ROYAL SOCIETY OF CHEMISTRY

Friends of Cotteridge Park

DISCOVER MATERIALS

This booklet belongs to:

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For **videos**, information about the **prize draws** and **safety information** about theses activities go to: https://discovermaterials.co.ukresourcecocoelectro-bag/ or scan the QR code.
(Password: CoCoElectroBag)

www.discovermaterials.co.uk

Introduction

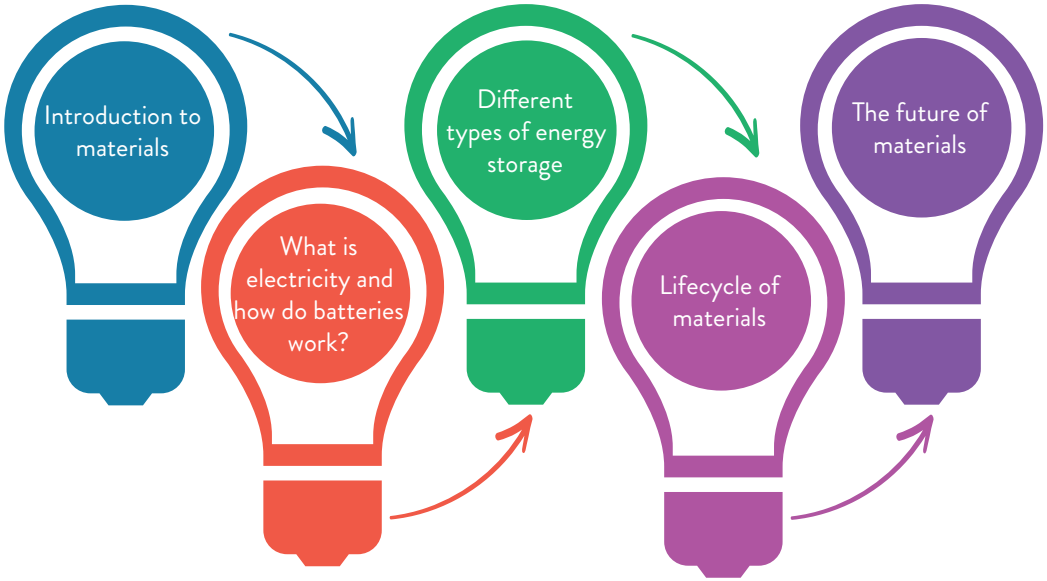
Thank you for taking part in the CoCoElectro bag project.

The purpose of the activities in this kit is to introduce young people to materials science and the applications they have in the real world. It will encourage them to think scientifically and carry out their own investigations.

If there is anything you are not comfortable with–or have any further questions – please contact us: info@discovermatierials.co.uk.

To watch the welcome video, scan this QR code or go to https://rb.gy/kdbgj

In this booklet take a journey ...

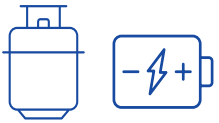


What is energy and why is it important?

Energy is needed to power our everyday devices from light bulbs and toasters to smartphones and tablets.

It is needed to power cars, trains, buses and planes so you can get around.

Storing energy and producing it is a very important area of materials science research.



The following three things need to be considered when deciding which source of energy to use:

Availability–it has to be easily available

Sustainability–it has to be sustainable (better for the planet) and

Cost–it has to be affordable

Image credit: Vauxford, CC BY-SA 4.0 <https://creativecommons.org/licenses/by-sa/4.0>, via Wikimedia Commons

Image credit:https://www.autodata1.com/media/renault/pics/renault-11-bc37-[8538].jpg

Cars used to be only powered by petrol or diesel engines because the fuel was readily available and affordable. Petrol prices are rising, and the costs of electric cars are falling, electric cars are becoming more common, and they are considered by many to be more sustainable.

What do you use energy for?

What are materials?

Materials are the stuff objects are made from - and choosing the right material to make something is really important. You need to think about the following:

What will you use it for (or the application)?

.....

What benefits or (properties) does the material(s) need?

.....

Which materials have these properties?

.....

Materials	Property	Possible use
Glass	Transparent (an optical property)	Windows
Metal		
Plastic		

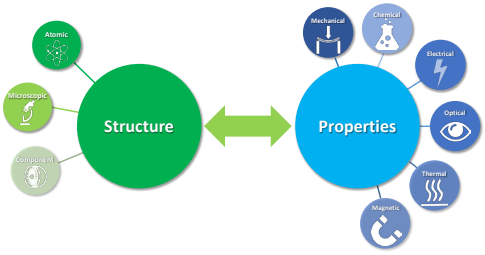
Have a look at things at home and outside - what materials are they are made from and why? (You can use our Materials Scavenger Hunt using this link: www.discovermaterials.co.uk/resource/materials-scavenger-hunt/).

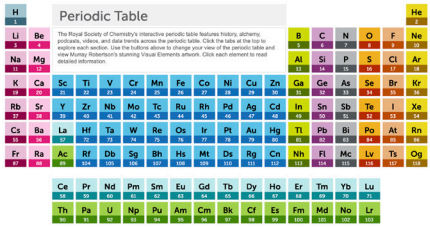
M	I	L	S	O	F	T	M	C	H
A	E	Z	E	S	L	O	A	O	D
T	A	T	T	I	E	U	T	N	R
E	V	S	A	P	X	G	E	D	A
R	S	M	L	L	I	E	R	U	H
I	A	F	S	A	B	X	I	C	T
G	L	A	S	S	L	H	A	T	O
I	P	F	O	T	E	A	L	I	U
D	O	O	F	I	M	L	S	V	G
S	T	E	M	C	R	O	S	E	H

Which material terms can you find in this wordsearch?

