Michael Faraday and Platinum

"THIS BEAUTIFUL, MAGNIFICENT AND VALUABLE METAL"

It is as an experimentalist in the field of electricity and magnetism, that Faraday is best remembered, but his investigations were many and various. To mark the bicentenary of his birth several accounts of his life and work have already been published elsewhere, none the less it is instructive to note just a few of his experiments that involved the platinum metals and to recall his long association with Johnson Matthey.

Michael Faraday, who was to become one of the greatest scientists of the nineteenth century, was born at Newington Butts on September 22nd, 1791. At that time Newington was a country village in the county of Surrey, but as London expanded to the south east its boundary spread far beyond Newington, which is situated south of the river Thames close to the well-known "Elephant and Castle" road junction from which Newington Butts and five other thoroughfares radiate. After the family moved to the west end of London, Faraday began to earn money by delivering newspapers for Mr. G. Riebau, a French emigré, who sold books and had a bookbinding business. At the age of thirteen, Faraday was apprenticed to Riebau as a bookbinder and worked for him conscientiously for some seven years. Although he had received only a rudimentary education, Faraday took advantage of the opportunity which his apprenticeship provided and read widely, including some of the scientific books stocked for sale or brought to the shop for rebinding. He later wrote that he had been greatly impressed with Mrs. Marcet's "Conversations in Chemistry" and the third edition of the "Encyclopaedia Britannica", published in Edinburgh in 1797. Interestingly, the five page section on PLATINA in that edition concludes:

> "As those motives which at first prepossessed the court of Spain against this metal no longer exist, it is to be hoped that the Spanish monarch will neither despise so rich a treasure as his mines of platina, nor refuse to the world the numerous advantages that may be derived from a substance that promises to be of so much importance in commerce and the arts."

Faraday's conduct had so impressed a Mr. Dance, a customer of Riebau's and a member of the Royal Institution of Great Britain (founded in 1799 for the encouragement of research and the application of science to the common purposes of life), that in the early part of 1812 he gave young Faraday tickets for the last four lectures delivered by the great chemist Humphry Davy at the Royal Institution, these being on February 29th, March 14th, and April the 8th and 10th; Davy being knighted by the Prince Regent on April 9th. Having taken notes during the lectures, Faraday "afterwards wrote them out more fairly in a quarto volume" and in December 1812 sent them to Davy, together with a request for employment. Early in the following year, when a laboratory assistant had to be sacked for brawling, Faraday was summonsed to the Royal Institution and on 1st March, 1813 he was engaged by Davy as his laboratory assistant for a weekly wage of 25 shillings. Later, Faraday was to be described as Davy's greatest discovery!

In the autumn of that year, despite the continuation of the Napoleonic war, Sir Humphry and Lady Davy went on a tour of the continent of Europe and Faraday accompanied them as an amanuensis. Thus, he visited many of the principal centres of learning and met many of the leading scientists of the day. He recorded in his journal the experiments he observed including "burning the diamond" by means of the sun's heat concentrated through the great lens of the Grand Duke of Tuscany, at the Accademia del Cimento in Florence. During this experiment, on March 29th, 1814, the platinum supporting the diamond "was observed to fuse".

On their return to England, Faraday was

Michael Faraday
1791–1867

An acute observer and brilliant experimenter, Faraday made many discoveries that contributed to the advancement of science and technology, and which are still important today. He obtained supplies of platinum for his investigation from Wollaston and from Percival Norton Johnson, and visited Hatton Garden from time to time, even suggesting that Members of the Royal Institution should "go into the workshops of Mr. Matthey, and see them hammering and welding away". Elected a Member of the Royal Society in 1824, he was one of the many distinguished people who sponsored Johnson for election to that Society in April 1846

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re-engaged by the Royal Institution on May 15th, 1815, working under the guidance of Davy, who was to have a profound influence on Faraday's scientific and intellectual development. It should be remembered that Davy, by his researches and his writings, made a significant contribution to the early history of platinum. Faraday soon began original researches, publishing his first paper in 1816.

Heterogeneous Catalysis

In a paper read to the Royal Society on January 23rd, 1817, Davy described the accidental "discovery of a new and curious series of phenomena." During his investigations of flames and combustibility (which led to the miners' safety lamp) Davy arranged a fine platinum wire above the coal gas flame in a small wire-gauze safety lamp. When he introduced more coal gas, the flame went out but "that part of the platinum wire which had been hottest remained ignited, and continued so for many minutes." He found that when a platinum or palladium wire was introduced into a mixture of coal gas and air the wire "immediately became ignited nearly to whiteness".

