PUPIL
RESEARCHER
INITIATIVE

# Michael Faraday and Electrolysis

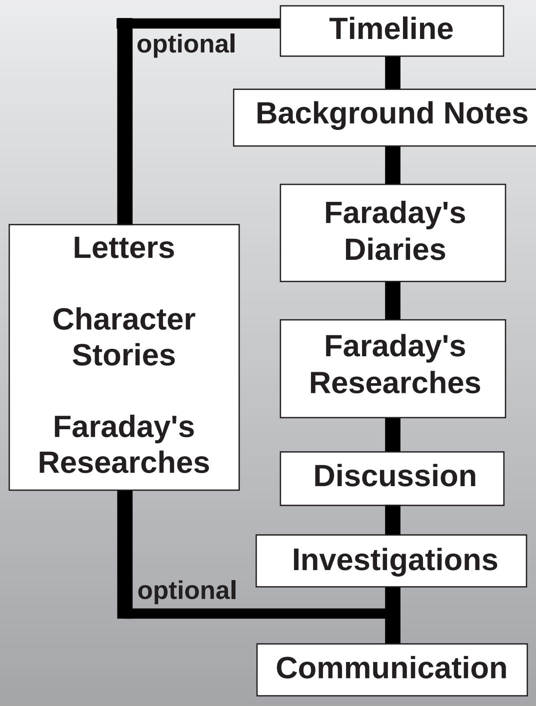
## Pupil Research Brief

## Teachers' Notes

### Syllabus Coverage *Subject Knowledge and Understanding*

- ❏ when substances which are made of ions are dissolved in water, or melted, they can be broken down into simpler substances by passing an electric current through them (electrolysis)
- ❏ during electrolysis, positively charged ions (e.g., metal ions) move to the negative electrode, and negatively charged ions move to the positive electrode
- ❏ during electrolysis gases may be given off, or metals may be deposited at the electrodes
- ❏ at the negative electrode the positively charged ions gain electrons (reduction)
- ❏ at the positive electrode the negatively charged ions lose electrons (oxidation)

### Route through the Brief




### Introduction

Pupils are invited to consider science and its place in society when Michael Faraday was researching into electricity and its effects on chemicals. Following discussion of the relevant extracts from Faraday's own diary and research notes they are then invited to undertake their own investigations into electrolysis and to compare their findings with Faraday's work. (Further optional work can be done by the pupils to gain insights into the life and times of Faraday from extracts of his letters to other scientists, and from a number of character stories. The letters and stories are found at the end of the main pupil materials).

**Experimental and investigative skills**

- planning experimental procedures
- obtaining evidence
- analysing evidence and drawing conclusions
- evaluating evidence

**Prior knowledge**

Before attempting this Brief pupils should have covered the basic vocabulary and background to the laws of electrolysis, and performed or observed a standard electrolysis experiment. The electrolysis of water would be a useful demonstration to have observed.

# Pupil Research Brief

## Teachers' Notes continued

### Running the Brief

**Pupil grouping**

Pupils could work in a number of groupings during this Brief. Suggestions are:

| | | |
|---|---|---|
| *Initial briefing* | - | whole class; teacher introduces and sets the context for the Brief |
| *Background Notes and Timeline* | - | pairs or groups or whole class, followed by discussion |
| *Scientific context* | - | pairs or groups study sections of the source material followed by discussion |
| *Investigation* | - | whole class discussion of factors involved and allocation of tasks to small groups |
| *Communication* | - | groups present their work to whole class |

**Timing**

This Brief should take about 3-4 hours of classroom time. This could vary, depending on the number of diary and research note extracts which are used, and on the number of factors considered in the investigation. If social and historical issues are considered using the optional material at the end of the main pupil materials, clearly more time will be required, although it may be possible for this work to be undertaken in different subject time, eg. history, social studies.

**Activities**

Pupils should be issued with the **Study Guide**, which provides them with a summary of what they should produce as they work through the Brief. It can also be used as a checklist so that they can monitor their own progress.

A variety of source and background material is provided and it is intended that only selected parts will be used by different pupils. Teachers will need to match the approach to the abilities and interests of their pupils, drawing on the differentiated approaches a, b or c.

