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THE

INSTITUTE OF CHEMISTRY

OF

GREAT BRITAIN AND IRELAND

FOUNDED 1877. INCORPORATED BY ROYAL CHARTER, 1885.

JOSEPH PRIESTLEY

1733—1804

BY

ROBERT MARTIN CAVEN, D.Sc., F.I.C.

(*Member of Council.*)

30, RUSSELL SQUARE, LONDON, W.C.1.

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This Lecture was delivered before the Institute of Chemistry at 30, *Russell Square, London, W.C.*1, *on the occasion of the Bicentenary of the birth of Joseph Priestley,—*13*th March,* 1933*—Professor Jocelyn Field Thorpe, C.B.E., D.Sc., F.R.S., President, in the Chair.*

JOSEPH PRIESTLEY

1733—1804

By ROBERT MARTIN CAVEN, D.Sc., F.I.C.
(*Member of Council.*)

I COUNTED it a great honour to be asked by the Council of the Institute of Chemistry to deliver a lecture in commemoration of the bicentenary of the birth of Joseph Priestley. I undertook the task of preparation with much pleasure, and my interest in the theme has increased as the work has proceeded. I hope

BIRTHPLACE OF PRIESTLEY.

that, as the result of the time we spend together, you will fully share with me the admiration I feel for the subject of our study.

As you entered this building to-night you passed under the figure of a man dressed in the style of a hundred and fifty years ago, and seated in an attitude of thoughtfulness, with a scroll across his knees. You may see the same figure above the doorway in the design of the cover of the Institute's *Journal and Proceedings*. This is Joseph Priestley, whose image is thus set to watch perpetually over the doings of our Institute.

Again, on the staircase you passed another figure of Priestley, this time standing and active, with both hands engaged upon a well-known experiment. This figure is a copy of a statue which was unveiled at Birmingham by Professor T. H. Huxley to commemorate the centenary of Priestley's discovery of oxygen; and when the Institute required a Seal Sir William Tilden, at that time Professor of chemistry at Mason College near by, suggested that the design of that statue should be adopted. Thus there was enshrined, not only in a local habitation, but wherever the Institute is known, the memory of a great chemist whom our founders delighted to honour, and whom we, their successors, honour to-day on the two hundredth anniversary of his birth. How wise and happy was that choice we are all agreed; and so it is my privilege to rehearse in your hearing to-night the life story of the man whom we have adopted as our patron—I had almost said: our patron saint, our hero.

For Priestley was more than a great chemist, he was a great man; and I am glad that the title of my discourse, "Joseph Priestley: 1733–1804," taken from the inscription below the figure on our building, gives me liberty to tell, at least in outline, the story, not only of his chemical labours, but also of those other activities which made his life so full. In the lives of some great chemists there is little of general interest besides chemistry; but it is not so in Priestley's life. If he were not known as a great chemist he would still be known as a pioneer of religious and civil liberty; and, while it is not our business to make comment on his theology or philosophy, either with approval or disapproval, it will be necessary for us to take account of the influence on his character and conduct of those great adventures in the realm of the spirit which added zest to his life and excitement and danger to his dealings with his fellow-men.

The Priestleys, we are told, were people of substance in the yeoman class, and noted for their simple piety. The names of their children were always Bible names, and our Joseph, born on 13th March, 1733, was so named after his paternal grandfather, and was the eldest of six: four sons and two daughters. His birthplace was Fieldhead, a wayside farmhouse in the parish of Birstall, near Leeds; and his father was a weaver and dresser of "homespun" which he sold in the district. The Priestleys were Congregationalists, and Joseph was taught by his mother the Westminster Catechism, which he could repeat at the age of four. His mother died when he was six years old, and when

he was nine he was adopted by his Aunt Sarah, Mrs. Keighley, "a truly pious woman who knew no other use of wealth, or of talents of any kind, than to do good, and who never spared herself for this purpose." Mr. Keighley was a churchman, but Mrs. Keighley, though a Calvinist, entertained dissenting ministers to a dish of tea, and made honest heretics welcome. No doubt young Priestley learnt much from those heretical divines.

He was sent to several private schools, also to Batley Grammar School; and at the age of twelve or thirteen he began to make progress with Latin and Greek, whilst learning Hebrew from John Kirkby, a Congregational minister. His aunt, whom he describes as "in all respects as perfect a human character as I have yet been acquainted with," designed him for the ministry; but, being delicate, he was removed from school and spent two years at home. During his schooldays, at the age of eleven, he performed his first scientific research by confining spiders in bottles and seeing how long they could live without fresh air.

That he was not idle while absent from school, however, is shown by the fact that he acquired a knowledge of geometry. algebra, and other branches of mathematics, and taught himself French, German, and Italian, with a view to entering trade. He also read books on Natural Philosophy and Logic, as well as Locke's *Essay on the Human Understanding*, and studied Chaldee, Syriac, and Arabic. These intellectual exercises led him to doubt the narrow Calvinism in which he had been brought up, and particularly he was troubled because he could not feel a proper repentance for the sin of Adam. Notwithstanding his growing heterodoxy, and the fact that he was refused admission as a communicant at his aunt's church, he was still encouraged by that worthy woman to prepare for the ministry; and as his health had improved he was sent at the age of nineteen to Daventry Academy, where he remained three years. The Principal spoke of the new student as one who "seemed to be a good, sensible young fellow, though he has unfortunately got a bad name—Priestley; those who gave him it I hope were no prophets." Certainly they were not; he hated priestcraft.

Here he was very happy, and he ever cherished the memory of his *alma mater*.

Free discussion on many questions was encouraged, and in 1754, at the age of 21, Priestley announced that he was a determinist. In spite of, or perhaps because of, his heterodoxy—and he was heterodox in many things—he was very earnest and

desirous to adorn his chosen calling; yet he suffered from one serious drawback: an inveterate stammer. In later life he wrote:

> "Without some such check as this I might have been disputatious in company, or might have been seduced by the love of popular applause as a preacher; whereas my conversation and my delivery in the pulpit having nothing in them that was generally striking, I hope I have been more attentive to qualifications of a superior kind."

Yet this may have contributed to his success in another direction. If he could not speak well, he could write fluently, as the length and diversity of his publications testify.

His first appointment was as Assistant to an aged Presbyterian minister at Needham Market, Suffolk. He was promised a salary of £40 per annum, but received only £30. His aunt provided another £20, but this was not enough. Moreover, stammer and heterodoxy made him unpopular. "At Needham," he says, "I felt the effect of a low, despised situation, together with that arising from the want of popular talents."

