ROYAL SOCIETY OF CHEMISTRY

Take charge

Global battery experiment

Investigation 1

Teaching notes

rsc.li/takecharge

Overview of the investigations

In the **Take charge: global battery experiment** learners can explore batteries and the important role they play in a sustainable future by making their own.

There are two investigations in this global experiment. Both experiments give learners a chance to build a coin battery and practise scientific enquiry skills.

Investigation 1

Make your own coin battery and use it to light up an LED. How many cells does it take?

- Uses only everyday materials.
- Can be done anywhere.
- Share your results and see how they compare with others around the world.
- Target age range: 9–14.

Investigation 2

Compare batteries made from different materials. Which battery performs best?

- Still simple to set up and do, but you will use a voltmeter and test different electrolytes.
- Should be done in a science laboratory.
- Generate and compare data with your class and globally.
- Target age range: 11–14.

These teaching notes will support you to join in with investigation 1. In addition, at rsc.li/takecharge there is:

- An introduction video to help link this experiment to the topic of sustainability and how scientists are currently working to develop better batteries. You can watch this with learners before or after running the investigation.
- A teacher video showing how to carry out the experiment.
- PowerPoint slides that can be used in the classroom, including some background and the instructions.
- A battery power worksheet, link to literacy while learning more about battery research and development from the past to the present day.

Contents

Introduction

To end climate change, we need to stop using fossil fuels in our homes and cars and switch to zero carbon and renewable power such as solar and wind.

We are developing more and more renewable energy resources but many of them only generate electricity in specific circumstances such as when it's sunny or windy. We need to be able to store the electricity generated at those times for use whenever and wherever it is needed.

That's where batteries come in. Batteries allow us to store energy to use whenever we need it. Batteries are a big part of the solution we need to achieve net zero carbon dioxide emissions and become a sustainable society.

Batteries are composed of different layers, each made of a different material. As we need so many batteries to meet the energy demand, the materials we use for these layers are very important. Scientists are trying to create better batteries that are efficient and made from abundant materials.

Learning objectives

- Understand that batteries are made up of layers of different materials.
- Understand that batteries store energy.

Enquiry skills

- Collaborate to accurately follow instructions and carry out a practical investigation.
- Make careful observations throughout and, where relevant, take and record accurate measurements.
- Ask questions based on observations and results.

Background science

Most of the science behind how a coin battery works is beyond what learners in this age group are expected to understand. However, in simple terms, batteries use chemical reactions to drive a current, when connected to a complete circuit. The current is made up of a complete loop of electrons which are driven from the negative electrode towards the positive one.

For a battery to function, the electrodes need to be made of different materials, usually two dissimilar metals. One will form the positive electrode and the other the negative electrode. It also needs an electrolyte which is a liquid (or gel) that allows charged particles to move through it freely.

Once the LED is connected, a closed circuit is created and an electrical current flows. Energy is transferred from the chemical energy store of the battery to the thermal store of the surroundings as the LED is lit.

Prior learning

Using all of the materials provided you can be confident that learners aged 9–14 will be able to access this investigation with no prior knowledge or experience. However, some learners may understand some or all of the following from previous study:

- Be able to identify common appliances that run on electricity.
- Know that batteries are a common store of energy for many devices that we use every day.
- Understand that energy can be transferred from one form to another. For example, when someone is moving down a slide gravitational potential energy is converted into kinetic energy.
- Know that chemical reactions occur between acids and other materials such as metals.

In your lesson

You can use the PowerPoint slides to introduce the topic and support learners as they carry out the investigation.

The introduction video helps link this experiment to the topic of sustainability and what scientists are currently working on to develop better batteries. You can watch this with learners before running the investigation.

What is a battery? (slide 4) shows images of different types of batteries. Use these to start a conversation about batteries – where they are used and different types.

- Image 1 shows AA batteries. This type of battery is familiar to most learners. They are used in toys, torches and many other everyday items. Rechargeable versions of these batteries are available.
- Image 2 shows what some people call a single-cell battery. These miniature batteries power items such as watches or hearing aids. (They are dangerous for small children as they can cause internal burns if swallowed.)
- Image 3 shows the voltaic pile, the first simple battery built by Alessandro Volta in 1799. The coin battery you build in this experiment is a version of Volta's battery.
- Image 4 shows a battery in a mobile phone. Mobile phone batteries are rechargeable, compact and lightweight. They are lithium-ion batteries, a different type of battery to those in image 1 and 2.
- Image 5 shows a battery at a wind farm in the Netherlands – 88 car batteries are connected to form a mega-battery. When the wind blows strongly the energy generated can be too much for the electricity grid to handle. This battery stores the extra energy to deliver to the grid when there is less wind.

