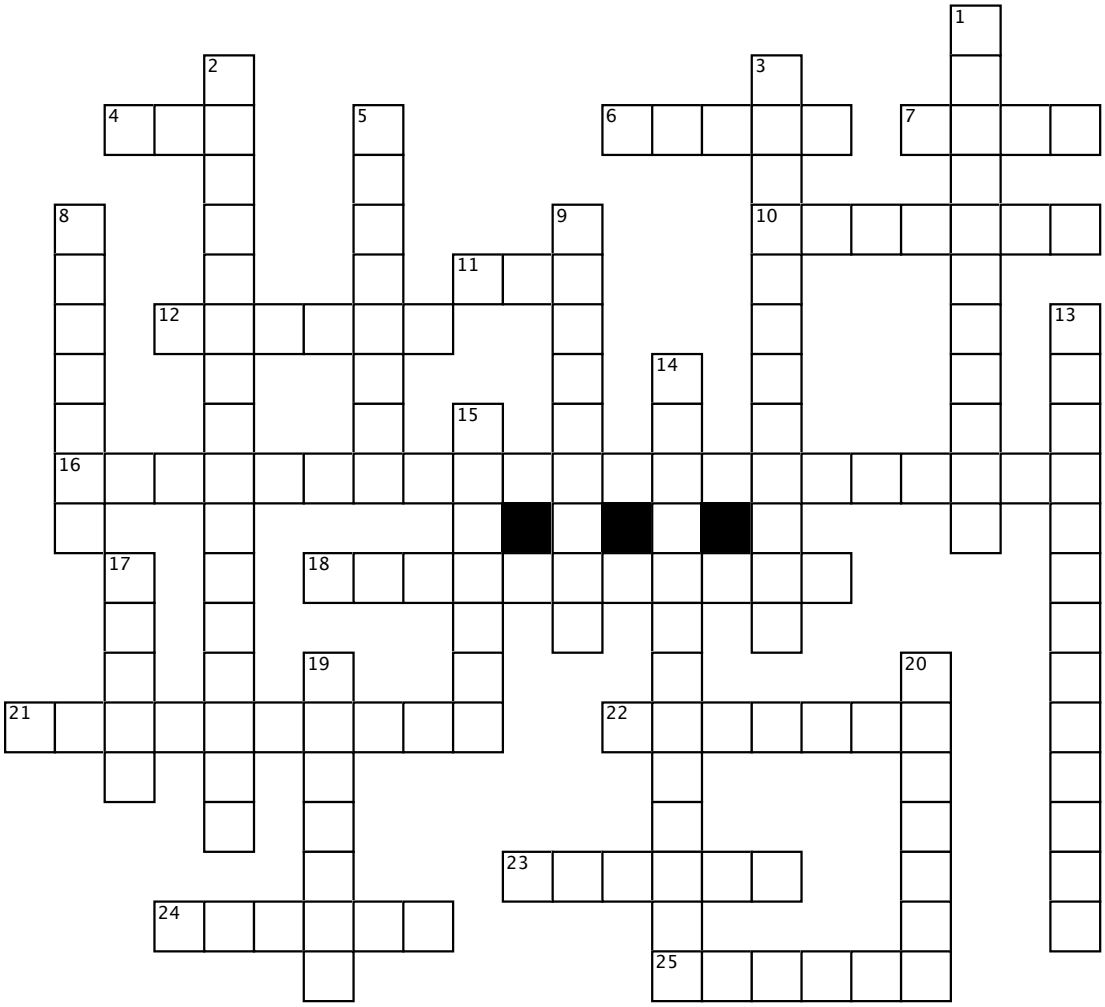
Variation - End of Chapter Puzzles

1. Use the clues at the bottom of the page to solve the crossword. The answers to the crossword are all contained in the word search on the opposite page.



Across

4. Human female gamete.
6. Human male gamete.
7. A length of DNA that holds the instructions for a certain characteristic.
10. Comes from the Greek word 'soma' meaning body. Another word for body cells.
11. Abbreviation for deoxyribonucleic acid.
12. A sex cell.
16. Name for the process whereby chromosomes line up in random order at the cell equator.
18. You have 46 of these in every cell in your body.
21. Type of variation in which there is a complete range of measurements from one extreme to the other (e.g. human height).
22. Type of cell division required for growth and repair of tissue.
23. A fertilised egg.
24. An alternative form of a gene.
25. Reproduction involving two individuals.

