Substantia
An International Journal of the History of Chemistry

Firenze University Press
www.fupress.com/substantia

OPEN ACCESS

Citation: Martins Idalgo e Silva, R., Baldinato, J.O., & Alves Porto, P. (2024) The wonderful and the useful: experiments in Samuel Parkes' *Chemical Catechism*. *Substantia* 8(1): 39-50. doi: 10.36253/Substantia-2252

Received: Jul 26, 2023

Revised: Oct 12, 2023

Just Accepted Online: Oct 13, 2023

Published: Mar 04, 2024

Data Availability Statement: All relevant data are within the paper and its Supporting Information files.

Competing Interests: The Author(s) declare(s) no conflict of interest.

Historical Article

The Wonderful and the Useful: Experiments In Samuel Parkes' *Chemical Catechism*

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Abstract. This article aims to present an overview of the experiments contained in Samuel Parkes' book, *Chemical Catechism*. In a context of great interest towards science in Britain, many popular chemistry books were published in the early 19th century. Among them, *Chemical Catechism* was a highly successful work, receiving several editions and translations into other languages. Its chemical content is presented in the form of short questions and answers, complemented by extensive footnotes that serve various purposes. One of these purposes was to guide the tutor in conducting demonstrations and experiments for the pupils, and to convince them of the practical nature of science. The experiments could have sensory, scientific, or industrial appeal, or could be integrated into discussions about theoretical aspects of chemistry. Analysis of the experiments reveals some of Parkes' conceptions about chemistry and its popularization. Once the pupils' attention had been captured by the experiments with great sensory appeal, the presentation of theoretical explanations would lead to an understanding of how chemists work and how chemistry could be useful for personal prosperity and the benefit of the nation.

Keywords: Samuel Parkes, Chemical Catechism, 19th-century chemistry, popularization of chemistry, chemical experiments.

INTRODUCTION

In the beginning of the 19th century, Britain was going through a period marked by conflicts and the increasing renewal of manufacturing processes in the context of the Industrial Revolution. Considering the growing need to follow the advances experienced by the Kingdom, and strongly driven by the technological adventures of the time, natural philosophy found in the United Kingdom a favourable place and time for its development and dissemination. The Royal Institution can be highlighted as an example among the various societies created in this period with the aim of spreading useful knowledge through lectures and demonstrative experiments. In addition to being appealing in terms of their usefulness in the development of crafts and manufacturing, the wonders of science were also attractive to audiences looking for an interesting and fun entertainment.[1]

Alongside the lectures, introductory chemistry books also received attention from individuals with a keen interest in science. Although some of these books presented technical concepts that could be difficult for beginners to understand, they played the role of promoting the communication of scientific knowledge to the public, without the ambition of training science specialists with their content.[2]

An introductory work that achieved sizeable prominence in the beginning of the 19th century was the *Chemical Catechism*, by Samuel Parkes (1761–1825), originally published in Britain in 1806 and later translated into several languages.[3] The book consists of a series of questions and answers, followed by extensive footnotes that complement the catechetical part of the text. A relevant feature is that, with each new edition of the *Catechism*, Parkes updated some of the topics covered according to the developments of chemistry, intending to keep his book up to date and close to the progression of science itself. This shows the proximity between the science produced at the time and the general public, who could follow the advances in science according to the updates of works dedicated to science popularization.[4]

One of the alluring aspects of Parkes' work is the inclusion of experiments, which are presented in both footnotes and a dedicated chapter at the end of the book. Some of them were personally referred to Parkes by Humphry Davy (1778–1829), one of the most celebrated chemists and science popularisers of the period. In Parkes' conception, the *Chemical Catechism* experiments were presented with the objective of establishing a way of accessing the truth that only experimentation and analysis of the facts could demonstrate.[5]

Considering the context of early-19th-century chemistry popularization books, this article aims to investigate the way in which experimentation and chemical demonstrations figure in Parkes' *Chemical Catechism*. The study of this theme aims to contribute to the reflection on how important experiments were in the scope of science popularization books, and what were their objectives in a time of great fervour for science itself – a time when important experiments and chemical works, such as those of Davy and Michael Faraday (1791–1867), took place.

This paper analyses the experiments and demonstrations included in the *Chemical Catechism*, focusing on Parkes' objectives and on his opinion about the issue of experimentation, either explicit or implicitly present in the book. In order to contextualize it, scientific popularization in late 18th century and early 19th century is discussed, the period in which the *Chemical Catechism* was written and published.

The different editions of Parkes' book, found in digital format on Google Books, Internet Archive and Hathi Trust databases, were used as sources for this article. Research sources also include reviews made at the time of the publication of the *Chemical Catechism* in British journals (also found in the abovementioned digital databases) such as *The Monthly Review*, and the works of historians of science such as David Knight, Frank James, Frederick Kurzer, Jonathan R. Topham, Jean-Luc Chappey, Jan Golinski and Bernard Lightman.[6]

BRITAIN'S ENTHUSIASM TOWARDS SCIENCE IN EARLY 19TH CENTURY

During the second half of the 18th century and the first half of the 19th century, science was regarded with intense enthusiasm and popularity in Britain. In particular, chemistry was responsible for much of this fascination which, according to Knight, found the height of its notoriety at that time.[7] Chemistry was seen not only as a fun curiosity with great sensory appeal, but also as a necessity and a considerable concern for society.[8]