Some years later, in 1823 Johann Wolfgang Döbereiner (1780–1849), Professor of Chemistry at Jena, developed a spongy platinum which catalysed the combination of hydrogen and oxygen at room temperature and caused the platinum to become red hot. The information was quickly passed to Faraday, who had been assisting Davy with his experiments when this phenomenon of heterogeneous catalytic oxidation was discovered. Faraday repeated Döbereiner's experiment, and having verified the result, announced "I think that every chemist will be glad to hear its nature."

In the same year Faraday prepared a review of the work that had been carried out on the action of platinum on mixtures of oxygen, hydrogen and other gases, but it was 1834 before he returned to the subject of catalysis.

The Birth of Alloy Steels

Faraday was the son of a north-country blacksmith, so it was perhaps fitting that one of the early investigations he carried out at the Royal Institution was to establish the effects of adding to iron small amounts of alloying elements, including platinum, palladium, rhodium, iridium and osmium. The work was carried out in collaboration with James Stodart (1760–1823), a London cutler, with a view to establishing whether alloys could be produced which would take a better cutting edge or which would be less susceptible to corrosion than the currently available materials. Their investigations began about 1819, with a first account reported to the Royal Institution in 1820 and a more substantial paper presented to the Royal Society in 1822. Their laborious metallurgical researches concerning the preparation and properties of alloys of steel during the years 1819 to 1824 have been thoroughly researched and documented by Sir Robert A. Hadfield, a metallurgist with fifty years of experience in the field of ferrous metallurgy, who in 1931 concluded "that Faraday's work was of real and lasting interest and value", and that his work pointed the way to the future development of alloy steels.

As noted by Hadfield, aluminium, chromium, cobalt, manganese, nickel, silicon and tungsten, the elements later used in alloy steels, were very difficult to obtain in the period 1819 to 1824, while platinum and some of its associated metals were readily available from Dr. William Hyde Wollaston; although it must be remembered that ruthenium was not identified until 1844. Hadfield summarised the information from the 1820 and 1822 papers by Faraday and Stodart, noting that perfect alloys of platinum and steel were obtained over a wide range of compositions.

> "From 1 to 3 per cent of platinum improves steel for edge instrument;. . . . Equal parts by weight form a beautiful alloy which takes a fine polish and does not tarnish; the colour is the finest imaginable for a mirror; 90 of platinum with 20 of steel also gives a perfect alloy with no disposition to tarnish; 10 of platinum to 80 of steel forms an excellent alloy, but one which is quite unfit for mirrors owing to a fine damask."

Wollaston provided rhodium for laboratory experiments and later for the manufacture of rhodium steel "in the large way." It was found that rhodium combines with steel in all proportions, but although these alloys were regarded as "perhaps the most valuable of all . . ." it was realised that the scarcity of rhodium would prevent them becoming of general use.

Entries in the Royal Society paper of 1822 suggest that ternary alloys of steel, iridium and osmium were investigated, but once again the scarcity of the metals was recognised as a deterrent to the general use of these alloys. At that time palladium was in short supply, but even so a 1 per cent addition of palladium to steel was valued for making instruments that required a perfectly smooth edge.

Following the death of Stodart on September 11th, 1823, Faraday appears to have devoted less time to work on steel alloys, although from the notes in his diary it is clear that he continued the work at least until the summer of 1824. In the same year the Sheffield firm, Green Pickslay & Co., having experimented with the alloys recommended by Faraday, sent him a steel specimen alloyed with silver, iridium and rhodium . . . "furnished by Mr. Johnson, No 79 Hatton Garden".

The Preparation of Optical Glass

In the second half of the 18th century British astronomers were able to purchase domestically produced achromatic telescopes incorporating the best optics then available, but in the first quarter of the next century technological supremacy was perceived to be passing to continental Europe and it was believed that leadership in observational astronomy would follow. In an attempt to counter this situation the British government funded, through the Royal Society, a programme to investigate the manufacture of the optical glass from which achromatic lenses were produced, and Faraday was one of those charged with this task. Initial experiments were conducted at the Falcon Glass Works of Apsley Pellat and James Green in Southwark, but in 1827 the work was transferred to the Royal Institution.

The investigations carried out by Faraday and his faithful assistant, Sergeant Anderson of the Royal Artillery, lasted some four years, the results being reported to the Royal Society in the 1829 Bakerian lecture, and published in 1830. As well as formulating a new glass, Faraday pioneered the use of platinum for the vessels, stirrers and ladles which came into contact with the molten glass, and also added fine platinum powder to the melt to eliminate gas bubbles which otherwise flawed the product.