Useful vocabulary

Understanding these terms will help your learners talk about the investigation. You may wish to hide the definitions on the PowerPoint (slide 5) and discuss learners' ideas first.

Cell – a device that stores energy and uses chemical reactions to make a current flow in a complete circuit.

Battery – made up of one or more cells joined together.

Circuit – contains a power supply such as (a battery) and a component (such as an LED) connected by wires. A circuit needs to be complete (closed) to work.

Electrode – a cell has two electrodes made of different materials, one positive and one negative. In this experiment the aluminium foil forms one electrode and the coin the other.

Electrolyte – a liquid that will conduct an electric current.

LED (light emitting diode) – an electrical component that produces light when an electric current flows through in one direction.

Did you know? Most of what we see when we look at an LED is actually the casing – the diode itself is tiny.

Equipment list

Each group of learners should have:

- 10 coins of the same size
- 1 x LED
- vinegar
- aluminium foil
- cardboard
- scissors
- pen
- 2 x dishes
- sticky tape (optional)
- tweezers (optional)
- salt (optional, for extension)

Equipment tips

Coins: it doesn't matter what type of coin is used – washers can also be used. Larger, slimmer coins are the easiest to work with.

LED: standard LEDs (rated at ~3V) work well for this investigation. Red and green LEDs are the easiest to see.

Vinegar: any type can be used; most standard vinegars have 5% acidity (equivalent to 0.8 M ethanoic acid).

Aluminium foil: standard household aluminium foil. Thicker foil (eg extra strong) is easier to handle.

Cardboard: the images and video give a good guide to the ideal thickness for the cardboard. If it is too thick it will be hard to cut out and require longer soaking, and if it is too thin it may disintegrate.

Sticky tape may help to secure the LED to the bottom of the stack as you add more cells and/or be used to tape the whole stack together.

Tweezers can be used to lift the cardboard out of the vinegar solution and/or to build up the stack to minimise hand contact with the solution.

Method

To set up

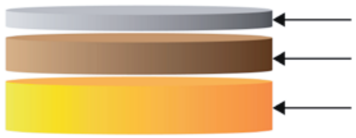
1. Cut out 10 cardboard discs using a coin as a template.
2. Fold a square of aluminium foil four times, draw around a coin, cut out and separate the layers.

> **TIP**
> Separate the foil carefully so the discs don't tear and remain full circles.
> (Depending on time available you could prepare steps 1 and 2 ahead of the lesson – it takes learners around 10 minutes to complete these steps themselves.)

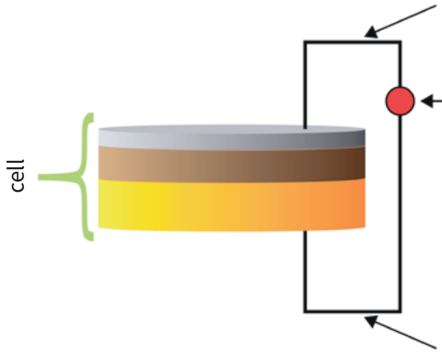
3. Soak the cardboard discs in the vinegar (the electrolyte) for about one minute.
4. Remove the discs from the vinegar (using tweezers) and place them in the second dish for a few minutes to drain off any excess liquid before assembling the battery.

Make the first cell

1. Create a cell by stacking a coin, a cardboard disc dampened with the vinegar and then a disc of aluminium foil.



2. Connect an LED to the stack (its short leg goes on the aluminium foil and its long leg on the coin) to see if it lights up.



Add more cells

3. Assemble a second cell, in the same order, on top of the first cell.
4. Test the two-cell device with the LED again.

> **TIP**
> Keep the stack of cells neat – don't let the foil move down the side as this could short circuit the battery.

5. Repeat the process of adding more cells until the LED lights up.

> **TIP**
> As the stack is built up, it might be helpful to secure the long leg of the LED to the bottom coin using sticky tape. This helps to maintain contact and avoids confusion about which is the longer leg.

6. Record the number of cells required to make the LED light up. Remember you are recording the minimum number of cells needed.