MATERIAL
METAL
PLASTIC
GLASS
RIGID
FLEXIBLE
TOUGH
HARD
SOFT
CONDUCTIVE

Structure of a material

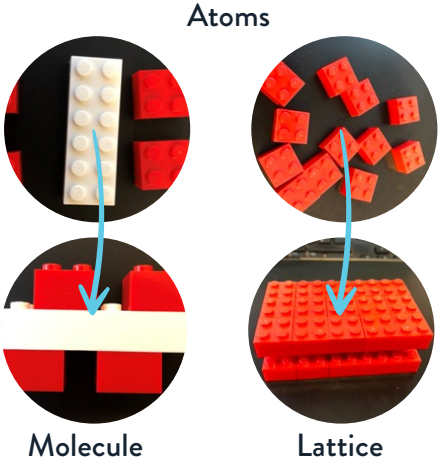




Atomic structure

All materials are made up of basic building blocks called atoms. There are 118 different types of atom (known as elements) which you can find in the periodic table.

Atoms can group together in different ways and this is called the **atomic structure**. They can react together and form strong bonds to make **molecules** or arrange themselves in giant structures called **lattices.**



Microstructure

The microstructure is what a material looks like under a microscope (or magnifying glass).

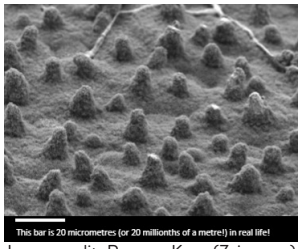


Image credit: Rumana Kann (Zeiss.com)

The waxy, bumpy microstructure of a lotus leaf helps it repel water – you can also see this effect using cabbage.

Component structure

The last type of structure we need to think about is the structure of the components of the object we want to make.

A good example of this is in computers and mobile phones where the components and devices can now be made to be much smaller than they used to be and so more can fit into a single device.

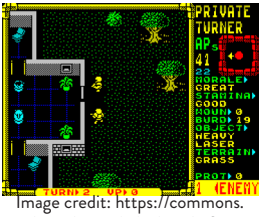
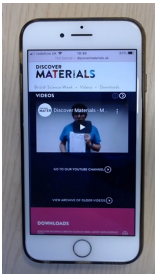


Image credit: https://commons.wikimedia.org/w/index.php?curid=1291963

In the 1980s the Sinclair Spectrum + 3 was launched and had **8 colours!**

Image credit: By Neverender 899 - Own work Public Domain https://en.wikipedia.org/wiki/SAGEM

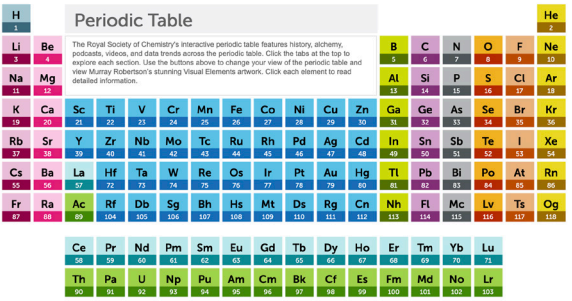
Mobile phones could be used for texting **AND** calling.



All this (and much much more) can be done with modern smartphones.

Image credit: By Frode Tennebø - Own work, Public Domain, https://commons.wikimedia.org/w/index.php?curid=1071389

There are up to 75 different elements in modern smartphones–no wonder they are so difficult to recycle (more about that later...).



Let's investigate properties of materials that are useful for energy and electricity.....

Scan the QR code to watch a video about the materials of mobile phones.
If the code doesn't work, try https://rb.gy/5kv6e

Materials and Electricity

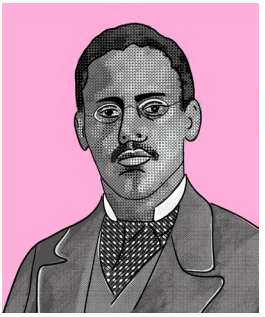
Electrons are tiny particles that are smaller than atoms (subatomic).

Electricity describes the movement of electrons. How well materials allow electrons to move is called conductivity.

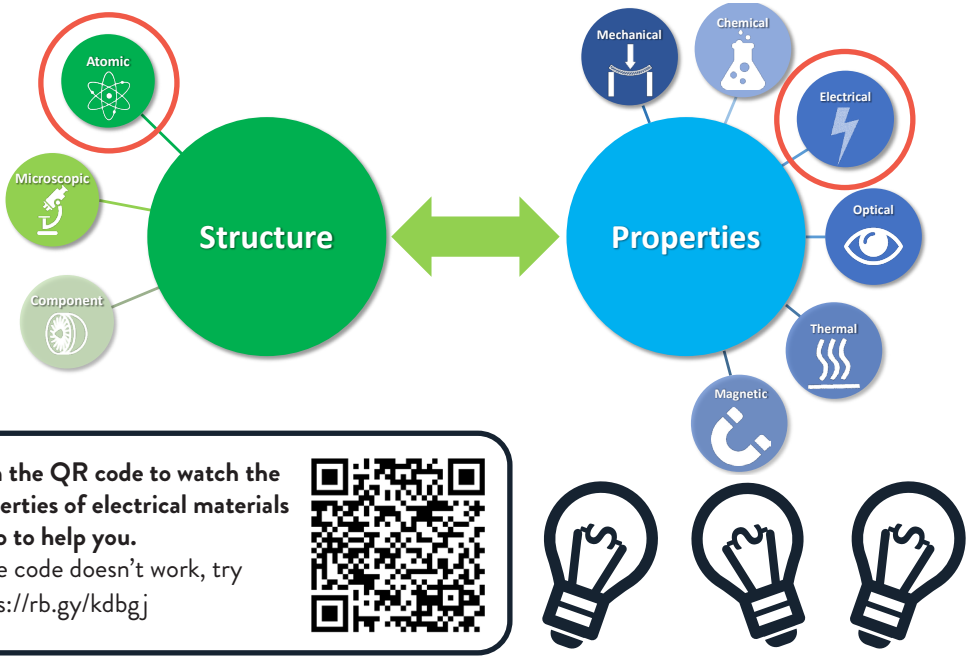
Materials can either be:

- **Conductors**–allow electrons to move easily
- **Insulators** (non-conductive)–do not allow electrons to move through them
- **Semi-conductors** – can be both conductive and insulating meaning they can be used as switches (which is why they are used in computer chips).

