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John Dalton's Lectures and Lecture Illustrations.

Parts I. and II.

BY

PROFESSOR W. W. HALDANE GEE, B.Sc., M.Sc.Tech.

Part III.

BY

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MANCHESTER:
36, GEORGE STREET.

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XII. John Dalton's Lectures and Lecture Illustrations.

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By Prof. W. W. HALDANE GEE, B.Sc., M.Sc.Tech.

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INTRODUCTION.

During last summer some members of a special committee of the Council of the Manchester Literary and Philosophical Society, whilst preparing a catalogue of the apparatus and other property in the House of the Society, had their attention directed to a roll of diagrams in one of the cupboards. Many of these were annotated with the unmistakable handwriting of John Dalton, and there was evidence that they had been made by him and used in his lectures. After further search, the collection reached 150 in number. They related to Mechanics, Physics, Chemistry, Astronomy and Meteorology. Some of the diagrams were exhibited and explained by Mr. R. L. Taylor and myself at the meeting of the Society on October 6th, 1914.

Since many of the diagrams had reference to the Atomic Theory, it was decided to ask Dr. Arthur Harden, who was associated with Sir Henry Roscoe in writing "A New View of the Origin of Dalton's Atomic Theory," to inspect the diagrams. This he did in conjunction with Dr. H. F. Coward and the writer.

The diagrams have been pressed and cleaned. In a few cases the ink has caused such corrosion that it has been necessary to paste thin transparent paper over the crumbling portions and to provide others with a backing of paper. In most cases, however, the sheets are in an excellent state of preservation.

The diagrams have been divided into two groups, those relating to :—

1. Mechanics, Physics, Astronomy and Meteorology.
2. The Atomic Theory.

It was decided to prepare catalogues of these two groups, and to include a description of any of special interest.

In carrying out this task it was found that it would be essential to examine the Dalton Manuscripts in the possession of the Society, especially with the object of finding references to the use of the diagrams. Among the manuscripts and miscellaneous packets of papers, a number of Lecture Notes and Syllabuses of Courses of Lectures were found.

Hitherto the accounts published of the lectures of Dalton have been very incomplete, and few have realized the important position that his lectures have had in his life-work. It is intended later to detail certain of these lectures more fully ; meanwhile, the following summary has been prepared.

Part I.

John Dalton's Lectures.

In 1787, when Dalton was twenty-one years of age, he added to his school duties that of giving lectures. He announced in a printed syllabus[1]—a framed copy of which is on exhibition in the Society's rooms—that twelve Lectures on Natural Philosophy would be read at the School at Kendal if a sufficient number of subscribers

[1] This syllabus is reprinted in "John Dalton and the Rise of Modern Chemistry," by Sir H. E. Roscoe, 1895. See p. 43.

were procured. The fee was half-a-guinea for the course, or one shilling per lecture. We have no information relating to the success or otherwise of this first attempt.

The next syllabus dates four years later, and the charge is reduced for the set of twelve lectures to 5s. This syllabus is reproduced on *Pl. I.* Dalton made it a rule to give a balance-sheet relating to his lectures and the one for these lectures, with its wrong addition, is shown on *Pl. II.* He has also recorded the names of the subscribers and the attendances at his lectures. The list includes 80 names; the attendance at each lecture varied considerably, the average being about 20.

In 1793, Dalton, now 27 years of age, came to Manchester to teach Mathematics and Natural Philosophy at the Manchester Academy, where he remained as tutor for six years.

In a letter to his brother Jonathan, dated "6th month, 13, 1796," he wrote:—

> "I have had some thoughts of delivering a course of lectures at Kendal this summer, as far as the apparatus there would admit and what additional might be made for the occasion. About 6 Lectures on Chemistry and 6 on the other branches would be my plan. I imagine you have had none lately. Twenty subscribers at Half a Guinea would be sufficient inducement to commence. Tickets to admit a Gentleman and Lady, or two Ladies; Single Lectures, 1/6. Thou may please to mention it to one or two to see how it is likely to take, and let me know by the end of the month, as I should wish to know before I quit this place. I do not however wish to press the subject; nor to engage myself absolutely."

The lectures were arranged. In a pocket-book giving details of his summer expenses to Kendal he records that he sold ten 10s. 6d. tickets, one at 5s., and a number of odd tickets bringing in a total sum of £7. 15s. 0d. His expenses were £1. 6s. 0d., giving him a profit of £6. 9s. 0d.

1803-1804.

