From Nantwich to Oxygen: Public Engagement in Chemistry at a Local-History Museum

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Abstract

Joseph Priestley, discoverer of oxygen, lived in Nantwich, Cheshire, UK, from 1758 to 1761. In 2019, an exhibition featuring his life and achievements, and also celebrating the International Year of the Periodic Table, was developed by Nantwich Museum. The historical research of Priestley's life, development of the exhibition and rationale behind the public-engagement events and activities are described. The integration of chemistry for all age groups throughout the exhibition and during events is discussed. Instructions for experiments and demonstrations are available as supporting information. The benefits of teamwork involving members with diverse subject expertise and the value of contributions from external organisations is emphasised. The exhibition successfully engaged Museum visitors with 18th century local history, the story of Joseph Priestley and chemistry concepts and experiments. Qualitative feedback from participants is presented along with the planned long-term legacy of the exhibition.

Graphical abstract

Keywords

General Public – History / Philosophy – Interdisciplinary / Multidisciplinary – Hands-On Learning / Manipulatives – Gases – Periodicity / Periodic Table

Introduction

Nantwich is a market town in south Cheshire, UK, famous for its Tudor buildings, salt, cheese and its role in the English Civil War; its small museum tells the story of the town's heritage.

The museum has a professional manager and its volunteer groups include an Education Team, Craft Group and Research Group. Research Group members have a diversity of backgrounds, including two chemists, who are also volunteers for the UK's Royal Society of Chemistry (RSC). Although predominantly focused on history, the museum is keen to incorporate STEM activities and exhibitions amongst its events and, for example, in 2017 successfully partnered with Keele University to host workshops for children who analysed the quality of the water in Nantwich's local river, the Weaver.

Although one of Nantwich's most eminent residents, it is not widely known amongst the local community that Joseph Priestley (1733-1804), polymath and discoverer of oxygen, was a minister and teacher there from 1758-1761, before his scientific discoveries.

UNESCO designated 2019 as the International Year of the Periodic Table (IYPT) to mark the 150th anniversary of Mendeleev's Table. This was widely recognised amongst chemists as an opportunity to raise awareness of the Table, and chemistry in general, to inspire people of all ages, experience and backgrounds. In the UK, the Periodic Table is introduced in the school National Curriculum at key stage 3-4 (11-16 year olds), making it an ideal entry point for engagement of this age group in chemistry.

The combination of local expertise, the opportunity provided by the IYPT, and the telling of the local-history story of Joseph Priestley's time in Nantwich being overdue, inspired the Museum's Research Group to develop the temporary "From Nantwich to Oxygen: Joseph Priestley's Journey of Discovery" exhibition, which ran from 14 August – 26 October 2019.

Approach

Science falls outside Nantwich Museum's usual scope and for the exhibition to be successful it needed to engage visitors of all ages, with diverse interests and different levels of scientific knowledge. The small size of the museum plus the timing (summer vacation period) and short duration of the exhibition necessitated that the learning opportunity should be informal and not a formal out-of-school program aligned directly with the UK's National Curriculum.

Of utmost importance was for visitors not to be put off by science. Roger Highfield, director of external affairs at the Science Museum Group, London, recently put forward approaches to public engagement with science,[1] suggesting that the place to begin is with the interests and preoccupations of the target audience. For visitors to Nantwich Museum, this is generally local history, with art, crafts, maps and shopping as secondary reasons for their visits. It has been suggested[2] that museums can be one of a number of facilitators for communicating science to the public. Recently a National Academies' report,[3] *Effective Chemistry Communication in Informed Environments* was summarised by Kirchoff,[4] who also discusses the multitude of channels through which chemistry can be communicated, along with the motivations of chemists who engage with the public in this way. A study by Sheng and Chen[5] concludes that an individual's museum expectations and experience are influenced by multiple factors. Mindful of the exhibition's science content, the Nantwich team realised that its scope might not align with the expectations of some visitors.

It was therefore decided that the exhibition should blend local history, religion and education in the 18th century, and science – all part of Priestley's story – and from there move on to the Periodic Table. This route was likely to work for adults, but other approaches would be needed to engage children.

Borrows[6] discusses the value of chemistry trails: "Once accustomed to looking at the environment through chemical eyes, it was almost impossible to avoid spotting further manifestations of chemistry in the surroundings." Although primarily focusing on outdoor trails, many of the concepts presented by Borrows also apply indoors, and lend support to our plan to develop a museum trail for children.