Down

1. Number of chromosomes found in a normal human gamete.
2. Occurs when the environment "selects" the best phenotypes. Often referred to as "survival of the fittest".
3. Name for the process whereby two chromosomes swap genetic material. Occurs during meiosis.
5. A change in the base sequence of DNA.
8. Cell division that results in four daughter cells.
9. The differences between individuals in a population.
13. Name of process when a sperm fuses with an egg.
14. Type of variation where the characteristics fall into a number of distinct classes or categories (e.g. human eye colour).
15. Type of cell division that produces gametes.
17. An organism that is an exact genetic copy of another organism.
19. Something that causes a mutation.
20. Reproduction involving only one parent.

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C	E	Q	V	A	R	I	A	T	I	O	N	L	O	M	D	J	W	N	W	E	C	M	O	O
L	N	B	D	K	T	Y	U	X	I	E	U	I	Z	M	U	M	E	I	O	S	I	S	D	R
A	A	T	U	C	G	C	B	N	G	S	A	M	W	S	O	T	S	T	I	X	U	N	I	N
C	J	W	D	M	L	Z	O	A	A	L	B	Z	W	N	C	T	A	I	Z	M	Q	O	Y	G
C	Q	E	Q	I	Z	O	T	N	G	T	I	A	O	G	P	O	Q	T	V	Q	R	W	A	T
O	B	N	T	P	S	U	N	D	Y	W	U	I	T	A	F	W	N	D	I	E	G	B	S	T
L	G	T	U	V	M	C	N	E	V	P	T	R	N	W	S	L	J	T	V	O	T	I	E	D
F	E	Y	A	A	U	N	O	E	R	A	L	D	A	I	Q	E	P	O	I	S	N	U	X	Q
Z	N	T	V	O	P	Z	V	N	S	X	M	E	S	L	X	F	G	V	G	N	J	C	U	N
U	E	H	L	R	D	Y	Y	I	T	G	C	O	K	C	S	N	P	Y	I	A	U	S	A	C
E	T	R	T	K	A	M	L	G	R	I	T	K	I	T	I	E	U	Q	K	Q	M	O	L	X
O	O	E	F	K	E	I	H	Z	O	I	N	T	C	S	A	D	L	C	T	F	G	E	U	I
V	O	E	Z	J	T	C	A	T	M	T	A	U	S	V	V	J	U	E	J	V	N	T	T	S
A	N	J	B	R	A	X	R	B	D	M	E	O	O	G	D	F	I	M	C	Z	Y	V	E	E
L	R	H	E	H	G	S	O	Y	O	H	R	N	Y	U	F	M	D	E	U	T	Q	T	F	S
K	Z	F	V	G	G	J	C	S	X	C	H	I	E	G	S	N	Z	Y	X	G	I	I	G	E
Z	F	Q	J	Q	H	M	E	I	O	S	I	S	U	E	V	Z	X	N	X	D	C	O	K	X
G	I	N	D	E	P	E	N	D	E	N	T	A	S	S	O	R	T	M	E	N	T	I	N	U
U	U	A	L	L	E	L	E	S	P	E	R	M	N	U	J	H	F	D	M	V	F	B	G	A
Z	C	A	D	T	C	T	V	S	C	H	R	O	M	O	S	O	M	E	S	J	X	R	H	L

2. There are 16 misspelt words in the following paragraph. Circle the incorrect words and write them correctly in the space provide below.

Organisms are all diffirent from each other - they show variashin. Genetic varyation is passted on from one jeneration to the next. Genetic variation occurz due to the process of crossin over and independent assortmint during a type of cell division called myosis. Mutashons can also cause variation if they occur in gameats. Mewtations which occur in body cells are not enherited. Variation that causes an individual to have an advintage over others means they are more likely to pass on their favourable jeans. This is called natural selecshin.

(a)_____ (i)_____

(b)_____ (j)_____

(c)_____ (k)_____

(d)_____ (l)_____

(e)_____ (m)_____

(f)_____ (n)_____

(g)_____ (o)_____

(h)_____ (p)_____

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Science Scramble - Genetic Variation

Using 3 or more of the letters below, create as many words as you can. Write the word and the point value into the appropriate box below. The winner is the one with the highest score. The scrambled word is a science term and is worth 20 points if you solve it.