*Timeline and Background Notes*

a. The teacher outlines the story of Michael Faraday and his times, drawing on the **Timeline** and **Background Notes**. Pupils work through relevant questions on the **Discussion Guidelines Sheet**

b. Pupils are given the **Background Notes** and the **Timeline** in advance. They work through the relevant sections of the **Discussion Guidelines Sheet** and are asked to prepare short presentations or poster displays. (History or Social Studies teachers may be able to help, or work could be linked with these lessons).

*Scientific Context*

The sources in this Brief are genuine, being Faraday's own **Diary** and **Researches** book.

a. The teacher leads pupils through some of the material, emphasising the many factors that Faraday investigated, the accuracy of his work and how he generalised to make his 'laws'. The teacher could show that Faraday recognised areas of inaccuracy, even failed to investigate all areas with the same thoroughness ('heat' / temperature, in this case), or

b. the class takes the diary sections and extracts from Faraday's Researches. They split into pairs or small groups and work through one or more questions set out on the pupil **Discussion Guideline Sheets**. The **commentaries** could also be used here, or

c. high-achieving pupils take sections of the Diary and/or Researches and work with only a minimum of the Commentary (e.g. Muriatic acid is hydrochloric acid), looking for the ideas that Faraday is trying to put over and placing these alongside their own ideas.

From this reading of source material, the teacher leads a discussion of the factors that Faraday did/did not take into account. (i.e. it looks as if he tried everything possible except the effect of 'heat').

**Investigation details**

Pupils can investigate for themselves the process of electrolysis, paying particular attention to some of the factors that have been considered following their reading and discussion of Faraday's Diary and Researches extracts.

## Teachers' Notes continued

For example, each group could be allocated a task to investigate how varying one or more of the following factors might affect electrolysis:

(i) size of electrodes
(ii) distance between electrodes
(iii) value of current and/or the time it passes for
(iv) temperature of electrolyte.

They could be asked to comment, where relevant, on how their conclusions compare with those of Faraday and perhaps identify and explain at least one advantage they had with their apparatus compared with Faraday's.

A Pupil **Investigation Guidelines Sheet** is provided if you wish to use it.

They could also take the opportunity to compare Faraday's methods of working (i.e. largely on his own, but discussing results and ideas with several other workers over a relatively long period of time) with present day methods (where often several researchers in a team, or different teams work together, often looking at different aspects of the same problem and discussing and pooling their results and conclusions. Such team work usually leads to a quicker solution, and where necessary, a more in-depth and rigorous investigation). Today, researchers are usually working 'against the clock', as a result of funding timescales and also due to competition from other groups working in the same field.

By allocating different tasks to pupils, relating to the same topic area, as suggested above, they will see for themselves the benefits of team work.

Increasing the size of electrodes, increasing the temperature and decreasing the distance apart of the electrodes in each case, results in an increase in current and hence an increase in the mass of copper deposited at the cathode (and a corresponding decrease at the anode).

Results can be displayed in graphical form by plotting mass loss and/or gain of electrode with time, for electrode size, distance apart and temperature. This can also be done for investigating change in current (by altering the voltage).

Faraday's Law of Electrolysis (expressed in his own words as: 'chemical action or decomposing power is exactly proportional to the quantity of electricity which passes) could be investigated by varying current and/or time and then plotting change in mass of electrode against the product of current x time (coulombs).

**Technical details**

The electrolysis of copper sulphate solution (0.25 - 0.5M) using copper foil electrodes and a 4.5 or 6V power source is a good starting point for the investigations. Ensure electrodes are clean and not handled with the fingers. It is useful if voltmeters and ammeters are also available. For temperature variation, values of 20, 40 and 60°C are suitable. Care should be taken when measuring increase in mass of the electrode, to remove it and dry it carefully before weighing.

### Safety issues

PLEASE NOTE: It is also important that you prepare your own risk assessments for the practical work in this Brief in the usual way.