With the intention of securing financial support, expertise and ideas, the possibility of partnerships with outside organisations was explored. Facilitated by the museum's RSC members, support was received from RSC staff and volunteer-led groups. A consequence of this was that, thanks to the anticipated publicity to RSC members, professional chemists would be amongst the visitors, so it was important for them not to be neglected in the exhibition's offerings. Fruitful partnerships were also established with the Joseph Priestley House [7] in Northumberland, Pennsylvania, and chemists at Keele University and the University of Manchester.

It was also decided to involve the full range of Nantwich Museum's volunteers, not only the Research Group, so that they became stakeholders in the project. For example, the Craft Group embroidered a Periodic Table and in the process members of that group became interested in the Table itself.

The Research Group, whose diverse range of expertise includes chemistry, sociology, art, map making, graphic design, history and IT, contributed to development of materials which would successfully engage visitors by contributing different approaches to presenting information.

STEM learning in history museums

A number of museums demonstrate public engagement in STEM subjects. Understandably, most are natural history and other science-based museums. Located about an hour from Nantwich is the Catalyst Science Discovery Centre,[8] Widnes, Cheshire, whose scope is the development of the chemical industry from ancient times up to the 1940s and includes a programme of workshops for school groups aligning with the UK school science curriculum.

Few history museums appear currently to provide opportunities for science education. Nantwich Museum's volunteer Education Team develops and organises primary school visits (5-11 year olds) which focus on local history, in particular the Tudors due to the town's many buildings from the period; this type of activity is common for museums of its type.

A recent local public-engagement example is a collaboration between Keele University and Blists Hill visitor centre, a reconstructed Victorian town in Ironbridge, Shropshire.[9] The town's pharmacy had >300 original jars with original contents, and under the supervision of chemists, volunteer members of the public analysed samples to determine their composition and associated risks.

The Joseph Priestley House[10] in Northumberland, PA, USA, has a number of learning opportunities in both history and science. One has been adopted by the ACS as a "Chemistry for Life Landmark Lesson Plan",[11] for use in schools for grade 9-12 students. The Joseph Priestley House also offers school tours, history camps and standards-based educational programming.

It is recognised in the museum sector that history museums need to attract visitors with interests outside their normal scope, including via STEM subjects, to increase their relevancy to the 21st century, in the process providing additional opportunities for engagement with science.[12] One example of a history museum which has achieved this is Conner Prairie,[13] an interactive living history site in Fishers, IN, USA, which was awarded a grant from the National Science Foundation (NSF) for this purpose. The goal of the project, entitled Prairie Science, was to develop a framework for integrating informal science experiences into exhibits, interpretation and programs at historic sites and museums. An aim was to demonstrate the importance of science, engineering and technology in shaping the past and creating ways for visitors, particularly families and children, to learn scientific methods and principles related to topics in history, while maintaining the overall historical focus. Although on a much larger scale, this objective chimes with that of Nantwich Museum's exhibition.

An interesting example of a UK organisation which offers a multitude of activities and services for the local community, but does not itself have a science focus, is the Byker Community Centre, Newcastle-upon-Tyne, where informal chemistry activities were delivered by eight volunteer scientists helped by four "Kemical Kids" who had attended previous pilot events and qualified as "Science Assistants".[14]

It has been reported widely that museums represent one of a range of important informal learning environments where children can broaden their cultural horizons and discover STEM subjects long

before they do so in school. Braund[15] articulates these benefits and the importance of contextual learning through presentation of exhibits in social, industrial and historical settings. A further example is the parent-child conversations which can take place,[16] and this is an aspect that was actively encouraged during Nantwich Museum's exhibition.
Nantwich Museum is fortunate to have several volunteers with a science background, but museums without this skill set should still be able to stage science-based exhibitions and events by engaging with local scientists, from, for example, universities, professional bodies, and science-based museums. For scientists involved with outreach, museums present opportunities for collaboration, sharing expertise and resources to relate science to historical and everyday objects, thereby inspiring people of all ages to make connections between disciplines.