At the end of the 18th century, France was in a period of intense political and social upheaval, and was also experiencing an intensive scientific euphoria. Being involved in internal and external conflicts, it depended on science to perfect goods and processes related to military purposes, while Britain needed scientific improvements to advance techniques aimed at its self-sufficiency.[9] Especially because of conflicts with France (which, after the furore of the French Revolution, were later involved in the Revolutionary Wars and the subsequent Napoleonic Wars), Britain had its access to Continental trade reduced and restricted. The Kingdom was then driven to make the most of its own resources for the subsistence of its manufactures, which, at the time, were increasingly demanding due to the advance of industrialization.[10] Therefore, according to Knight, "France around 1800 led the world in science, but Britain led the world in technology".[11]

Following the Industrial Revolution, significant changes were brought about in Britain. With the advancement of manufacturing techniques, growth of trade and accumulation of capital, a social class of wealthy manufacturers, traders and bankers rose. Such class was also gradually convinced of the usefulness of scientific advancement to foster their economic objectives.[12]

In the midst of this historical and social context, while representing a promising path for the technological development necessary for British manufacturing, science also lured large audiences with explosions, colour changes and odours. The public flocked increasingly to auditoriums to have a first-hand view of the wonders that science could present.[13] One of the institutions that stood out in the introduction of science to the public was the Royal Institution, founded in 1799 with the aim of "diffusing the Knowledge, and facilitating the general Introduction, of Useful Mechanical Inventions and Improvements; and for teaching, by Courses of Philosophical Lectures and Experiments, the application of Science to the common Purposes of Life".[14]

The American chemist Benjamin Silliman (1779–1864) noted that science lectures attracted audiences of different ages and of both sexes, interested in the wonders that science, especially chemistry, could perform.[15] This can also be seen in the diary of the young French traveller Louis Simond, who documented his visit to London in the years of 1810 and 1811. In his journal, Simond wrote that, although many were the subjects covered by the lectures at the Royal Institution, such as astronomy, mechanics and natural history, these sciences were not as "fashionable" as chemistry. According to Simond, the reason was that they were not "susceptible of any brilliant exhibitions; there is no noise, no fire, – and the amphitheatre never fills, but for Mr. Davy".[16]

Although the lectures represented the main course of action of the Royal Institution, soon its members realized that they alone were not enough, and the institution needed to expand its appeal to the public. Thus, it didn't take long for the great scientific experiments performed to the public to become a popular featuring, in which the execution was often dangerous by our current safety standards.[17] This effort to bring science to a large audience and show it in an fascinating way, aiming at practical learning, was one of the aspects that marked the popularization of chemistry during this period.[18]

Golinski[19] described two lines of thought on how science popularization should be, quite different in their purposes. The first, which comprised a minority of authors, was prompted by a more radical ideal, being driven mainly by Enlightenment goals. This group included authors such as Joseph Priestley (1733–1804) and Thomas Beddoes (1760–1808), who supported a useful natural philosophy, linked to political aspects. For them, if natural philosophy was used by the population, it would be a powerful tool to understand the Universe, something that could put an end to the undue authority usurped by the nobility. Following this line of thought, Priestley was one of the leaders of the movement which called for a reformation of the British Parliament, but ended up being forced into exile in the United States in the 1790s. The second group was formed by the vast majority of natural philosophers from industrialized regions in Britain, who sought to keep radicals away from national scientific institutions and fought the so-called "Jacobin" ideals.[20] For this group the popularization of science aimed to entertain and empower workers so that they could exercise their functions even better, but maintaining the established hierarchical system.[21]

SCIENTIFIC POPULARIZATION IN BOOKS

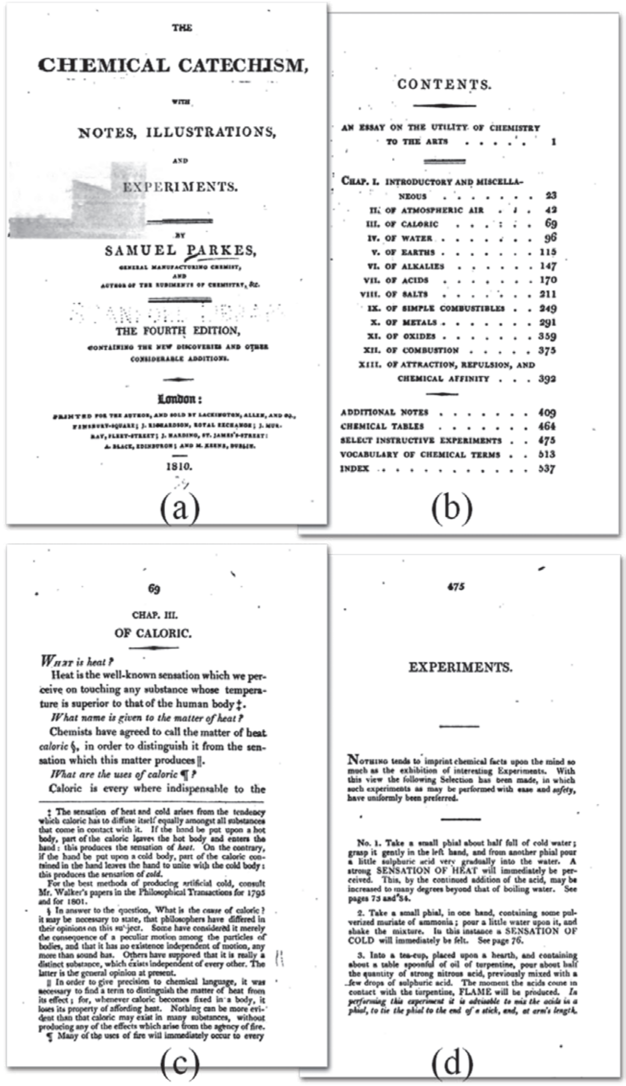
Along with the growing enthusiasm for science which encouraged institutions to offer more and more scientific lectures and demonstrations to their audiences, there was also a significant increase in the number of scientific publications during the 19th century. Among the reasons leading to this gradual expansion were the technological advances that took place, mainly, during the first half of the century. The very improvement of printing techniques allowed books to become more accessible. Publishers then targeted new audiences, including the middle and working classes in their markets.[22] Consecutive reprints of books designed to popularize chemistry attest to the widespread allure this genre held at the time.