Beginnings of Electrochemistry

The idea that in some way electricity was responsible for chemical attraction, and should therefore be able to overcome it, was formulated by Davy. He successfully demonstrated this in 1807 when he isolated potassium, using the current from a powerful battery to decompose solid caustic potash arranged on a platinum spoon and contacted with a platinum wire. A few days later he similarly liberated a second new element, sodium, by the decomposition of caustic soda. In 1832 Faraday followed up Davy's work with a series of studies on electrochemical decomposition, using platinum for the electrodes so that they "shall not be acted upon by the elements to be evolved." His investigations led to the formulation of his two laws of electrolysis and also to the introduction of the terms still used today in electrochemistry. He consulted William Whewell (1794–1866), later Master of Trinity College, Cambridge, about terminology, who wrote to Faraday in a letter dated May 6th, 1834 "I still think *anode* and *cathode* the best terms beyond comparison for the two electrodes"; the first use of these words in Faraday's diary occurring on May 13th.

The electrochemical properties of the platinum metals continue to attract wide interest. Indeed, in view of the title and content of the conference reported by D. G. Lovering in this issue of *Platinum Metals Review*, it is perhaps worth recording that on October 22nd, 1842, William R. Grove wrote a private letter to Faraday in which he described the use of platinised platinum electrodes in the first practical fuel cell. The following week Grove communicated his invention to the editor of *The Philosophical Magazine.*

Magnetism and Diamagnetism

The last major piece of research carried out by Faraday involved a study of the magnetic properties of many materials, including the platinum metals, and led to the discovery of diamagnetism, a term decided upon after further consultation with Whewell. On November 4th, 1845 Faraday was using a new horse shoe electromagnet, the compound coils around each leg of the magnet consisting of some 520 feet of copper wire. A bar of heavy glass was suspended between the poles of the magnet by a silk thread, and when the poles were activated by the application of an electric current through the coils the glass bar changed its position, taking up an equatorial position. "How well this shews the new Magnetic property of matter" wrote Faraday. He experimented with a very wide variety of materials and found that all liquids and solids were either attracted to, or repelled by, a magnet, if the magnet was powerful enough. He examined many samples of platinum metals and compounds obtained from Johnson, and among the many items recorded in his diary it was noted that palladium wire and foil from Johnson "were clearly magnetic" while palladium chloride was not.

During the year Faraday also discovered the phenomenon that later came to be known as the "Faraday Effect", the ability of a normally isotropic transparent substance to rotate the plane of polarisation of light when subjected to a magnetic field. This was the foundation of magneto-optics, on-going studies of which indicate that platinum has great potential for use in magneto-optic data storage systems.

Faraday's Diary

Mention has been made previously to dated entries in Faraday's diary, which was in fact his handwritten record of the various experimental investigations he made from September 1820 to the early part of 1862. An edited version of his manuscript was published in 1936 and provides a fascinating insight to his many scientific activities, giving details of his procedures, successes and failures, many of which did not appear in the formal papers that reported the results of some of his major investigations. From the diary it is possible to obtain an indication of his wide involvement with the platinum metals, either as the subject of one of his investigations or as a component of some piece of apparatus. Two interesting instances of his use of platinum are given below.

The Concept of Power from Magnetohydrodynamic Generation

Following his discovery of electromagnetic induction in August 1831, which is regarded by many as his most noteworthy contribution to science, on January 12th, 1832, Faraday was conducting electrical experiments in the river Thames, from Waterloo Bridge "by leave of Mr Bridell the Secy." Two clean bright copper plates, 2 feet by 1 foot, were suspended in the river by thick copper wires, one at the toll house on the north side of the river, and the other at the sixth pier. The latter was fastened to an horizontal copper wire running along the parapet of the bridge, and as the ends of the two wires were connected by cups of mercury with the ends of a galvanometer wire "the whole became one wire from plate to plate; and the circuit was completed by the water between the plates, which being in motion up or down, was expected to produce, by magneto-electric induction, currents rendered sensible at the galvanometer." Faraday noted that evidence of an electrical current was soon obtained.

He returned the next day to continue his experiments and to consider whether any source of electricity could exist in the river, other than magneto-electric induction. On this occasion two platinum plates about 10 inches square were lowered into the river, one from the second and the other from the seventh pier of the bridge, placing them about 700 feet apart. When the circuit was completed the galvanometer indicated that "there was plenty of electricity" both when the platinum plates were kept under the water by means of iron weights attached to them by ropes and when the plates were allowed to float on the surface.

Although both plates had been cleaned prior to the experiments they became somewhat tarnished, one being discoloured by red oxide of iron, due to earlier furnace experiments on glass.