Historical research

The availability of Priestley's memoirs[17] simplified the gathering of information about his life, and a number of biographies and articles provided more detail about his discoveries.[18,19,20,21,22,23,24,25] Many of Priestley's original documents are available through Archive.org and Google books. Priestley's time in Nantwich is also described in local history books and records, which also provided insight into the environment in which Priestley lived while in the town.[26] The RSC Library's image collection was a source of high-quality images for the printed information panels.
Much has been written on the origins and development of the Periodic Table. A range of publications were consulted, including: books with broad coverage;[27,28] papers on specific aspects[29,30] and the discoverers of the elements;[31] topical articles published for the IYPT. [32,33]

Joseph Priestley's life and achievements

Priestley was a polymath and his diversity of interests, skills and passions make him an ideal focal point to engage exhibition visitors interested in but one aspect of his character and then lead them in other directions, including chemistry.
Even if he had not achieved greatness as a scientist, Priestley would have been recognised as a pioneer of education and religious and civil liberty. His many publications reflect his diverse interests and he found no conflict between science and religion – scientific enquiry uncovering the workings of providence.
Priestley was born in Fieldhead, near Leeds, on 24 March 1733, to a Congregationalist family and was the eldest of six children. His mother died when Joseph was six. He was adopted by his aunt, Sarah Keighley, a Calvinist and Joseph was exposed to people who debated radical religious ideas. During his school years he studied languages, geometry, algebra and mathematics. When 11, he performed his first scientific experiment, confining spiders to bottles to see how long they lived without fresh air! Ideas of the Enlightenment – the 'Age of Reason' – had great influence, and modern science, described at the time as 'natural philosophy', was beginning.
Aged 19, Priestley went to the dissenting academy at Daventry to prepare to join the ministry, studying there for three years. Although religious freedom was increasing, Dissenters had fewer civil rights than members of the Church of England. His first appointment after Daventry was to a chapel in Needham Market, Suffolk. His time there was difficult, but in 1758, he was appointed as a minister at the Presbyterian chapel in Nantwich, staying until 1761. Priestley established a school in Nantwich and enjoyed teaching there. The school had about 30 boys and about half a dozen "young ladies" in a separate room. Priestley worked six days per week from 7am-4pm, with one hour off for dinner. The subjects he taught included Latin, Greek, geography, natural philosophy and mathematics. He encouraged free enquiry, argument and debate. He supplemented his income by private teaching after school hours.
Priestley established a small school library and purchased some "philosophical instruments", including a small air pump and an electrical machine. He used these to teach his older students and to entertain their parents and friends with his experiments. It has been suggested that Priestley's scientific teachings constitute the first ever school science lessons.[34,35] He also wrote *Rudiments*

of English Grammar, based on the lessons he taught at his school, first printed in 1761 just after he left Nantwich – a seminal work used by teachers for many decades. In Nantwich, Priestley was laying the foundations for his future scientific work.

In September 1761, he was appointed tutor in languages and polite learning at the dissenting academy at Warrington. In 1762 he married Mary, daughter of Mr Isaac Wilkinson, a well-known ironmaster. Priestley extended his connections with influential and learned people, including Benjamin Franklin and his interests in science grew. He worked on electricity, publishing *The History and Present State of Electricity, with Original Experiments* (1767) and, in 1766, was elected a Fellow of the Royal Society.

In 1767, Priestley was appointed minister at Mill Hill Chapel, Leeds. He lived next to a brewery and investigated carbon dioxide (known then as 'fixed air'), produced by fermentation. He found that water impregnated with fixed air became fizzy, thereby inventing soda water though he did not commercialise it.

Priestley discovered oxygen, which he called 'dephlogisticated air', in 1774, while librarian and companion to Lord Shelburne in Calne, Wiltshire. He adhered to the theory of phlogiston, which dated back to 1669, and argued that metals consisted of an inflammable part (phlogiston) and a 'calx' or ash (the non-flammable portion). Combustion liberated the phlogiston from the burning metal. Dephlogisticated air should be able to take up more phlogiston than the same volume of ordinary air. Flammable materials would burn more brightly in dephlogisticated air (since they could give up their phlogiston more readily) and it should be able to support life for longer. Priestley's experiments confirmed both.