To eke out a livelihood he proposed to become a schoolmaster, but efforts to secure boarders failed, partly because of his unpopularity, but also because he was unmarried. Then he gave a course of twelve lectures to adults on "The use of the Globes," but barely succeeded in paying for his globes. At this juncture a relative procured for him an opportunity to preach at Sheffield; but his style was thought "too gay and airy," and he was not chosen. Through the good offices of a Sheffield minister, however, he was appointed to a church at Nantwich, Cheshire, and here he was more successful; for though his congregation never exceeded sixty persons they were tolerant and kind. Here he learnt to play the flute, and also started a school. Regarding music he said:—

> "I would recommend the knowledge and practice of music to all studious persons; and it will be better for them if, like myself, they should have no very fine ear or exquisite taste, as by this means they will be more easily pleased and be less apt to be offended when the performances they hear are but indifferent."

And regarding his school:—

"My school consisted of about thirty boys, and I had a separate room for about half a dozen young ladies. Thus I was employed from seven in the morning until four in the afternoon, without any interval except one hour for dinner, and I never gave a holiday on any consideration, the red letter days, as they are called, excepted."

He was now better off, and could afford to purchase books and philosophical instruments, such as an air-pump and an electrical machine. Moreover, his friend Joseph Brereton, vicar of Acton, near Nantwich, gave him a telescope made with his own hands! We may be sure that Priestley's pupils profited by these acquisitions.

In 1761, at the age of twenty-eight, he was appointed tutor in classical languages and polite literature at "The Warrington Academy for the Education of young men of every religious denomination for the Christian Ministry, or as laymen." He was six years at Warrington, and whilst there published a *Chart of Biography*, which procured for him the L.L.D. degree of Edinburgh University. There also he undertook two other responsibilities. On 18th May, 1762, he was ordained, and on 23rd June he was married at Wrexham to Mary, only daughter of Isaac Wilkinson, Ironmaster, of Bersham Foundry, near Wrexham. Mary was eighteen, Joseph twenty-nine. His wife is said to have been a woman of sound culture and strong sense. She once sent her famous husband to market with a large basket, and he so acquitted himself that she never sent him again! Priestley described her as very orthodox, but his brother Timothy thought not. At the wedding the bride was to have been given away by Priestley's pupil Thomas Threlkeld, but Thomas found a Welsh Bible in the pew, and was so absorbed in it that he forgot what he was there for.

The earliest known portrait of Priestley was produced while he was at Warrington. He appears as a frail young man with an intellectual face; his long neck surrounded with the white stock or choker of the period, while he wears a full-bottomed wig, which he always did until he went to America.

It must be recorded, too, that a certain Dr. Matthew Turner of Liverpool visited Warrington Academy to lecture on chemistry, and that it was these lectures which started Priestley's interest in the science. He admits that at this time he knew very little chemistry.

In 1764, when he was 31, Priestley published an *Essay on Education*, and the following paragraphs from the introduction show his enlightened views:—

> "There is certainly a call upon us to examine the state of education in this country, and to consider how those years are employed which men pass previous to their entering into the world; for upon this their future behaviour and success must, in a great measure, depend. A transition, which is not easy, can never be made with advantage; and therefore it is certainly our wisdom to contrive that the studies of youth should tend to fit them for the business of manhood; and that the objects of their attention, and turn of thinking in younger life, should not be too remote from the destined employment of their riper years. If this be not attended to they must necessarily be mere novices upon entering the great world, be almost unavoidably embarrassed in their conduct, and, after all the time and experience bestowed upon their education, be indebted to a series of blunders for the most useful knowledge they will ever acquire.
>
> That man is the friend of his country who observes and endeavours to supply any defects in the methods of educating youth."

These are surely wise views; but lest you should think the plea for vocational training too strong, it must be pointed out that, as Priestley says, the whole plan of education, from the Grammar School to the University, was framed for those who were intended for Holy Orders; and others had to be satisfied with this plan or go without. Thus we can understand why Priestley wished to add to such a curriculum, or substitute for it, such subjects as: civil history, civil policy, the theory of laws, government, manufactures, commerce, etc.; because he was concerned with education for citizenship and for public service. It is said that Herbert Spencer owed some of his ideas concerning education to Priestley.

About this time Priestley spent a month annually in London, to his great intellectual refreshment. Here he met and established a valuable friendship with Benjamin Franklin; also with Canton, the discoverer of the "phosphorus" which bears his name, and with Dr. Price who figures later in the story. In a letter to Canton, dated 14th February, 1766, he wrote:—

"The time I had the happiness to spend in your company appears upon revision like a pleasing dream. I frequently enjoy it once again in recollection, and ardently wish for a repetition of it. I wish, but in vain, that it may ever be in my power to return in kind your generous communication of philosophical intelligence and discoveries."

Franklin encouraged Priestley to write *The History and Present State of Electricity*. This included some of Priestley's own investigations, and secured his election to the Fellowship of the Royal Society on 12th June, 1766. Sir Edward Thorpe says it was Franklin who made Priestley into a man of science. Priestley was singularly happy at Warrington, though his salary was only £100 a year with a house. This he augmented by taking in a few boarders at £15 each. Concerning his life at Warrington he writes:—

"The tutors in my time lived in most perfect harmony. We drank tea together every Saturday, and our conversation was equally instructive and pleasing."

His wife, however, was in indifferent health, and he resolved to seek another pastorate.

In September, 1767, he accepted a call to Mill Hill Chapel, Leeds. His salary there was little more than at Warrington, but he had more leisure. Whilst waiting for his house, he lodged in Meadow Lane, next door to a public brewhouse. This is of great significance because it led him to experiment with "fixed air," and a little later to the invention of soda water, which was used at sea with the idea of preventing scurvy.

For this refreshing contribution to applied science Priestley was awarded the Copley medal of the Royal Society; and it was proposed that he should accompany Captain Cook on his second voyage to the South Seas; but, although his congregation would have liberated him for a period, he forfeited the appointment because of his heretical opinions, which it was feared might undermine the piety of the sailors.

Priestley was six years at Leeds, and founded the Leeds circulating library. It was also during this period that a woman supposed to be possessed of an evil spirit asked "the great philosopher who could perform miracles" to cure her. He exorcised the demon by the use of his electrical machine! When he left Leeds he gave away the earthen trough in which he had

made all his experiments on air. "It was such an one," he says, "as is commonly used for washing linen."