3 letter words	4 letter words

5 letter words	6 letter words

7 or more letter words

Unscrambled Science word

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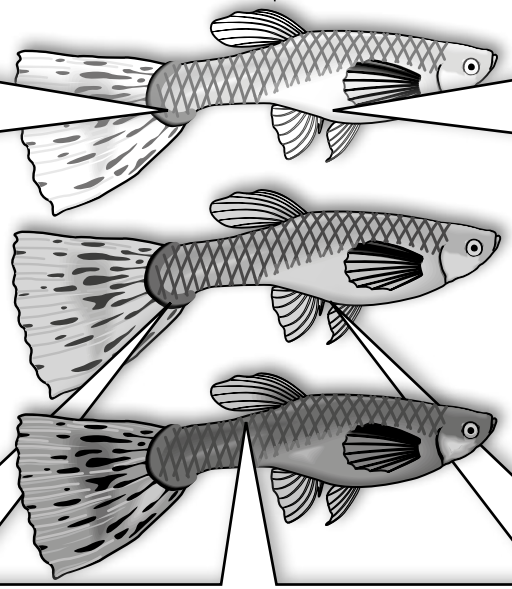
Variation Chapter Review

Use the boxes to write down the key points from this chapter. Ensure that all key words from the front of the chapter have been used.



Variation

Mutations

Asexual and Sexual Reproduction

Natural Selection

Meiosis

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End of Chapter Review Questions

1. Mix and match the following terms and definitions.

Allele •	• A section of DNA that codes for a specific trait or characteristic.
Gene •	• Cell division required for growth and repair of tissue.
Zygote •	• The differences between individuals.
Meiosis •	• A change in the base sequence of DNA.
Mitosis •	• An alternative form of a gene.
Mutation •	• Cell division that leads to variation. Produces gametes.
Gamete •	• A fertilised ova. Contains a full set of chromosomes.
Variation •	• A sex cell. Contains half the normal number of chromosomes.

2. Takahè have 84 chromosomes in each of their cells. Cells can divide in one of two ways – mitosis or meiosis. Use this information to complete the table below.

	Mitosis	Meiosis
Number of chromosomes in body cell.		
Number of daughter cells produced.		
Chromosome number in daughter cells.		
Does it lead to variation?		
Where does it occur within the body?		

3. Meiosis is a particular form of cell division that produces male and female gametes.

(a) Describe what gametes are and explain why they are needed for sexual reproduction. _____

_____

_____

_____

(b) Discuss how meiosis contributes to genetic variation. In your answer you should:

- Describe what is meant by genetic variation.
- Explain how the process of meiosis leads to genetic variation.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

Hints for answering these NCEA style questions

Define '*gamete*'.

Discuss chromosome numbers in gametes and zygotes.

Define the term '*genetic variation*'.

Describe '*meiosis*'.

Describe *crossing over* and *independent assortment*.

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4. A mutation occurs in a chicken resulting in a new DNA sequence.

(a) Describe how the mutation could produce a new allele.

A section of the original DNA strand and the mutated DNA strand is shown below.

DNA Strand **before** mutation	DNA Strand **after** mutation
GCTCTAGCCTAGACGATGCCC	GCTCTAGGCTAGACGATGCCC

(b) Circle the mutation.

(c) Explain why this is a mutation.

(d) As a result of this mutation the chicken produces eggs with thicker shells. The shells are not thick enough to prevent the chicks from hatching. However, it results in fewer eggs (and therefore offspring) being lost due to accidental crushing when the hen sits on the eggs or moves around the nest.

(i) Describe the conditions in which this mutation will be passed on to future generations.

(ii) Assuming the mutation is able to be inherited, discuss whether you would expect the mutated allele to increase in frequency within future generations of chickens.

Hints for answering these NCEA style questions

State that meiosis leads to new combinations of alleles at fertilisation.

Define '*allele*'.

Describe how a change in base sequence could make a new allele.

Examine each base on the DNA sequence before the mutation and compare it to the sequence after the mutation.

Define "*mutation*" and relate this definition to the DNA strand.

Discuss the effect of a mutation that occurs in *somatic* cells, compared to their effect on *gametic* cells.

Will the mutation give the offspring a survival advantage? If so, describe how it would become more frequent within the population. Consider their breeding success and the number of offspring that survive to reach breeding age.