Unbeknown to Priestley, he was not the first to isolate the gas, as Swedish apothecary Carl Wilhelm Scheele had done this shortly beforehand; Priestley was the first to publish the discovery, however. Shortly after this, he travelled to Paris where he met Antoine Lavoisier,[36] now widely considered to be the founder of modern chemistry, who repeated Priestley's experiment, subsequently renaming the gas oxygène. Lavoisier challenged Priestley's phlogiston-based explanation, despite the latter's continued defence of the theory (which he continued for the rest of his life).[37,38,39] All three, Scheele, Priestley and Lavoisier can be considered to be the discoverers of oxygen.

Priestley's discoveries of gases and experiments are recorded in his most famous publication, a six-volume work *Experiments and Observations on Different Kinds of Air* (1774-86). Humphry Davy stated of Priestley "No other person ever discovered so many new and curious substances".

After Calne, Priestley moved to Birmingham, taking a position as a minister. There he became a member of the Lunar Society, a group of progressive thinkers that included Josiah Wedgwood and James Watt.

Priestley's political and religious opinions angered many and worried his supporters. His notoriety contributed to the eruption of the 'Priestley Riots' in Birmingham in 1791, when several buildings, including his own residence, were burnt down. His liberal viewpoint led him to support the French revolution, American independence[40] and ending the slave trade.

After a spell in Hackney, London, in 1794 Priestley followed many others who had been persecuted for their beliefs by moving, with Mary and one of their sons, to America. Despite being offered prestigious positions in Philadelphia, Priestley chose Northumberland, Pennsylvania, as his home, as two of his sons had already moved there. Sadly, Mary and one of his sons died soon after the move. Joseph Priestley died there on 6 February 1804.

The exhibition

A key objective of the exhibition was to engage visitors with Joseph Priestley and the Periodic Table through a diversity of media and making connections between chemistry and history. Oxygen served as the link between Nantwich and the Periodic Table, with information presented on engaging display panels. Visitors were guided from Priestley's life and achievements before, during and after Nantwich to his oxygen discovery and to its place in the Periodic Table.

In order not to overwhelm readers, Nantwich Museum's policy is to restrict the number of words to about 200 per information panel and to aim for written content to be suitable for young high-school-age students. Since the key themes were Joseph Priestley, Nantwich, oxygen and the Periodic Table, it was necessary to limit the quantity of information about Priestley's time spent in other locations, his discoveries other than oxygen and full detail of the Periodic Table.
The text was accompanied by images, including paintings by the museum's artist (Figure 1), images from the RSC's historical collection image library, Priestley's publications, and historic Periodic Tables. A map, designed by a museum volunteer, showed Priestley's travels across the UK and his emigration to the USA. The Joseph Priestley House allowed the introductory panel in their display, which included a timeline of Priestley's life and achievements, to be reproduced.

Figure 1. Painting of Priestley's school in Nantwich by Les Pickford, the Museum's artist. Reproduced with permission.

Panels with chemistry content featured the Periodic Table, explanations of Priestley's experiments and modern-day uses of oxygen. Non-scientist members of the Research Group helped ensure that the content was appropriate for the anticipated broad audience. Past experience at Nantwich Museum has shown that art is very popular amongst visitors. Framed pictures, including a view of Nantwich painted around 1790 which would have been much as when Priestley resided in the town, a portrait of Priestley and a reproduction of John Dalton's atomic symbols were on display. Exhibits included two pairs of Priestley's spectacles, some of his original written works including sermons, letters and notebooks (loaned by Warrington Archives and Harris Manchester College Oxford). Molecular models, a children's chemistry set from the 1960s, a photosynthesis experiment and the

museum's Craft Group's embroidered Periodic Table were displayed. More in-depth information was provided in folders, including material developed by the RSC specifically for the IYPT, historical articles about Priestley's life, reproductions and transcriptions of sections from Priestley's original hand-written books and sermons, detailed content developed internally which could not be accommodated on the information panels, and relevant cuttings from local newspapers. This content was noticeably more used than anticipated.

Children's activities

Throughout the exhibition games and quizzes were available for children, including magnetic element symbols for arrangement on a whiteboard, books, crosswords and a giant Top Trumps card game.

