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THE CHEMICAL MANIPULATOR

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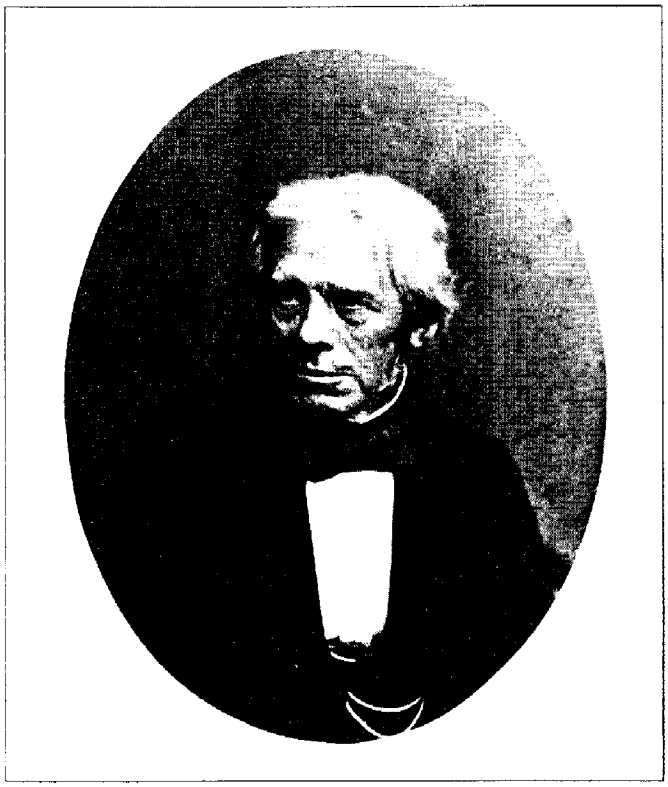
Faraday's *Chemical Manipulation* was published in 1827 (1). It was Faraday's first book; no doubt after the tedious work of its preparation he was proud to see it in print. He took a copy, divided it into three parts, placed a large (quarto) sheet of writing paper between each page, and rebound it into three volumes.

The binding was examined by Mrs. Fiona Anderson, bookbinder, who furnished me with the following technical description (2):

This quarto book has been made up from an octavo. The original book has been split into single sheets and these are tipped in between blank sheets. The blank sheets are made up from folio sheets of laid paper folded down the middle to form quarto sheets. The sections are made up from four folio sheets (making a quarto gathering of eight) and four printed pages. B = blank; P = printed. B/P/BB/P/BB/P/BB/P/B. The binding is 3/4 roan with green French shell marbled sides. Headbands are flat-silk over parchment strips. The sewing is on six sawn-in cords.

The three quarto volumes of Faraday's interleaved copy of *Chemical Manipulation* were part of the Honeyman collection of early works of science, which was sold at auction by Sotheby on 1983, when I acquired it. Sir George Porter (now Lord Porter), at that time the Director of the Royal Institution, told me that the Royal Institition was the runner-up at the bidding, and that my final bid was successful only because it exceeded the limit he had assigned for the purchase. "But", he said, "I don't mind too much for after all we have the whole of Faraday's original manuscript of the book, so perhaps we can do without his later emendations." With such a wealth of Faraday material in its archives, the Royal Institution should not grudge a few crumbs to private collectors.

Clearly Faraday's intention was to use the interleaves as the repository of additional material, although most of it never appeared in any later edition. As it turned out his interest in the subject was destined to make way for more pressing concerns after his discovery of electromagnetic induction in 1831, when he became preoccupied with his experimental researches in electricity. So the ambitious provision of so many blank pages,



Faraday in later life.

if intended for the revision of *Chemical Manipulation*, had only limited fulfillment. A second and revised edition was published in 1830, but it contained only a few of the revisions included in Faraday's interleaved copy. Most of these notes are references to periodicals containing information on topics already discussed in the printed text, which often lacked acknowledgments to the source of the information, or they are references to articles that brought that information up to a later date.

Obviously such an undertaking is open-ended and once commenced has to be kept up until the time when a new edition is in active preparation. After a promising start in which he probably copied his outstanding notes on to the interleaves, he seems to have abandoned the project (if he ever entertained it) of providing his readers with a complete set of references, for only a few of those written on his interleaves were included in later editions. The interleaves contain some 575 references. Far from including this large store of references in a later edition, Faraday actually reduced the number originally present from 78 foot-noted references in the first edition to 57 in the third. In the introduction, Faraday declared that his book was principally for beginners, and that he disclaimed any scientific character for it. He may well have thought that it was inappropriate to load it with references. In that case, the collection on the interleaves would have been entirely for his own private purposes, in a convenient form and location,

perhaps in case he was ever challenged to back up a statement in his text with an external authority.