In 1803 Dalton went to London and on his return to Manchester he wrote to his brother:—

" . . . . I have fallen into business again much as usual, except with regard to private pupils, who have nearly all of them left the study of Mathematics and Natural Philosophy for that of military affairs, for a season at least.[2] I have not heard from the manager of the Royal Institution yet since I left London; am therefore undetermined on that head." This last sentence refers to the arrangements respecting a course of lectures (for which he received a fee of 80 guineas) which he commenced at the end of 1803 and concluded on the 23rd January, 1804.

The Syllabuses of the lectures issued by the Royal Institution show that they covered a wide range and included Mechanics, Electricity, Magnetism, Optics, Astronomy, Use of the Globes, Sound, Heat, Constitution of Mixed Gases, and Meteorology. A search for notes relating to these lectures has not been successful, the only details available are from his letters.[3] He tells us that it required great labour to get acquainted with the apparatus at the Royal Institution and to draw up the order of experiments and repeat them in the intervals between the lectures. However, with the aid of an expert assistant, not one of the experiments failed. The first lecture was written out completely, and the evening

[2] In 1803 the second war with France was declared. This is the only reference that I have found in Dalton's letters to the French wars (1803-1815).

[3] See "Memoir of John Dalton," by R. Angus Smith, pp. 55-58. 1856.

before the lecture Davy and Dalton went to the theatre. Dalton read the whole lecture to Davy, who was in the furthest corner of the room. Then Davy read the lecture and Dalton was the audience, and then they criticized each other's methods. Next day he gave the lecture to an audience of 150 and was complimented on his début. After this he scarcely wrote anything, all being experiment or verbal explanation. This seems to have been his usual plan with all his lectures.

On returning to Manchester he gave to the Literary and Philosophical Society, on February 24, 1804, "A review and illustration of some principles in Mr. Dalton's Course of Lectures on Natural Philosophy at the Royal Institution in January, 1804." This was not published; this review was probably intended to fill up what would otherwise have been a blank evening.

It is unfortunate that we have no record of his 1804 lectures, which he states contained his views on certain primary laws. He left a statement for publication in the Journal of the Royal Institution, but he was not informed whether this was done. I have not been able to trace this.

1805.

After returning from London Dalton decided to give lectures in Manchester and issued the following preliminary statement:—

PROSPECTUS

of an intended course of

Lectures on Natural Philosophy

IN MANCHESTER,

BY

JOHN DALTON.

In a populous town like this, where the Arts and Manufactures are so intimately connected with various branches of science, it may be presumed that public encouragement will not be wanting to a person qualified to exhibit and illustrate the truths of experimental philosophy upon a liberal and extensive scale.

Notwithstanding this, it would be imprudent for one of limited resources to purchase a large and expensive apparatus adequate to the object, upon a mere presumption. Something like a certainty of remuneration in a degree may fairly be expected.

With this view I propose, if a competent number of subscribers at two guineas each be procured, to extend the apparatus already in my possession so as to give a course of twenty lectures on the various branches of experimental philosophy, in the ensuing spring. Having for many years been engaged in the cultivation of the sciences of Mathematics and Natural Philosophy, and having lately delivered a course of lectures similar to the one proposed, in the Royal Institution at London, I may perhaps have some claim upon public confidence.

Each subscription ticket will admit a gentleman and a lady, or two ladies. The lectures will be delivered twice, if the number of subscribers exceed sixty, in order to their greater accommodation.

Those who wish to favour the undertaking will oblige me by putting down their names as early as may be on papers left for the purpose at Messrs. Clarkes' or Messrs. Thomson & Son's, booksellers,

Falkner Street, Jan. 2nd, 1805.

Russell, Printer, Manchester.[4]

[4] The last section of Vol. ii. of Dalton's Manuscript Notes is made up of some spare copies of the above Prospectus. (See Roscoe & Harden, p. 66). The spelling of Falkner Street was subsequently changed to Faulkner Street. In 1805 Dalton went to live with the Rev. William Johns, at 10, George Street, where he remained until 1830. He then took a house at 27, Falkner Street. This he occupied until his death in 1844. The house was then taken by H. P. Rée and Co. (see Manchester Directories).