Their conductivity depends on their atomic structure (what element they are made up from).



Lewis Latimer (1848 – 1928) invented a way of making carbon filament for light bulbs and he worked with Thomas Edison to patent the electric lightbulb. He also helped Alexander Graham Bell patent the telephone.



Scan the QR code to watch the properties of electrical materials video to help you.
If the code doesn't work, try https://rb.gy/kdbgj

Which materials are conductive?

A battery (or cell) stores energy and the electrons in the battery want to move between the electrodes. They move from the anode to the cathode.

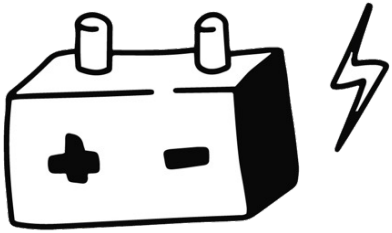
Equipment

- LEDs (little light bulbs)
- Copper tape
- Plastic tape
- Circuit print out
- Coin cell battery e.g. C2032

Instructions

1. Carefully cut the copper tape into thin strips and stick them to the lines indicated on the circuit printout.
2. Put the LED in the place indicated on the circuit printout.
3. Place the battery where indicated and see the LED light up.
4. Take the other printout and repeat steps 1-3 but using the plastic tape instead of the copper tape.

What happens? Which material is conductive and which is insulating?



Scan the QR code to watch the properties of electrical materials video to help you.
If the code doesn't work, try https://rb.gy/kdbgj

STEP 1

Stick 2 lengths of tape to a piece of paper next to each other with a gap in between to make tracks.

STEP 2

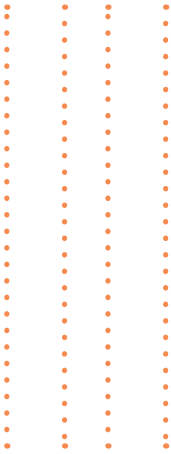
Stick one leg of the LED to each track.

STEP 3

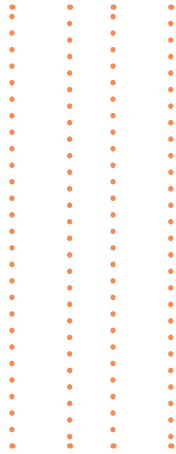
Put the coin cell battery so the bottom touches the track connected to the short leg of the LED and the top of the cell (with a + sign on) pointing upwards.

STEP 4

Put the coin cell battery so the bottom touches the track connected to the short leg of the LED and the top of the cell (with a + sign on) pointing upwards.



Use copper tape to build this circuit



Use plastic tape to build this circuit

Which circuit tape lit up the LED?

.....

.....

Batteries and cells

Batteries are used in loads of everyday devices such as tablets, cars and even the torches in your CoCoElectro Bag.

They store energy which is used up when they are plugged into a device. Their stored energy makes electrons flow around the circuit-this is electricity! This also uses up the energy in the battery (discharging).

Each battery may be made up of several cells which are made up of two electrodes (an anode and cathode) and an electrolyte.

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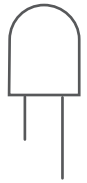
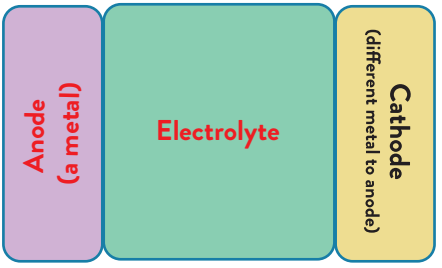
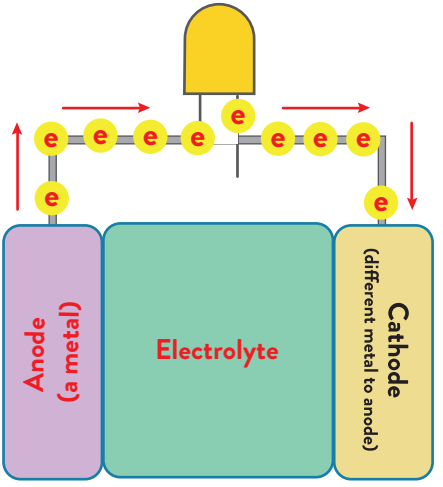
Electrons are tiny particles that are much smaller than atoms.



What do you use batteries for at home?





There are different kinds of cells – let's have a look at how to make two different kinds .....

Electric Pile (Penny Battery)

A battery (or cell) stores energy and the electrons in the battery want to move between the electrodes. They move from the anode to the cathode.

Equipment

- LEDs (little light bulbs)
- Wires (with crocodile clips on)
- Copper coins
- Zinc washers
- Piece of foil
- Kitchen roll
- Salt
- Small mixing bowl

Scan the QR code to watch the making the penny battery video to help you.
If the code doesn't work, try https://rb.gy/kdbgj

Instructions

1. Dissolve the salt in the water
2. Put a piece of foil and place a washer in the middle of it.
3. Dip one piece of the kitchen roll in the salt solution and shake off excess water (you do not want salty water dripping from the kitchen roll onto your battery pile!)
4. Put the 2p pieces on top of the kitchen roll and then more kitchen roll on top of them.

