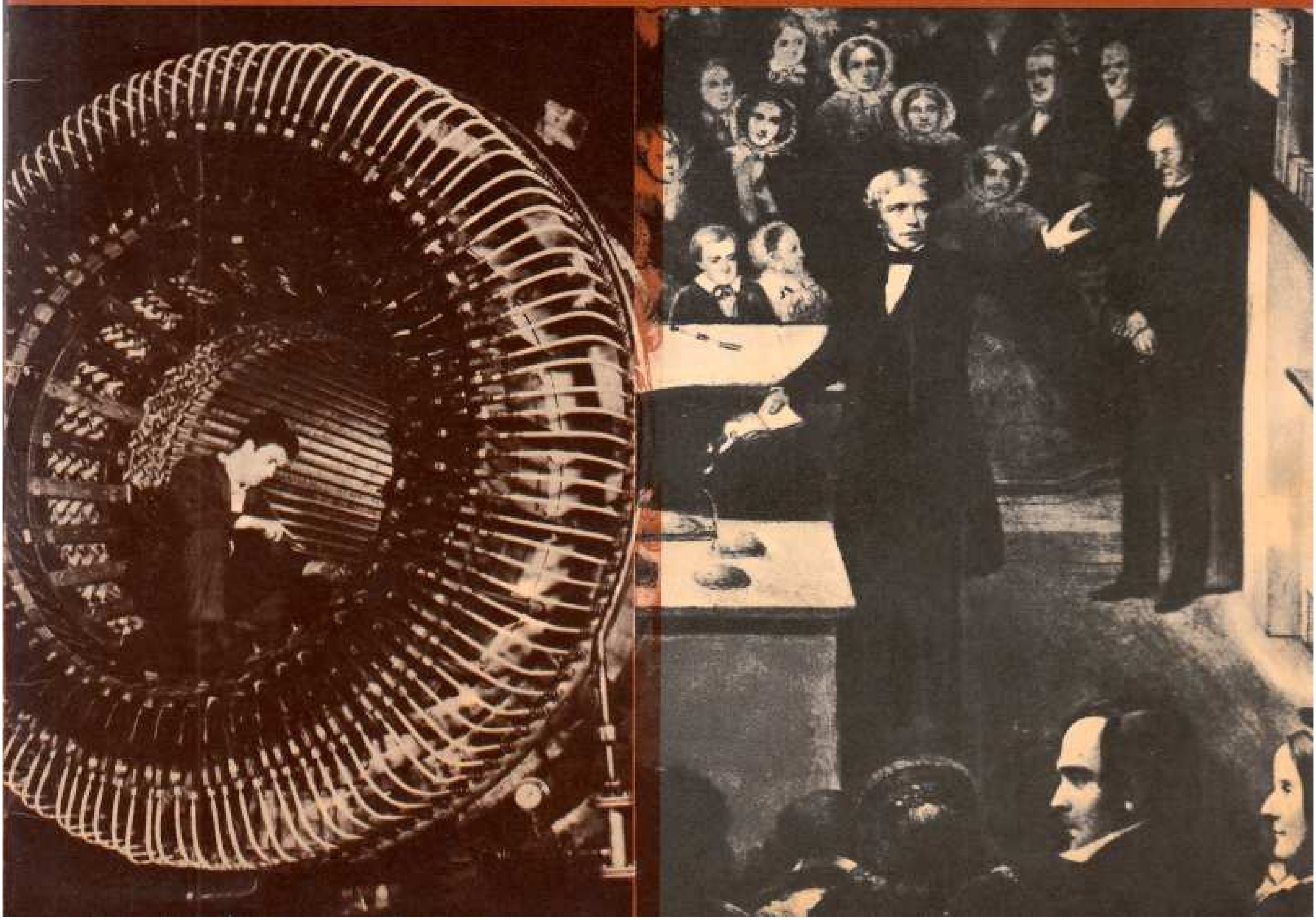
Chemistry Background Book

Michael Faraday



Michael Faraday
1791–1867

Michael Faraday 1791–1867
Royal Institution

One day in 1813 an extraordinary thing happened at the Royal Institution. The laboratory assistant William Payne was found fighting with the instrument maker Mr Newman. Payne was dismissed and someone had to be found to take his place. Humphry Davy, Lecturer in Chemistry and Director of the Laboratories, recommended a youth of about twenty years of age who wished to be considered for work at the Institution. Davy reported: 'His name is Michael Faraday. His habits seem good, his disposition active and cheerful, and his manner intelligent.' Faraday was appointed at a salary of twenty-five shillings a week, with rooms at the Institution. He was then twenty-one. How did Davy know about him?

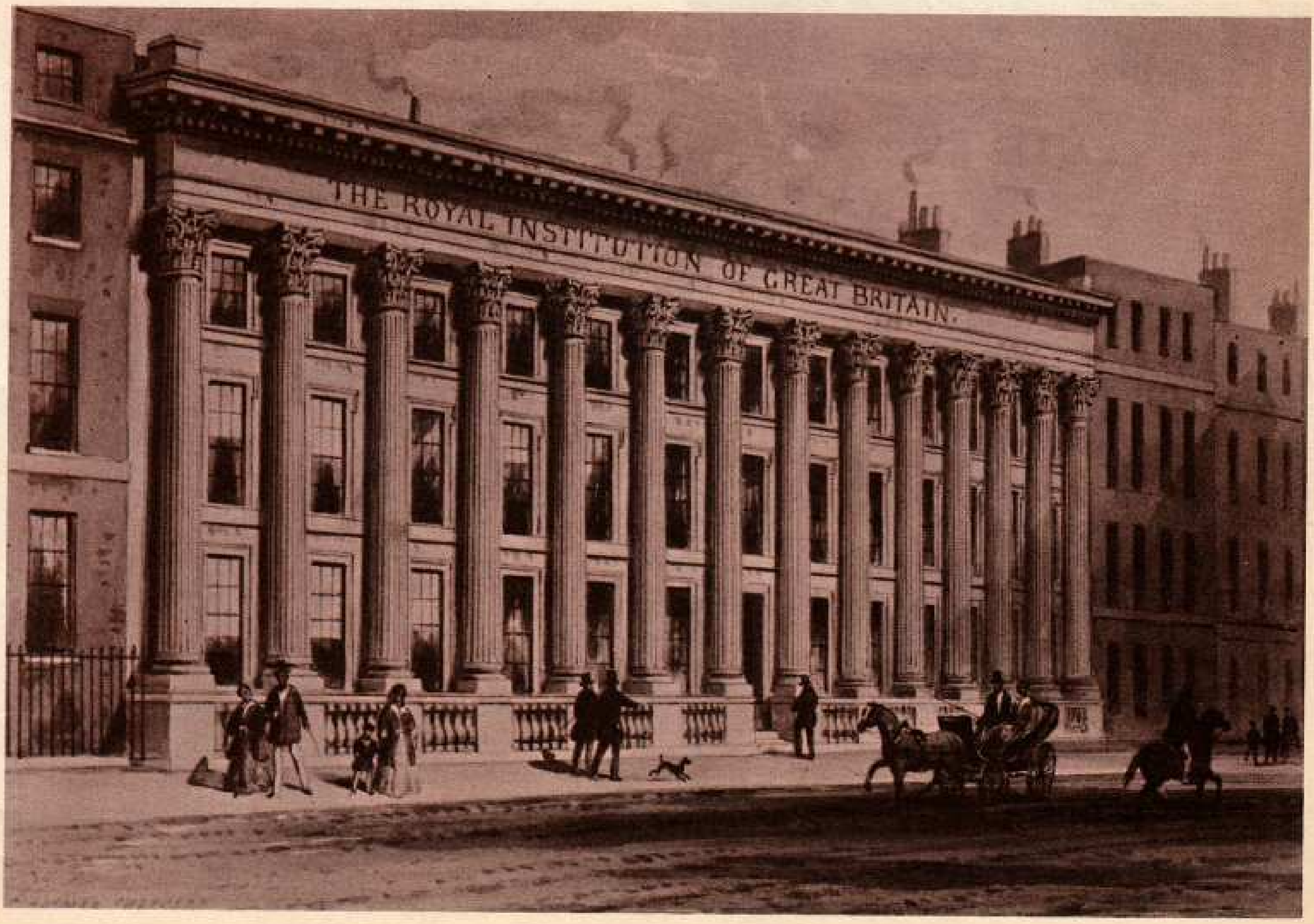
Michael Faraday was the second son of a Yorkshire blacksmith who had moved to London. Faraday senior and all his family were members of a strict religious sect called Sandemanians which had separated from the Presbyterian Church of Scotland in 1730. The small London group of Sandemanians devoted every Sunday to religious service at a meeting-house in one of the worst slums of London. The elders of the group held the services and took turns to give the sermons.

Faraday's family was poor. His father had difficulty in finding regular work, particularly when his health began to fail. In 1801 the Faradays were forced to ask for public relief and young Faraday's share worked out at one loaf of bread, which had to last a week.