Shortly after the issue of the prospectus he informed his brother that he intended setting off to London "with a view to purchase apparatus; the number of subscribers the first week were upwards of 30, but it would be two or three months before the Lectures would begin." Some of the more important pieces of apparatus that he purchased are in possession of the Literary and Philosophical Society. The collection cost about £200, and was obtained from W. & S. Jones, Instrument Makers, of 30 Holborn, London. Dalton drew up a special syllabus for the lectures which were arranged as shown :—

	No. of Lectures.
Matter, Motion and Mechanical Principles ...	2
Hydrostatics	1
Pneumatics	2
Hydraulic and Pneumatic Instruments ...	1
Electricity and Galvanism	3
Magnetism	1
Optics	2
Heat	2
Elements of Bodies and their Composition ...	1
Mixed elastic Fluids and the Atmosphere ...	1
The Absorption of Gases by Water, etc. ...	1
Meteorology	1
Astronomy	2
Total	20

Writing to Jonathan Dalton in May, 1805, he tells us that the course is about half-finished, and that "a more respectable audience has seldom been had on a similar occasion, and things have gone on very well so far." Dalton evidently intended to detail in his Ledger the financial result, but beyond giving the heading no figures were added.

1806.

The success of the Lectures induced him to repeat the course in the following year and he inserted in the *Manchester Mercury and Harrop's General Advertiser* an advertisement .—

LECTURES
ON NATURAL PHILOSOPHY.

J. Dalton intends to deliver a course of Lectures on Natural Philosophy, comprising Mechanics, Pneumatics, Electricity, Galvanism, Magnetism, Optics and Astronomy; together with the doctrines on Heat and Pneumatic Chemistry, containing recent discoveries on those subjects. The whole to be illustrated by experiments with select apparatus, executed by the most modern artists.

The course will consist of about twenty Lectures. Tickets for the Course £2. 2. Each ticket admits a Gentleman and a Lady, or two Ladies. If the proposal meets with encouragement, the Lectures will commence about the end of January, in a central situation in Manchester, of which due notice to the subscribers will be given.

Those who wish to become subscribers will please give in their names at Clarks' or Thomsons' Booksellers, or to

J. Dalton, No. 10, George Street,
January 6, 1806.

He wrote to his brother on the 30th Nov., 1806:—"I am very busy, being in the midst of a Course of Lectures, and having a good deal of private tuition besides." The lectures added considerably to his small income. The total receipts were £65. 9s. 6d., which after deducting expenses gave him a balance of £58. 2s. 0d.

1807.

This year marks an important era in his lectures. He went to Edinburgh and he tells us that "soon after my arrival I announced my intention to lecture by advertisement of handbills; I obtained introduction to most of the professional gentlemen in connection with the college, and to others not in that connection, by all of whom I have been treated with the utmost civility and attention; a class of 80 appeared for me in a few days; my five lectures occupied me nearly two weeks." He was afterwards induced to give a second course, and then proceeded to Glasgow, where he also lectured. He was very pleased with his reception, for "on these occasions he was honoured with the attention of gentlemen, universally acknowledged to be of the first respectability for their scientific attainments; most of whom were pleased to express their desire to see the publication of the doctrine." This stimulated Dalton to prepare for the press "A New System of Chemical Philosophy," Part I. of which appeared in 1808. It is dedicated "to the Professors of the Universities and other Residents of Edinburgh and Glasgow, who gave their attention and encouragement to the lectures on Heat and Chemical Elements, delivered in those cities in 1807; and to the members of the Literary and Philosophical Society of Manchester, who have uniformly promoted his researches."

He issued a special syllabus of the course of the Five Lectures, of which two were devoted to heat and the remainder to chemical elements. He was absent in Scotland for eight weeks and his expenses were £30, but no record has been found of his receipts.

1808.

Dalton prepared for his next course of 15 lectures in Manchester a 24-page pamphlet forming a very full epitome of his lectures. The title is:—

SYLLABUS

OF

A COURSE OF LECTURES

ON

Experimental Philosophy

BY

JOHN DALTON.

It is divided as shown below :—

Lect. 1 and 2.	On Matter, Motion and Mechanics.
Lect. 3.	Hydrostatics.
Lect. 4 and 5.	Pneumatics.
Lect. 6.	On Hydraulics.
Lect. 7.	On the Steam Engine.
Lect. 8 and 9.	On Electricity.
Lect. 10.	On Galvanism.
Lect. 11 and 12.	On Optics.
Lect. 13.	On Meteorology.
Lect. 14 and 15.	On Astronomy.

From these lectures he realised nearly £50.

1809-10.

On the 21st December, 1809, Dalton commenced a second course of lectures on Natural Philosophy at the Royal Institution, London. After an introductory lecture he dealt with :—

Lectures 2 and 3.	Laws of Motion.
„ 4 „ 5.	Pneumatics.
„ 6.	Hydrostatics.
„ 7 „ 8.	Steam Engine.
„ 9 „ 10.	Electricity.
„ 11 „ 12.	Meteorology.
„ 13 „ 14.	Astronomy.
„ 15 „ 16.	Heat.
„ 17, 18, 19 and 20.	Chemical Elements.