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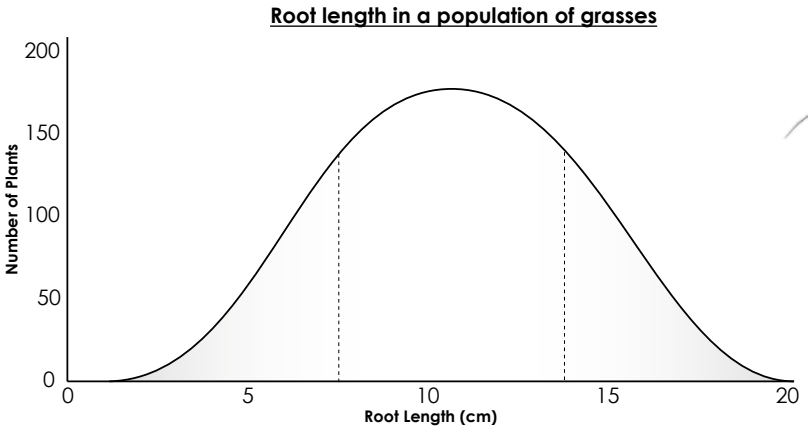
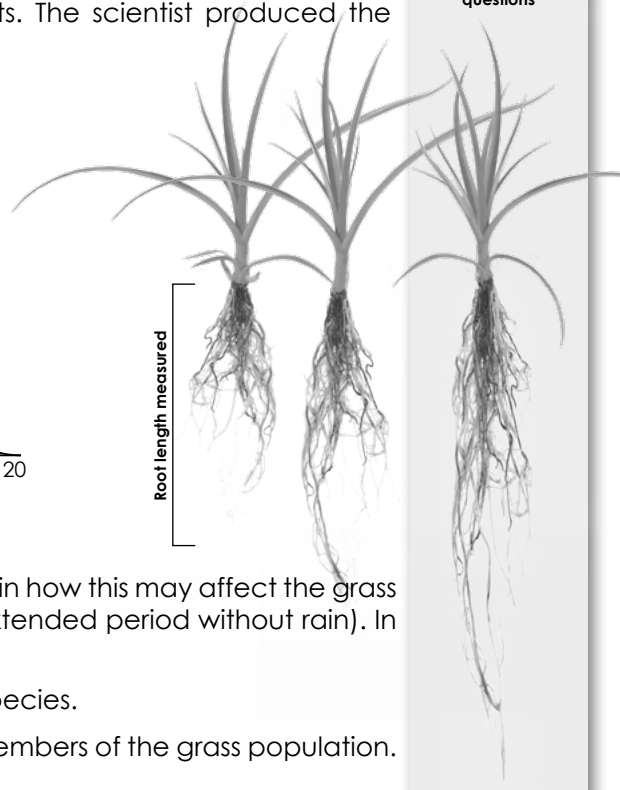
A scientist measured the root length of a species of grass plant living in a particular area. Individuals of the species showed variation. A few plants had very short root length, most had medium length roots, while a few had very long roots. The scientist produced the following graph.





5. Discuss how variation in root length occurs, and explain how this may affect the grass species' survival during a drought (a drought is an extended period without rain). In your answer, you should:

- Discuss the source of variation within the grass species.
- Explain the effect of drought on the individual members of the grass population.

Hints for answering these NCEA style questions

Define 'variation'.

State that root length will be controlled by a gene.

Explain how meiosis and mutation lead to genetic variation.

Outline which root length is going to be more successful during a drought.

Explain what this means for their survival and ability to pass on their genes.

Discuss how the drought is likely to change the appearance of future generations of grasses.

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Genetics and Variation (90948) Practice Exam

NZPQA

NEW ZEALAND **PRETEND** QUALIFICATION AUTHORITY

Level 1 Science

90948 (1.9): Demonstrate understanding of biological ideas relating to genetic variation

Credits: Not this time

You should answer ALL parts of ALL questions in this exam.

If you need more space for any answer, use some refill paper. (Ideally, you should concentrate on trying to write more concise answers).