Until the beginning of the 19th century, books were considered to be luxury items, as they were printed on manually-controlled presses and illustrated with metal engravings, which made them really expensive. It was only after 1820 that literature, whether philosophically based or not, gained considerable impetus, thanks to advances such as the steam-powered printing press, and the improvement of techniques which made paper production cheaper and more accessible.[23] During the 1840s, the production of books had already improved to the point that their circulation was four times bigger than at the beginning of the century. With the advent of the new techniques, journals became more popular and numerous, making Britain one of the pioneers in the mass production of printed publications.[24]

According to Knight, another element to consider is that even though a good part of the population was still illiterate, there was an increasing demand for literary works from the minimally educated layer of the population, which also tended to see science as a considerably interesting subject and helped to boost the publication of scientific popularization books.[25]

Several branches of natural philosophy were covered in popular works during the period. One can cite Margaret Bryan (1750-1816) with her *Compendious System of Astronomy* (1797) and *Lectures on Natural Philosophy*

(1806); Jeremiah Joyce with his *Scientific Dialogues* [on mechanics, astronomy, hydrostatics, pneumatics, optics, magnetism, electricity and galvanism] (1800-1803) and *The Wonders of the Microscope* (1812); Jane Marcet (1769-1858) with *Conversations on Natural Philosophy* (1819) and *Conversations on Vegetable Physiology* (1839); and Mary Somerville (1780-1872) with *The Mechanism of the Heavens* (1831) and *The Connexion of the Physical Sciences* (1834).[26] However, in a context of industrial rise associated with tensions with France and the Continental Blockade, chemistry emerged as an eminently useful and necessary science. Its image was connected to an idea of progress in industry and crafts, exactly as it would be explored by Parkes in his life and work.[27]



THE CHEMICAL CATECHISM, WITH NOTES, ILLUSTRATIONS, AND EXPERIMENTS. BY SAMUEL PARKES, GENERAL MANUFACTURING CHEMIST, AND AUTHOR OF THE RUDIMENTS OF CHEMISTRY, &c. THE FOURTH EDITION, CONTAINING THE NEW DISCOVERIES AND OTHER CONSIDERABLE ADDITIONS. London: PRINTED FOR THE AUTHOR, AND SOLD BY LACKINGTON, ALLEN, AND CO., FINSBURY-SQUARE; J. RICHARDSON, ROYAL EXCHANGE; J. MURRAY, FLEET-STREET; J. HARDING, ST. JAMES'S-STREET: A. BLACK, EDINBURGH; AND M. KEENE, DUBLIN. 1810.

(a)

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CHAP. III.

OF CALORIC.

What is heat?

Heat is the well-known sensation which we perceive on touching any substance whose temperature is superior to that of the human body ‡.

What name is given to the matter of heat?

Chemists have agreed to call the matter of heat *caloric* §, in order to distinguish it from the sensation which this matter produces ‖.

What are the uses of caloric ¶ *?*

Caloric is every where indispensable to the

‡ The sensation of heat and cold arises from the tendency which caloric has to diffuse itself equally amongst all substances that come in contact with it. If the hand be put upon a hot body, part of the caloric leaves the hot body and enters the hand: this produces the sensation of *heat*. On the contrary, if the hand be put upon a cold body, part of the caloric contained in the hand leaves the hand to unite with the cold body: this produces the sensation of *cold*.

For the best methods of producing artificial cold, consult Mr. Walker's papers in the Philosophical Transactions for 1795 and for 1801.

§ In answer to the question, What is the *cause* of caloric? it may be necessary to state, that philosophers have differed in their opinions on this subject. Some have considered it merely the consequence of a peculiar motion among the particles of bodies, and that it has no existence independent of motion, any more than sound has. Others have supposed that it is really a distinct substance, which exists independent of every other. The latter is the general opinion at present.

‖ In order to give precision to chemical language, it was necessary to find a term to distinguish the matter of heat from its effect; for, whenever caloric becomes fixed in a body, it loses its property of affording heat. Nothing can be more evident than that caloric may exist in many substances, without producing any of the effects which arise from the agency of fire.

¶ Many of the uses of fire will immediately occur to every

(c)

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EXPERIMENTS.

Nothing tends to imprint chemical facts upon the mind so much as the exhibition of interesting Experiments. With this view the following Selection has been made, in which such experiments as may be performed with ease and *safety*, have uniformly been preferred.

No. 1. Take a small phial about half full of cold water; grasp it gently in the left hand, and from another phial pour a little sulphuric acid very gradually into the water. A strong SENSATION OF HEAT will immediately be perceived. This, by the continued addition of the acid, may be increased to many degrees beyond that of boiling water. See pages 73 and 84.

2. Take a small phial, in one hand, containing some pulverized muriate of ammonia; pour a little water upon it, and shake the mixture. In this instance a SENSATION OF COLD will immediately be felt. See page 76.

3. Into a tea-cup, placed upon a hearth, and containing about a table spoonful of oil of turpentine, pour about half the quantity of strong nitrous acid, previously mixed with a few drops of sulphuric acid. The moment the acids come in contact with the turpentine, FLAME will be produced. *In performing this experiment it is advisable to mix the acids in a phial, to tie the phial to the end of a stick, and, at arm's length.*

(d)

Figure 1. Overall layout of Parkes' *Chemical Catechism*. (a) Title page; (b) Table of contents; (c) Example of a page showing the main text in catechism form and the footnotes; (d) First page of the numbered "select instructive experiments".