The electrolysis of copper sulphate solution (0.25 - 0.5M) using copper electrodes (or a carbon anode and a copper cathode suggested in 'Further pupil research opportunities section') are fairly standard experiments. However care should be taken over risk assessments for both the chemical solution used (and its strength) and the products of electrolysis (singly and in combination).

Electrolysis of water, with its flammable gas products (explosive in combination) should be left as a demonstration or done under the supervision of the teacher.

### Assessment issues for *Experimental and Investigative Science* (National Curriculum for England and Wales)

| | | | |
|---|---|---|---|
| P | Planning | O | Obtaining evidence |
| A | Analysing evidence | E | Evaluating evidence |

Each of the factors of the electrolysis process suggested for investigation can be investigated separately and the level of difficulty will depend on the scientific knowledge and understanding used. Equally, the level of skills required will be a factor in the assessment; e.g. size or distance apart of the electrodes can be more easily controlled and measured than can the temperature of the electrolyte.

Care with the uncertainties involved in quantitative measurement will allow higher levels of analysis and evaluation. This may be particularly so where results of more than one experiment on a factor are considered, and where all the factors are considered as a whole in an evaluation of the laws of electrolysis.

# Teachers' Notes continued

This Brief provides a range of opportunities for pupils to carry out investigative work. Pupils should be able to achieve high marks in each of the skill areas. However, the Brief contains a number of descriptions of actual experiments carried out by Faraday, and so this must be taken into account when awarding marks for **Skill Area P**.

### Assessment issues for *Experimental and Investigative Science* (Northern Ireland Curriculum)

P Planning O Obtaining evidence
I Interpreting and Evaluating

See also notes for England and Wales.

This Brief provides a range of opportunities for pupils to carry out investigative work. Pupils should be able to achieve high marks in each of the skill areas. However, the Brief contains a number of descriptions of actual experiments carried out by Faraday, and so this must be taken into account when awarding marks for **Skill Area P.**

### Scottish syllabus coverage

Standard Grade Chemistry - *Proportions of Subtances* and *Corrosion*

### Further pupil research opportunities

1. Pupils could read and discuss further paragraphs from the diary and/or researches book, for example:

(i) pupils read "The Volta-electrometer" (Researches paras 732-739) and discuss this in relation to Hoffmann's voltameter and the problems of using this as a measuring instrument;

(ii) pupils read "The Volta-electrometer" and compare this as a measuring instrument for current with the swinging needle of a moving-coil ammeter;

(iii) pupils could design and possibly carry out an experiment under teacher supervision to show how a Hoffmann's voltameter could be used as a current measuring device.

2. Pupils could also investigate the copper sulphate electrolysis using a carbon anode and a copper cathode, comparing it with the electrolysis using copper electrodes.

3. Pupils could read the article *Batteries for the 21st Century* in Issue 2 of PRISM and write a short piece comparing batteries in Faraday's time with those currently being developed.

## Further notes on use of Optional Source Material: the historical and social context

### Introduction

The materials in this section of the Brief offer additional ideas and resources to help pupils gain insights into the life and times of Faraday. They could be integrated with scientific work in the main part of the Brief, but equally, it could be beneficial to develop the opportunity for cross-curricular work with the History, Social Studies, English or French departments.

The material includes some of Faraday's actual correspondence with other scientists working in the field at the time, and also four character stories, which although not based on fact, reflect the reality of the time.

**Source material: Letters from and to Michael Faraday**

Apart from the science contained in these letters, a great deal can be absorbed from the (then) conventional beginnings and ends of letters and the social chit-chat also involved. Intended mainly for teachers' personal background, excerpts could clearly be used with some classes to illustrate points. You may wish to devise some questions or DARTS (Directed Activities Related to Text - see General Teachers' Notes, Pack 1) to help pupils actively interrogate these letters. There is some useful and relevant science in them.

*Faraday and Benjamin Abbott*

Benjamin Abbott was a friend from Faraday's youth. Pupils who can translate the French postscript might enjoy it !

*Faraday and Mary Somerville*

Mary Somerville came from the landed gentry and was an academic and keen scientist. Somerville College bears her name and hers is the only statue of a woman in the Royal Institution.