For Assessor's use only	**Achievement Criteria**	
Achievement	**Achievement with Merit**	**Achievement with Excellence**
Demonstrate understanding of biological ideas relating to genetic variation. ☐	Demonstrate in-depth understanding of biological ideas relating to genetic variation. ☐	Demonstrate comprehensive understanding of biological ideas relating to genetic variation. ☐
Overall Level of Performance ☐		

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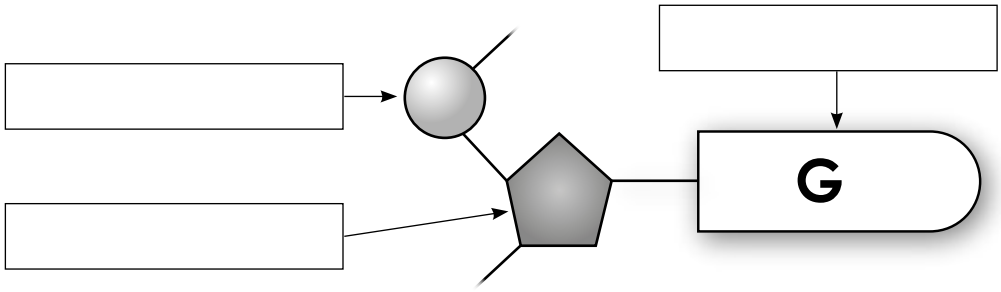
QUESTION ONE - DNA

DNA is made up of repeating units called nucleotides.

(a) Label the nucleotide shown below.



(b) Genes determine many of the features of organisms, such as the colour of the fur on rats.

A gene is a part of a DNA molecule.

The type of rat shown in the photograph on the right can have black or white fur.

Black fur is due to a dominant allele and white fur is due to a recessive allele.

Discuss how information in DNA gives organisms (like the rat pictured) their individual features, such as black and white fur. In your answer, you should:

- Explain the difference between a gene and an allele.
- Explain how the base sequence on DNA determines a particular feature (e.g. fur colour) and the different forms (variations) of that feature (e.g. black and white fur).

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QUESTION TWO - HAIRLESS RATS

A rat breeder produced a rat that was unable to produce normal hair. He suspected it was due to a mutation. The rat breeder noted that the parents of the hairless rat had normal hair.

A hairless rat **A normal haired rat**

(a) Describe what a mutation is. In your answer you should:

- Define the term '*mutation*'.
- Explain what determines whether a mutation is able to be *inherited* or not.
- Explain why mutations may be described as the "*ultimate source of variation*".

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(b) Discuss how hairlessness could possibly be inherited when both parents have normal hair. In your answer you must

- Give the genotypes of both parents.
- Complete the Punnet square below. Use 'A' to represent the dominant allele and 'a' to represent the recessive allele.
- Give the phenotype ratio of the rats produced.

Male rat's genotype =

Female rat's genotype =

Phenotypic ratio of the offspring =

(c) Explain why the ratio of rats born with normal hair and hairlessness may not match the ratios you have predicted in (b).

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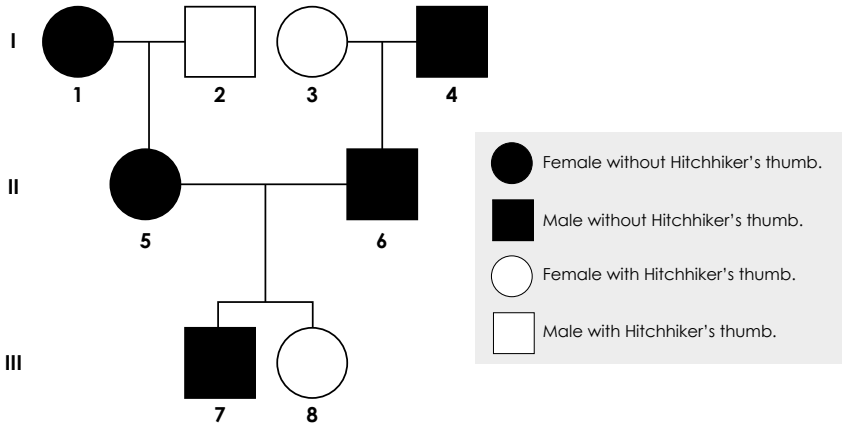
QUESTION THREE - HITCHHIKER'S THUMB

The allele for a normal thumb (T) is dominant over the allele for a Hitchhiker's thumb (t).

The pedigree diagram below shows the thumb types in a family.



(a) State the genotype of individual 6 in the pedigree chart above.

Explain how you worked out the genotype for individual 6.