Among the books published at that time, *Conversations on Chemistry*, by Jane Marcet, and the *Chemical Catechism*, by Parkes, both published for the first time in 1806, are noteworthy. Their objective was to introduce basic concepts of chemistry to those who knew nothing, or just a little, about it, mainly children and young people. Although Marcet made it clear in the preface that she targeted the female audience when writing *Conversations on Chemistry*, contemporary reports revealed that her book reached a much broader audience than the one to which it was allegedly directed. Parkes, in turn, claimed to have the education of his only daughter as the initial reason for writing the *Chemical Catechism*. However, when he realized that his work reached a much larger dimension than initially expected, and encouraged by friends, Parkes decided to publish his book to help to educate children, who could use chemical knowledge to boost and improve any activities they came to dedicate themselves to in the future.[28]

The way Marcet and Parkes introduced chemistry in their works was quite different from previous chemistry books, and their approaches were also different from each other, even though their formats had already been used in publications from other areas. According to Lightman, the new formats adopted for popularization probably had the objective of attracting new readers to the subject by making chemistry as attractive as prose fiction, which was quite popular at the time.[29]

While Marcet wrote her text in the form of dialogues, introducing three characters – two girls, Caroline and Emily, and their tutor, Mrs B. –, Parkes used the catechism form, with short assertive questions and answers, fostering the pupils to know and repeat it by heart. In his preface to the third edition of the *Chemical Catechism*, Parkes explained that this form was chosen because it had "[...] at least all the advantages that any other mode of instructing youth in chemistry can claim". In this way, pupils' learning would be guaranteed, as "if the author's original intention be followed, the progressive improvement of the student will be pleasant, rapid and correct".[30] Figure 1 illustrates the overall layout of the book.

In the next section, some of Parkes' biographical data that may help to understand the context and content of the *Chemical Catechism* are presented.

SAMUEL PARKES – BIOGRAPHICAL SKETCH

Samuel Parkes was born in Stourbridge, Worcestershire, on May 26, 1761. At the age of five, he began to attend a children's school in his town. At ten he became a pupil of the independent minister, Dr. Stephen Addington (1729–1796), remaining under his guardianship until the age of fourteen. After passing through the brief tutelage of a blacksmith in Ross-on-Wye, Parkes returned to Stourbridge, where he joined his father in the family's grocery business for the next 18 years. Parkes was an avid reader from an early age and collected many books in his personal library along his life. This was an important feature of Parkes' self-taught education, as he did not attend a university. Around 1790 Parkes helped set up a public library in Stourbridge, of which he himself acted as administrator for some years. At the same time, Parkes helped create a chapel for Unitarian worship in his city.[31]

In 1793, Parkes moved to Stoke-on-Trent, where he started a soap-making business and married Sarah Twamley (1766–1813). In 1797 their only child, Sarah Mayo, was born. According to Kurzer (1997), his interest in controlling the soap manufacturing process in a more effective way led Parkes to the study of chemistry, which soon became his main professional interest.[32]

Financial problems led Parkes to move with his family to London in 1803. With a loan from a friend and a small amount of his own, he settled in the city and began his career as a chemical manufacturer. After just three years in London, Parkes managed to settle all the debts incurred, which indicates the success of his new trade. However, although the activity as a manufacturer of chemical products required him intense attention and dedication, it did not prevent Parkes from continuing other personal projects. In 1806, he published the first edition of *Chemical Catechism*; in 1809, the volume entitled *Rudiments of Chemistry*; and, in 1815, his third book, *Chemical Essays*.[33]

In addition to the abovementioned works, Parkes also published short texts, which often dealt with chemistry and its usefulness in issues of economic interest to the United Kingdom, such as *Thoughts on the Salt Laws* (1817) and *Letter to Farmers and Graziers on the Use of Salt in Agriculture* (1819). Furthermore, due to his knowledge in practical chemistry matters, Parkes also participated in legal and parliamentary hearings as a witness or expert consultant on several occasions.[34]

After the unexpected death of his wife in 1813, Parkes's daughter helped him to run the household and accompanied him on some travels. In June 1825, a year after his daughter's marriage to Joseph Wainwright Hodgetts (1797–1851), Parkes fell seriously ill during a journey to Edinburgh and, as soon as it was deemed prudent, was taken back to London by his son-in-law. After months of illness Parkes died on December 23, 1825.[35]

THE *CHEMICAL CATECHISM*

Entitled *A Chemical Catechism for the use of Young people*, the first edition of Parkes' most popular work was released in May 1806, with a print run of fifteen hundred copies – the smallest compared to the print runs of subsequent editions. The *Chemical Catechism* had a total of thirteen editions, twelve of which were released between the years 1806 and 1826. The thirteenth edition was released posthumously in 1834, after revision and adaptation by Edward William Brayley of the London Institution.[36]

Parkes relied on a number of publishers and many editions of his *Catechism* were translated into Spanish, French and German, also circulating in the United States and Russia.[37] It is difficult, therefore, to estimate the popularity of the book, as well as its financial return, even in comparative terms with other scientific popularization books of the period. Kurzer suggests measuring the social ascension experienced by Parkes by observing the title pages of successive editions of the catechism.[38] While in the first edition, from 1806, the author is briefly introduced as "Chemist of preparations", in the fifth, from 1812, the presentation changes to "Author of *Rudiments of Chemistry* and one of the Owners of the Haggerstone Chemical Works". In the author's last edition, in 1826, Parkes devotes no less than nineteen lines to listing his affiliation with the various philosophical and literary societies to which he was associated, or from which he received honours, in England and abroad, including Portugal, France, the United States, Scotland and Russia.[39]