This is your first battery cell!

See if it can light up an LED. Take an LED and put one of its legs on the 2p piece (that is on the foil) and the other leg on top of the battery stack-does it light up?

Repeat steps 1-4 and make three more battery cells. Experiment with trying to light the LED with more battery cells.

Saiful Islam made the world's biggest Lemon Battery and is in the Guinness World Record!

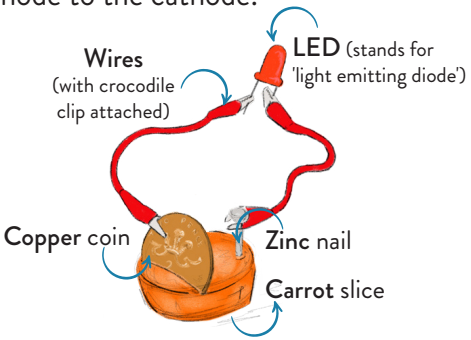
Scan the QR code to watch a video to find out more.

Electrolytic cell battery

A battery (or cell) stores energy and the electrons in the battery want to move between the electrodes. They move from the anode to the cathode.

Equipment

- Thick carrot slices (at least 5)
- LEDs
- Wires (you will need one more wire than you have carrot slices)
- Copper coin
- Zinc nails

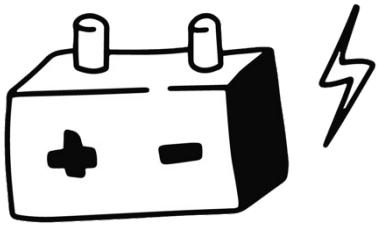


Instructions

1. Slice a carrot into thick slices (be careful with your fingers!).
2. Put a copper coin and a zinc nail into the carrot slice (make sure they do not touch each other).
3. Connect the copper coin to the long leg of the LED.
4. Connect the zinc nail to the short leg of the LED.

Draw out your first cell battery, does the LED light up?

The LED probably didn't light up because it the carrot cell didn't produce enough current (a measure of how many electrons flow between the electrodes). Let's make more cells and connect them up to see how many we need to light up the LED.



Scan the QR code to watch carrot power video to help you.

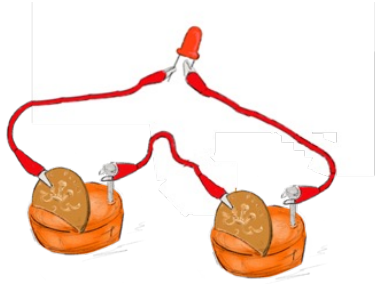
If the code doesn't work, try try https://rb.gy/kdbgj

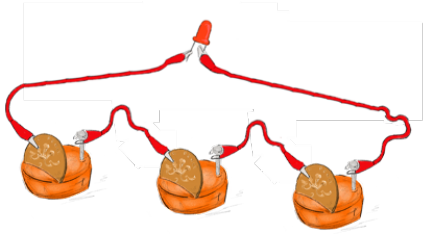
Instructions

1. Prepare more carrot slices with copper coins and nails in–the same as you did on the previous page, then line them up.
2. Connect the long leg of the LED to the coin on the left-most carrot cell.
3. Connect the short leg to the nail on the right-most carrot cell.
4. Then connect each nail on one carrot cell to the coin on its neighbouring carrot cell until all of them are connected and the circuit is complete.
5. How bright is the LED now?

Experiment with different numbers of carrots and write how bright they are in the table:

Number of carrot cells	How bright is the LED?
1	
2	
3	
4	
5	





As healthy as they are you do not have to just make batteries out of carrots–why not try other fruit and vegetables. Put the cells together in the same way.

Which fruit / veg did you use?

Did it work better than a carrot?

DO NOT EAT CARROTS AFTER USE

Recycling and Sustainability

Materials scientists are not just interested in understanding how to make new materials, how they behave and what to use them for but also how to use them sustainably.

This is because there is only so much material on Earth so we must make the most of the materials we have. But reusing and recycling them is much better for the environment than making brand new materials.

If something cannot be reused then the next best thing is to recycle it.

Scan the QR code for sustainability resources from BBC Bitesize.
If the code doesn't work, try https://rb.gy/qt7dk

Dame Ellen MacArthur broke the world record for sailing around the world on her own and she then set up the Ellen MacArthur Foundation to tackle climate change by using materials in a more sustainable way.

Separating materials

Before materials are recycled they need to be separated. You may easily be able to separate these materials at home but imagine how long it would take if you were to separate tonnes of mixed materials!

Equipment

- Magnet
- Tea strainer
- 250ml beaker
- 500ml beakers
- Glass marbles
- Plastic bottle tops
- Metal bottle tops

You will also need:

- Water
- A tray (to catch spills)

What material properties could you use to separate mixed materials (e.g. density, magnetic, optical)?

.....

.....

.....

.....

Scan the QR code for the separating materials video to help you.
If the code doesn't work, try https://rb.gy/kdbgj

Scan the QR codes for circular economy information.
If the code doesn't work, try https://rb.gy/tqrfi or https://rb.gy/itl29

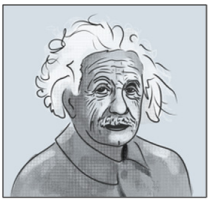
Solar Energy

The sun is the greatest source of energy in our solar system and you can feel the effect of the sun's rays every day.