December, 1772, marked a notable turning point in Priestley's life. William Fitzmaurice Petty, second Earl of Shelburne, afterwards first Marquis of Lansdowne, offered him an appointment as Librarian and Literary Companion to himself. His chief duties were to be the preparation of Parliamentary information for the Earl, and the education of his sons; whilst he would have leisure to pursue his studies, and might preach when he pleased. His salary was to be £250 with an allowance of £40 for experiments. He would occupy a pleasant house at Calne, Wiltshire, during the summer, and rooms in his patron's house in Berkeley Square in winter.

Priestley resigned Mill Hill in December, 1772, preached his farewell sermon on 16th May, 1773, and removed to Calne in June. Regarding this change Josiah Wedgwood wrote:—

> "I am glad to hear of Dr. Priestley's noble appointment, taking it for granted that he is to go on writing and publishing with the same freedom he now does, otherwise I had much rather he remained in Yorkshire."

It was under the patronage of the Earl of Shelburne that Priestley did his most notable work in chemistry, as we shall see later; and when in London he was a member of the Whig Club which met at the Coffee House in Ludgate Hill; thus he continued his intercourse with Franklin and Canton, who were also members of the club. In the autumn of 1774 he travelled with his patron on the Continent and met Lavoisier in Paris, with what results we shall see.

During this period, also, he continued his philosophical and theological writings. Indeed it was these that were his undoing so far as Lord Shelburne was concerned. His Lordship was a broadminded man, who was greatly interested in Priestley's experiments, and did not desire to interfere with his intellectual and religious liberty; but Priestley's writings greatly scandalised the orthodox, who raised an outcry against a man whom they regarded as a materialist and little better than an atheist. Moreover, Priestley's political radicalism was dangerous to his patron, who was Pitt's Secretary of State; and so Priestley as well as Lord Shelburne recognised that it was well the engagement should be terminated. They parted good friends, and Lord Shelburne,

as long as he lived, continued to pay Priestley a promised annuity of £150.

In May, 1780, Priestley went to London, where he renewed his friendship with Franklin, and many friends rallied to his help. Parker, the optician of Fleet Street supplied him with glass apparatus, including the celebrated lens of sixteen inches diameter, and Wedgwood gave him retorts and tubes of earthenware. His brother-in-law, John Wilkinson, however, prevailed upon him to move to Birmingham, which he did after about five months in London. Here he was surrounded with friends; and soon an opportunity arose for him to resume his ministerial duties, which he desired to do. On 31st December, 1780, he became Junior Minister of the New Meeting, Birmingham, at a salary of £100 a year. Here he had leisure from pastoral duties, and with the generous help of friends the salary sufficed. In the Lunar Society of Birmingham, founded about 1760 by Matthew Boulton and Erasmus Darwin, Priestley found congenial company. The members of this society, ten or twelve in number, dined monthly at each other's houses at the time of full moon, so as to return home by moonlight; and on 3rd January, 1781, James Watt, who was a member, sent the following letter to Darwin:—

> "I beg that you would impress on your memory the idea that you promised to dine with sundry men of learning at my house on Monday next, and that you will realise the idea. For your encouragement there is a new book to be cut up, and it is to be determined whether or not heat is a compound of phlogiston and empyreal air, and whether a mirror can reflect the heat of the fire. I give you a friendly warning that you may be found wanting whichever opinion you adopt in the latter question, therefore be cautious. If you are meek and humble perhaps you may be told what light is made of, and also how to make it, and the theory proved both by synthesis and analysis."

So it appears that Priestley soon made his mark in Birmingham; and it also appears that he had indoctrinated the Lunar Society with phlogiston, for in March of the same year Boulton wrote to Wedgwood:—

> "We have long talked of phlogiston without knowing what we talked about; but now that Dr. Priestley hath brought the

matter to light we can pour that element from one vessel to another."

And Priestley writes:—

"Before my late experiments, phlogiston was indeed almost given up by the Lunar Society, but now it seems to be re-established."

Meanwhile his theological activity continued. He was now definitely a Unitarian, and from 1786 onwards published an annual defence of his doctrine. He became intimate with Burke, but was never involved in the hurly-burly of politics. He was active in the initiation of Sunday Schools, and was strongly opposed to the political establishment of religion, so that he advocated the repeal of the Test and Corporation Acts, as well as the abolition of the slave trade. Popular feeling was growing against him in Birmingham, because of his liberalism and catholicity, and was greatly increased by a letter he addressed to Burke on 1st January, 1791, in which he vindicated the principles of the French Revolution.

Nevertheless he was loyal to King, Lords, and Commons, and did not desire the British Constitution changed, except the ecclesiastical part of it. A man might be loyal to his wife, he said, without thinking her the handsomest and best tempered woman in the world.

We are now approaching the great crisis of his life. On the fourteenth of July, 1791, the second anniversary of the storming of the Bastille was celebrated throughout England generally without disturbance. It was celebrated also in Birmingham, but not without disturbance. On this day the "Constitutional Society" held a dinner in Dadley's Hotel, Temple Row, to which any friend of freedom was invited. By this time attacks had been made on Priestley from pulpit and press, and in reply to these he had written:—

"The present silent propagation of truth may even be compared to those causes in Nature which lie dormant for a time, but which in proper circumstances act with the greatest violence. We are, as it were laying gunpowder, grain by grain, under the old building of error and superstition, which a single spark may hereafter inflame, so as to produce an instantaneous explosion; in consequence of which that edifice, the erection

Published as the Act directs for W. Locke, July 1st 1791 Nimbal Scratch fect

DOCTOR PHLOGISTON,
The PRIESTLEY politician or the
Political Priest!

THE ESCAPE OF PRIESTLEY.

From a panel in the City Museum and Art Gallery, Birmingham. Reproduced by permission of the Museum and Art Gallery Committee of the Corporation of Birmingham.

THE BIRMINGHAM RIOT—DESTRUCTION OF PRIESTLEY'S HOUSE AT FAIRHILL.

of which has been the work of ages, may be overturned in a moment, and so effectually as that the same foundation can never be built upon again."

This can hardly be called tactful; it earned for him the title "Gunpowder Priestley" and the honour of being compared with Guy Fawkes and burnt in effigy with Tom Paine. His allusion was taken to mean that the Dissenters were going to destroy the churches, and Priestley's enemies decided to have their explosion first.

Priestley took no part in arranging the anniversary dinner, but intended to be present. His friends, however, prevailed upon him not to attend. An angry crowd watched eighty-one diners arrive, at three o'clock, but no Priestley. Meanwhile an opposition dinner was being held at the Swan, in Bull Street, and by eight o'clock a crowd had gathered again round Dadley's Hotel in the hope of finding Priestley; but the diners had departed and the hotel was empty. Thereupon the cry "*Church and King*" was raised, a signal was given, and every window on the hotel front was broken. Then the crowd made a rush for the New Meeting, burst open the gates and doors, destroyed the pews, made a bonfire of the cushions in the open, and finally carried fire into the building and destroyed it. The magistrates were powerless to quell the mob, which then proceeded to the Old Meeting and similarly destroyed that.