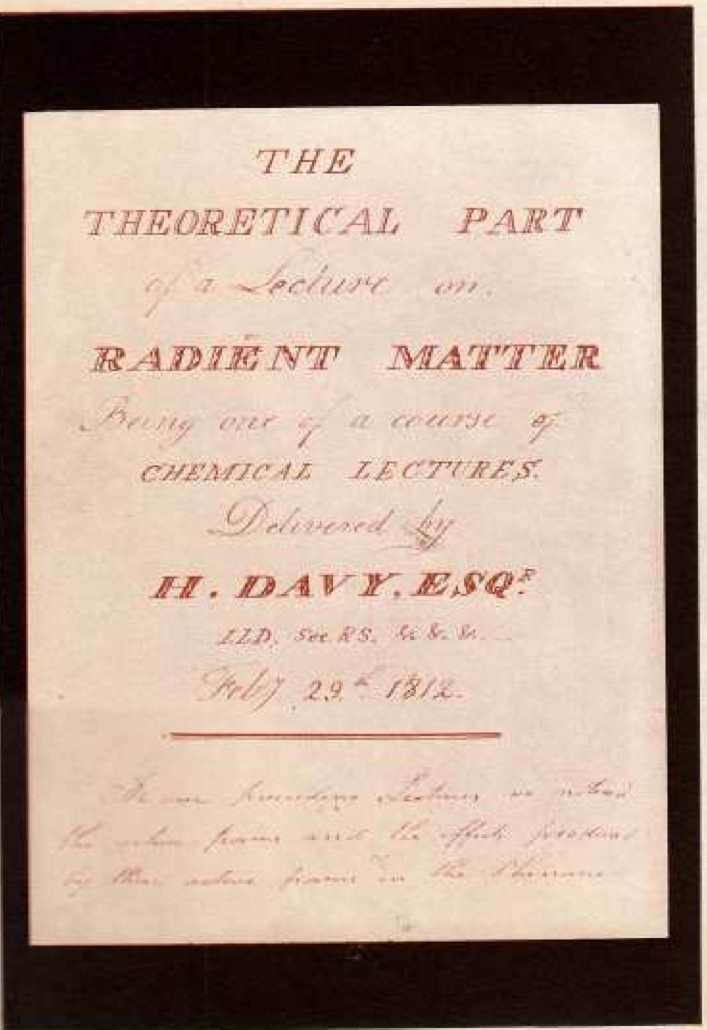
When he was thirteen Faraday became errand boy to a bookseller called Riebau, for whom he delivered morning newspapers and collected and delivered books. Riebau soon came to like the boy and, knowing that the Faraday family could not possibly afford to pay a premium, offered to accept him as an apprentice bookbinder without fee. In 1810

Faraday's father died, and his brother Robert, by then a working blacksmith, had to support the family. His mother took in lodgers.

Progress – Before he went to Riebau, Faraday had received no education beyond learning to read, write, and do the simplest arithmetic. But while bookbinding he found time to read some of the books on which he worked, and was particularly fascinated by works of scientific interest. He particularly liked encyclopaedias.



An old print of the Royal Institution where Faraday worked for the greater part of his life. The building is in Albemarle Street, London, and looks much the same today as it did then.
Royal Institution



A page from the notes taken by young Faraday of four lectures by Davy that he attended. These notes were instrumental in persuading Davy to take on Faraday as his assistant at the Royal Institution.
Royal Institution

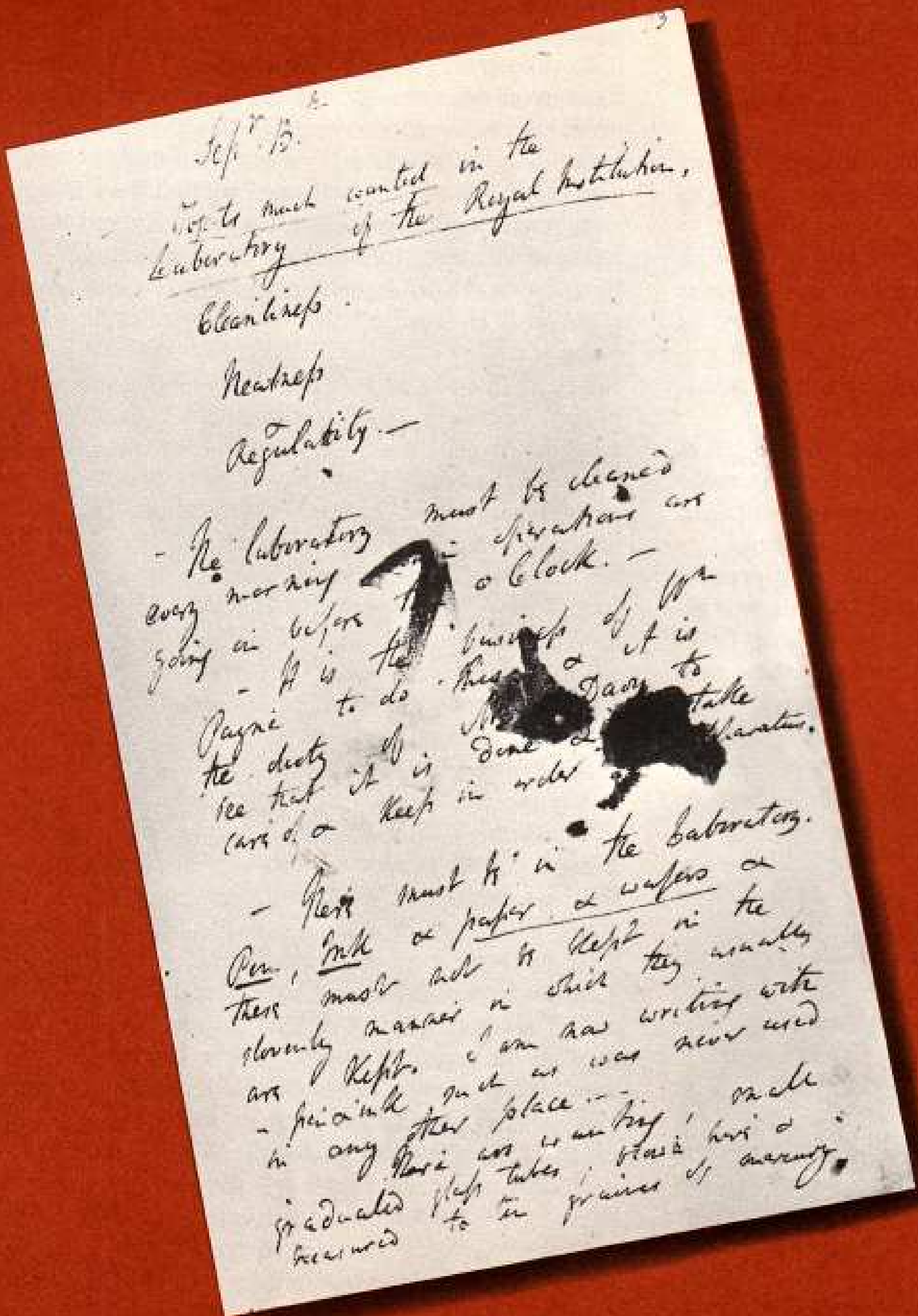
Towards the end of his apprenticeship, Faraday went to scientific lectures by a Mr Tatum of Fleet Street. Tatum's lecture courses eventually resulted in the formation of Birkbeck College, London. Early in 1812, a customer of Riebau called Dance, who was a member of the Royal Institution, gave him tickets to hear four lectures by Humphry Davy. Faraday took careful notes of all he saw and heard, illustrated the notes, and bound them. These notes were to serve him well.

In October 1812 Faraday's apprenticeship with Riebau came to an end, and reluctantly he left to work as a journeyman bookbinder for De La Roche, a rather hasty-tempered French immigrant. Although he could now make some contribution to the family finances, Faraday was no longer as happy as he had been as an apprentice. His desire to find some employment of a scientific nature made him more and more restive.

He had previously written to Sir Joseph Banks, President of the Royal Society, asking whether the Society could find him laboratory work, however menial, but the letter was returned marked 'no reply'. Encouraged by Dance and the Riebaus, Faraday next wrote to Sir Humphry Davy, asking for a job as a laboratory assistant. He sent with the letter his bound notes of the four lectures by Davy. On Christmas Eve, 1812, Davy replied saying how pleased he was with the notes, arranged an interview, but pointed out that Faraday would be much better off as a bookbinder, and that at that moment there was no vacancy at the Royal Institution.

Two days later, much to his surprise, Faraday received another letter from Davy asking him to write a fair copy of some of his notes for the next issue of the *Quarterly Journal*. Davy could not write them himself because he had injured his eye in an explosion resulting from an experiment with nitrogen chloride. (This dangerous substance had been discovered in 1811 by Dulong who continued to investigate it, despite the loss of one eye and three fingers in its first preparation.)