Although originally designed as a book for his daughter, the final audience Parkes addressed the *Chemical Catechism* to was a male audience. In the first essay of the book, he directs arguments to parents about the use of chemistry to benefit the development of their children's future profession. Parkes argues that the content of the book had the objective of teaching chemistry to young people, so that, if they were land owners, they could apply chemistry for its better use and exploitation; or, if the young man intended to be a physician, he might understand the principles of chemistry and use them in his profession; or even, for those who wanted to venture into industry, chemical knowledge would definitely be of enormous value for the execution of their functions.[40]

The main part of the text is explicitly aimed at learners and adopts the catechetical style, consisting of short, direct questions and equally short answers. The text also includes a large number of footnotes. Unlike the main text, the notes bring larger and more elaborate paragraphs, which discuss the most diverse issues – including, for example, suggestions of experiments to be carried out by the tutor together with the young learner, or even details of industrial processes involved in obtaining compounds cited in the main text. Also in the footnotes, the author makes several exaltations to divine wisdom and goodness, in allusion to natural theology[41], and makes comments on contemporary chemistry, mentioning studies and scholars – in most cases, authors affiliated to the "new chemistry" disseminated by Antoine Lavoisier (1743–1794) and his collaborators[42]. The footnotes offer not only a reference to how science was presented at the time, but also cover aspects of history, culture and even the morality prevailing among the British aristocracy in early 19th century.

CHEMISTRY *AD OCULI*: THE EXPERIMENTS IN THE *CHEMICAL CATECHISM*

Being a professional of chemical preparations, Parkes emphasized the use of experiments by young people to improve their chemical knowledge. According to him, "Nothing tends to imprint chymical facts upon the mind so much as the exhibition of interesting experiments".[43] To help tutors to perform experiments, the *Chemical Catechism* included illustrative figures of laboratory equipment, as well as descriptions of chemical utensils.

The experiments suggested by Parkes can be found in two different sections of the book. The catechetical part of the text, due to its question-and-answer format, was not designed to include experiments, although there are some brief mentions of them. Experiments are described and explained in the footnotes and in an additional section at the end of the work, entitled "Select Instructive Experiments", which constitutes an entire chapter dedicated only to experiments and chemical demonstrations.[44]

The main goal of the footnote experiments is to illustrate, explain or even "prove" the theories presented in the several chapters. In the footnotes, the discussion of the experiment would start from the observation of the procedure performed by the tutor and contemplation of the results by the pupil.[45] The following example was extracted from a chapter on the composition and properties of atmospheric air. The footnote presents an experiment designed to illustrate combustion, one of the properties of oxygen gas:

> The necessity of oxygen for supporting combustion may be shown by the following simple experiment. Pour a little water on a flat dish, place two or three lighted wax tapers of different lengths in the water, and invert a tall glass jar over them. The flame of the different tapers will soon be seen to grow smaller, and at length will be extinguished in succession. That which is highest will be extinguished first, and the shortest taper the last, owing to the purer air occupying the lower part of the jar.[46]

It can be seen, in this example, that not only instructions are given for carrying out the experiment, but a brief explanation about the relation between tapers sizes and the order in which they go out is also introduced. Another example is an experiment designed to show the role of caloric in expansion and condensation of fluids:

> Put a little ether into a small retort, tie a bladder to the beak of it, and hold the retort over a lamp. The ether will quickly boil, and the gas which arises from it will soon occupy the bladder and distend it to its full size. If the bladder be then held in water, the gas will be condensed by the loss of its heat, and the bladder will collapse. In order for this experiment to succeed, it is necessary previously to warm the bladder to 80 or 90 degrees [*F*], to prevent the gas from being condensed in the first instance.[47]

Here Parkes uses simple instruments and materials, such as an animal's bladder, a retort, a little ether, water, and a lamp, to demonstrate the phenomenon and provides instructions to guarantee the expected effects.

While visual appeal was prevalent in the designed demonstrations, it was not the sole sensory aspect explored by Parkes in the footnotes. Some experiments also engaged the sense of smell, as seen in the production of ammonia described in the chapter entitled "Of Alkalies":

> By the following process ammonia may be formed, so as to become evident to the senses in a short time. Take some filings of tin or zinc, pour on them some moderately dilute nitrous acid. After a short time stir into the mixture some quick-lime [*i.e., calcium oxide*], or caustic alkali[48], and a very strong pungent smell of ammonia will be produced.[49]

The so-called "select instructive experiments" had a different objective from the experiments that figure in the footnotes. In the introduction to this chapter, Parkes points out that its original intent was to explain the reason for each experimental result and the concepts that the experiments illustrate to the pupil. However, he claims, such approach could undermine the inquisitive spirit that must be cultivated in youth; therefore, Parkes decided that he would only present the way of conducting the experiments and that it would be up to the student to seek the explanation of the causes and effects as presented in the previous chapters of the *Chemical Catechism*. At the end of each experiment, Parkes mentions the pages which refer to the respective concepts, so that the pupil would be able to consult them when trying to understand the observed phenomenon. Parkes also points out that one should not proceed to the next experiment if not completely satisfied with the self-elaborated explanation for the previous one.[50]

The "select instructive experiments" were presented in a numbered list which grew from one edition to another. The first edition of the *Chemical Catechism* lists 154 experiments, a number greatly increased in the following edition, with the addition of 91 experiments. Later editions had further additions, including nine experiments recommended by Humphry Davy, to whom Parkes thanked in a note: "For the following Experiments I am indebted to the polite communication of Professor Davy".[51] The latest editions featured 255 experiments in all.[52]