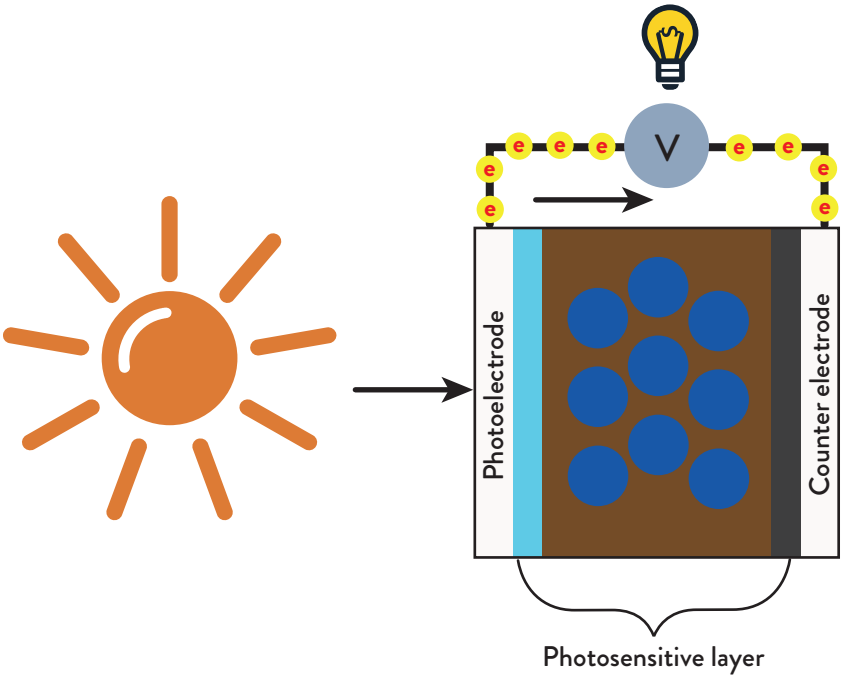
We can use the sun's energy to power our electrical devices by using solar panels.

These cells contain a semiconductor and dye which are sandwiched in between a cathode and anode. The dye then releases electrons when the light hits them (because of the energy of the sunlight)–this if known as the photoelectric effect.

These electrons then move around the circuit toward the anode producing an electric current.



Albert Einstein is one of the most famous scientists who has ever lived and he discovered that light can be changed into electricity–this is known as the **photoelectric** effect.



Making A Solar Cell

A solar cell converts (changes) light from the sun into electricity. But how is a solar cell made? What properties do the materials need to have?

Equipment

- Biscuit cutter

Also needed (but not included):

- Icing sugar and your favourite biscuit recipe, (scan the QR code)

Gluten free recipe, (scan the QR code)

Serving a solar cell

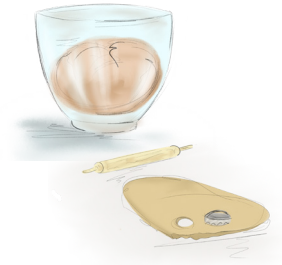
Solar cells are made a little bit like how you would make and ice a biscuit. You could buy some plain biscuits and skip steps 1-3 but making biscuits is fun.

Instructions

1. Make the biscuit dough using your favourite recipe.
2. Cut out your biscuit using the cookie cutter from your CoCoElectro Bag.
3. Bake it.
4. Ice your biscuit.

Making a biscuit

1. Make your biscuit and cut to shape



2. Make icing

3. Let it dry

Making a solar cell

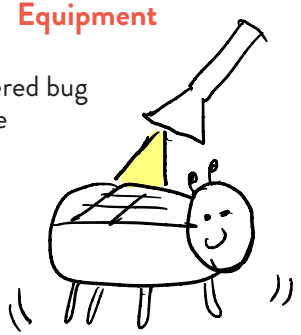
1. The substrate (the material that lets the light through) is cut to shape
2. Make and put the photosensitive layers (the materials that change UV light to electricity) into the substrate
3. Allow the photosensitive layer(s) to dry

Solar Energy

Ultraviolet (UV) light is invisible to the human eye but comes from the sun and causes sunburn. It also gives solar cells enough energy to produce electricity – let's investigate how well UV light travels through the air and through different materials.

Equipment

- UV torch
- Solar powered bug
- Cellophane
- Ruler



Question?

What optical properties does the top layer of the solar panel have to have?

.....

.....

.....

Experiment 1

Hold the UV torch close to the solar panel on the back of the bug and turn the torch on – what happens?

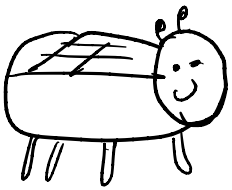
.....

Next, slowly move the torch away from the solar panel until the bug stops moving and use the ruler to measure how far away the torch is from the bug.

.....

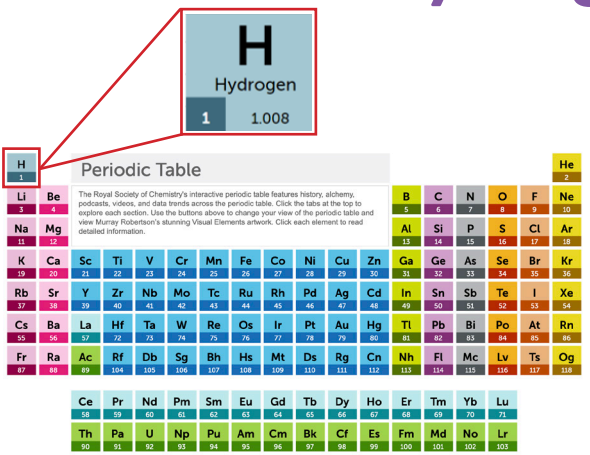
Experiment 2

UV light can cause our skin to burn (sunburn) so we need to find materials that block UV light. Use different colours of transparent cellophane to investigate which colours are best for blocking UV light. When would we want to use transparent materials?