Faraday, quickly learning to read Davy's untidy and almost illegible writing, rewrote the notes in his own immaculate hand. For the three days' work he received thirty shillings and, at the same time, consolidated the good impression he had originally made. Shortly afterwards the fight in the laboratory took place, William Payne was dismissed, and



Sept^r. 13.

Objects much wanted in the Laboratory of the Royal Institution,

Cleanliness.

Neatness

Regularity —

Davy's laboratory regulations written at a time when William Payne, Faraday's predecessor, was laboratory assistant. The regulations read as follows:

'September 13th (1809). Objects much wanted in the Laboratory of the Royal Institution. Cleanliness. Neatness and Regularity. The laboratory must be cleaned every morning when operations are going on before ten o'clock. It is the business of Mr. Payne to do this and it is the duty of Mr E. Davy to see that it is done and to take care of and keep in order the apparatus. There must be in the laboratory. Pen, ink and paper and wafers and these must not be kept in the slovenly manner in which they usually are kept. I am now writing with pen and ink as was never used in any other place. There was wanting small graduated glass tubes, blown here and measured to ten grains of mercury.'
Royal Institution

Davy sent for Faraday. He offered him Payne's former position and asked him also to act as his personal laboratory assistant and secretary. Faraday started his work at the Royal Institution on 6 March 1813. The stage was set for his life's work.

Travel – Davy had planned a scientific tour of Europe, starting the same autumn, and asked Faraday to accompany him as scientific assistant and secretary.

At the time of the proposed tour England was at war with France. The Emperor Napoleon had suffered his disastrous retreat from Moscow; Waterloo and the second Peace of Paris were yet to come. Davy obtained special permission to travel through France, because of the high esteem in which he was held by French scientists.

Among the baggage was Davy's own coach, taken to pieces to be reassembled in France, and 'scientific equipment sufficient for most investigations'. The equipment was contained in two quite small boxes, no larger than modern suitcases.

The party sailed from Plymouth with a rather apprehensive crew on 17 October, and on landing at Morlaix was interrogated for two days before being allowed to leave. However, in Paris, where they stayed two months, they were generously treated. All public museums and libraries were made open to them every day, although they were open to Parisians only twice a week. Ampère, Cuvier, Humboldt, Gay-Lussac, Clement-Desormes, and many other scientists entertained the party during their stay in France. Faraday helped Davy to investigate a peculiar black solid given him by Ampère. Using their portable apparatus, they soon decided that the substance (discovered two years earlier by M. Courtois, a saltpetre manufacturer) was a new element, for which Davy proposed the name 'Iodine'. Some of the French chemists were rather put out that the nature of the new substance had been so quickly determined under their noses.

From France the party journeyed to Italy, visiting Florence, Rome, and Naples. In Milan they met Volta, and for three months they were guests in Geneva of De La Rive, who was noted for his work on electrolysis. The tour, which by then had lasted eighteen months, was intended to include Greece and Turkey, but suddenly Davy decided to return to England.

London – On his return to England Faraday was immediately re-engaged at the Royal Institution, this time at a generous salary of thirty shillings a week, soon to be increased to one hundred pounds a year, with two rooms at the Institution.

Faraday joined the City Philosophic Society, and it was to them, after a careful study of the art of lecturing, that he gave his first talk. At about the same time, he published his first paper, 'An Analysis of Lime from Tuscany', in the *Quarterly Journal of Science*. He continued routine work at the Institution, preparing lecture apparatus for Davy and Brande (Professor of Chemistry at the Institution), rearranging the collection of minerals, and giving private lessons in mineralogy and chemistry. He read all the available scientific publications, often repeating experiments he read about.

In 1821, when he was thirty, Faraday made his first important discovery. It was in the subject of electro-magnetism, a science in which he was soon to lead the world. The year before, Oersted of Copenhagen had shown that if a wire carrying an electric current was held above, and parallel to, a compass needle, the needle was deflected.

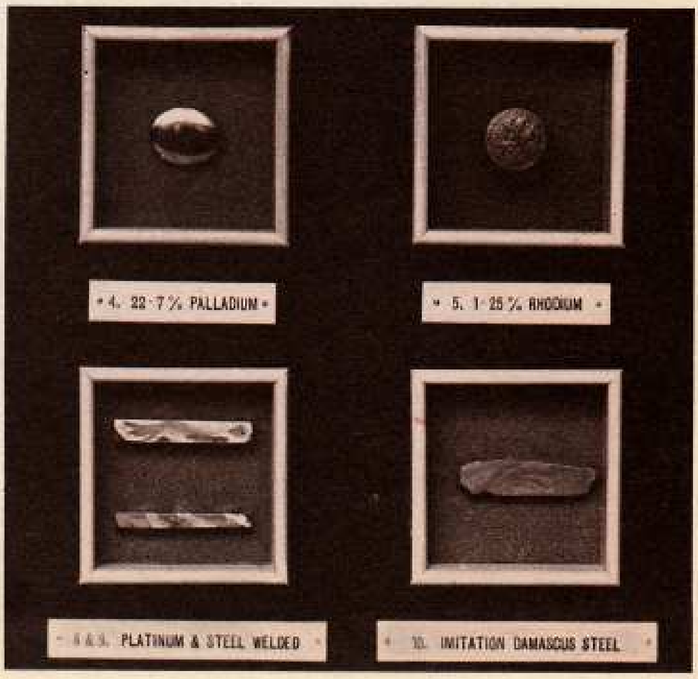
Oersted's discovery was followed up by many scientists, in particular by Faraday and Wollaston in London, by Henry in America, and by Ampère in Paris. Oersted had said that the magnetic forces seemed to act in circles round the wire. It was Ampère who showed that parallel currents flowing in the same direction attract one another and so worked out the laws relating the current to the direction in which a magnetic needle moves.

The first efforts of the British scientists were directed to using a magnet to rotate a wire carrying a current. Wollaston was convinced this could be done, despite the doubts of Davy with whom he discussed it, but he was unable to devise a workable experiment. Faraday, who knew of Wollaston's idea, eventually set up an ingenious apparatus in which one end of a bar magnet protruded through the surface of some mercury in a cup. Supported above the magnet was copper wire, freely suspended at the top, hanging down by the side of the magnet, and with its lower end dipping in the mercury (see Faraday's sketch). When a battery was connected to pass current through the wire from its support to the mercury, the wire steadily rotated round the magnet. This was the very first electric motor. Later, by making the apparatus more delicate, Faraday was able to dispense with the magnet and make the current-carrying wire rotate in the earth's magnetism. He promptly published his experiments in the *Quarterly Journal*. This publication, without any acknowledgement of the help he had received from the ideas of Davy and Wollaston, brought Faraday some criticism and made Davy rather cautious about discussing his ideas with him. Eventually Faraday apologized to both Davy and Wollaston and after his first excursion into electricity he returned to chemistry.

For nearly six years Faraday investigated the properties of steel. Bearing in mind the primitive equipment at his disposal, he produced some excellent samples, some of which were

The Danish scientist Oersted discovers the magnetic effect of an electric current. He found that a magnetic needle placed parallel to a current-carrying wire was deflected. *From 'An Illustrated History of Science' by F. Sherwood Taylor*

Faraday's original sketch of the first electric motor. A bar magnet is placed upright in a cup of mercury with one end protruding above the surface. A straight piece of copper wire is suspended above the magnet with one end (to which is attached a small piece of cork to float it clear of the magnet) dipping into the mercury. A second piece of wire is hooked over the rim of the cup and also dips into the mercury. If the two wires (marked Z and C in the sketch) are attached to the poles of a battery, an electric circuit is formed. The wire Z then begins to rotate round the magnet. If the magnet is turned the other way up or if the poles of the battery are transposed, the wire rotates in the opposite direction.