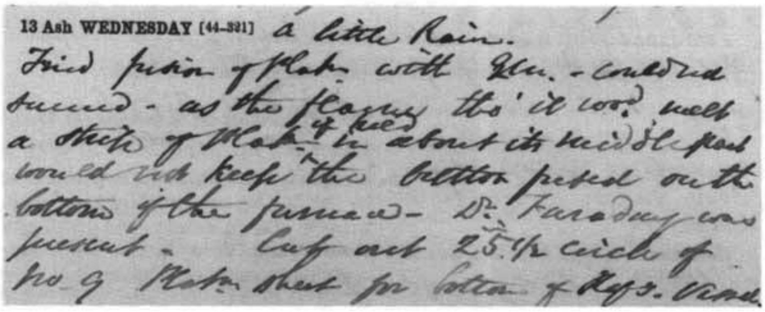
Faraday had in fact demonstrated that when an electrically conductive liquid, in this case the water in the Thames, flows through a magnetic field (here, the earth's magnetic field) electromagnetic induction occurs. This is the principle behind the operation of magnetohydrodynamic generators, which offer an opportunity to produce electricity efficiently and with lower environmental pollution than conventional fossil fuelled power stations.

A Platinum Light

During July and August 1857 when investigating the performance of various galvanometers, Faraday required a light source "as narrow as possible to cause its sudden appearance and disappearance in the mirror." One of the sources he tried was a platinum wire 1 inch long and 1/120 of an inch thick ignited to just below the fusing point by the electric current from two pairs of Grove's plates, the circuit requiring the insertion of 34 inches of 1/64 inch diameter copper wire to prevent the platinum melting. Although this gave a very bright light, Faraday initially concluded that a platinum wire light would not do, the task requiring "either the lime light or the Electric light." Lime light was more diffuse than the platinum light, however, and he later employed both sources, even making a copper variable resistance to regulate the electric current passing through the platinum wire.

The Platinum Lecture

Faraday was one of the great popularisers of nineteenth century science, striving to interest politicians and educationalists in the need to advance science teaching. The Friday Evening Discourses which he started at the Royal Institution in 1826 remain to this day an important channel of communication between leading scientists and the general public. At one of these, on Friday February 22nd, 1861, towards the end of his active life, he delivered his famous "Lecture on Platinum.". Drawing upon his vast knowledge of platinum "this beautiful, magnificent, and valuable metal;" he demonstrated many of its remarkable properties and spoke also of some of the other five platiniferous metals. Having acknowledged that Dr. Wollaston had been mainly responsible



for making platinum available until that time, Faraday then went on to describe the process developed by "my friend Deville" and which had "been adopted by Messrs. Johnson and Matthey, to whose great kindness I am indebted for these ingots". In fact, Faraday had not planned to deliver this lecture; he had intended that Henri Sainte-Claire Deville would come from France and demonstrate the fusion of some thirty or forty pounds of platinum before the assembled members. In 1857 Deville and Jules Debray had devised the lime-block furnace fired by a mixture of oxygen and coal gas in which it was possible, for the first time, to melt platinum on a large scale. In August of that year the English rights to the patented process had been acquired by Johnson Matthey and before accepting the invitation to demonstrate the process to the Royal Institution, Deville consulted George Matthey who, on February 5th, advised that there were still many practical difficulties to be overcome, and that he would not welcome the process being exhibited. It seems that Matthey was charged with passing Deville's decision to Faraday, for on 21st February he wrote to Deville that "Dr Faraday has behaved most kindly and did not appear in the least annoyed when I gave him your letter." It would appear that Faraday wished to see the problems for himself, for on Wednesday, February 13th, W. J. Cock, a former partner in the Hatton Garden firm, recorded in his diary "Tried fusion of platinum with GM . . . Dr. Faraday was present." The entry is reproduced above. In fact it was the end of May before this process was successfully employed by Johnson Matthey.

Another Imperfect Account

In the space available it has only been possible to present a limited and very selective account of Faraday's work with the platinum metals. During his investigations he established some of their electrochemical and magnetic properties, made use of them on a laboratory scale and indicated possible new industrial uses. Additionally he took a personal interest in the development of the use of the lime furnace, which enabled platinum to be melted commercially on a large scale for the first time. Apologising to the Members of the Royal Institution for being unable to have the process demonstrated to them, he referred to his lecture on platinum as "this imperfect account". Despite his failing health and the short time available for its preparation, it became a classic, disseminating a knowledge of the platinum metals to a wider audience. It was published in 1865, being bound with "The Chemical History of a Candle", which is probably the most famous series of Christmas lectures given for children by Faraday at the Royal Institution; another of his innovations in scientific communication which flourishes to this day.

Acknowledgements

The information in this account has been gathered from numerous sources, especially papers published previously in this journal, the relevant section of "A History of Platinum and its Allied Metals", and the references therein. I.E.C.