Priestley must be found, however; and so with another cry of "*Church and King*" the rioters marched to Fairhill, Priestley's house, about a mile from the town. Meanwhile the chief subject of their fury had spent a quiet day in the company of his friend Adam Walker, a lecturer in physics from London, and was now playing backgammon with his wife. From the graphic record of Miss Martha Russell, a friend of the family, we learn that a messenger arrived to say that the mob had destroyed the New Meeting, was engaged in destroying the Old Meeting, and intended next to march on Priestley's house. During the consternation which ensued, and while Miss Russell's father was preparing to ride out and meet the mob, Mr. Samuel Ryland arrived with a chaise and hurried Dr. and Mrs. Priestley away. The story is too long to tell in words, but the picture shows what happened to Priestley's house, and how the rioters fortified themselves during their ugly work. Priestley beheld the ruinous proceeding from near Mr. Russell's house. Miss Russell writes thus:—

"Undaunted he heard the blows which were destroying the house and laboratory that contained all his valuable apparatus and their effects, which it had been the business of his life to collect and use. All this apparatus, together with the uses he made of them, the laborious exertions of his whole life, were being destroyed by a set of merciless, ignorant, lawless banditti, whilst he, tranquil and serene, walked up and down the road with a firm yet gentle pace that evinced his entire self-possession, and a complete self-satisfaction and consciousness which rendered him thus firm and resigned under the unjust and cruel persecution of his enemies; and with a countenance expressing the highest devotion, turned as it were from this scene and fixed with pure and calm resignation on Him who suffered the administration of this bitter cup. Not one hasty or impatient expression of murmur or complaint, not one tear or sigh escaped him; resignation and a conscious innocence and virtue seemed to subdue all these feelings of humanity."

Fire was not easily obtained in those days, and the rioters tried to obtain it by using Priestley's electrical machine, "with that love for the practical application of science," said Professor Huxley, "which is the source of the greatness of Birmingham." To which it is only fair to add that the midland city has since nobly atoned for the wrong-doing of its eighteenth-century citizens.

The refugees found sanctuary in Mr. Russell's house at Showell Green, and had retired to rest when news came that the rioters, not yet satisfied, were after Priestley and threatening to take his life. This time the same friend drove them to Heath, near Dudley, where their married daughter lived. Priestley intended to preach on the following Sunday, weather permitting, amongst the ruins of his Meeting House, and chose his text, but was dissuaded from that dramatic and dangerous proceeding. On the Saturday afternoon the fugitives started for Worcester, but lost their way and wandered about all night. With the help of Mr. Ryland, who met them at Kidderminster, they reached Worcester in time to take the Sunday coach to London, where they arrived early on Monday morning, and found a resting place in the home of their friends the Lindseys, in Essex Street, Strand. Thence Priestley wrote an expostulatory letter to his late "townsmen and neighbours," pointing out that the riot had

delivered a greater blow at the Church of England than he had ever aimed at it. He also prepared a discourse on forgiveness of injuries, but did not convert his spirited wife, who wrote to a friend: "I do not think that God can require of us as a duty, after they have smote one cheek to turn the other. They will scarcely find so many respectable characters a second time to make a bonfire of. So much for '*King and Church for ever.*'"

It may be added that before they had finished, the rioters destroyed six other houses belonging to Priestley's friends, and that about a dozen persons lost their lives among the wreckage. It was this accumulation of ruin and tragedy that Pitt attributed to the "effervescence of the public mind."

Priestley settled at Hackney and was elected morning preacher at Gravel Pit Chapel. In spite of some compensation, his net losses amounted to £2000, but kind friends more than made up for these, and he was happy again. Soon, however, the spirit of persecution followed him to London. He became, indeed, a sort of bogey-man to frighten babies of all ages. A servant girl asked her mistress to allow her to leave when she discovered she was living near Priestley, and the Priestleys themselves could not keep their servants. More serious was the fact that their sons could not find employment: that is why they emigrated to America. Even the Fellows of the Royal Society fought shy of Priestley, and he says "I found myself exposed to continual insult." Thus he was driven from the native land he loved, and followed his sons to the land of the Pilgrim Fathers. He resigned his charge on 21st February, 1794, sailed on 7th April, and reached New York on 4th June. Whilst Priestley was on the high seas, Lavoisier was executed in Paris. Thus England and France declared simultaneously that they had no use for their greatest men of science.