Faraday's intention to create a bibliography of articles on the various topics of chemical manipulation may well have been inspired by the example of Thomas Young, who in his *Lectures on Natural Philosophy* (1807) included a comprehensive bibliography of every topic treated in his lectures (3). These lectures had been delivered as a course at the Royal Institution, and so created a precedent that Faraday, who as a serious student appreciated such helps to self-study, would have considered worth emulating.

At the end of his book Faraday listed the reviews that it had received in various periodicals. Before giving examples of his other annotations on the interleaves, it will help to appreciate the character of *Chemical Manipulation* to cite some of these reviews. They were generally favorable, but that is not altogether surprising since, although published anonymously as was then the practice, internal evidence shows that they were written by personal friends of the author.

The *Philosophical Magazine* devoted eight pages to a review of *Chemical Manipulation*, but a large part was taken up by a long extract from the book itself, dealing with what Faraday called "tube chemistry," that is, the carrying out of chemical and physical operations in apparatus formed partly or altogether of glass tubing of about half an inch or less in diameter (4). Chemical operations can thus be carried out with great economy of materials; and indeed Faraday's tube chemistry is much like the microchemistry taught in our academic laboratories today. For physical operations, such as successive distillations or rectifications, a tube with several bends allows the volatile liquid to be evaporated in one U-bend by the application of heat, and condensed in the adjoining U-bend by the application of cold; and then by repeating the evaporations and condensations to drive each succeeding distillate to the next U-bend and finally to its last receiver. This and other physical operations in tubes of appropriate design are recounted in meticulous detail and with the utmost clarity by Faraday.

The anonymous reviewer was evidently himself a chemist. He wrote (5):

> In p. 172 excellent directions are given on the very simple subject of glass stirrers, to which however we would add one hint more; - they are extremely apt to roll from the experiment-table. Now this is easily prevented by softening them near the centre in the spirit-lamp, and then very slightly bending them.

Faraday included this useful tip in his second edition, and in so doing acknowledged his indebtedness to Mr. Phillips, thus incidentally identifying the reviewer as Richard Phillips (1778-1851), an old friend of Faraday and one of the editors of the *Philosophical Magazine*. Richard Phillips and Faraday had been members of an association of young men who sought mutual self-improvement by composing and reading essays to one another and then submitting to group criticism. Faraday was always grateful for and heedful of such criticism, which he deemed to be beneficial; but the practice of extending criticism to others on their invitation to do so tends to breed nit-picking and pedantry. Some trace of this disposition is apparent in Phillips' next remarks (6):

> There are however, two passages which contain (as we think) a figure of speech which we will not name, but which the author will probably guess at, and in a future edition alter.

The phrasing of this sentence suggests that Phillips had already conversed with Faraday and had rallied him in a friendly way on his stylistic misdemeanors. Phillips continued (7):

> The first [of these] occurs in the Introduction, p. iii. "There are also two parts in an experiment; first, it has to be devised" &c. Now as a thing does not exist until it is devised, we do not see how the devising of it is a "part" of it. In p. 174 we are informed that "the simplest step in the application of heat is to obtain a solution saturated when cold." To us it appears on the contrary that the obtaining of a cold solution is no step at all in the application of heat. - We observe also that the author uses the term "lute" in two and very different senses: first, in its proper sense, that of stopping the orifice between a retort and receiver; and secondly, in that of coating. Now *luting* a retort and *coating* one are two different operations.

Phillips goes on to take Faraday to task for crediting Lavoisier with the first use of oxygen as a means of increasing heat, whereas, as he shows by citing Priestley, the credit really belongs to the latter. But despite these strictures, Phillips concludes (8):

> After a careful perusal of the work, we strenuously recommend it, as containing the most complete and excellent instructions for conducting chemical experiments: there are few persons, however great their experience, who may not gain information in many important particulars; and, for ourselves, we beg, most unequivocally to acknowledge that we have acquired many useful and important hints, on subjects even of every-day occurrence.

The anonymous reviewer's praise of *Chemical Manipulation* had every appearance of a disinterested judgment, especially because of his previous rebukes of minor stylistic errors. But this was a skillful ruse to simulate impartiality: actually Richard Phillips was not entirely indifferent to the success of the book for, besides his close friendship with the author, he was also the younger brother of the publisher, William Phillips (1775-1828). When William Phillips died about a year later, the remaining unsold sheets were acquired by the publisher, John Murray, who issued them with a new title page. Murray also published Faraday's revised second and third editions.