As mentioned above, explanations for the phenomena are not given with the description of the procedure of the "select instructive experiments", but should be found in the body of the preceding chapters. In the upcoming example, Parkes describes a mixture that produces heat and directs the reader to previous pages discussing the generation of caloric from mixtures (p. 73) and its role in maintaining bodies in a fluid state (p. 84):

> No. 1 . Take a small phial about half full of cold water; grasp it gently in the left hand, and from another phial pour a little sulphuric acid very gradually into the water. A strong SENSATION OF HEAT will immediately be perceived. This, by the continued addition of the acid, may be increased to many degrees beyond that of boiling water. See pages 73 and 84.[53]

In this instance, perceiving the phenomenon involves the sense of touch. Furthermore, other senses could also come into play. Experiments designed to engage sight, hearing, and smell are also described, as exemplified below:

> 33. Fix a small piece of solid phosphorus in a quill, and write with it upon paper. If the paper be now carried into a dark room, the writing will be BEAUTIFULLY LUMINOUS. See page 262 [*on the properties of phosphorus*].
> (...)
> 36. Take about six grains of oxymuriate of potass [*i.e., potassium chlorate*], and three grains of flour sulphur; rub them together in a mortar, and a smart DETONATING NOISE will be produced. (...) If the same mixture be wrapped in paper, laid on an anvil, and smartly struck with a hammer, the report will be as loud as what is usually produced by a pistol. See page 221 [*on chlorates (then called oxymuriates or hyperoxymuriates) and their explosive properties*].[54]
> 159. Take a small piece of phosphuret of lime [*i.e., calcium phosphide*], a little moistened by the air, and let a single drop of concentrated muriatic acid fall upon it. In this case phosphuretted hydrogen will also be evolved, accompanied by SMALL BALLS OF FIRE darting from the mixture, and the most intolerable fetid smell that can be conceived. See page 256 [*on the production and properties of hydrogen phosphide*].[55]

In this last example, the appeal is related to both smell and vision, and several other experiments jointly appeal to more than one sense. The only sense that is not explored is taste, although there are very few mentions of the taste of compounds produced in an experiment. The production of ammonium chloride, also known as *sal-ammoniac*, is illustrative:

> 24. Take carbonate of ammonia (the common volatile *smelling* salt), and pour upon it muriatic acid so long as any effervescence continues. The produce will be a SOLID SALT, perfectly *inodorous*, and of little taste. See page 165 [*on the production and properties of ammonium chloride*].[56]

The brief mention of the taste of ammonium chloride is neither part of the experiment's attractiveness nor of the analysis in discussion, but rather a passing description of an evidence that a new substance was produced in the chemical reaction.

The sensorial appeal was not only for Parkes, but for most of the popularisers of science at the time, a powerful asset to amaze the public, exciting curiosity for the scientific phenomena by means of explosions, colours, odours and lights. Such breath-taking experiments gained popularity and aimed the public of chemical lectures and demonstrations, as well as the readers of the introductory chemistry books. In the first half of 19th century, the public image of chemistry was that of "a science of the secondary qualities (colours, tastes, and smells), where thinking had to be done with fingers, nose, and eyes".[57]

Although Parkes stated that the experiments in his book were chosen because they could be carried out with "ease and *safety*",[58] many of them involve the handling of dangerous, toxic, easily flammable or potentially explosive substances, such as potassium chlorate (explosive), phosphorus (flammable), mercury and ammonia gas (toxic). In spite of the danger, Parkes not only teaches how to obtain such substances, but also suggests several experiments which require their manipulation. An example may be seen in the chapter on hydrogen, in which Parkes explains in a footnote how to obtain gaseous hydrogen sulphide:

> To obtain sulphuretted hydrogen gas [*i.e., hydrogen sulphide*], melt together in a crucible three parts by weight of iron filings and one of sulphur; reduce the mass to powder, and put it with a little water into a glass vessel with two mouths: lute one end of a crooked glass tube into one of these mouths, and let the extremity of the tube pass under a glass jar in a pneumatic trough, the jar being inverted and full of water. Then pour diluted muriatic acid through the other mouth of the vessel, which must immediately be closed up. Sulphuretted hydrogen gas will now be disengaged in abundance and flow into the glass jar, displacing the water.[59]

In addition to the seemingly light-hearted description of how to obtain dangerous substances, Parkes also suggests various experiments with explosive effects intended to amaze learners, some of them with the added risk of resulting in toxic products. Hence, the main criticism Parkes received in periodicals at the time was about the dangerousness of some of his experiments, which were certainly not recommended for beginners, much less for young people. According to an anonymous article published in *The Monthly Review*:

> The 'select instructive experiments' (...) are judiciously chosen. The only objection that we shall make to them is, that several of them appear of a hazardous nature. Desirous, probably, of exciting curiosity as much as possible, Mr. Parkes has too frequently introduced explosive or detonating substances, the management of which requires the greatest caution, and the most experienced dexterity. We should not deem it safe for a tyro in chemistry, even of advanced age, to repeat all the processes described by Mr. Parkes; much less would we trust such substances as phosphorus and the fulminating powder in the hands of 'young people'.[60]

However, Parkes is not completely reckless. In a few selected experiments, he gives safety warnings and explains how the demonstration could be done in a more cautious way, as in one of the experiments from the chapter on combustion:

> If one ounce of strong nitrous acid be mixed with about half its weight of concentrated sulphuric acid, and poured into a little oil of turpentine, the whole will immediately burst into flame. In this experiment it is the oxygen of the nitric acid which produces the combustion. The phial from whence the mixed acid is poured, should be tied to the end of a long stick, to preserve the operator from being injured by the splashing of the materials.[61]

The warning clearly seeks to protect the demonstrator from a possible projection of reagents due to the violence of the chemical reaction. Despite this caveat, however, the demonstration is still highly dangerous and possibly disastrous. Furthermore, warnings like these in the *Chemical Catechism* are much less frequent than desired or even necessary.