You should support your answer using evidence from BOTH the parents AND children of individual 6.

(b) Explain why the genotype of female 5 in generation 2 of the pedigree diagram shown above must have the genotype Tt.

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QUESTION FOUR - GUPPIES

A species of guppy were found to have two distinct phenotypes, the majority of the guppies were a light form, while a few were a dark form. The bottom of their river habitat was covered in a fine light-coloured sand. The guppies are predated upon by various other, larger fish.

Explain how the two phenotypes of this species of guppy would help the population to survive if the environment changed so that the sediment on the bottom of the river gets covered in dark mud.

In your answer you should:

- Explain how colour helps individual guppies to survive.
- Explain why the environmental change to a darker sediment affects the ratio of the phenotypes in the guppy population over time.

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QUESTION FIVE - MENDEL'S PEA

In pea plants, flower colour is controlled by a single gene. Purple flowering plants are controlled by the allele (F) which is dominant to the white flower allele (f).

Purple Pea Flower

White Pea Flower

A plant breeder suspects that one of his purple flowering pea plants is pure-breeding.

Explain how the plant breeder could determine the genotype of the purple flowering plant using simple crossing techniques. You should complete Punnett squares as part of your answer.

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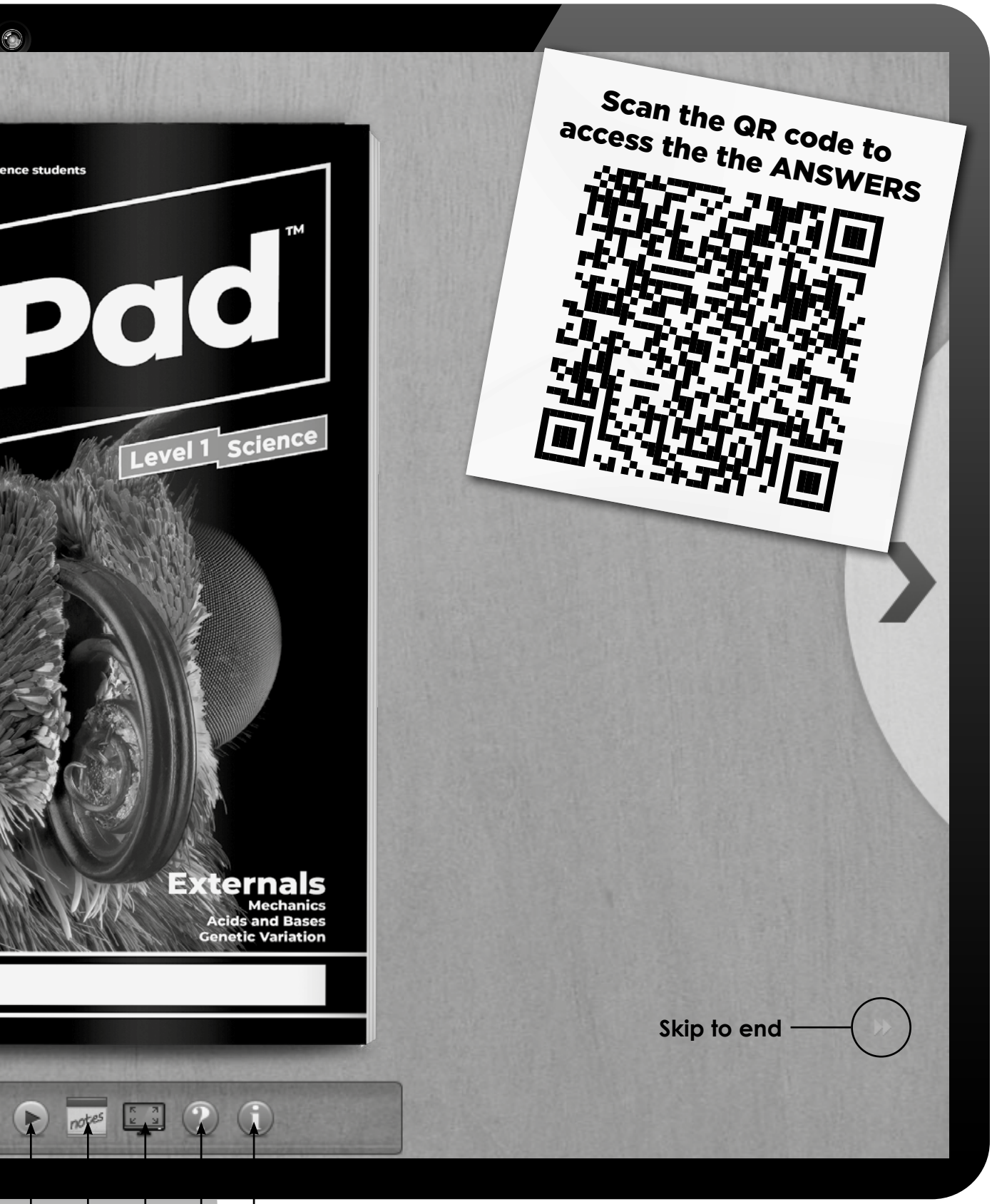
THE ANSWERS WEB APP