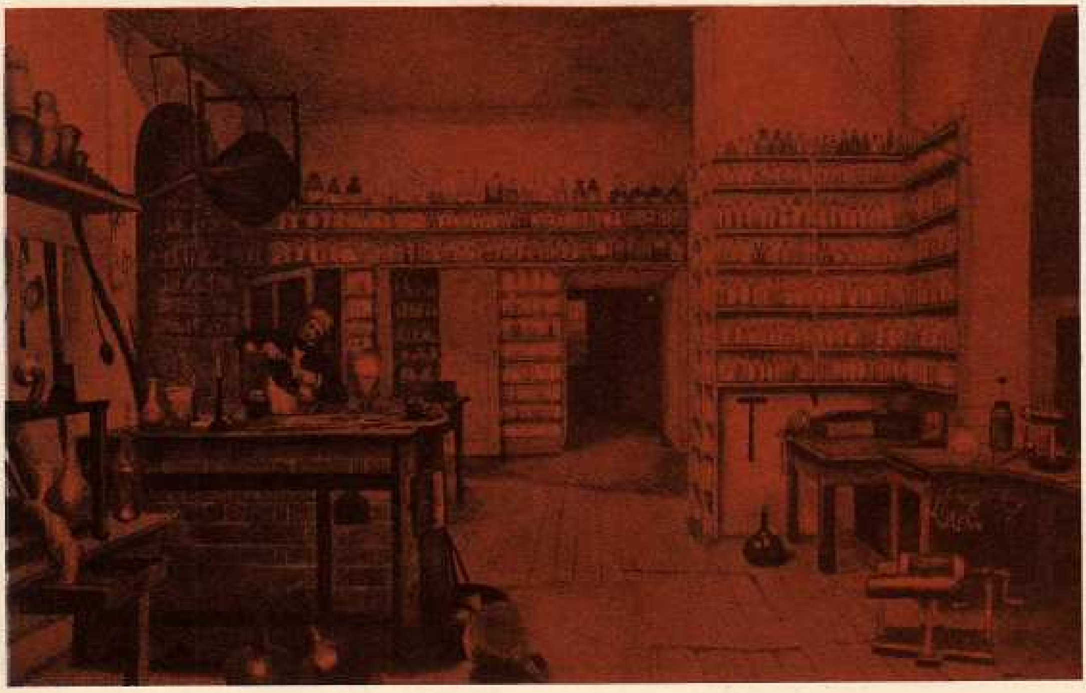
Some specimens of steel made by Faraday.
Crown Copyright. Science Museum

made into razors for his friends. His investigations did give rise to the first reliable 'stainless' steel but as it contained 50 per cent of platinum, it was too expensive to be of any real use.

During the same period Faraday also investigated chlorine and its compounds in which he had always been particularly interested. In 1823 he prepared chlorine hydrate – white crystals formed by cooling a solution of chlorine in water. At Davy's suggestion, he heated the crystals in one end of a sealed tube and noticed that oily drops collected in the cold part of the tube. Faraday recognized the drops as liquid chlorine and noted how rapidly they evaporated when the tube was broken open.

By similar methods he subsequently liquefied sulphur dioxide, carbon dioxide, and ammonia. The tubes occasionally burst and on one occasion he suffered a serious eye injury. Again his publication of the results was thought to have made too little recognition of Davy's ideas and relations between the Director and his assistant became more strained.

Success – Late in 1823, two years after his marriage to Sarah Barnard, a daughter of one of the Sandemanian elders, Faraday was proposed for election as a Fellow of the Royal Society. This was the greatest recognition which then, as now, could be given to a scientist. After the list of sponsors had been read out at the customary ten consecutive meetings, a vote was taken. Davy, who had become President of the Royal Society after the death of Sir Joseph Banks, opposed the election. Davy had not yet forgotten the liquid chlorine episode, though it had since become known that liquid chlorine had been prepared earlier by several other chemists. Everyone else was in favour. Even Wollaston gave his support. Faraday was elected. Davy's health was by then deteriorating and he was more and more away from the Institution. In 1825 he recommended to the Managers that Faraday should be appointed Director of the Laboratory, although still officially to be under the supervision of Professor Brande. This strong support, so soon after the opposition to his election to the Royal Society, greatly surprised Faraday, but really it represented the respect these two great men had for each other. The new position brought no increase in salary above his one hundred pounds a year. But this was of small consequence to Faraday for he was a man of simple tastes and already was collecting considerable



Faraday at work in his laboratory at the Royal Institution.
Royal Institution

fees for work as a consultant. He was often consulted on problems of chemical analysis.

Faraday soon put new life into the Institution. He helped to introduce evening meetings and demonstrations. These later became the famous Friday Evening Discourses which have continued to the present day. In 1826 he helped start the equally famous Christmas Lectures for young people. He also made many economies but without greatly stabilizing the precarious financial position of the Institution. When he was

Faraday's chemical cabinet.
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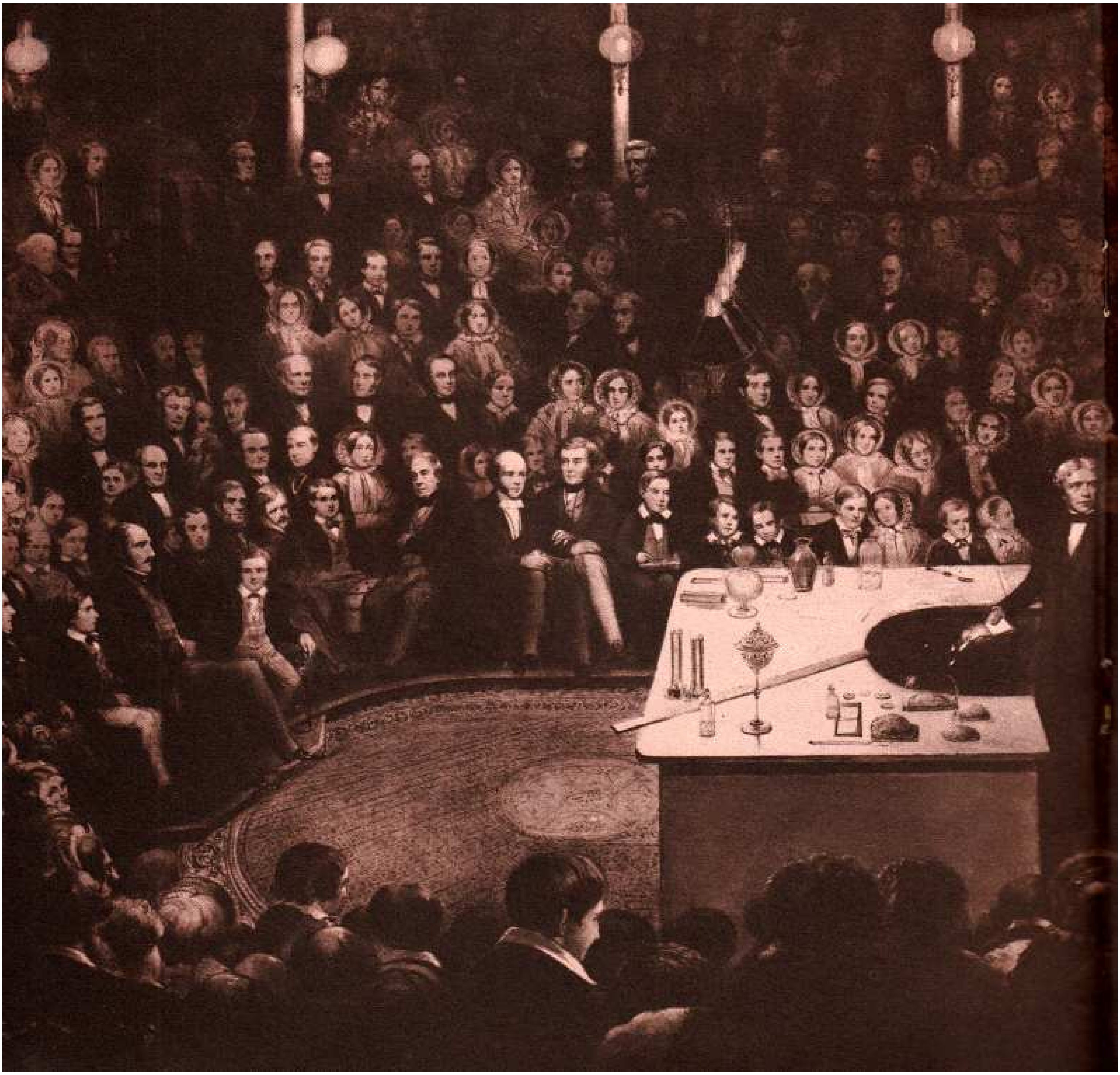
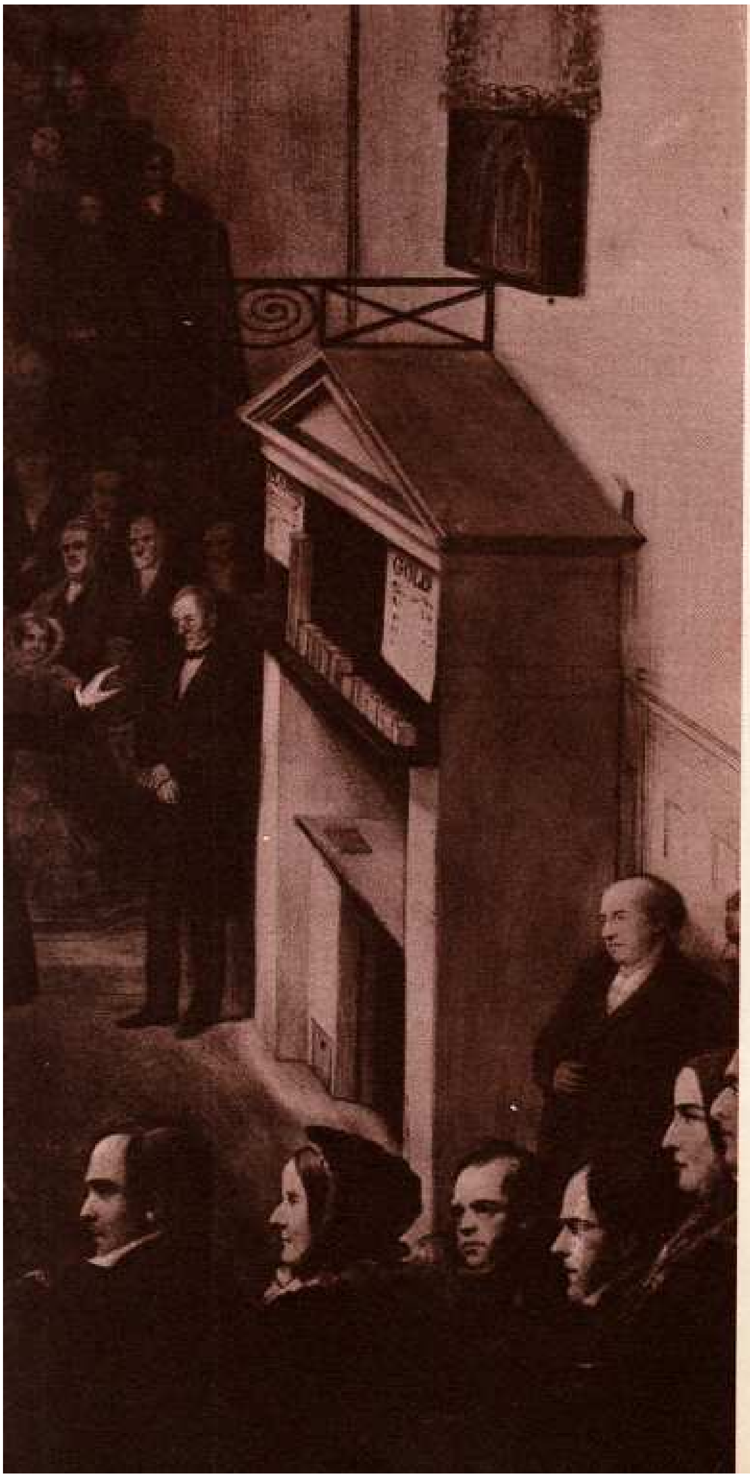