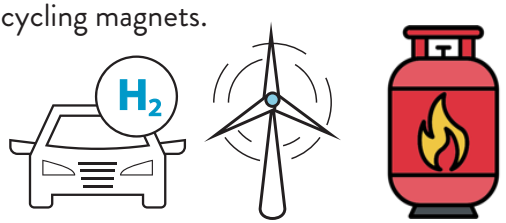


Scan the QR code to watch the solar power video to help you.
If the code doesn't work, try https://rb.gy/kdbgj

Hydrogen

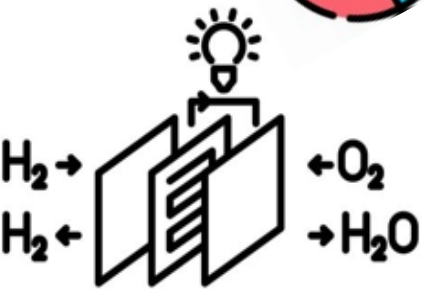


Low carbon fuel sources are needed to reduce our need for coal, oil and gas. Hydrogen can be used for a variety of different applications such as powering vehicles, storing energy and recycling magnets.



Hydrogen can be used for a variety of different applications such as powering vehicles, storing energy and recycling magnets. Best of all is when hydrogen is burned (combusted) it only gives off water.

Professor Sara Walker is a researcher focusing on renewable energy policy and how best hydrogen can be used in the UK.

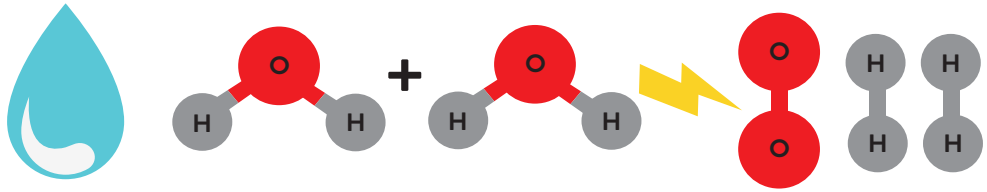


Find a fact

The air we breathe is made up of less than 1% hydrogen (H_2), but up to 4% water (H_2O)!

Scan the QR code to watch the hydrogen storage video to help you.
If the code doesn't work, try https://rb.gy/kdbgj

Making Hydrogen



Electrolysis means splitting liquids using electricity. Water molecules are made up of one oxygen atom and two hydrogen atoms.

Equipment

- Brass drawing pins
- 9V battery
- Plastic cup

Also needed but not included:

- Bicarbonate of soda
- Water

Questions

1. Was the amount of gas bubbles the same at each pin?

2. Which gases do you think were made by electrolysis of water?

Hint – which elements is water made from?

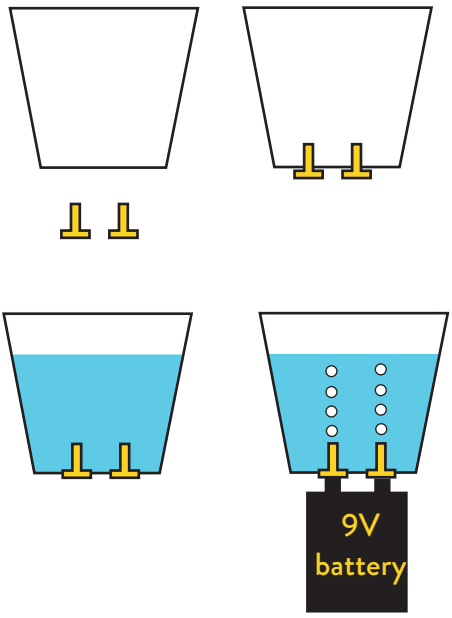
Instructions

1. Take the 9V battery and cup, measure how far the electrodes of the battery are apart and mark this on the bottom of the cup.

2. Carefully push the drawing pins up through the bottom of the cup so that they point into the cup.

3. Fill about two-thirds of the cup with water and add a little of the sodium bicarbonate.

4. Place the cup on top of the 9V battery so that the electrodes of the battery touch the drawing pins.



Hydrogen storage

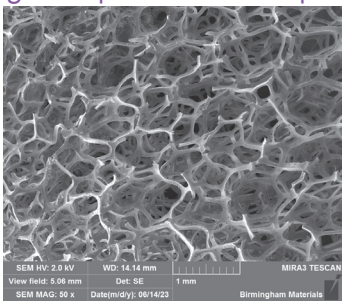
Equipment

- Sponge
- 25ml measuring cylinder
- Square petri-dish

Other things needed:

- Water

Magnified porus material-sponge



Instructions

1. Put the sponge in the square petri-dish.
2. Fill your measuring cylinder to the 25ml mark.
3. Slowly pour the water onto the sponge until it can't soak up any more water (you may need to refill the cylinder but make sure that you record how many times you refill it).
   How much water did it soak up?

   .....

4. Now squeeze all of the water out of the sponge and cut the sponge up.
5. Repeat steps 1-3.
   Did the cut up sponge absorb more or less water than the complete sponge?

   .....

Porous materials are great for storing gases as these gases stick to the surface of the solid. Porous materials have a huge amount of surface to which the hydrogen can stick.

This means that they can be stored in a safer way than using high pressures and low temperature (which are risks involved with using big, pressurised cylinders).

There are two ways that can be used to store hydrogen:

1. By squashing as much of it into a cylinder as you can (pressurising)
2. On the surface of porous* materials.

* A porous material is a solid with loads of holes in it (these are 'pores') like a sponge

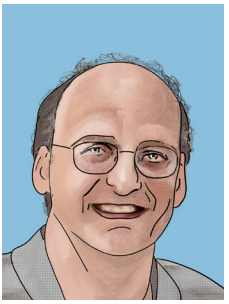
Li-batteries: How do they work?