In a small memorandum book some of the lectures are written out almost in full. Lectures 15 to 20 have been transcribed and printed.[5]

He informs his brother in April, 1810, that his twenty lectures were attended by an audience "of 1, 2, or 3 hundreds and he received the strongest marks of approbation."

The fee for the lectures was again 80 guineas and Dalton estimates his expenses for 7 weeks at £35.

1811.

In *Cowdroy's Manchester Gazette* (January 19th, 1811) Dalton advertises a course of Lectures on Experimental Philosophy and Chemistry to be given at the Lecture Room of the Literary and Philosophical Society. He states that the course will be nearly the same as that he delivered in London. In a letter to Jonathan Dalton, dated 4 mo., 29, 1811, he writes: "The engagements I allude to above have been to give a course, or rather two courses of lectures on Natural Philosophy and Chemistry, which have required extraordinary exertion, as I was obliged to attend a good deal of private tuition in the meantime. They continued for 10 weeks and ended about a fortnight ago.—The produce of the lectures was nearly £130, which exceeded any I have had before."

For these 20 lectures he prepared a new syllabus, which includes the subjects of Mechanics, Hydrostatics, Pneumatics, Hydraulics, Electricity, Galvanism, Optics, Meteorology, Astronomy and Chemistry. The last subject included Heat.

1814.

In this year Dalton gave a course of Lectures on Natural Philosophy and Chemistry in Manchester. For

[5] See Roscoe and Harden. Chaps. I. and IV.

the introduction to these lectures see Roscoe & Harden, p. 125. The lectures were well attended.

1817-18.

In 1817 Dalton received an invitation to lecture at the Birmingham Philosophical Institute. He dealt with Chemistry. In the following year he again visited Birmingham, this time the lectures being on Mechanics. For each set of lectures he received 40 guineas.

Writing to his brother on the 13th January, 1818, he expresses his satisfaction with his reception in Birmingham and adds :—

" I was pleased with the philosophical taste displayed by the Society, especially the leading characters amongst them ; they have an excellent lecture room, a good apparatus in several departments and raise two or three hundred subscribing members of the institution."

During this year he also gave 15 lectures in Manchester on Mechanics, etc., the subscriptions amounted to nearly £57, the expenses were about £17, which included £10. 10s. for the hire of the lecture-room.

1820.

In this year he decided to give Electricity the first place in his lectures. He advertised in *Cowdray's Gazette* and the *Manchester Mercury* as shown below :—

LECTURES ON NATURAL PHILOSOPHY.

J. DALTON intends to commence his COURSE of LECTURES on NATURAL PHILOSOPHY on Monday evening, the 6th of March, at seven o'clock, at the Rooms of the Literary, and Philosophical Society, George-street.

The Course will consist of ten Lectures, viz. three on

Electricity, one on *Galvanism*, two on *Optics*, two on *Astronomy*, and two on *Meteorology*.

Tickets for the Course, at *One Guinea* each, may be had at Messrs. Clarkes', or Mr. E. Thomson's, booksellers; or at No. 10, George-street.—A Ticket will admit *one* Gentleman or *two* Ladies.

⁂ Part I of Vol. 2 of the New System of Chemical Philosophy will be published in a few months.

February 26, 1820.

A new syllabus for the lectures was prepared and many electrical experiments arranged. The nature of the electrical lectures will be seen from the detailed notes:—

"*Lect.* 1, 2 & 3. ELECTRICITY. Historical sketch of the science—attraction—repulsion—positive and negative electricity—conductors and non-conductors—insulation. Electric machine—theory of its action. Experiments on attraction and repulsion with cork ball—feathers—head of hair—dancing images—musical bells. Different influences of balls and points in attracting the electric fluid—snapping tube. Leyden phial or electric jar—charging and discharging ditto—electric shock. Magic picture. Nature of the electric fluid—compared with light and heat—electric stool—human body a good conductor—jar charged from it. Electric spider—dancing pith-balls. Electrometers—pith-ball—quadrant—Cuthbertson's—medical—Bennet's gold-leaf. Medical electricity—the spark—shock—aura. Paper perforated by the discharge of a jar. Electricity prefers a bad *short* conductor to a good *long* one. Inflammation of bodies by electricity—as cotton—spirits—hydrogen gas, &c.—thunder and lightning—thunder house—conductors. Electric battery—fusing wires, &c. Electrophorus, experiments on it—luminous experiments.