*Faraday and André-Marie Ampère*

They met while Faraday was on the Grand Tour and corresponded throughout their lives; Ampère writing in his native French. The original French version is

# Teachers' Notes continued

included for use instead of the English translation for pupils with linguistic ability. They will almost certainly need help from their language teacher as the French is of the period in the same way as is the English.

**Character Stories**

Using Faraday's letters on their own to give pupils a flavour of society would make very high demands on their language abilities and their historical knowledge, although this might be done if the project were joint between Science and History departments. Consequently, four character stories have been developed to give more access to ideas and historical knowledge.The **map** is for pupils to follow as they read the stories.

*Jane and James Deval*

Two roles loosely based on the types of families and life-styles of Michael Faraday and Benjamin Abbott when they were youths.

*Alice, Lady Mesbury and Albert, Lord Mesbury*

Two roles typical of landed gentry of the time but with some of the ideas from Mary Somerville.

The characters' names are fictional, as are the titles and the houses they inhabited. The rest is as accurate as it has been possible to make it; for instance, the *Marylebone Literary and Scientific Institute* existed at that time and that place; Faraday was lecturing on metals on those dates.

**Faraday's Researches**

Language and electrolysis paragraphs 661- 667.

## Some suggestions for using the optional source materials

**1. Faraday's correspondence**

a. Pupils read the Mary Somerville letters, with perhaps parts of the Abbott letters, looking in particular at the beginnings and ends of the letters and at selected scientific middle sections.
(This could be combined with work in English).

b. Pupils read the Abbott letters and selected parts of the Ampère letters. The teacher leads pupils through the controversy between Faraday and Ampère (who nevertheless remained as good friends).

c. Higher ability pupils report back on the Ampère letters they have been studying, leading to a discussion on the controversy between Faraday and Ampère.

In addition, as a continuing task across the whole timespan of the Brief, higher-achieving pupils could be given one or more sets of the Faraday Letters and asked to prepare short verbal presentations on one of:

- the style of letter writing
- historical context
- scientific controversy (as in the Ampère selection)

Pupils with high skills in French might try the Ampère letter in the original French (with the help of their French teachers, since the French is archaic too).

**2. Character stories**

Groups of four pupils could be formed and each member takes a character story (and map) and studies it, perhaps for homework. They highlight key information about their character such as: who they are; family background; work and interests; leisure pursuits and, particularly, any reference to scientific background.

Each pupil can exchange this information (possibly in role) with the rest of the group, followed by a general discussion of the characters and their lives and times.

**3. Faraday's Researches**

Possible uses of this material include the following:

(i) The teacher leads pupils through the evolution or creation of new words to describe his discoveries.

(ii) Pupils discuss the uses of these 'new' words in the 1840s and in the present day

(iii) Higher-achieving pupils research the Latin and Greek roots of the scientific language, with the help of their language teachers.

# Background Notes - Michael Faraday and Electrolysis

## Early 1800s

*General*

People who were owners of large areas of agricultural land were only just starting to come to terms with the idea of industrialisation (the Industrial Revolution as it is now called); the Napoleonic Wars had finally finished in 1815 and the aristocracy in Britain were still very nervous of the idea of working people having any power. Railways were being built, weaving was now done in mills, industrial towns were being built. Overall, industrialisation was developing and the elites were trying to control it against a background of civil unrest.

Parliament was being pushed to reform and slavery was gradually being outlawed in Britain and elsewhere. Britain was exploring and colonising remote parts of the world; convicted people were being transported to these colonies. The first official Census had taken place in 1801 and the Ordnance Survey was in the process of systematically mapping the whole country (1791-1860s).

*Place of Science*

The large-scale landowners, the elite aristocracy, wanted to be roundly educated. This meant learning in all areas of knowledge including Science. Some scientists (or 'natural philosophers') had a great deal of their own money and did not work at any job. In some circles it was considered the fashionable thing to have your own laboratory and scientific equipment and some wealthy people had them. Educated people who needed to earn money - the professional classes -carried out science as a sideline to other careers, such as medicine. Many scientific insights came from the vast leaps in technology that accompanied the Industrial Revolution.