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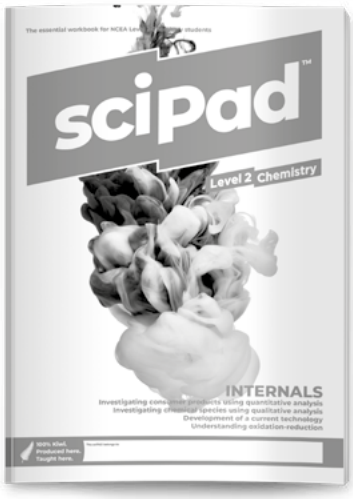
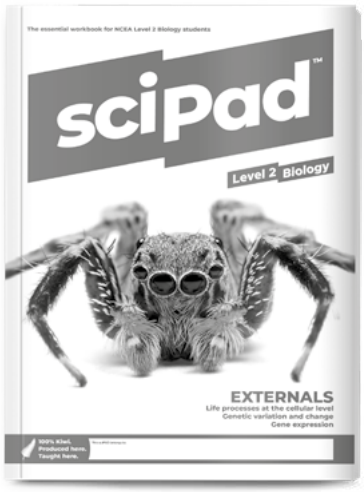


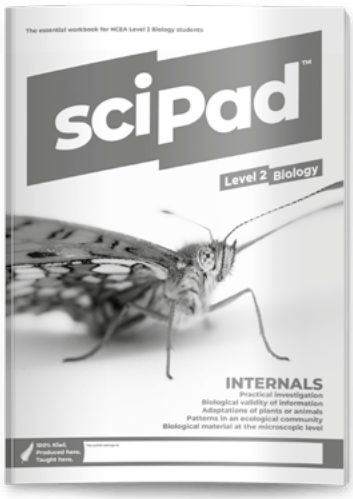
INTERNALS

BIOLOGY



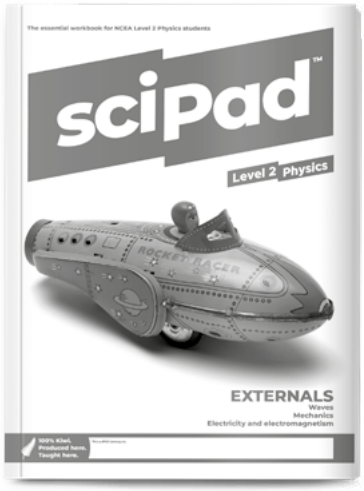
EXTERNALS

SINGLE STANDARD SCIPAD MICROS



INTERNALS

PHYSICS



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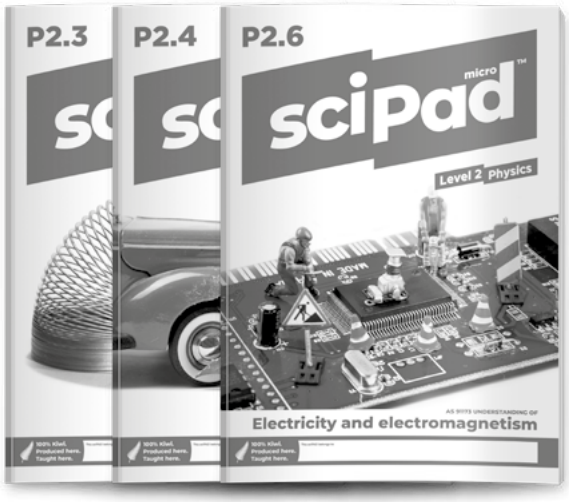
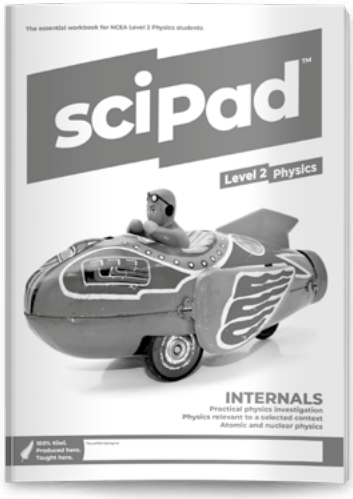