Lect. 4. GALVANISM. Discovery of Galvanism in 1791—a very distinct branch of electricity. Experiments with silver and zinc. Perfect and imperfect conductors—simple galvanic train—a number of these connected constitute a battery. Galvanic trough. Galvanic charge supposed to differ from an electric as a low charge of an electric battery differs from a high charge of a jar—hence the little importance of insulation. Tin end of trough positive—copper end negative. Galvanic shock—acid and alkaline tastes by positive and negative wires. Decomposition of water, alcohol, &c. by galvanism. Medical application. Theory of the battery—*number* and *magnitude* of plates, &c."

The financial result was again satisfactory. £74. 15s. 0d. was paid by the subscribers, the chief items of expenditure were advertising, printing the syllabus and hire of lecture room, the total being £12. 6s. 0d.

1823.

Lectures at Leeds Philosophical and Literary Society. He gave six lectures, four being on Mechanics and two on Meteorology. He was paid 50 guineas. In his memoranda of expenses amounting to £10. 8s. 0d. there is a bill for three weeks' board and lodging for £4. 6s. 0d.

1824.

This year commences Dalton's association with the Medical School, when Thomas Turner proposed to establish a School of Medicine and Surgery. The project being well received, Turner took a house in Pine Street, a small street between George Street and Falkner Street. Dalton joined the staff of seven, taking Pharmaceutical Chemistry as his subject.[6]

[6] See "Sketches of the Lives and Work of the Honorary Medical Staff of the Manchester Infirmary." By E. M. Brockbank. 1904. Manchester: at the University Press.

Apparently the arrangement was that Dalton should receive the fees of the students attending his lectures and pay all expenses. In the *Manchester Guardian* for December 4th, 1824, will be found the first announcement relating to the lectures :—

TO MEDICAL STUDENTS.

John Dalton, F.R.S., President of the Literary and Philosophical Society, intends to commence a course of about fifteen lectures on Pharmaceutical Chemistry at Mr. Turner's Lecture Room, Pine street, on Tuesday evening, the 7th December, at seven o'clock.

The Lecturer, after explaining the first principles of Chemistry, will proceed to apply them to investigations respecting the Materia Medica, and to other purposes relating to the profession.

Tickets for the Course at One Guinea each may be had of Mr. Dalton, at No. 10, George street.

According to his usual custom Dalton prepared a printed syllabus for these special lectures, the chief subdivisions being :—Introduction, Heat or Caloric, Constitution of Bodies, Chemical Syntheses and Analyses, Simple or Elementary Gases, Elementary Solids, Compound Bodies, Alkalies, Acids, etc., Earths, Sulphurets, Metals, Vegetable Kingdom, and Animal Kingdom.

He received fees amounting to £27. 8s. 0d., but his expenses were £10. 10s. 0d.

Mr. Turner, in his report in 1825 relating to the work of the previous session of the Medical School, says :—

On the Application of Chemistry to Medicine and Surgery.

Mr. Dalton, whose philosophical attainments were too well known to require any panegyric, had last year delivered a course of Lectures which he would shortly repeat.[7]

[7] *Manchester Guardian*, Oct. 1st, 1825.

The Ledgers and Memorandum Books of Dalton show that he continued his connection with the Medical School for at least six sessions; in the later periods he had each session three separate classes attended by 8 or 9 students.

In responding to the toast of "Dr. Dalton and that excellent Institution, the Literary and Philosophical Society, of which he is the distinguished President," at the Anniversary Dinner of the Pine Street School of Medicine and Surgery, in 1833, Dalton made a short but memorable speech in which he says:—

"With regard to myself I shall only say, seeing so many gentlemen present who are pursuing their studies, that if I have succeeded better than many who surround me, in their different walks of life, it has been chiefly, nay I may say almost solely from unwearied assiduity. It is not so much from any superior genius that one man possesses over another, but more from attention to study and perseverance in the objects before them, that some men rise to a greater eminence than others."

1825.

In the *Manchester Guardian* for October 1st, 1825, Dalton advertises that he intends to give a course of six lectures on Meteorology. He prepared a new syllabus and wrote out an introduction to the course. This is reproduced below:—

METEOROLOGY.

Manchester, Sep. 22, 1825.

Introduction: The Science of Meteorology is that which treats of the various Phenomena of the Atmosphere; as *Winds*, *Clouds*, *Rain*, *Snow*, *Dew*, &c.—and of Meteors more strictly so called, as *fiery Meteors* or *falling* *stars*, *Luminous balls*, *Thunder* and *Lightning*, *Aurora borealis*, &c.

Most men who have cultivated the Physical Sciences with success, have had their attention drawn to this branch in an especial manner. Indeed it is not surprising that this should be the case, from the interest which every one must feel in the state of the weather, not only as it influences their own health and comfort, but as it affects the enjoyment of society at large.