*The Royal Institution*

The Royal Institution of Great Britain was founded in 1799 at 21 Albemarle Street, London. A group of scientists headed by Count Rumford founded it and Humphry Davy was the first popular lecturer there.

The famous lecture theatre at the Royal Institution had a gallery for the tradespeople with a separate entrance from the street, so that they would not be 'embarrassed by having to sit with the fancy'. It is worth noting that women as well as men came to lectures and were members of the RI; educated women bringing their daughters. This was at a time when women were still regarded as intellectually frivolous by some men.

*Faraday*

Faraday was one of four children in the family whose father was a blacksmith. He started work at 13 years as a errand boy to a bookbinder and bookshop keeper, Mr Riebau. His education up to this point was the basic one that most boys and girls of his class had: reading, writing and arithmetic at a fee-paying school (the fees were very low and only the very poor could not afford them). Mr Riebau took him on as an apprentice bookbinder when he was 14 years old and did not charge a fee for this, which was unusual. (Apprentices in those days lived with their apprentice-masters rather than with their own families).

While he learned how to bind books, Faraday started reading them; in particular the *Encyclopedia Britannica* (3rd edition, 1797). He then started to improve his own education by going to what we would now call a 'self-help group', attending talks and lectures, collecting articles and reading chosen ranges of books. Talks were given in halls and in people's homes - remember there was no such thing as radio, let alone television. This type of self-education was quite common for a lot of people. It's strand continues today in evening classes, the Workers Education Association and also the Open University. It was, and still is, particularly strong in Scotland.

Religion played an important part in many peoples' lives and much education went on in church buildings. Michael Faraday himself was a life-long member of a small sect of Protestants called the Sandemanians.

Books on science interested Faraday greatly and one called *Conversations in Chemistry* by Jane Marcet, which was written from lectures of Humphry Davy, really captured his imagination. There were many 'self-improving' books around this time and science was considered especially interesting. This one showed how to do experiments and Faraday made his own battery, called then a 'voltaic pile' after Volta who had invented it around 1786. He wrote to a friend in his self-help group, Benjamin Abbott.

"I, Sir, my own self, cut out seven discs of the size of half-pennies each! I, Sir, covered them with seven half-pence and I interposed between seven or rather six pieces of paper, soaked in a solution of Muriate of Soda!!! - but laugh no longer Dear A----- rather wonder at the effects this trivial power produced, it was sufficient to produce the decomposition of the Sulphate of Magnesia; an effect which extremely surprised me, for I did not - could not have any idea, that the agent was component to the purpose."

# Background Notes - Michael Faraday and Electrolysis cnt'd

When he was about 20, Faraday was given a ticket to go to the RI to listen to a series of four lectures by Humphry Davy, who was then a very fashionable lecturer and a researcher at the Royal Institution. Faraday sat in the gallery, was very impressed and took very full notes. Because he was fascinated by science - and not so very fascinated by bookbinding - he expanded these notes, illustrated them, and bound them. Having done this he sent the bound copy to Humphry Davy and asked him for a job. Davy was very impressed by the bound notes; they are on view these days in the Faraday Museum at the RI in London. There was no job available at the time, but one became available in 1813 and Davy gave it to Faraday; assistant in the laboratories at 25 shillings per week, two rooms in the attic, coals and candles.

Humphry Davy himself originally started training as an apothecary (pharmacist). He was also a poet and was friends with people like Wordsworth, Coleridge, Southey and Walter Scott. Davy was doing some of his main work at the time (1803) that Dalton was promoting the atomic theory (atoms - basic building blocks and indivisible) but he never did really accept this. Faraday probably did accept the theory but was wary of it.

Very soon afterwards, in 1813, Humphry Davy and his wife set out on a Grand Tour of Europe. Davy used the opportunity to talk to a great many scientists and to work on experiments. For this, he took along Michael Faraday who became an indispensable assistant. At the time, the Napoleonic Wars were still going on, but Emperor Napoleon was very keen on science and admired Davy's work. He had already given Davy a medal for his science work (while France and England were at war!) and now allowed the party to travel through France. They visited Switzerland and then went on into Italy. While in Florence, one of their more famous experiments was to burn a diamond with the aid of the 'great lens in the Academia del Cimento' (in the same way that a small converging lens today can set fire to a piece of paper by concentrating the Sun's rays). In doing so they showed that diamond was pure carbon, the same substance as graphite; this view was still being argued over many years later. Faraday made many friends on this tour and corresponded with some for a long time afterward, having learned French and Italian on his travels.