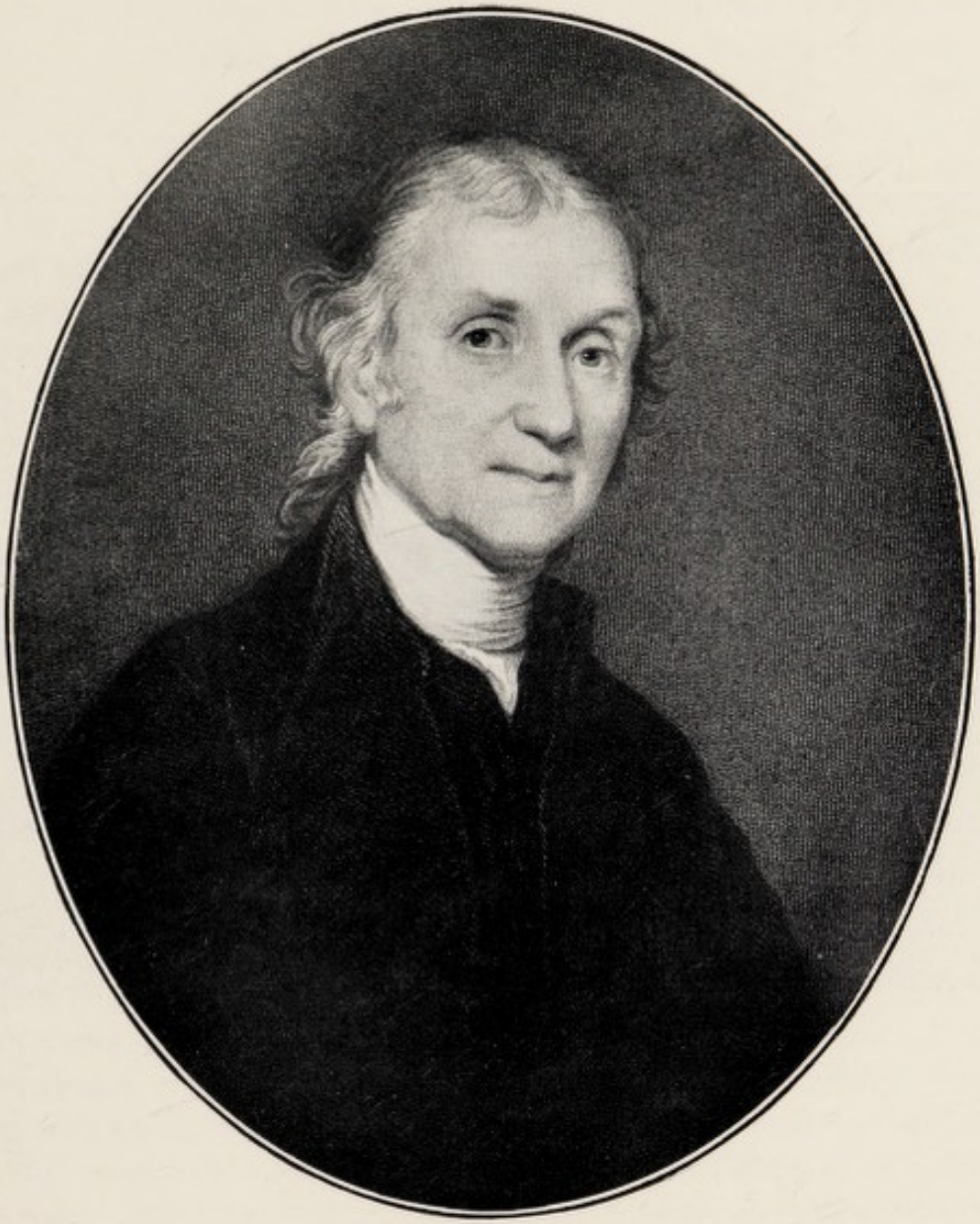
Just twenty years after his discovery of oxygen, Priestley arrived in Northumberland, Philadelphia, and on 27th August he wrote to a friend: "I have just now fixed upon a spot on which to build a home." About this time he was offered the chair of Chemistry in the Philadelphia Medical School, and was at first inclined to accept it; but, having settled at Northumberland with all his belongings, he decided otherwise. The site chosen for his house was on the banks of the Susquehanna River, with a fine view of the surrounding country; but there was much delay

in building in so remote a spot, and before the house was finished his wife died. In October, 1796, a month after the death of his wife, he wrote to his friend Lindsey: "Could I pay you one visit in England, I should sing my *nunc dimittis*." By the end of 1797, however, he was established in his American home, with its laboratory and library complete. Here is a sentence taken from an address delivered by William H. Walker, Consulting Chemical Engineer, during a pilgrimage of the American Chemical Society to the house in 1926:—

> "Priestley thoroughly enjoyed his house, his laboratory, and his garden. Concerning the latter he wrote: 'Plants, as well as other objects, engage more of my attention than they ever did before. . . . I wish I knew a little more botany; but old as I am, I learn something new continually.' One can readily imagine the dear old man—for such he surely was—stepping from his study or his laboratory after a morning of earnest work to labour among his flowers; or possibly to wander under the trees which bordered the river; or perhaps, to sit awhile on the bank and watch the limpid waters of the Susquehanna flow onward to the sea."

He held no public pastorate in America, but preached in his own house, and was successful in forming a small Unitarian congregation. In 1800 he thought of returning to Europe, but in March, 1801, became seriously ill, and was permanently enfeebled. In 1803 he might have had the Principalship of the University of Pennsylvania, but was quite unable to consider such a proposal. In May of that year he had a fall and lamed his left leg; then his digestion began to fail; but until the end of 1803 he was the first to rise in the morning, and always lighted his own laboratory fire. On 2nd February he made the last entry in his diary and, less than an hour before his death, dictated clearly to his son some improvements in a theological work, which was published subsequently. After this had been read to him he said: "That is right; I have now done," and shortly afterwards, covering his face with his hands, he passed peacefully away. He was buried in the Quaker burial ground near by, and the grave is marked by a simple headstone.

It is gratifying to record that the establishment of the American Chemical Society in 1876 was the outcome of the centenary celebration in America of "Oxygen Day" on 1st August, 1874; and that in 1926, to celebrate the jubilee of that Society, the old



Joseph Priestley, LL.D., F.R.S.

Priestley's Home on the Susquehanna River,
Northumberland, Philadelphia.

home which had been restored by the generosity of some American public men, with a museum erected in the grounds, was opened as a Priestley Memorial.

It is now time to consider Priestley's chemical work, and attempt an estimate of its value. Two things stands out prominently. First, his experimental work on gases which earned for him the title: *Father of pneumatic chemistry*, and second, his adherence to Stahl's *Doctrine of Phlogiston*, which he defended to the last.

While at Nantwich he acquired a few books and instruments which he used for his own amusement and that of his pupils; and when writing his *History of Electricity* he carried out some original experiments in that science. In Part II of that work he said that the object of science was to comprehend things clearly, and that hypotheses were useful only to ascertain facts, and must not be valued for their own sake. Here we are tempted to ask, what about phlogiston?

His first interest in gases was aroused in 1770 by the brewery next door to his lodging at Leeds; and his first paper, dealing with the solution of carbon dioxide in water and the production of soda water, was published in 1772; but his most notable work on gases, which was carried out in Wiltshire under the wing of Lord Shelburne, was described in his *magnum opus, Experiments and Observations on different kinds of Air*, the first volume of which appeared in 1775.

After referring briefly to the work of Boyle, Black, and Hales, and mentioning the work of Cavendish on the relative densities of fixed and inflammable air, he described his method of collecting and storing gases. His invention of the pneumatic trough and of the method of collecting gases over mercury, which led to the isolation of hydrogen chloride and ammonia, are noteworthy. How superior is Priestley's method of collecting gases to that of Scheele, which consisted in inflating a bladder with them!

He prepared a gas, supposed to be fixed air, by heating limestone in a gun barrel, but found that some of this gas, which could not be absorbed by water, burnt with a blue flame. Thus he isolated carbon monoxide, though he did not understand this at the time, and we cannot claim that he discovered this gas. He next dealt with the restoration of *vitiated air*, that is air in which candles had burnt, and made the notable discovery that

the properties of such air could be restored by plants, which, he said, imbibe "the phlogistic matter with which it is overloaded by the burning of inflammable bodies." On 17th August, 1771, he put a spray of mint into a quantity of air in which a candle had burnt out, and ten days later found that another candle would burn in the air thus restored. He then discovered that air vitiated by respiration of animals could be similarly restored, and reached the great conclusion "that plants, instead of affecting the air in the same manner with animal respiration, reverse the effects of breathing and tend to keep the atmosphere sweet and wholesome when it is become noxious in consequence of animals either living and breathing, or dying and putrefying in it."