Meteorological Journals are now kept in almost every part of the globe where Natural Philosophy is cultivated ; and it is to be regretted that we have not observations in all parts of the globe ; as facts and observations form the most stable bases for Theories on this or any other subject of Philosophy.—For instance, the late warm and dry Summer, &c., &c.

I began to register my Meteorological Observations 38 years ago, and have continued them to the present time. The *Aurora borealis* was a principal cause to induce my commencement of a register. This splendid phenomenon was of frequent occurrence at that time, and afforded me great scope for investigation for 4 or 5 years at Kendal. Since that period the phenomena have been rare in this part of Europe.

On leaving Kendal I published a small volume of meteorological observations and essays ; the chief merit of which (if it have any) consists in explaining the two great causes of wind—and in describing the observations of the *Aurora borealis* so as to lead to a theory of this wonderful appearance.—In the succeeding years I have published occasional Essays in the Memoirs of the Literary and Philosophical Society of this Place on meteorological subjects.

Abundance of light has been thrown on the nature of elastic fluids during the last 50 years. Indeed, before that period, the atmosphere may be said to have been considered as a homogeneous fluid. As soon as it was discovered that elastic fluids of very different chemical properties existed in the atmosphere, and were mostly or always found in a state of intimate mixture, it became a question how this mixture was effected and maintained; especially as the elastic fluids are of very different specific gravities. A notion was adopted that it must be the result of chemical affinity, and analogous to the solutions of salt, sugar, &c., in water. But the analogy does not hold; for salts do not dissolve in water without agitation; whereas airs dissolve in each other without agitation. Also, salts produce cold, or heat, and condensation of volume; whereas airs produce none of these.

Considerations of this kind, together with the enormous disproportion in which the elastic fluids constituting the atmosphere are found mixed, put me upon thinking, about 25 years ago, whether a more rational account might not be given of the constitution of the atmosphere. This led to such views of the subject as terminated in a new theory of chemical combination in general, or what is called the *atomic* theory.—But this is a subject we must not enlarge upon at present.

The Manchester lectures realised £27. 12s. 0d. The same course was also given at the Birmingham Philosophical Institute, for which he received 40 guineas.

1827-29.

During these years his lectures in Manchester were devoted to Heat and Chemistry. The printed syllabuses for the three years differ but little and are chiefly based on his "New System of Chemical Philosophy." His account books show that he received on an average about £80 for each public course of lectures. In addition he gave private courses of lectures to small classes, each with about eight pupils.

1834.

During March and April of this year a course of lectures on Meteorology was delivered by Dalton at the Royal Manchester Institution, for which he received 20 guineas.

1835.

At a meeting of the Directors of the Manchester Mechanics' Institution in 1834, Mr. Benjamin Heywood was appointed to see Dr. Dalton and to ask him if he would favour the Institution with a course of lectures on any subject. At a subsequent meeting Mr. Heywood reported that he had seen Dr. Dalton "who in a very handsome manner had consented to deliver a course of lectures in the Institution. Dr. Dalton proposed to deliver five lectures on Meteorology and at once agreed to the suggestion of fifteen guineas as remuneration."[8] Reports of the lectures, which commenced in March, are given in the *Manchester Guardian* for 1835, where it is stated that the lectures were well attended.

Later in the year Dalton gave a lecture at the Mechanics' Institution on the Atomic Theory. To the audience was distributed a lithographed sheet of Atomic Symbols. This lecture attracted great interest, the *Manchester Times* of October 25, 1835, reported that "the lecture-room was crowded in every part and the greatest anxiety was manifested by the audience not to lose a single word which fell from the lips of the speaker." This is his last public lecture of which any record has so far been found.

[8] See the Minutes of the Manchester Mechanics' Institution, which are preserved in the Library of the Manchester School of Technology.

The Directors of the Institution in November, 1835, resolved that a silver inkstand of the value of ten guineas be presented to Dr. Dalton, with an inscription expressive of the sense of the Directors of his patronage of the Institution. The inscription decided upon was as shown below :—

JOHN DALTON, D.C.L., F.R.S.,
President of the Manchester Literary and Philosophical Society,
&c., &c., &c.,
From the Directors of the Manchester Mechanics' Institution
in grateful acknowledgment of services rendered by their distinguished Townsman.
January, 1836.

The inkstand, on the death of Dalton, became the property of Peter Clare, who presented it to the Literary and Philosophical Society, with the added inscription :—

This silver Inkstand was bequeathed by the late Peter Clare, F.R.A.S., to the Literary and Philosophical Society of Manchester, of which he was one of the Vice-presidents, to be used at their ordinary and other meetings. Nov., 1851.