> **TIP**
> It can be hard to see the light from the LED – dim the classroom lights and work on a piece of white or black paper for contrast.

7. Take it further by repeating the experiment using a different electrolyte or get different groups of learners to test different electrolytes such as:
   - saline solution (1 tsp salt dissolved in 100 ml water)
   - 50:50 mixture of vinegar and saline solution

Expected results

This investigation will generally need about five cells to light up the LED with vinegar as the electrolyte. Salt solution will require more cells. The mixture of salt solution and vinegar will need fewer cells (about three). If you add more cells the LED gets brighter.

Learners may observe small holes in the aluminium foil after using the battery for some time. Ask learners if these holes are a problem and link it to sourcing materials to make batteries and the importance of battery recycling.

Troubleshooting

If your LED doesn't light up here are some things to check:

- LED is connected the wrong way round: LEDs will only work in one direction.
- Foil bending down the side of the pile touching other cells and short circuiting the battery.
- Poor connections between the layers: some pressure on the top of your battery can help to increase the connections and light up the LED.
- Battery placement: holding the battery in the air increases the chance of short circuiting or losing connection. Working on a table helps to keep the stack neat. Once you have made a working battery you can tape it to keep everything together and make it easier to handle.
- Cardboard too dry: if the electrolyte has not soaked all the way through the cardboard the charge will not be able to travel through the cell (but it doesn't need to get too soggy).

Question prompts

1. How many cells did it take to light up an LED? Did we all get the same result?
2. Did using different solutions as the electrolyte give different results?
3. What happens if you connect the LED the other way around in the circuit?
4. Once you have enough cells to light up the LED what effect does adding more cells have?
5. Is there anything we want to change about this experiment? What else could we test?

Extension activities

Here are some ideas for how you can extend this investigation:

- Investigate exactly how much electricity is being generated – if you have access to a voltmeter or multimeter you could repeat the experiment and record the potential difference (voltage) when each additional is cell added. (Guidance for using a voltmeter is included in the resources for investigation 2.)
- Investigate whether you can power any other electrical components from a coin battery, for example a buzzer, light bulb or motor.
- Investigate how long your coin battery will light up the LED for.

Write-up and follow-up

Once you have completed your investigation don't forget to share your results on the website (rsc.li/takecharge) and see how they compare with other schools around the world.

Learners can draw a labelled diagram of their battery showing the detail of the individual cells and how the LED completes the circuit.

Learners can explain in their own words how their battery works and record how many cells were needed to make the LED light up.

Use the information and activities in the battery power worksheet (available at rsc.li/takecharge) to find out more about batteries and how they will be important for supporting our energy needs in the future.

Explore how learners use electricity in their daily lives and the impact that has on the environment. What can they do to reduce their electricity usage and become more sustainable citizens? Use the website (rsc.li/takecharge) to find and share ideas and to make a commitment.

FAQs

These are some questions your learners may ask you along with some suggested answers:

1. Do batteries store electricity?
   Batteries don't store electricity, they store energy. The rate at which the LED emits light depends on how quickly energy is transferred from the chemical energy store of the battery.
2. Can you use other metals as the electrodes?
   Yes, as long as the electrodes are made of different metals you can use almost any metal.
3. Are there other electrolytes you can use?
   Yes, lemon juice works well and you could use a carbonated drink too.
4. What else can you make a battery out of?
   You can make good batteries out of citrus fruits where the juice inside acts as the electrolyte. You can also make a battery out of a potato.
5. Is this how 'real' batteries work?
   Pretty much yes, the electrolyte and materials for the electrodes vary but the basic principle is the same.
6. Why does the battery run out?
   Batteries 'run out' when one of the chemicals taking part in the reactions has fully reacted and is no longer available.
7. How do rechargeable batteries work?
   A rechargeable battery works in the same way as a coin cell when being used (eg to light an LED). However, the chemicals inside are different. When they 'run out' they can be connected to a charger to reverse the chemical reactions and 'recharge' them.
8. Could we get a shock if we made a really high stack?
   If you make a voltaic pile with more than 10 cells it is possible to get a small electric shock from it. This is how Volta originally measured how powerful his batteries were by giving himself electric shocks.

Acknowledgements
With thanks to the resource authors, Paul Tyler (investigation 1) and Harry Lord (investigation 2), and reviewers, Alex Farrer, Karen Marshall and Sandrine Bouchelkia. Further thanks go to the other teachers and advisers who have supported with the development of this global experiment.