Sometimes the dangerousness of experiments is indicated by acknowledging the risks instead of an explicit warning. An example may be found in the chapter on metals, in which Parkes describes the combustion of metallic arsenic as a spectacular experiment: "If metallic arsenic be previously inflamed in oxygen gas, it will burn till the whole is consumed. The combustion is very brilliant, and forms a striking experiment".[62] In fact, Parkes acknowledges elsewhere that arsenic is poisonous, and that if a grain of white arsenic were administered all at once to a person, the result could even be death. Still, Parkes gives no instructions on how to manipulate the experiment's product, or on how to make the procedure more cautious. He just adds that if any amount is ingested on purpose or by mistake, "the best medicine is sulphuret of potash" (*i.e.*, potassium sulphide) dissolved in water.[63]

As editions went by, some security warnings were added, as one can see in the experiment that received the number 55 in the first edition and 60 in the second.

> 55. Take three parts of nitre [*i.e., potassium nitrate*], two of potash [*i.e., potassium carbonate*], and one of sulphur; make them thoroughly dry, and then mix them by rubbing them together in a warm mortar. The resulting compound is called *fulminating powder*. If a little of this powder be placed upon a fire-shovel over a hot fire, it gradually blackens, and at last melts. At that instant it EXPLODES WITH A VIOLENT REPORT.[64]

In the second edition, the same text is followed by a warning in italics: "60. (...) *Note, This mixture is not dangerous, like the metallic fulminating powders; none of the which should be entrusted in the hands of young people.*"[65] However, even with the additions, such alerts are very few compared to the number of dangerous experiments.

Parkes also adds in the footnotes of the *Chemical Catechism* many recommendations of other works with interesting experiments related to the topics discussed in his book, so the tutor could look for more demonstrations if he considered it necessary. Among these recommendations are works by Lavoisier, John Roebuck (1718–1794), Richard Chenevix (ca. 1774–1830) and Joseph Priestley.

EXPERIMENTAL CHEMISTRY: THE WONDERFUL AND THE USEFUL

In our analysis, the experiments presented in the *Chemical Catechism* were classified into six categories, according to their different objectives: (1) proof of statements; (2) attractive or curious phenomena; (3) demonstration of specific chemical phenomena; (4) laboratory procedures; (5) production of substances in laboratory; (6) processes related to industrial or large-scale production.

The first category (proof of statements) predominantly appears in the footnotes and encompasses the objective of articulating the main text with supporting experiments to validate the given scientific claims. Such experiments were proposed from a dogmatic perspective: Parkes presents them as a safe way to reach the truths of Nature, because, according to him, the rationalization of investigation and experiment would lead the young mind away from sophistry, fanaticism and superstition, which could deceive the unprepared mind.[66] An example is the way Parkes describes an experiment after stating that liquid substances are solid substances that have been converted into fluid by heat:

> The following experiment will *prove* that it is caloric which converts solids to fluids: – Expose a pound of water and a pound of ice, both at 32º [*F*], in a room the temperature of which is above the freezing point. The water will arrive at the temperature of the room several hours before the ice is melted. The caloric, therefore, which has all the time been entering into the ice, but is not to be found in it by the thermometer, must have become *chemically* combined with it in order to give it fluidity.[67]

Parkes' emphasis on the word "prove", together with the choice of terms when introducing other experiments in the footnotes – such as: "The operation of this principle may be made apparent by the following experiment";[68] "[*The pressure of the atmosphere*] may be shown by a simple experiment";[69] "This may be made evident by the following striking experiments";[70] "In order to be convinced that...";[71] and "[*That ice contains a large portion of air*] may be seen by the following experiment"[72] – show Parkes popularizing an image of science in which experimentation has a validation role. In these experiments, practice was a means of proving the theory that had previously been explained to the learner.

The second category (attractive or curious phenomena) includes experiments intended to fascinate the pupil to the point of provoking his mind to unravel the concepts behind the experiment. An example is the experiment to produce combustion under water:

> 39. Put a little oxymuriate of potass [*i.e., potassium perchlorate*] and a bit of phosphorus into an ale-glass, pour some cold water upon them cautiously, so as not to displace the salt. Now take a small glass tube, and plunge it into some sulphuric acid: then place the thumb upon the upper orifice, and in this state withdraw the tube, which must be instantly immersed in the glass, so that, on removing the thumb, the acid may be immediately conveyed upon the ingredients. This experiment is an example of a very singular phenomenon, COMBUSTION UNDER WATER.[73]

Other examples of this category are the abovementioned experiments numbered 1 and 36.