For 64 years this inkstand has been in regular use at the meetings of the Society and is a memorial of the local appreciation of John Dalton's services as a lecturer.

DESCRIPTION OF PLATES.

PLATE I.—Syllabus of Dalton's Lectures given in 1791. Reproduced from Dalton's corrected copy.

PLATE II.—Extract from Dalton's Ledger of 1791, showing a profit of £6. 4. 2 from the above lectures.

KENDAL, Nov. 2, 1791.

J. DALTON'S

PHILOSOPHICAL LECTURES

WILL BEGIN

On Monday Evening the 14th of November, at 6 o'Clock, and continue on Mondays and Thursdays following.

Admittance Sixpence each Lecture, or five Shillings the whole.

LECTURES I. & II. MECHANICS.

On Matter, and its Properties. Attraction and Repulsion in general. Experiments upon electric, chymical, and particularly magnetic Attraction and Repulsion. On Gravity. The Laws of Motion. Mechanic Powers. Vibration of Pendulums.

LECTURES III. & IV. OPTICS.

Nature and Properties of Light. Simple Vision. Doctrine of Colours. Of reflected Vision, Mirrours, &c. Of refracted Vision, Lenses, &c. Burning Glasses. Description of the Eye, and manner of Vision. Of Optic Glasses. The Rainbow explained.

LECTURES V. & VI. HYDROSTATICS & PNEUMATICS.

Of Fluids in general. Properties of non-elastic Fluids. Specific Gravity of Bodies. Of the Atmosphere. Description of the Air-Pump. A great variety of Experiments on the Air-Pump, proving the spring, weight, and other Properties of the Air. Account of Discoveries upon fictitious Air, and common Air injured by Respiration, Putrefaction, Combustion, &c.

LECTURE VII. ON FIRE.

The Thermometer: Discoveries relative to Heat consequent thereto. Of the source of Animal Heat, and the nature of Combustion.

LECTURES VIII. IX. & X. ASTRONOMY.

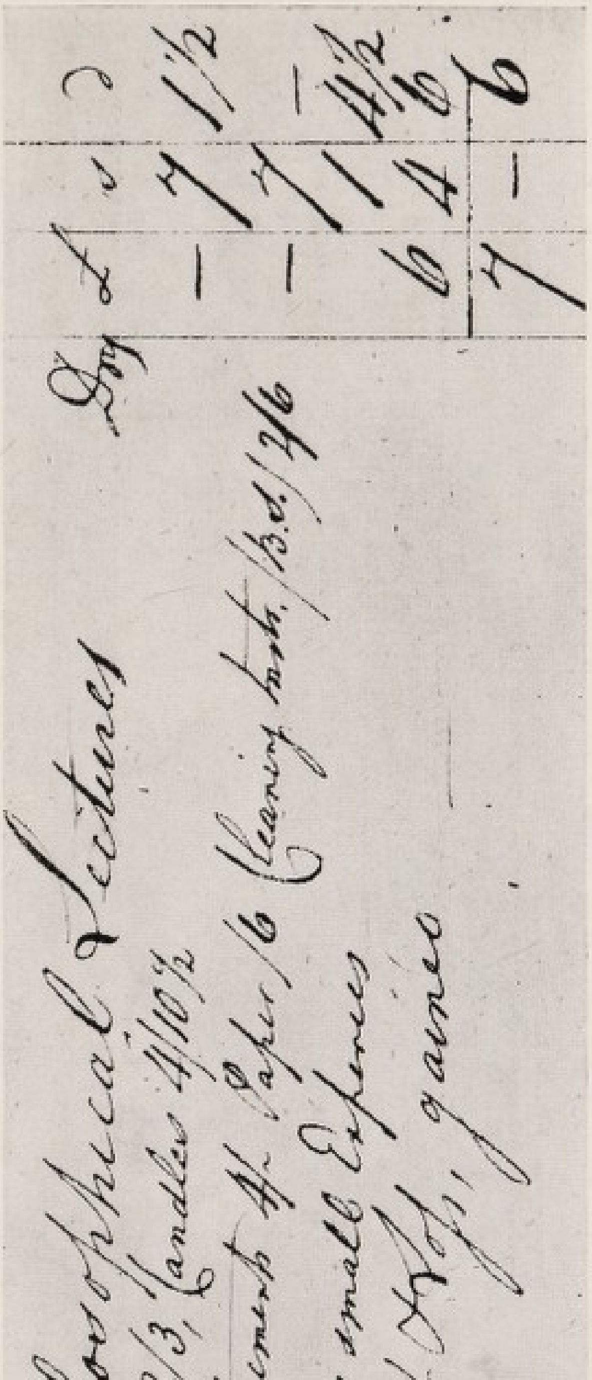
Of the Solar System, and System of the Universe. Various astronomical Phenomena as the Phases of the Moon, Eclipses, Occultations, Transits, &c. explained. Of Tides.