Another review of *Chemical Manipulation* appeared in the *London Literary Gazette and Journal of the Belles Lettres, Arts, Sciences, &c* (9). The reviewer made a point of "calling the attention of our *juvenile* readers to the very valuable work before us". He pointed to the rapid advances being made in Britain in the physical sciences and the incalculable advantages that must result; but the sole advantage that he chose to mention was from "the avenues to science being thrown open to men in the ordinary and lower ranks of life". This comment is rather surprising since there are many other more obvious advantages of the rapid progress of science; but taken in conjunction with our knowledge of Faraday's humble social origins, it suggests that the reviewer was equally well aware of them, and therefore was either a personal friend or an acquaintance of Faraday. The reviewer returns to the same theme further on. That man may be said to confer a benefit on his country, he wrote, who places the various manipulations of chemical research "within the grasp of the middling (and may we add, the most industrious) classes of society". Promoting the same theme is the reviewer's commendation of Faraday for furnishing the chemical laboratory on the most economical scale. At the time great efforts were afoot to extend education beyond the privileged classes, as witness the various kinds of Mechanics' Magazines of the 1820s, the Society for the Dissemination of Useful Knowledge, the *Penny Cyclopaedia*, the journal *The Mechanic and Chemist* (1836-1842), the founding of the University of London, and of Mechanics' Institutes throughout the kingdom. While this movement almost certainly gave some occasion for the reviewer's remarks, yet his pointed use of Faraday's book to make mention of the opportunity for self-advancement provided by learning chemical manipulations suggests rather strongly that the example of its author was also in the reviewer's mind.

Table 1. Faraday's annotations for Section XVII: *Electricity*, §2. Voltaic Pile.

Pepys Galvanometer	Phil Mag	X. 38. XV. 94
Pepys Voltaic apparatus	Quar Journ	I. 193
Hare's Voltaic trough	Quar Journ	XVII. 378
Nobili's Galvanometer	Quar Journ	XX. 170
Wollaston's Elementary galvanic battery	Thom Annals	VI. 209
Power of Electrical batteries	Nich Journ 4to	II. 527
Hare's deflagrator	Phillips Annals	V. 129
Gold leaf test of Electro magnetism	Phillips Annals	VIII. 321
Poggendorffs galvanometer	Edin Phil Journ	V. 122
Marsh's apparatus	Trans Soc Arts	XLI. 47
Sturgeon's apparatus	Trans Soc Arts	XLIII. 37
Wilkinson's Galvanic trough	Phil Mag	XXIX. 243
Children's voltaic pile	Phil Mag	XXXIV. 26
Improved galvanic trough	Phil Mag	XLIV. 15
Children's voltaic battery	Phil Trans	CV. 363
Pepys voltaic conductor	Phil Mag	XLI. 15

Table 2. Faraday's annotations for Section XVIII: *Lutes - Cements*.

Lute	Saussure Essais sur l'Hygrométrie	§83
Good paste	Quar Jour	XV. 141
Cement	Nich Jour 4to	I. 355
Cement	Edin Phil Jour	XIII. 199
Cement	Tech Rep	I. 373. 412
Cement	Ure Dict	311
Cement	Phil Mag	XIV. 117
Cement for iron vessels	Phil Mag	IV. 216
Cement to exclude damp	Trans Soc Arts	XXIV. 81
Coating or luting	Ure Dicty	345
Lutes	Henry Chem	I. 9
Lutes	Tech Rep	II. 18
Lutes	Ure Dict	567
Lutes	Nich Jour or Phil Mag	VI. 140 XVI. 236
Lutes	Lavoisier	468
Lutes	Thenard Chem	IV. 294
Lutes and Cements	Aikins Dicty	I. 273
Preservation of bladder	Phillips Annals	I. 426

A third review of *Chemical Manipulation* appeared in the *Quarterly Journal of the Arts and Sciences* (10). This periodical was in effect the house organ of the Royal Institution, and was edited by William Brande with the assistance of Faraday. The review was long and laudatory, which was only to be expected. The reviewer was probably William Brande himself.

Let us return now to the contents of Faraday's interleaved copy of *Chemical Manipulation*. Tables 1 and 2 give some sample pages that show the range of topics that were included in the book. As can be seen, the references in the interleaved copy are grouped according to each Section of the text of *Chemical Manipulation*. Many of them refer to the statements in the text that lacked reference; others would have extended the information included in each Section. In the revised second and third editions, however, Faraday was at some pains to keep the book to a moderate size. In the Preface to the second edition, he wrote:

> I found it impossible to introduce any additional matter without displacing that which was more important; nor do I anticipate that I shall incur blame by withholding that which has not been tried, and, in my own judgment, is of less moment than that which experience has proved to be useful and desirable.