Faraday giving one of the Royal Institution's Christmas Lectures. Seated on the left, directly in front of the bench, is Albert, the Prince Consort.
Royal Institution

offered the Professorship in Chemistry in the newly founded University of London in 1827 he declined the offer, saying that, such was his gratitude to the Royal Institution, he wished to remain there and do all that he could to further its interests. He did, however, accept a part-time lectureship at the Royal Military Academy at Woolwich, where he gave about twenty lectures a year.

The responsibilities of directorship did nothing to hinder Faraday in his work. On the contrary, he intensified his research, his restless experimental curiosity grappling with one scientific problem after another. Nothing was too small to interest him, nothing too great to deter him. Nature was continually throwing up problems to be solved, and the answers, he believed, were always to be found through careful experiment. During his first years in office he investigated the liquid residue in cylinders of compressed gas which were used to light some of the richer homes in London. The gas was made by heating whale oil and was supplied in iron containers at a pressure of about 30 atmospheres.

The liquid proved to be a mixture of substances, one of which Faraday separated, purified, and analysed. This substance was previously unknown and he called it 'bicarburet of hydrogen'. We now call this substance *benzene*. It is obtained in quantity from coal-tar, and is an important substance in the dye industry.

This first year of office also found Faraday starting a long series of experiments, sponsored by the Royal Society, to find better glass for optical work. His findings were not specially remarkable, but one glass, consisting chiefly of lead borosilicate, he used in an important discovery twenty years later – that a beam of polarized light passed through the glass was affected by an electro-magnet, so demonstrating a connection between magnetism and light. The problem that continued to preoccupy Faraday's mind was that of obtaining electricity from magnetism. Before looking at the experiments which slowly led up to what was, perhaps, Faraday's most significant discovery, we must think of the formidable difficulties he and his contemporaries had to face.

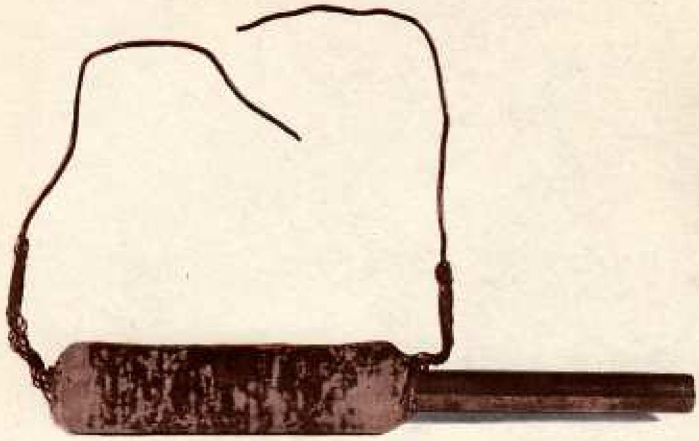
They did not have the sensitive instruments found even in school laboratories today. The instruments for detecting 'ordinary' (or static) electricity were called electroscopes; those for measuring it, electrometers. Similarly, 'voltaic' (or current) electricity was detected by galvanoscopes, and measured by galvanometers. Faraday's first galvanometer was no more than a single wire stretched over a compass needle. Any school laboratory now has instruments a thousand times more sensitive. The magnets of the day were feeble compared even to those we can now buy for a few shillings. Also, it was impossible adequately to magnetize any large piece of steel. Large magnets had to be built up of smaller pieces of steel, magnetized separately, and then clamped together. A large 'compound' magnet (shown in the picture on page 12) was made in this way for the Royal Military Academy at Woolwich. In the summer of 1831 the Royal Society agreed that the experiments on glass should be suspended. Faraday's work on electro-magnetism then began in earnest.

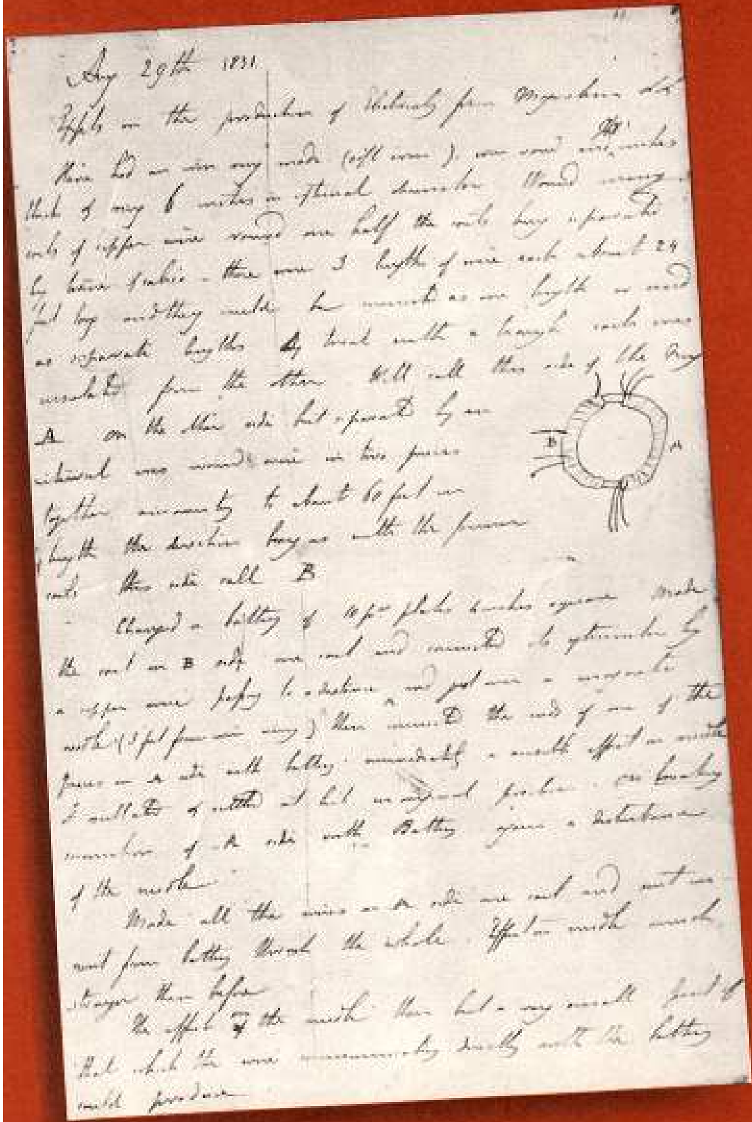
The problem solved – Oersted had shown the magnetic effect of a current; Ampère had determined the laws governing the effect; Arago had shown that a rotating copper disc deflected a magnetic needle suspended above it. Faraday repeated Oersted's experiments and became convinced that, since electricity could produce magnetic effects, magnetism could be used to produce electricity. Over a period of ten years up to 1831, he pondered hard how a magnet could be made to induce an electric current in a wire. It is said that he used to carry a little bar of iron and a small coil of wire in his waistcoat pocket and would bring these out at spare moments, trying to imagine by what sort of arrangement the iron bar could produce an electric current in the coil. In an experiment in 1831 Faraday wound two separate coils of insulated wire round opposite sides of an iron ring. One coil he connected to a battery, the other to his simple galvanometer. He noticed that there was a slight deflection of the galvanometer needle when the battery was first connected, and again, in the opposite direction, at the moment the battery was disconnected. But, while the current flowed, nothing appeared to happen. This experiment, modified in various ways, he repeated many times. He found the iron ring was unnecessary, although the effects were always relatively feeble without it. His first 'iron-ring experiment' was the first use of what we now know as an electrical transformer.