Davy had resigned from the Royal Institution when he got married in 1813 but continued as honorary professor for life, directing a great deal of Faraday's initial work. As Davy became even more part of fashionable society and President of the Royal Society, so Faraday did more of the work and became a very successful lecturer in his own right . He became Superintendent of Laboratories, married and brought his wife Sarah to live in the RI . A great deal of his work comprised 'useful science'; a lot of analytical chemistry on water quality, sewers , steel alloys, optical glass and so on. It was in 1834 that he became Professor Faraday, with the 'chair' paid especially for him by John Fuller, a Member of Parliament.

Michael Faraday had a modest nature and although he had a temper, he kept it in check, preferring to reason with people and help them. The Royal Institution carries on many of his traditions in lecture demonstrations, often using Faraday's own equipment along with that from other famous scientists who lived and worked at the RI. One of his innovations was lectures for children, which carry on throughout the year to this day and have their high point in the annual RI Christmas lectures, which are televised.

Faraday actually did his experimentation at the RI with only one lab assistant. However, the pace of life itself was not nearly so fast in the 1830s and he certainly talked to a lot of people about his work. He talked informally at the RI and other people's houses; he lectured in the famous theatre - often about his latest discoveries; he published his findings - most often via the Royal Society; wrote occasional letters to the papers, and corresponded (by letter) with a vast range of people both in Britain and in other countries.

His modest nature and obvious skills as a lecturer (he published a book on lecturing still used today) meant he met and talked to a great number of the fashionable people. Prince Albert went to his lectures and was a friend; also the artists Turner and Constable, Dickens and Ruskin the authors - both concerned for the lot of the working classes, Darwin and Huxley, Roget (of Thesaurus fame), Talbot - one of the first photographers (demonstrating flash photography in RI) and others. Many of these also lectured at the Royal Institution.

*Faraday's Laws of Electrolysis*

Michael Faraday was always interested in electricity. In 1833 he put together a series of experiments to show that electricity was the same no matter from where it came. This was something that was by no means agreed on at the time. Different types of electricity were referred to as *animal* (galvanic); *chemical (*voltaic;) *frictional* (electrostatic;) and electromagnetic.

# Background Notes - Michael Faraday and Electrolysis cnt'd

Building on the work of famous scientists such as Oersted and Ampère, Faraday showed that electricity could make things move when put with a magnet. This led directly to the electric motor. He went on to electromagnetic induction (the idea of making electricity from magnetism and movement). This turned the idea of the electric motor around and led to the dynamo and the transformer. From these discoveries came the ability to generate useful electricity by mechanical means rather than by chemicals. This is now the basis of the whole electrical industry - and our mains electricity system.

Humphry Davy had developed voltaic piles (original batteries made by Volta) into much better batteries, so that research could be done far more easily. He used these to decompose chemical compounds which had been difficult or impossible to separate before that. In decomposing solutions and melts around 1806 he isolated potassium and sodium. On his Grand Tour he and Faraday studied the properties of iodine, which the French had isolated. Davy also isolated barium, strontium, calcium and magnesium; in other words he discovered the 'reactive metals'.

Faraday built on this use of electricity to decompose chemical solutions and developed the ideas into what are now known as Faraday's Laws of Electrolysis. These followed really extensive experimentation on water and many other electrolytes during 1833 -1834. In his own words:

"Chemical action or decomposing power is exactly proportional to the quantity of electricity which passes";

"Electrochemical equivalents coincide and are the same with ordinary chemical equivalents".

Electrochemistry was very quickly put to work in existing and new industries:

- electroplating - gold and silver plating of cutlery (replacing Sheffield Plate)
- electrorefining - purifying copper
- electroforming - first phonograph records

However, such industries could only develop with a reliable, easily produced form of electricity - from Faraday's own dynamos!