Lithium ion (Li-ion) batteries are a type of battery which are used in loads of things from smartwatches and tablet devices to electric cars.

These batteries are rechargeable so they need to be charged, used (discharged) and then recharged and have a similar layered structure to Jenga which will be used to help demonstrate this charging / discharging and recharging process.

Equipment

- Mini Jenga
- Mini Jenga sticker set

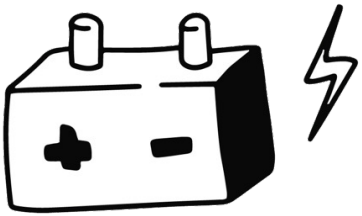


Prof. Peter Slater and **Prof. Emma Kendrick** work in the field of energy materials at the University of Birmingham. Peter's focus is on new materials development from fuel cells to novel electrode materials for Li-ion batteries. Emma's focus is on circular battery research from manufacture to recycling to developing models, all with sustainability being at the core!

Instructions - build your electrodes

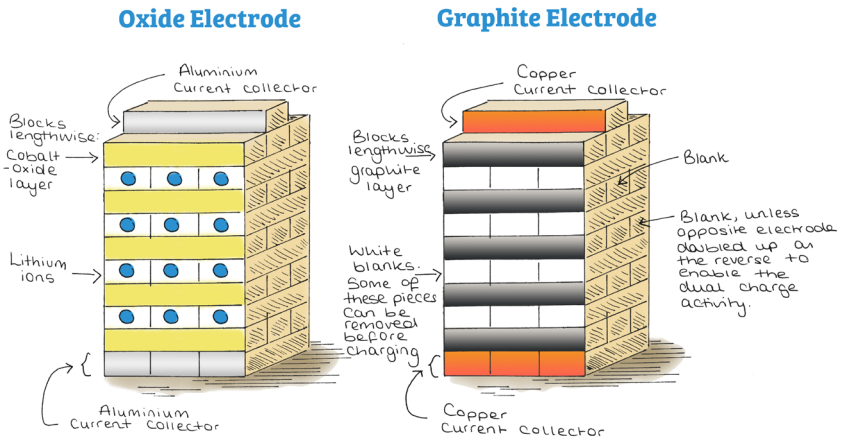
1. Split your Jenga in half, one half will be your oxide electrode and the other graphite electrode.
2. Cut out all of the stickers.
3. The two electrodes will require the following stickers that represent the following parts of the battery:

Electrode	Sticker Description	Battery Component
Oxide Electrode	Yellow sticker with cobalt oxide layer White square with blue circles Gradient grey square	Cobalt oxide Lithium ion Aluminum current collect
Graphite Electrode	Gradient grey square with graphite layer White square Orange square	Graphite layer Empty space between the layer of graphite Copper current collector



Scan the QR code to watch a video about battery jenga.

If the code doesn't work, try https://rb.gy/kdbgj



Next, build your 2 electrodes:

Oxide Electrode	Graphite Electrode
Three aluminum current collectors	Three copper current collectors
One cobalt oxide layer with two blanks	One graphite layer with two blanks.
Three Li-ion blocks	Three white blank blocks
Repeat steps 2 & 3 until you've used all blocks designated for the oxide electrode.	Repeat steps 2 & 3 until you've used all blocks designated for the graphite electrode.

Things to investigate

1 Charging

How long mobile phones take to charge? Would you like them to charge faster? Let's investigate the effect of speed of charging on the battery (also known as rate of charging) – we will do this by moving the Li-ion blocks from the oxide electrode to the graphite electrode at different rates.

What to do

1. Move 5 Li-ion blocks from the oxide electrode to the graphite electrode every 5 seconds (rate and describe what the oxide electrode looks like afterwards).

2. Rest your electrode and try again by moving the Li-ion blocks every 10 seconds.

Move a block every	5 seconds	10 seconds	20 seconds
What does the oxide electrode look like?			

2 Degradation

In the next demonstration we're going to think about the lifetime of the batteries.

Pick one charging rate (from your previous experiment) and move the blocks from the oxide electrode to the graphite electrode and then back again - this is a charging / recharging cycle.

Charge and recharge your electrodes up to five times and write down what the electrode looked like after each cycle - did they collapse or do they not change?

Charging cycle	1	2	3	4	5
What does the electrode look like?					

Scan the QR code to watch a video about Lithium shuffle.

If the code doesn't work, try https://rb.gy/th3p4

Scan the QR code to watch a video about Li-ion batteries.

If the code doesn't work, try https://rb.gy/261qm

Li-Ion Batteries: How are they made?

Equipment

- Cake tin

Also needed (but not included):

- Ingredients to make your favourite sponge cake

Cake Recipes (scan the QR code)

Cake recipe:

Gluten-free cake recipe:

Instructions

Making a cake		Making a battery
Weigh out and prepare ingredients.		Weigh out and prepare our battery materials. We need: Material to make the electrodes A binder A conductive additive
Mix the ingredients together until the mixture is uniform.		The materials are mixed together in the right order and mixed with a special liquid to form a slurry.
The batter is then added to a cake tin.		The electrode ink is poured onto aluminium or copper foil.
The mixture is then cooked.		The slurry is then dried and the layers squeezed together.
Icing or drizzle is put onto the cake.		An electrolyte (the liquid needed for the electrons to move through) is soaked into the electrodes.
The cake is assembled.		The cell is assembled.
And placed into a tin to keep it safe.		A cover is put onto the battery to help avoid damage.

Li-Ion Batteries: How are they recycled?

As you have found out you can recycle Li-ion batteries but they do, eventually, degrade and stop charging up.

We then need to recycle them – which can be difficult.