Then Faraday connected a coil of wire to his galvanometer, and thrust a bar magnet into the coil. He noticed that a current was set up as the magnet was moved in, and that a current was set up in the opposite direction when the magnet was drawn out.

When the magnet was still, nothing happened. What no one had grasped about Oersted's observation was that, although the wire had been stationary, it was moving (current) electricity that had caused the deflection of the magnet and so, for the magnet to induce an electric current, it too had to be moving. As Faraday wrote in his diary: 'May not these transient effects be connected with causes of difference between power of metals in rest and in motion in Arago's experiments?'

Cylindrical coil and bar magnet with which Faraday showed that magnetism could be used to produce electricity. Faraday noticed that an electric current was set up as he pushed the magnet into the coil and another current in the opposite direction as he drew out the magnet. The wires from the coil are for attachment to a galvanometer. *Royal Institution*





Page from Faraday's notes describing his 'iron ring experiment' – in effect, the first use of what we now know as an electrical transformer. The notes read as follows:

'August 29th, 1831. Experiments in the production of electricity from magnetism. Have had an iron ring made (soft iron) iron round and $\frac{7}{8}$ inches thick and ring 6 inches in external diameter. Wound many coils of copper wire round one half, the coils being separated by twine and calico – there were 3 lengths of wire each about 24 feet long and they could be connected as one length or used as separate lengths. By trial with a trough each was insulated from the other. Will call this side of the ring A. On the thin side but separated by an interval was wound wire pieces together amounting to about 60 feet in length, the direction being as with the former coils. This side call B.
Charged a battery of 10 pairs of plates 4 inches square. Made the coil on B side one coil and connected its extremities by a copper wire passing to a distance and just over a magnetic needle (3 feet from wire ring). Then connected the ends of one of the pieces on A side with battery. Immediately a visible effect on needle. It oscillated and settled at last in original position. On breaking connection of A side with Battery, again a disturbance of the needle.
Made all the wires on A side one coil and sent current from battery through the whole. Effect on needle much stronger than before. The effect on the needle then but a very small part of that which the wire communicating directly with the battery could produce.'
Royal Institution

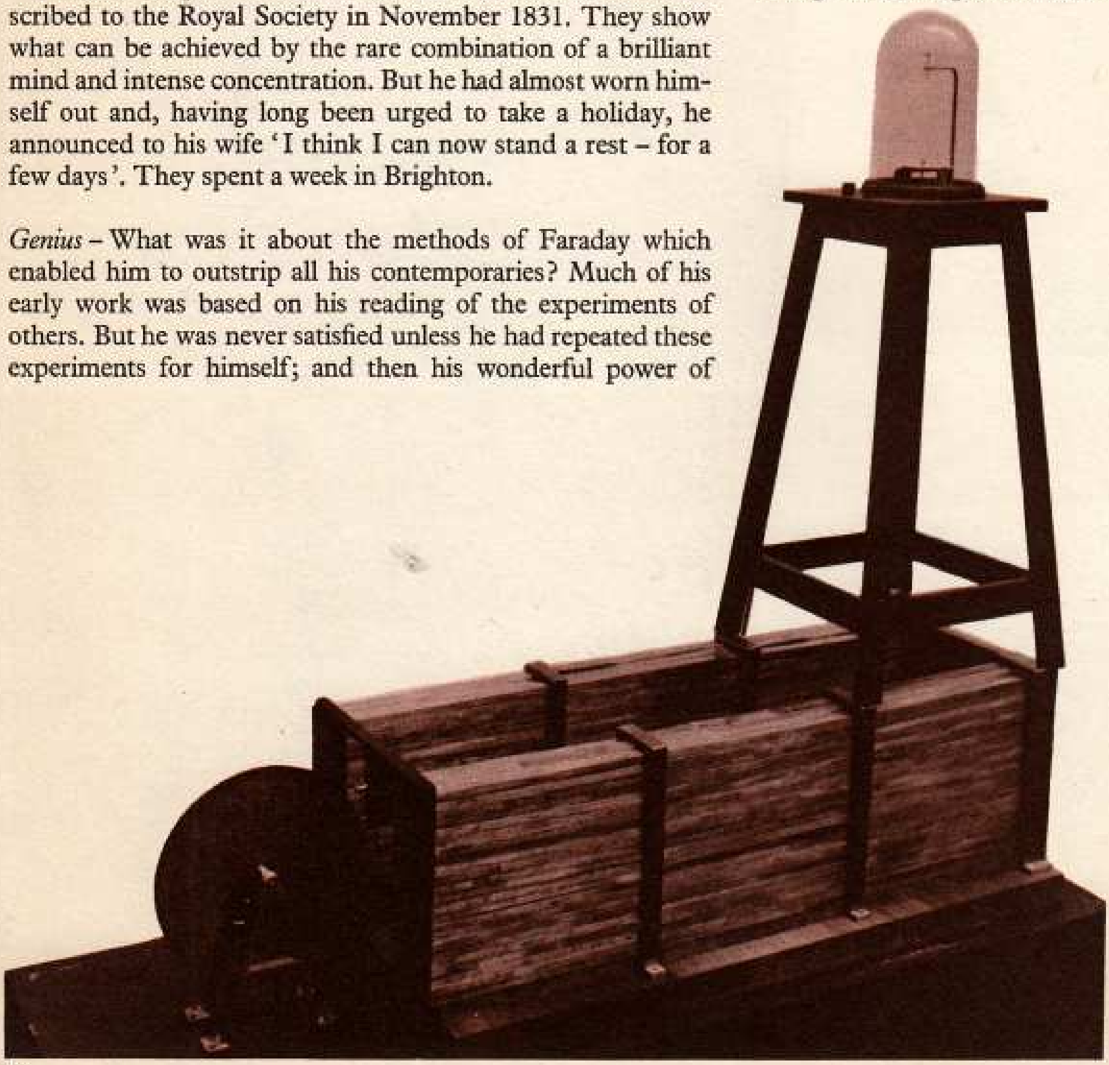
The original iron ring used by Faraday in this experiment.
Royal Institution

Strenuously, almost fanatically, Faraday sought to produce electricity continuously. With Arago's experiment in mind, he mounted a copper disc between the poles of the compound magnet at the Royal Military Academy at Woolwich. He made a rubbing contact to the edge of the disc and another to its axle, and connected these contacts to a galvanometer. When he turned the disc there was a continuous deflection of the needle, increasing as the disc speeded up. The apparatus was the conception of a genius. It was the first dynamo.

Faraday's experiments, all made in two months, were described to the Royal Society in November 1831. They show what can be achieved by the rare combination of a brilliant mind and intense concentration. But he had almost worn himself out and, having long been urged to take a holiday, he announced to his wife 'I think I can now stand a rest – for a few days'. They spent a week in Brighton.

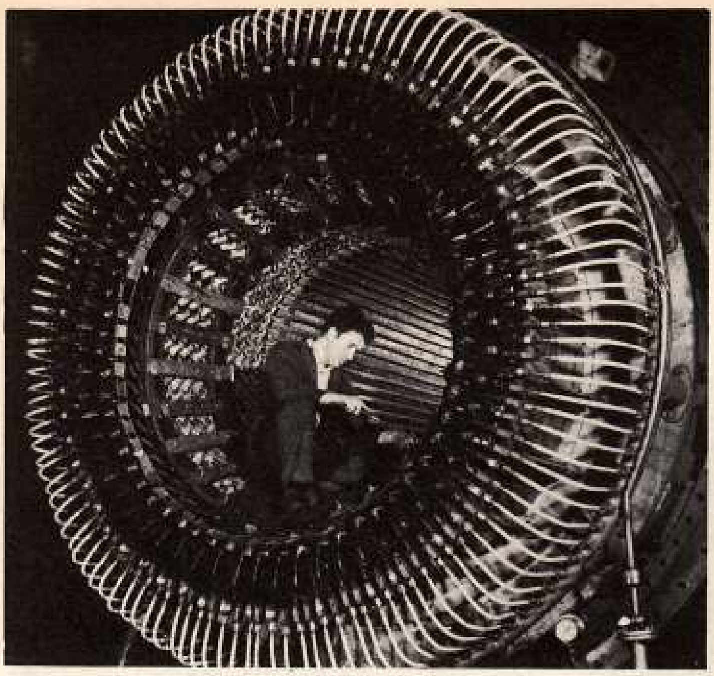
Genius – What was it about the methods of Faraday which enabled him to outstrip all his contemporaries? Much of his early work was based on his reading of the experiments of others. But he was never satisfied unless he had repeated these experiments for himself; and then his wonderful power of observation usually enabled him to see new facts which had previously escaped notice. As Kohlrausch said, he seemed to 'smell them out'.