SINGLE STANDARD SCIPAD MICROS



INTERNALS

PERIODIC TABLE AND COMMON IONS

+1	+2	+3	−3	−2	−1
H^+ Hydrogen	Ca^{2+} Calcium	Al^{3+} Aluminium	P^{3-} Phosphide	O^{2-} Oxide	F^- Fluoride
Na^+ Sodium	Mg^{2+} Magnesium	Fe^{3+} Iron(III)	PO_4^{3-} Phosphate	S^{2-} Sulfide	Cl^- Chloride
Li^+ Lithium	Cu^{2+} Copper			CO_3^{2-} Carbonate	Br^- Bromide
K^+ Potassium	Pb^{2+} Lead			SO_4^{2-} Sulfate	I^- Iodide
NH_4^+ Ammonium	Fe^{2+} Iron(II)				OH^- Hydroxide
Ag^+ Silver	Be^{2+} Beryllium				HCO_3^- Hydrogen carbonate
	Zn^{2+} Zinc				NO_3^- Nitrate
	Ba^{2+} Barium				

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** Hydrogen 1.0																	2 **He** Helium 4.0
3 **Li** Lithium 6.9	4 **Be** Beryllium 9.0											5 **B** Boron 10.8	6 **C** Carbon 12.0	7 **N** Nitrogen 14.0	8 **O** Oxygen 16.0	9 **F** Fluorine 19.0	10 **Ne** Neon 20.2
11 **Na** Sodium 23.0	12 **Mg** Magnesium 24.3											13 **Al** Aluminium 27.0	14 **Si** Silicon 28.1	15 **P** Phosphorus 31.0	16 **S** Sulfur 32.1	17 **Cl** Chlorine 35.5	18 **Ar** Argon 40.0
19 **K** Potassium 39.1	20 **Ca** Calcium 40.1	21 **Sc** Scandium 45.0	22 **Ti** Titanium 47.9	23 **V** Vanadium 50.9	24 **Cr** Chromium 52.0	25 **Mn** Manganese 54.9	26 **Fe** Iron 55.9	27 **Co** Cobalt 58.9	28 **Ni** Nickel 58.7	29 **Cu** Copper 63.5	30 **Zn** Zinc 65.4	31 **Ga** Galium 69.7	32 **Ge** Germanium 72.6	33 **As** Arsenic 74.9	34 **Se** Selenium 79.0	35 **Br** Bromine 79.9	36 **Kr** Krypton 83.8
37 **Rb** Rubidium 85.5	38 **Sr** Strontium 87.6	39 **Y** Yttrium 88.9	40 **Zr** Zirconium 91.2	41 **Nb** Niobium 92.9	42 **Mo** Molybdenum 95.9	43 **Tc** Technetium 98.9	44 **Ru** Ruthenium 101	45 **Rh** Rhodium 103	46 **Pd** Palladium 106	47 **Ag** Silver 108	48 **Cd** Cadmium 112	49 **In** Indium 115	50 **Sn** Tin 119	51 **Sb** Antimony 122	52 **Te** Tellurium 128	53 **I** Iodine 127	54 **Xe** Xenon 131
55 **Cs** Caesium 133	56 **Ba** Barium 137	71 **Lu** Lutetium 175	72 **Hf** Hafnium 179	73 **Ta** Tantalum 181	74 **W** Tungsten 184	75 **Re** Rhenium 186	76 **Os** Osmium 190	77 **Ir** Iridium 192	78 **Pt** Platinum 195	79 **Au** Gold 197	80 **Hg** Mercury 201	81 **Tl** Thallium 204	82 **Pb** Lead 207	83 **Bi** Bismuth 209	84 **Po** Polonium 210	85 **At** Astatine 210	86 **Rn** Radon 222