First it is *phlogiston* and then *putrid matter* that plants remove from the air! Yet his first experiments had been with carbon dioxide. How strangely blind he seems to have been.

Next he made a paste of iron filings and sulphur, placed it in confined air, and found the volume of air to diminish. Hales had observed this fact, but Priestley found about one-fifth of the air to be thus absorbed; also that the remaining air was lighter than common air, and differed from fixed air by not affecting lime water. Thus again, unwittingly, Priestley isolated atmospheric nitrogen; nevertheless Daniel Rutherford must be credited with the discovery of that gas.

Having obtained from Hales and Cavendish a hint about a red gas obtainable from spirit of nitre, he investigated the interaction of nitric acid and metals, and discovered *nitrous air* or nitric oxide. This gas he employed to determine the "goodness" of atmospheric air, and thus laid the foundation of eudiometry. Concerning this experiment he says:—

> "One of the most conspicuous properties of this kind of air is the great diminution of any quantity of common air with which it is mixed, attended with a turbid red or deep orange colour, and a considerable heat. . . . I hardly know any experiment that is more adapted to amaze and surprise than this is, which exhibits a quantity of air which, as it were devours a quantity of another kind half as large as itself, and yet is so far from gaining any addition to its bulk that it is considerably diminished by it."

He next exposed nitrous air to the action of iron, and reduced it to nitrous oxide, observing that in the new gas a candle would

burn with a flame that might be "five or six times larger" than its flame in ordinary air. This gas he called *dephlogisticated nitrous air* because combustibles burnt more readily in it than in nitrous air. He did not understand that it contained less dephlogisticated air than nitrous air; according to the phlogiston theory it should have been called *phlogisticated nitrous air*, the extra phlogiston having been derived from the iron with which the nitrous air had been in contact.

We are now introduced to the burning glass. By its means Priestley heated charcoal in air over water or mercury, and observed that the volume of the air diminished by one-fifth by contact with lime water. Then by heating lead and tin in air, thus repeating the experiments of Rea, he observed that a calx was formed, and that the volume of air diminished, whilst the residue did not react with nitrous air. Yet he failed to understand the nature of the calx, for he thought he had phlogisticated the air. The pity of it! It is perhaps appropriate here to quote Priestley against himself:—

> "We may take a maxim so strongly for granted that the plainest evidence of sense will not entirely change, and often hardly modify our persuasions; and the more ingenious a man is, the more effectually he is entangled in his errors, his ingenuity only helping him to deceive himself by evading the force of truth."

He next obtained hydrogen chloride, or *marine-acid-air* by heating spirit of salt, or oil of vitriol and salt, and collecting the evolved gas over mercury. He concludes his first volume by describing the result of heating nitre in a gun barrel. He says:—

> "A candle not only burned but the flame was increased, and something was heard like a hissing similar to the decrepitation of nitre in an open fire." And after noting the effect of nitrous air upon the gas he says that "this series of facts relating to air extracted from nitre appear to me to be very extraordinary and important, and in able hands may lead to considerable discoveries."

Of their importance, historically, there is no doubt, for they prove that Priestley had already obtained oxygen in 1771.

The second volume opens with a description of *alkaline air*, or ammonia gas, obtained from volatile alkali and collected over mercury; and the naïve experiment in which he brought marine acid air and alkaline air together, "having a notion," he says,

"that these two airs, being of opposite natures, might compose a *neutral air*, and perhaps the very same thing with common air." He then records that instead of a neutral air a beautiful white cloud of sal ammoniac was formed.

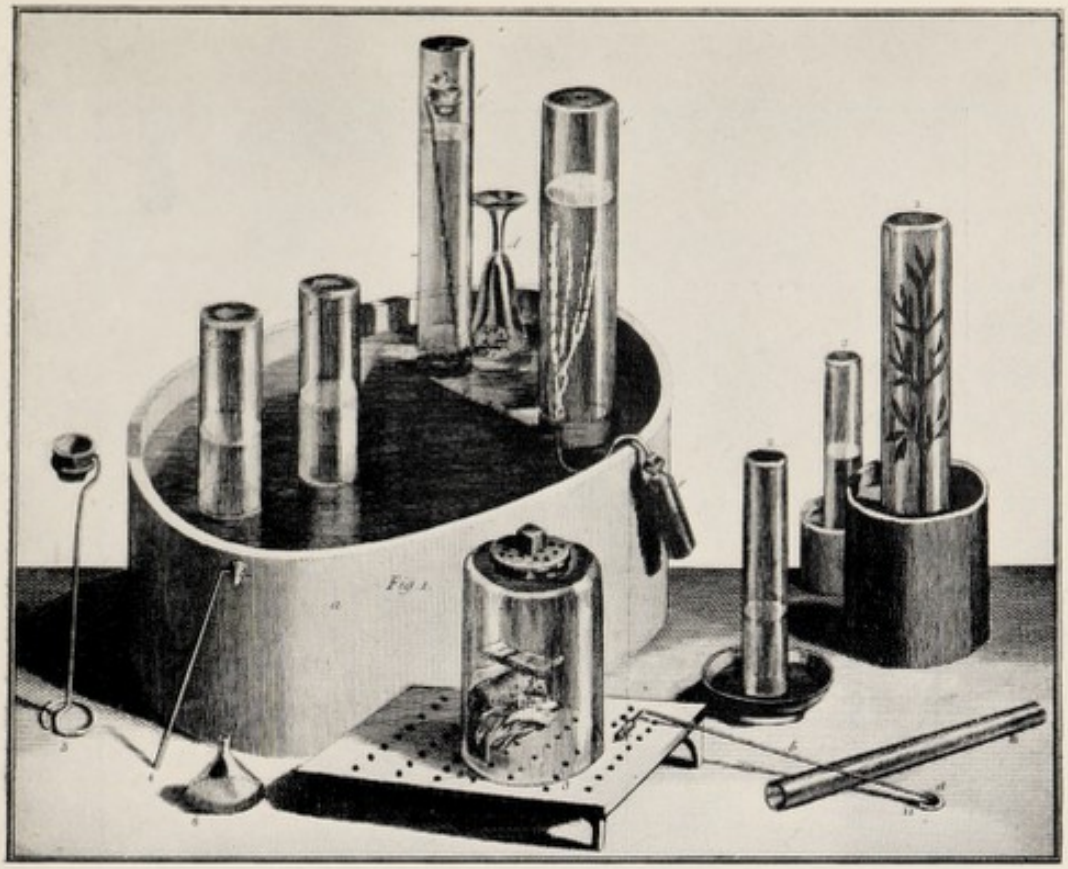
After this Priestley began to theorise a little, lest he should be deemed a "dry experimenter." To theorise meant to talk about phlogiston. "Priestley then gives reins to his imagination," says Sir Edward Thorpe, "or rather allows phlogiston to drive the halting, ambling thing for him, with the result that he utterly loses his way and is eventually landed into an impassable quagmire."