In 1833, at the height of his powers, Faraday directed his attention to the chemical effects of electricity. He first examined the identity of electricity from different sources to show that all electricity (static or current), whatever the source, was of a similar nature. He followed this observation by measuring the quantity of electricity involved in chemical change and the quantity of change produced. He did this by



The apparatus with which Faraday first produced a continuous current of electricity – in other words, the first electric dynamo. The copper disc, mounted between poles of the compound magnet, is attached by leads to a galvanometer (in the glass case at the top). When the disc is rotated, there is a continuous deflection of the galvanometer needle. The compound magnet shown here is the original one used by Faraday in his famous experiment: other pieces of apparatus are replicas.
Science Museum

Component parts of a modern dynamo or generator. Top right is the stator, composed of wire coils. Bottom right is the rotor, an electro-magnet which rotates inside the stator and thereby generates electricity in the stator's coils. Compare these giant pieces of machinery with Faraday's coil and bar magnet on page 10.
Associated Electrical Industries



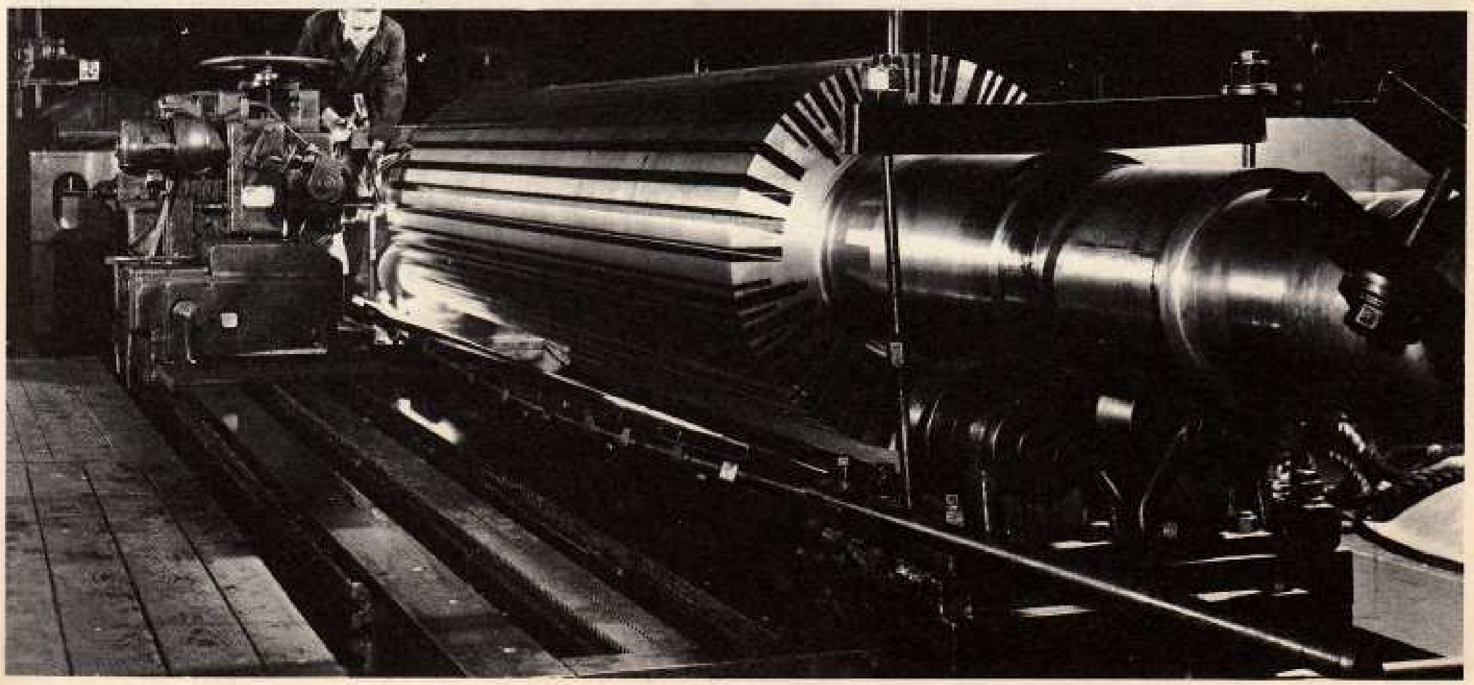
passing electricity through acidified water, collecting and measuring the hydrogen given off, and taking the volume of hydrogen as proportional to the quantity of electricity that had passed. This was the first time such measurements had been made and they led to some far-reaching advances. These are analogous to the advances made in chemistry half a century before when Lavoisier, Black, Cavendish, and, later, Dalton and Berzelius, had measured the *quantities of substances* reacting chemically.

From his measurements, Faraday formulated two laws. The first law is:

The quantity of a substance deposited, evolved, or dissolved at an electrode during electrolysis is directly proportional to the quantity of electricity passed through the electrolyte,

or in Faraday's own words, 'the chemical decomposing action of a current is constant for a constant quantity of electricity'. The second law is:

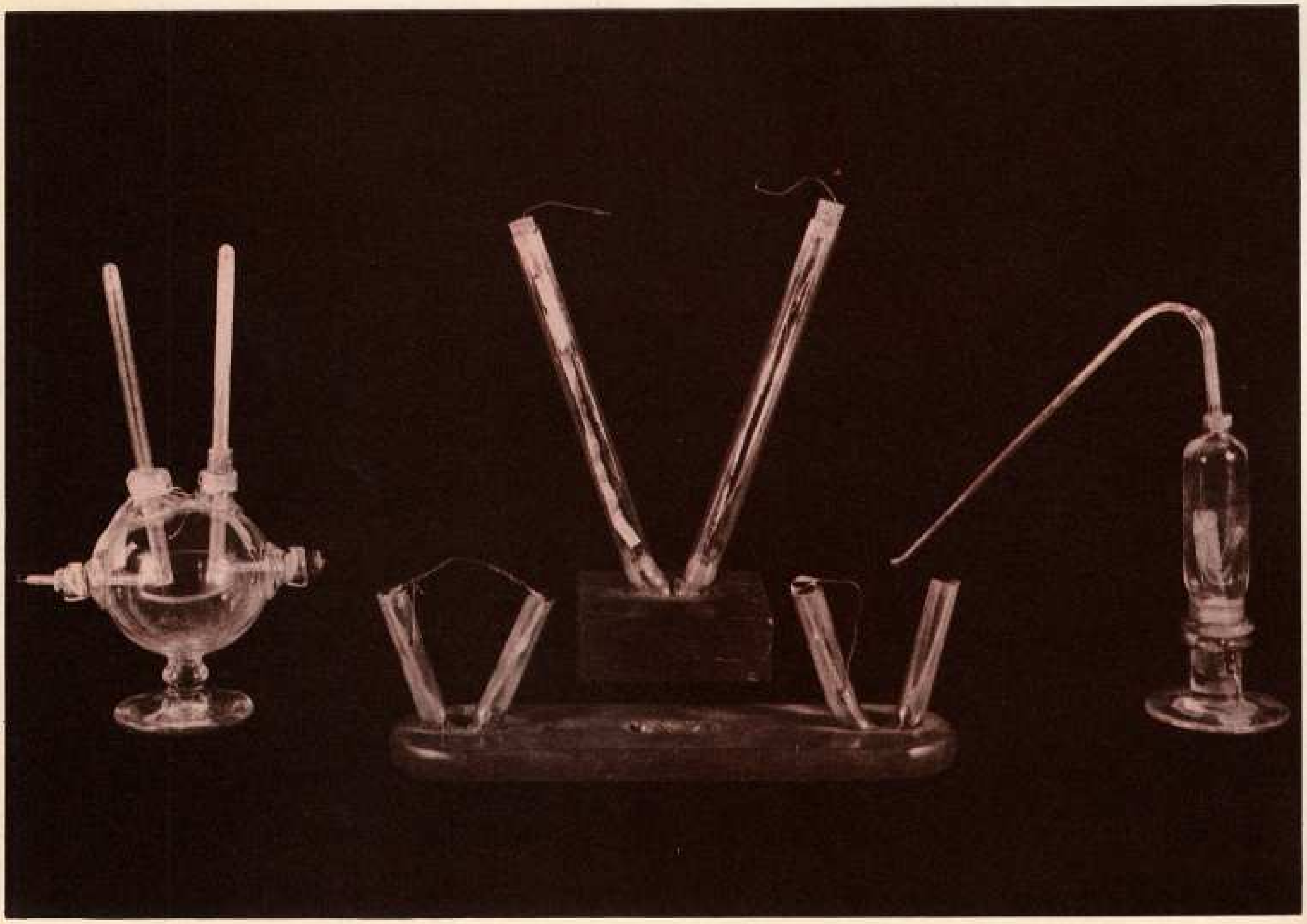
The quantities of different substances deposited, evolved, or dissolved at electrodes by the passage of the same *quantity of electricity is directly proportional to the combining weights of the substances.*



For example, 1 gram atomic weight of silver (108g) combines with 1 gram atomic weight of chlorine (35·5g), and to deposit 1 gram atomic weight of silver or to evolve 1 gram atomic weight of chlorine requires the same quantity of electricity, 96,540 ampere seconds or, as this quantity is called, 1 'Faraday'.