In consequence of this decision, many of the references in the interleaved copy bear no correspondence to anything in the text of the revised editions.

Yet Faraday continued to add references between the dates of the second and third editions, that is, between 1830 and 1842. One of these is in Section XIX, "Bending, Bowing and Cutting of Glass", which begins on page 522. It is listed as "Grinding of Glass" and refers to Silliman's Journal, **XVII,** page 345. The reference is to a paper by Elisha Mitchell, Professor of Chemistry, Mineralogy, &c. at the University of Carolina, entitled "On a Substitute for Welther's Tube of Safety, with Notices of Other Subjects" (11). This paper is interesting as it contains a reference to *Chemical Manipulation* and a practical suggestion on how to cut glass with a hot iron (11):

> Mr. Faraday has devoted four pages of his recent work on chemical manipulation, to an account of the methods of cutting glass with a hot iron. His directions are valuable to the young chemist, because they are drawn out into that minuteness of detail, which alone can make them of any use; and yet he has omitted one precaution, which I have found important in cutting large tubes, vials, etc. - that of not making the iron too hot. It should be heated to a redness barely visible in daylight. If in this state, it be caused to vibrate a few times around the tube, along the track where the division is to be made, and a drop of water put upon the spot, a simple fracture, without side flaws, will be obtained.

Faraday did not, however, include this tip in the third edition.

Another of these later references occurs in Section XIII, "Crucible Operations - Fusion - Reduction", which begins on page 281. The reference is to a paper entitled "On the Existence of Titanic Acid in Hessian Crucibles", by R. H. Brett and Golding Bird, published in *The Philosophical Magazine* in 1835 (12). Faraday noted on his interleaf:

> Dr. Wollaston told me in 1827-28 that Hessian crucibles contained Titanate and also that Cornish crucibles resembled them in that respect.

Again, Faraday did not carry this defense of Wollaston's priority into his third edition, although the fact that he entered it in an appropriate place in his interleaved copy of the text, indicates that at one time he had meant to do so.

One change, however, he deemed important for the third edition. It consisted of introducing the terms of his own coinage, "electrolyte" and "electrodes", into the section on voltaic electricity, instead of the terms he had used originally, namely, "imperfectly conducting matter" and "poles".

It may seem surprising that so creative a worker as Faraday should have employed himself in so routine task as combing the printed literature for references with the diligence that these annotations display. Nevertheless, a copy of the cumulative index to volumes 1-20, 1816-26, of the *Quarterly Journal of Science and the Arts*, published in 1826, in the possession of the Royal Institution, has added in manuscript on its title-page "Made by M. Faraday". Since the cumulative index was largely drawn from the separate indexes of each volume, it is likely that the recurrent task of making those was also undertaken by Faraday. If such were indeed the case, he would have had considerable experience in that kind of harmless drudgery, dating from the days when his position at the Royal Institution was still that of an assistant to William Brande.

References and Notes

1. M. Faraday, *Chemical Manipulation; Being Instructions to Students in Chemistry, on the Methods of Performing Experiments of Demonstration or of Research, with Accuracy and Success*, Phillips, London, 1827.
2. Private communication from Mrs. F. Anderson, 6 July 1989.
3. T. Young, *Lectures on Natural Philosophy and the Mechanical Arts*, Vol. 2, Johnson, London, 1807, pp. 87-520.
4. Anon., "Notices Respecting New Books", *Phil. Mag.*, **1827**, *2 (ser. 2)*, 58-66.
5. *Ibid.*, pp. 64-65.
6. *Ibid.*, p. 65
7. *Ibid.*, p. 65
8. *Ibid.*, pp. 65-66.
9. Anon., "Chemical Manipulation; &c", *Literary Gazette and Journal of the Belles Lettres, Arts, Sciences, &c*, **1827**, *22 (July 21)*, 472-473.
10. Anon., "Chemical Manipulation; &c", *Quart. J. Arts Sci.*, **1827**, *24*, 275-283.
11. E. Mitchell, "On a Substitute for Welther's Tube of Safety, with Notices of Other Subjects", *Amer. J. Sci. Arts*, **1830**, *17*, 345-350.
12. R. H. Brett and G. Bird, "On the Existence of Titanic Acid in Hessian Crucibles", *Phil. Mag.*, **1835**, *6 (ser. 3)*, 113-117.

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UNPUBLISHED LETTERS OF FARADAY AND OTHERS TO EDWARD DANIEL CLARKE

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The letters printed here are part of a collection of autograph letters made by Edward Daniel Clarke (1769-1822) based on his own private correspondence. His biographer, William Otter, wrote (1):