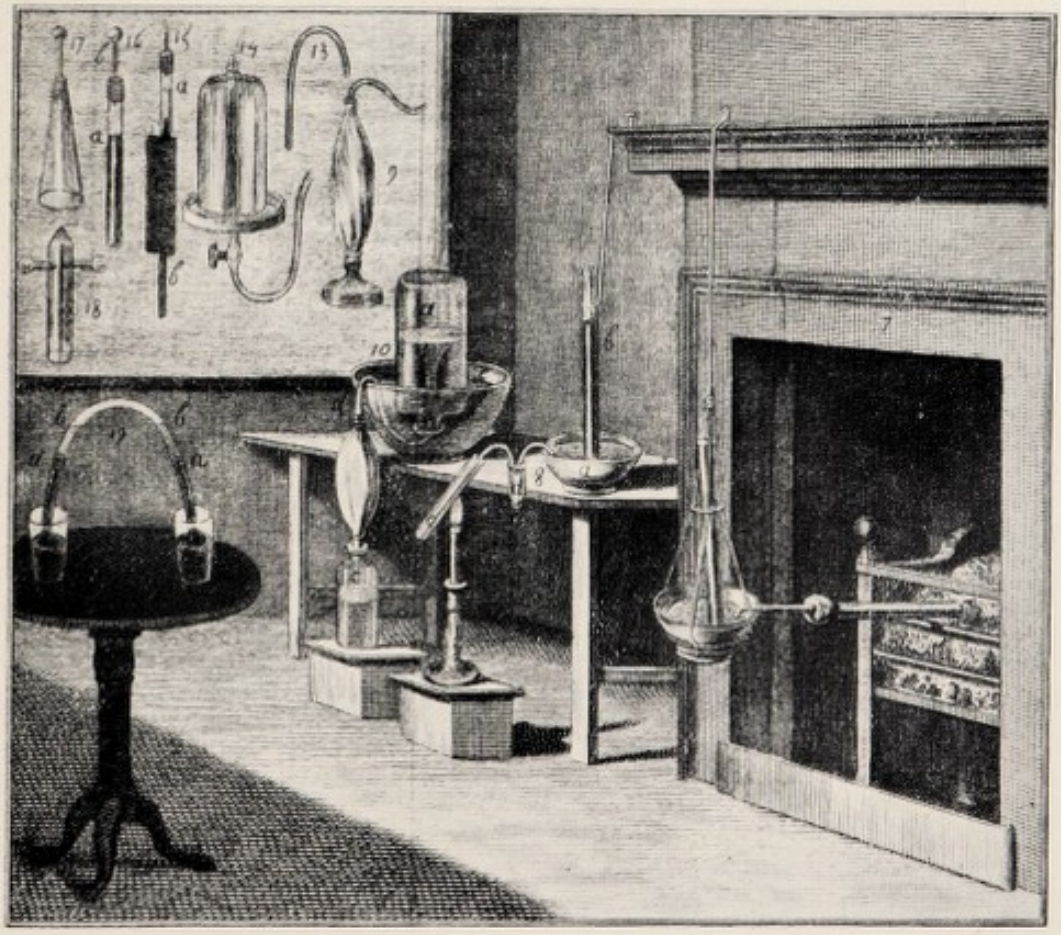
Since marine acid had yielded an air when heated, what about vitriolic acid? So Priestley heated first olive oil and then charcoal with oil of vitriol, and collected over mercury a gas which he called *vitriolic acid air*. Then he wondered if vitriolic acid alone would yield a gas, as marine acid had. Long heating of his phial by candles produced no effect, so he removed his candles before disconnecting the phial from the vessel containing the mercury. Some mercury consequently passed over into the hot acid, and in addition to getting vitriolic acid air he suffered a bad burn. Next day, however, since the discovery was more important than the burn, he heated mercury with sulphuric acid, and later discovered that copper would serve equally well for obtaining the air from vitriolic acid. Then he studied, and accurately described the properties of the new gas.

Now we approach classic ground. The place is Calne, and the day, a day of sunshine, the first of August, 1774.*

> "Having procured a lens of twelve inches diameter and twenty inches focal distance, I proceeded with great alacrity to examine, by help of it, what kind of air a great variety of substances, natural and factitious, would yield, putting them into vessels [short, wide, round-bottomed phials] which I filled with quicksilver and kept inverted in a basin of the same. Mr. Warltire, a good chemist, and lecturer in Natural Philosophy, happening to be at that time in Calne, I explained my

* Lord Brougham, in his *Life of Priestley* (1845), implies that the great experiment was performed at Lansdowne House, and the *Dictionary of National Biography* makes the same statement, which has been repeated by several recent writers. Yet it is known that Priestley worked at Calne during the summer months, as Sir Edward Thorpe states, and his own words indicate; and I can find no evidence that this particular experiment was done in London.





APPARATUS.

From *Experiments and Observations on Different Kinds of Air*, 1775.

Engraving by Stodart from the Statue,
by J. F. Williamson, at Birmingham.

views to him, and was furnished by him with many substances which I could not otherwise have procured.

With this apparatus, after a variety of other experiments, an account of which will be found in its proper place, on the 1st August, 1774, I endeavoured to extract air from *mercurius calcinatus per se ;* I presently found that, by means of this lens, air was expelled from it very readily. Having got about three or four times as much as the bulk of my materials, I admitted water to it, and found that it was not imbibed by it. But what surprised me more than I can express was that a candle burned in this air with a remarkably vigorous flame, very much like that enlarged flame with which a candle burns in nitrous air exposed to iron or liver of sulphur, but as I had got nothing like this remarkable appearance from any kind of air besides this particular modification of nitrous air, and I knew no nitrous acid was used in the preparation of mercurius calcinatus, I was utterly at a loss how to account for it."