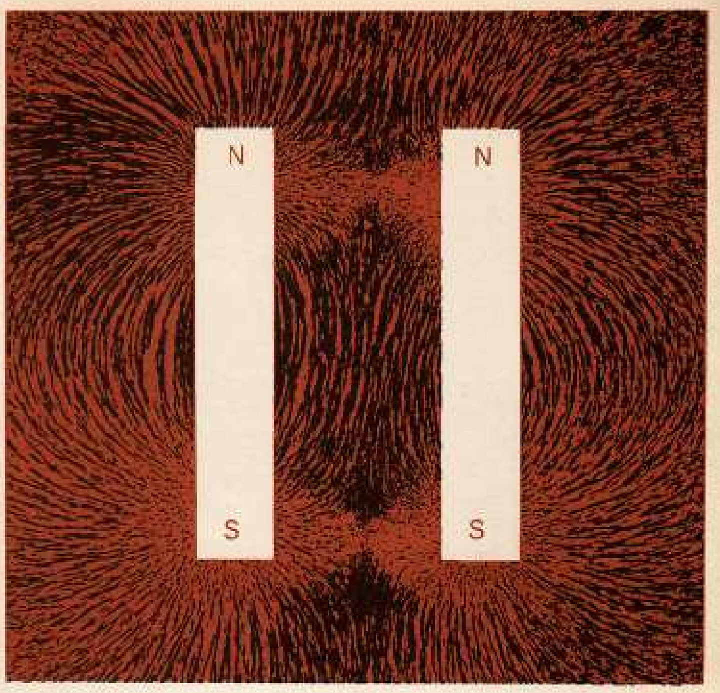
In describing electrolysis, Faraday had to look for new names. For these, he consulted William Whewell, afterwards Master of Trinity College, Cambridge, who devised such now familiar terms as *anode*, *cathode*, *electrode*, and *ion*. Faraday thought the earth's magnetism was caused by an electric current which flowed round the earth from east to west, i.e. in the direction the sun appeared to follow. He liked to think of currents in his electrolysis experiments as flowing in the same direction. This led to the choice of *anode* (from the Greek 'way up') for the electrode by which electricity entered the apparatus, and, conversely, *cathode* (or 'way down') for the opposite electrode.

Method – Faraday, even from the days of his apprenticeship, made careful notes. In his published *Experimental Researches*,



The arrangement of iron filings round a bar magnet, which led Faraday to think of magnetism and electricity in terms of 'lines of force'.

Apparatus used by Faraday in his electrolysis experiments. *Royal Institution*



he numbered the paragraphs and welded them together with continual cross-references. His private notes, which are fortunately preserved, show the same method. The last paragraph is numbered 16,041. This same meticulous care is shown in his experiments. In his work on electrochemistry, he first devised, and then thoroughly tested, his method for measuring quantities of electricity; then he showed that the method did not in any way depend on the size of the battery, the number of plates in the battery, or the nature of the connecting wires. Only then did he proceed to his main investigations. The accuracy of his measurements is quite remarkable and, even with modern equipment, it is difficult to improve on many of them. He anticipated almost all sources of error and possessed phenomenal skill as an experimenter.

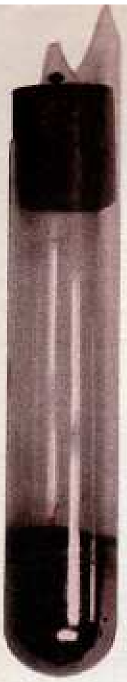
He was without mathematical training and he substituted visual models to explain (initially to himself) electrical and magnetic action. Impressed by the beautiful way in which iron filings arrange themselves round a magnet, he pictured 'lines of force' between magnetic poles and between electrified objects, and these lines of force became his working model. About them he once wrote: 'I have been so accustomed to employ them and especially in my last researches, that I may have become prejudiced in their favour. However, I have always tried to make experiment the test and the controller of theory and opinion: but neither by that, nor by close cross-examination in principle, have I been made aware of error involved in their use.'

Illness – In 1831 Faraday gave up much of his consulting work to devote more time to electrical research. His loss of income (about eight hundred pounds a year) was partly balanced by his election in 1833 to the newly endowed chair of Fullerian Professor of Chemistry at the Institution, and in 1836 by his appointment, at two hundred pounds a year, to be Scientific Advisor to Trinity House, the authority responsible for sea-marks, lighthouses, and warning systems.

His friends also pressed for a civil list pension for him. Faraday at first refused because the Prime Minister, Lord Melbourne, had mentioned at an interview that some civil list pensions were 'humbugs'. Faraday indignantly walked out and Melbourne became the target for a good deal of critical comment. He subsequently apologized to Faraday, and a pension of three hundred pounds a year was granted and accepted. This was in 1835.

After his painstaking investigation into electrolysis, Faraday began to suffer from lapses of memory and giddy spells. He severely cut his hours of work, and eventually, on medical advice took a holiday in Switzerland for nine months, and, on returning to England, rested completely for four years.

Then in 1845 his health was almost miraculously restored. His mind recovered its former brilliance and he resumed work which was to continue, with only occasional respite, for seventeen more years. He finally retired from all Royal



Test-tube containing a film of gold. The preparation of this film, to demonstrate the green colour of gold seen by transmitted light, is believed to be the last experiment that Faraday carried out.
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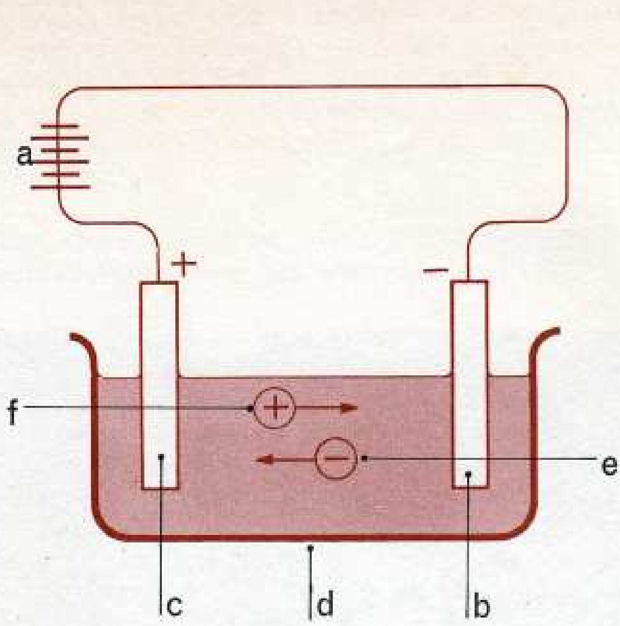

Institution activities in 1865, very much an invalid, to a house at Hampton Court offered to him by Queen Victoria.

His last period of work covered many aspects of chemistry and physics. He investigated the reaction (called sulphonation) between naphthalene and sulphuric acid and the supercooling of sulphur; he measured critical temperatures of gases; he determined the chemical nature of rubber; he studied the nature of colloids; and he explained the action of bleaching solutions. He discovered diamagnetism (the tendency of some materials to move within a magnetic field to where the field is weakest); he examined thermoelectric effects and produced the first electrochemical series; he explored the conduction of electricity through rarefied gases; and he investigated the regelation of ice. He also produced a complete descriptive theory of electricity and of magnetism in terms of 'Lines and Tubes of Force'. He showed how the capacity of an electrical condenser varies with the insulator between the plates; and he measured the values we call the dielectric constants.

Many honours were offered to him, but his Sandemanian creed, to which he remained devoutly attached throughout his life, led him to reject worldly fame. Twice he refused the Presidency of the Royal Society, and he also declined a knighthood. He preferred to remain plain Michael Faraday, scientist, to the end. He died peacefully at Hampton Court in his seventy-seventh year, remembered and commemorated as one of the greatest of all scientists, to be thought of with such names as Newton, Galileo, Lavoisier, and Einstein.

Questions

1. What qualities of Faraday as a man made him so successful as a scientist?

2. List six of Faraday's inventions or discoveries.

3. Explain how the dynamo on a bicycle works.

4. What are the correct electrical terms for the letters used to label the above diagram? What are some useful applications of electrolysis?

5. Would you rather have been Davy or Faraday? Why?

Faraday's statue in the Royal Institution. The large painting above the staircase is a portrait of Davy.
Royal Institution

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