The third category (demonstration of specific chemical phenomena) consists of a selection of experiments in which Parkes gives an example of a concept or phenomenon. In their very statement Parkes makes it clear that the given experiment is an example, using expressions such as "This experiment will afford an example of...",[74] "This shows how...",[75] "This is illustrative of...",[76] as one can see in the example below:

> 118. Put a little alcohol in a tea-cup, set it on fire, and invert a large bell glass over it. In a short time an aqueous vapour will be seen to condense upon the inside of the bell, which, by means of a dry sponge, may be collected, and its quantity ascertained. This may be adduced as an example of the formation of WATER BY COMBUSTION.[77]

The fourth category (laboratory procedures) is characterized by the objective of teaching aspects of scientific methodology, general techniques – such as a test for analysing the components of a mixture – or even operations commonly used in the laboratory and in industry. In this category, there are experiments to which Parkes explicitly relates a given laboratory process as well as experiments whose application is implicit – such as when a precipitation is used to detect a substance. As examples, we quote below the experiment which teaches how to detect volatile acids and muriates (*i.e.*, chlorides) using ammonia, and also the description of the crystallization technique:

> 61. Whenever uncombined muriatic, or any volatile acid is suspected to be present in any chemical mixture, it may be detected by ammonia. A single drop of ammonia on a feather, or small slip of paper, held over the mixture, will immediately render the VAPOUR VISIBLE.[78]
> Take a portion of sulphate of soda (Glauber's salt) and dry it over a common fire, which will reduce it to less than half its weight. Dissolve this dried salt in three times its weight of boiling water, set the liquor aside, and, when cold, beautiful crystals resembling the original crystals will be found in the liquor. By an attentive examination

> of the liquor, the crystals may be seen to form as the liquor cools. This is a cheap and easy experiment, and may be exhibited to the pupil as an example of crystallization in general.[79]

The fifth category (production of substances in laboratory) covers the objective of teaching tutor and pupil how to produce some of the compounds mentioned in the main text, or how to obtain compounds necessary for the execution of other experiments. Unlike the demonstrations included in the previous categories, such experiments were neither intended to appeal to the senses nor to prove a concept, but only to produce something. In the following example, Parkes describes in a footnote to the chapter on acids how to obtain chlorine gas for experimental use:

> Oxymuriatic acid [*i.e., chlorine gas*] gas may be obtained for chemical experiments by the following method: Put into a retort a little black oxide of manganese in powder; and pour upon this double its weight of strong muriatic acid; connect the retort with the pneumatic trough, and receive the gas over water. When the ascension of the gas slackens, apply the heat of a lamp, and it will be disengaged in abundance.[80]

The sixth category (processes related to industrial or large-scale production) built in this analysis gathers experiments related to manufacturing processes found in British industries. Some of such industrial processes were of great economic interest at the time, such as dyeing and bleaching fabrics, or the application of prints on calico, silk and linen.[81] This category promptly refers to one of the first objectives presented by Parkes for writing and publishing the *Chemical Catechism*: to instruct young people so that they could better apply chemistry to improve their future professional activities.[82] One example is the experiment which describes printing on calico:

> 90. Dip a piece of white calico in a strong solution of acetate of iron; dry it by the fire, and lay it aside for three or four days. After this, wash it well in hot water, and then dye it black, by boiling it for ten minutes in a strong decoction of Brazil wood. If the cloth be now dried, any figures printed upon it with a *colourless* solution of muriate of tin, will appear of a BEAUTIFUL SCARLET, although the ground will remain a permanent BLACK.[83]

The analysis of the experiments reveals some of Parkes' conceptions about chemistry and its popularization. In the first place, it was necessary to attract the attention of the pupils, so that they would be interested in what chemists had to say – for this, nothing better than to amaze them with experiments and demonstrations that appealed to the senses by means of explosions, flames, colours, odours, unusual phenomena, which should also create emotional impact. Once their attention had been gained, it was necessary to make sense of such observations and explain what chemistry is all about. Hence the importance of experiments demonstrating phenomena or "proving" theoretical explanations. It was also necessary for pupils to understand how chemists work, what their devices and procedures are, so that they could also perform the same tasks – if not while young, perhaps in the exercise of their future professional activities. To make it possible, many experiments described laboratory techniques and processes. Experiments dedicated to the preparation of substances had a similar goal, providing chemicals which could be used in different manufactures and industrial processes.

Thus, the experiments that demonstrated processes related to the manufacture of useful things justified and served as a crowning achievement for learning chemistry, as it leads to the benefit of the nation and personal prosperity. One can imagine that, in a sense, Parkes projected his own personal trajectory into these experiments: he saved himself from bankruptcy, amassed fortune and fame by producing and selling chemicals.

FINAL REMARKS

In this paper, we aimed to analyse the different types of experiments described in the *Chemical Catechism*, considering their form and objectives. The experiments had different objectives, which determined their place in the text and the way they were described. Experiments could offer sensory, scientific and industrial appeal or be part of discussions of theoretical aspects of chemistry.

The experimental dimension of science can be singled out as one of Parkes' major concerns in writing the *Chemical Catechism*. Besides suggesting experiments in the footnotes throughout the main chapters, Parkes also devoted an entire section of his book to them.

One can observe that Parkes presented experiments with different objectives in mind: amazing pupils with attractive or curious phenomena; validating or demonstrating the main points of the chemical concepts presented in the catechetical part of the text; introducing laboratory processes; producing substances; and introducing processes related to manufacturing. The success of the *Chemical Catechism* may be seen as an index of the popularity of chemistry in a period in which this science was teeming with conceptual novelties and possibilities of applications to feed industrial development.

Given the variety of experiments proposed by Parkes, the contemporary reader may wonder whether they could still be used today to teach or promote chemistry to students or the general public. Many of the described demonstrations are ingenious and could serve as good starting points for discussions on chemical concepts. However, as seen in this article, current safety standards are much more stringent than in Parkes' time. Therefore, any of his experiments need to be carefully assessed for safety in order to evaluate their feasibility for use in the current context.

ACKNOWLEDGEMENTS

This work was supported by the National Council for Scientific and Technological Development – CNPq (Brasil) under Grants 426519/2016 and 312351/2020-8.

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