We pass from this classical experiment to Priestley's thoughts concerning it. Since red precipitate gives the same gas, and is prepared by the action of spirit of nitre on mercury, mercury when heated must extract something of nitre from the air. Yet the alleged mercurius calcinatus may have been only red precipitate, thought Priestley. Therefore he obtained from Mr. Warltire some mercurius calcinatus warranted genuine, and, repeating the experiment, obtained the same results.

At this juncture the Continental Tour occurred, and Priestley met Lavoisier in Paris. Full of enthusiasm over his new discovery, he told the company at Lavoisier's dinner table all about the experiments he had made and intended to make. What a pity he did not keep his own counsel till his work was finished! Even then he had the facts in his hands to establish the source of the oxygen obtained by heating mercurius calcinatus, and he gave them all away to Lavoisier. Lavoisier was not slow to profit by the hints he received, for he quickly carried out his celebrated experiment, which was the quantitative counterpart of Priestley's work, and in consequence was soon able to publish to the world the true theory of combustion. How simple it all seems. Here is a substance called mercurius calcinatus, known to be formed by heating mercury in the air, and known to give off an air when further heated. How could one help supposing that the air given off was the air absorbed; and how could one

fail to test the supposition and find it true? Nevertheless that is just what Priestley failed to do, and just what Lavoisier did. And that made all the difference. Upon that simple experiment hung the tremendous issue of the true theory of combustion, and the utter overthrow of the theory of phlogiston. We must not say that Priestley refused to perform the experiment because he knew it would destroy phlogiston; but we may say that phlogiston so darkened Priestley's mind that he could not see his way to perform the experiment.

One word here on a celebrated controversy. Priestley, not Lavoisier, discovered oxygen, as all the world agrees; but Lavoisier's place is secure among the Immortals because of the light he brought to dissipate the darkness of phlogiston. Scheele's claim to the discovery is clearer, for he recognised "Fire Air" as a distinct species in 1773, although unable to publish his results until after Priestley; but again it is clear that Priestley was in possession of the gas before November, 1771, though he did not know it then.

On his return from Paris, bringing with him some mercurius calcinatus obtained from Mr. Cadet, of the genuineness of which he had no doubt, he continued his experiments on "*dephlogisticated air,*" and described the brilliant effects of burning combustibles in it, as well as its physiological effect on himself and on a couple of mice. At length he says he was led "though very gradually . . . to the complete discovery of the constitution of the air we breathe." Alas! for Priestley; his complete discovery was that "atmospheric air, or the thing that we breathe, consists of the nitrous acid and earth, with so much phlogiston as is necessary to its elasticity."

It would lead to an anticlimax to describe in detail his later experimental work. It must, however, be recorded that on account of his devotion to phlogiston he missed discovering the composition of water. He was the first to make silicon tetrafluoride and observe its behaviour with water; this he did by preparing Scheele's *fluor acid air* in glass vessels. Also he decomposed ammonia into its constituent elements by passing electric sparks through the gas; but perhaps the most important of his later discoveries was the fact that plants in water evolve oxygen by decomposing aqueous carbon dioxide. After his arrival in America the subject of phlogiston seems greatly to have occupied his mind; and he felt the necessity of stemming the rising tide

of anti-phlogistic ideas. The attempts of the old man are indeed pathetic. At one time he himself had been almost persuaded of the truth of Lavoisier's doctrine. This is what he wrote:—

> "Of late it has been the opinion of many celebrated chemists, Mr. Lavoisier among others, that the whole doctrine of phlogiston has been founded on a mistake and that in all cases in which it was thought that bodies parted with the principle of phlogiston, they in fact lost nothing, but on the contrary gained something; and in most cases an addition of some kind of air; that a metal, for instance, was not composed of two things, viz. an earth and phlogiston, but was probably a simple substance in its metallic state; and that the calx is produced not by the loss of phlogiston, or of anything else, but by the acquisition of air."

And then he admits that the arguments of Lavoisier were "so specious" that he was almost inclined to adopt them. It has been pointed out that according to the phlogiston theory Priestley's experiment with calx of mercury ought never to have been performed; for how can a gas be obtained by decomposing a calx which itself is an element? Since, however, the experiment was performed, and a gas obtained, how can the phlogistic view that a calx is an element be maintained?

For a brief period his vision cleared, as the above passage shows, but soon the mists descended on his mind again. That Phlogiston was not the true light he could not confess, though he knew that in his opinion he was alone in America and almost alone in the world. In attacking the antiphlogistic doctrine he supposed that he was engaged in "taking down a false light which misleads the mariner, and removing a great obstacle in the path of knowledge." So his last scientific work, *The Doctrine of Phlogiston Established*, stands as a dark and solitary monument of a delusion from which an old man could not be freed.

Then at last he turned away from science, and found a refuge in his theology and the consolations of his religion.

"My philosophical friends," he said, "must excuse me if, without neglecting natural science I give a decided preference to theological studies, and here, as in Europe, I give the greatest part of my time to them. They are unquestionably of unspeakably more importance to men."

What shall we say, then, about the character of this man whom Coleridge addressed as "patriot and saint and sage"?

Toplady, the Anglican hymn writer, said of Priestley: "I love a man whom I can hold up as a piece of crystal and look through him"; and Emerson has said: "Whoso would be a man must be a nonconformist." Great then must have been the moral stature of this man among his religious and social contemporaries. The more strange, therefore, is it that he conformed to and so earnestly defended an outworn theory in science.

"If," says Mr. Frederic Harrison, "we choose one man as a type of the intellectual energy of the eighteenth century, we could hardly find a better than Joseph Priestley, though he was not the greatest mind of the century. His versatility, eagerness, activity and humanity; the immense range of his curiosity in all things, physical, moral or social; his place in science, in theology, in philosophy and in politics; his peculiar relation to the Revolution, and the pathetic story of his unmerited sufferings, may make him the hero of the eighteenth century.

Lastly, let this great man, this hero, speak for himself:—

> "The Philosopher ought to be something greater, and better than another man. The contemplation of the works of God should give a sublimity to his virtue, should expand his benevolence, extinguish everything mean, base and selfish in his nature, give a dignity to his sentiments, and teach him to aspire to the moral perfections of the Great Author of all things. What great and exalted beings would philosophers be, would they but let the objects about which they are conversant have their proper moral effect upon their minds. A life spent in the contemplation of the productions of divine power, wisdom and goodness, would be a life of devotion. The more we see of the wonderful structure of the world, and of the laws of nature, the more clearly do we comprehend their admirable uses to make all the percipient creation happy; a sentiment which cannot but fill the heart with unbounded love, gratitude and joy."

If I have succeeded in portraying the character and achievements of the writer of these noble words with any degree of adequacy, you will perceive that they were fulfilled in the life of our Joseph Priestley.

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