There is lots of research going on into how to do this. To recycle the batteries they are shredded (which can be very dangerous!) and then the material is separated.

You separated materials using a magnet and water but the materials in batteries can also be separated using electricity. **Let's find out more...**

Equipment (not provided)

- Shredded aluminium foil
- Shredded plastic bag
- Balloon
- Woolly jumper

Scan the QR code to watch Lithium-ion batteries video to help you.

If the code doesn't work, try https://rb.gy/kdbgj

Instructions

1. Get some aluminium foil and an old plastic bag and shred them by cutting them into thin strips (take care when using scissors!)
2. Mix the shredded material together
3. Inflate a balloon and rub it on a jumper
4. Hold this near to (but not touching) the mix of shredded materials – what happens?

The Future...

Equipment

- A pen or pencil

You may also need:

- Colouring pens / pencils

Competition

Take a photo of this page and upload this to enter a prize draw to win cool materials science prizes. Scan the QR code or try https://rb.gy/kdbgj

In the future we will need to make sure that we get the energy needed to power the things that we use.

What to do?

1. Get a pen or pencil write your first name and in the circle draw your face and think about what you want to do when you grow up.

Name:

.....

When I am older I want to be a

.....

I will use electricity for

.....

.....

When choosing materials for future energy uses scientists must consider:

.....

.....

.....

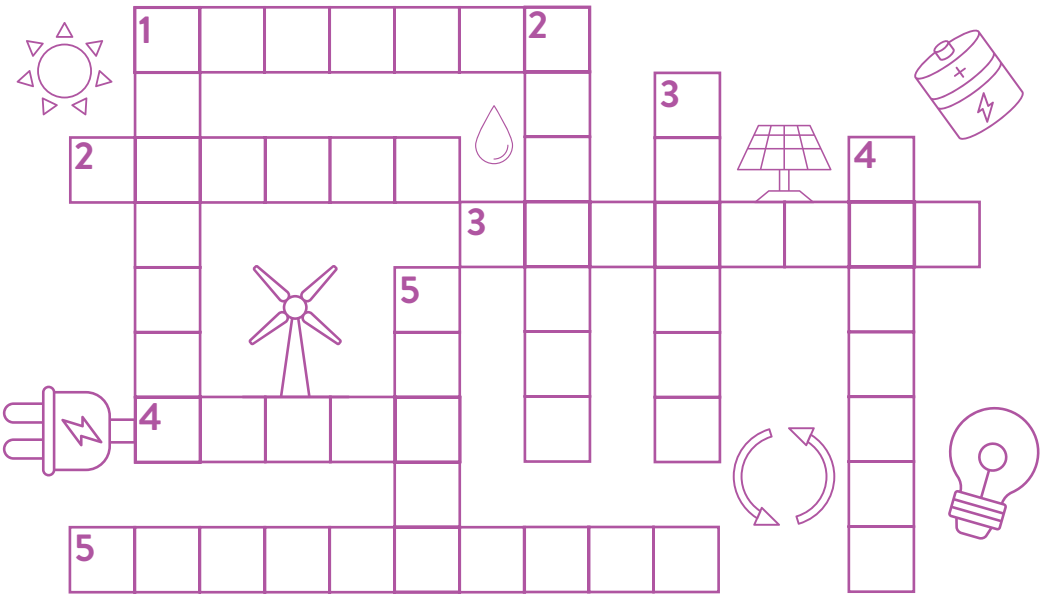
What do you think are the important issues for energy in the future?

.....

.....

What did you learn?

Use your knowledge of energy, materials and batteries to complete the crossword



Across

1. Invented a way of making a carbon filament lightbulb (7)
2. Type of electricity used to separate shredded aluminium and plastic (6)
3. A gas that produces water when it is electrolysis (8)
4. The bottle top attracted to a magnet (5)
5. These are used in a battery cell (10)

Down

1. _____ - ion battery used in mobile phones (7)
2. What you should do with something if you cannot reuse it (7)
3. A sponge is this type of material (6)
4. The property of a material used to separate glass from plastic and metal (7)
5. A type of energy source that uses the sun's rays (5)

For the chance to win Discover Materials prizes
Send in a photo of your completed crossword to: **info@discovermaterials.co.uk.**

Parents / guardians
Please take a photo of the completed crossword and email it to: **info@discovermaterials.co.uk by 14 September 2023** for an entry into the Discover Materials prize draw.
In your email please use '**CoCoElectro Bag Crossword competition**' as the email title.

Notes

Notes

THANK YOU

Thank you for taking part in the CoCoElectro bag activities. We hope you have enjoyed them and had fun learning about materials and energy. Make sure you keep the science kit and we hope you enjoy using it for your own awesome experiments.

If these activities have made you want to learn more about chemistry and materials science then you can learn more.

www.discovermaterials.co.uk

Thank you to everyone who helped develop the activities especially:

Booklet design and activity development
Words Chris Hamlett
Illustrations Lizzie Driscoll
Booklet design Kathryn Downey
Penny battery experiment Becky Waldram
Li-Ion battery activities Lizzie Driscoll
Solar Energy activities Lizzie Mushangwe
Hydrogen activities Una O'Hara
Video editing and post production Jon Wood

Events

Huge thanks to Emma Woolf (Friends of Cotteridge Park) both Martin Khechara and Heather Angell (University of Wolverhampton) and Anita Shervington (BLAST Fest) for helping to organise the events to get the CoCoElectro Bags to you.

Funding

Many thanks to the Royal Society of Chemistry (RSC) for funding this project through their Outreach Fund scheme and to the Henry Royce Institute for their in kind support for Discover Materials.

We would love to know what you think about our CoCoElectro bag project.

Scan the QR code to connect to the form.

If the code doesn't work, try https://rb.gy/utnhf

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