An Element Trail around the museum enabled children to learn about elements present in historical exhibits as well as extend this learning to modern-day context. To complete the trail, children had to locate objects labelled with Element Trail posters. For example, the museum has a Medieval gold brooch in its collection – as well as finding the brooch and learning that it is made of gold, the poster provided information about gold's low reactivity, malleability, rarity and modern-day uses. Children who found all the elements were awarded a small prize. Museum volunteers at the reception desk encouraged children to complete the challenge. The volunteers themselves, as well as parents and other adults, also often completed the activity. A child's entry in the museum's visitors' book confirmed that she "Really enjoyed the elements exhibition and trail". This is an approach to incorporating science that Nantwich Museum is aiming to deploy more widely in the future, as it delivered the double benefit of engaging visitors closely with the historical exhibits as well as making connections between science and history. Posters and the stamp card for the Element Trail are available on Nantwich Museum's website.[41]

An activity with teenagers in mind was a "Priestley Poser" selfie competition, where visitors were provided with period wigs in which to pose for photos.

"Priestley's Element", a drop-in event, was delivered as the finale for engagement of the younger/family audience. Heidi Dobbs, the RSC's local education coordinator developed and facilitated the potentially repeatable event. Delivery was led by trained volunteers from the RSC's North Staffordshire Local Section. Five hands-on experiments were available, including for young children a "crafty molecule" activity to make oxygen models using pipe cleaners and beads, and for older children a "Priestley's molecule" experiment to investigate the properties of carbon dioxide. Over 70 thoroughly engaged children and adults, learnt about carbon dioxide, properties of metals, spectroscopy and more. Feedback from children included: "It's really good where you can come and make things and do lots of experiments" and "I enjoyed testing all the different metals with magnets. It's a great day out and you should definitely come"; and from a parent: "Very interesting, lots going on, plenty of activities for the children, caters for all ages. We've had a great morning." Details of the organisation of the Priestley's Element event and the risk assessment are available as Supporting Information.

Events for adults

A range of unique public-engagement events was organised and featured invaluable contributions from Nantwich Museum and RSC volunteers.

The first event was a celebratory reception for museum members, sponsors, local politicians and supporters of the exhibition, with entertainment ranging from flute music (Priestley learnt to play the flute while in Nantwich) to live chemistry. The keynote speaker was chemist Professor Mark Ormerod, Deputy Vice Chancellor and Provost at Keele University. A demonstration by Keele's Dr Katherine Haxton featured the catalytic decomposition of hydrogen peroxide, producing "elephant's toothpaste".[42] The reception proved to be a valuable opportunity for word-of-mouth publicity, by guests to their families and friends, for the exhibition and subsequent events.

A Periodic Table themed community coffee morning, featuring cakes decorated with Periodic Tables plus quizzes and activities, was organised and attracted participants from far afield as well as Nantwich residents, including a family with home-schooled children. "Joseph Priestley's Footsteps" walking tours around Nantwich were also organised, showing where Priestley lived, the site of his school and chapel, and describing what he would have seen in the 18th century.

A sold-out programme of talks, "Joseph Priestley in his Element", was chaired by Professor Dame Janet Finch and featured Priestley's time in Nantwich (Dr Helen Cooke, Nantwich Museum), his alliance with Josiah Wedgwood and Thomas Bentley (Gaye Blake-Roberts, Wedgwood Museum), his membership of the Lunar Society (Cameron Arthur, Soho House Museum), and exciting chemistry demonstrations bringing Priestley's work to life (Dr Fabio Parmeggiani, University of Manchester), about which an attendee commented "If only my school chemistry lessons had been half as entertaining!". Others said, "Thank you for an excellent afternoon of talks...I came for the history, but I really enjoyed the science too!" and "Warm congratulations for putting together such a great event. It was excellent in every way."

The demonstrations involved the preparation and hydropneumatic collection of oxygen gas and its combustion-enhancing properties (Figure 2). In order to avoid the handling of mercury compounds, oxygen was generated by the catalytic decomposition of hydrogen peroxide, but the collection method and the experiments performed are the same as Priestley's. In particular, the relighting of a wooden splint and the vigorous combustion of a hot coal were performed, along with the most famous demonstration of the comparison of a candle flame in pure oxygen and in air. Specific quotes from Priestley's works were read alongside each of the demonstrations, strengthening the link between science and history. Detailed instructions, videos of the demonstrations and the selected quotes are available in the Supporting Information.

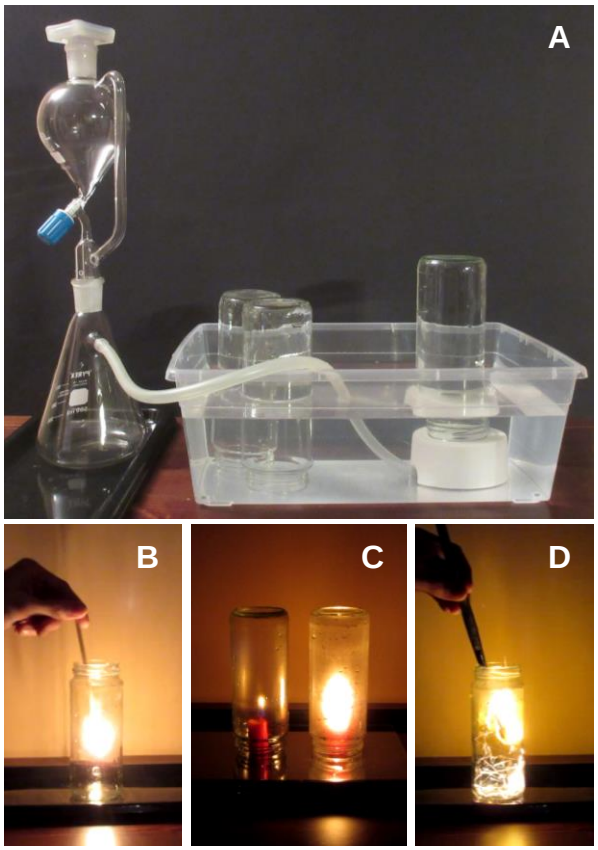

Figure 2. Reproduction of some of Priestley's experiments on oxygen for a lecture demonstration. (A) Apparatus for the generation of oxygen from hydrogen peroxide, with hydropneumatic collection of

the gas into glass jars. (B) Relighting of a wooden splint in oxygen. (C) Comparison of a candle flame in air and in oxygen. (D) Combustion of a hot coal in oxygen, producing bright white sparks.

In total, the events attracted around 250 participants, ranging from school-age children to senior citizens. Details are included in the Supporting Information. During the exhibition period there were around 3000 visitors to the museum, either coming specifically to see the exhibition or for a general visit. A summary of the exhibition and events has been published in the RSC's newsletter.[43]

Legacy

Nantwich Museum is keen to ensure that although the exhibition was only temporary, its impact will live on.

- The exhibition materials and images of the exhibits and events are available on Nantwich Museum's website,[44] acting as a reminder to exhibition visitors and making them available to those unable to visit in person.
- A local history booklet about Priestley's time in Nantwich was published to accompany the exhibition and will continue to be available in the museum's shop in print and digital form.[45]
- The museum is planning to remodel its main galleries, which will provide the opportunity to develop a permanent exhibit focussed on Priestley, based on the research undertaken.
- Due to the positive experience of delivering STEM activities during the exhibition and feedback received, the museum has increased confidence to develop similar events and activities and is planning to produce a customised educational activity pack for children which will be permanently available.
- The information panels and embroidered Periodic Table are being made available for loan to local schools and other interested organisations.
- Contributions are being made to the forthcoming new edition of Joseph Priestley's memoirs currently under development by the Joseph Priestley House.

Conclusion

Relating chemistry to the museum's exhibits and local-history stories was key to success, as was having a range of activities and events to engage all age groups. The embroidered Periodic Table was a popular talking point amongst children and adults interested in embroidery as well as history and chemistry. The live chemistry demonstrations were hugely popular but need to be well planned and scaled to the fit the size of the venue.

Partnering with external organisations proved to be invaluable, their contributions including:

- Access to a wide range of publicity channels.
- Speakers and demonstrators for events.
- Knowledge and expertise.
- Loan of exhibits.

Through this project, the museum was able to develop and consolidate relationships with external organisations which will help enable future STEM activities.

One museum member commented: "At last we've had a proper tribute to Joseph Priestley in Nantwich".

Associated Content

Supporting information:
Event attendance numbers.docx

Priestley's Element drop-in workshop - activity plan and risk assessment.pdf
Priestley's experiments demonstration - Movie S1.mp4
Priestley's experiments demonstration - Movie S2.mp4
Priestley's experiments demonstration - Movie S3.mp4
Priestley's experiments demonstration - Movie S4.mp4
Priestley's experiments – procedure for demonstration on oxygen.pdf

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