LECTURES XI. & XII. USE OF THE GLOBES.

Description of the Globes, and a variety of Problems performed, and Phenomena illustrated by them.

KENDAL: PRINTED BY W. PENNINGTON.

7" × 9½".



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Part II.

John Dalton's Natural Philosophy Diagrams.

Mechanics.

Sheet 1.

(17″ broad × 21″ high.) Three diagrams illustrating the principle of the lever.

Sheet 2.

(32″ × 21″.) Four diagrams illustrating the pressure on fulcrums and supports.

Sheet 3.

(22″ × 31″.) Three diagrams relating to the pressures produced when beams are suspended horizontally.

Sheet 4.

(13″ × 19″.) Three diagrams illustrating the inclined plane. A weight of 12 units is shown balanced by 3, 4 or 6 units according to the inclination of the plane.

Sheet 5.

(21″ × 17″.) Two diagrams illustrating statical principles.

(1) Three equal forces act at an angle of 120° on a body.
(2) Forces of 14, 8 and 15 act on a body.

Sheet 6.

A large diagram (34″ × 41″) illustrating the principle of moments. Weights are suspended at three points on the circumference of a disc which is pivotted about a central horizontal axis.

Sheet 7.

(20″ × 16″.) Relates to the parabolic path of projectiles.

Sheet 8.

(22″ × 32″.) Illustrates the simple pendulum. Two pendulums are shown vibrating through the same angle. Ratio of length of pendulums are as 1 : 4.

Sheet 9.

(21″ × 17″.) Compares the rates of efflux of water from the same head of water with five different kinds of jets.

Sheets 11 to 21.

These are copied with some modifications from Peter Ewart's paper on "Moving Force."[9]

Peter Ewart was elected a member of the Literary and Philosophical Society in 1798, and for 22 years was a Vice-President. In 1835 he became the Chief Engineer and Inspector of Machinery in the Government Dockyards at Woolwich. In writing his paper on "Moving Force" he was assisted by Dalton, who suggested some of the experiments described. In his Royal Institution Lectures in 1909-10 Dalton tells us "that several have been wonderfully struck with Mr. Ewart's doctrine of Mechanical Force." Part I. of Vol. II. of "The New System of Chemical Philosophy" (1827) is dedicated to

John Sharpe, Esq., F.R.S.,
and to
Peter Ewart, Esq.,

Vice-President of the Literary and Philosophical Society of Manchester, "on the score of friendship, but more especially for the able exposition and excellent illustra-

[9] See *Manchester Memoirs*, **2**, 2nd Series, p. 105. Also see "Some Account of the late Mr. Ewart's Paper on the Measure of Moving Force," by Eaton Hodgkinson, *Memoirs*, **12**, p. 138; also an account of the same by J. Bottomley, in the "Centenary of Science in Manchester," by R. Angus Smith, p. 246.

tion of the fundamental mechanics, in his essay on the Measure of Moving Force."

Up to 1686 the force of a body in motion was measured by the product of the mass of the body into its velocity. Leibnitz thought that this was erroneous, and maintained that it should be the product of the mass into the square of the velocity. This he termed the *vis viva*, which is equal to twice the kinetic energy. The great controversy was not ended until the resistance to be overcome was taken into account. This may sometimes be conveniently measured by a space integral ($\frac{1}{2}mV^2$), and in other cases by a time integral (mV).[10]

Heat.

Sheet 22.

Shows Fahrenheit, Centigrade and Réaumur thermometers, each with a length of 14 inches. They are marked in steps of 10 degrees between the freezing and boiling points. The spherical bulbs in each case are represented as full of mercury up to the freezing point. The Fahrenheit has two scales, one being the ordinary scale marked from -20° to 212°, and the other Dalton's new scale.

The new scale is described in Part I., section 1 of Dalton's "New System of Chemical Philosophy." It is based on Dalton's assumption that all pure homogeneous liquids expand from their point of congelation or greatest density by an amount proportional to the square of the rise of temperature from that point.

Dalton arranged that his new scale should agree with the Fahrenheit scale at 32° and 212°, and -40°F. was taken as the freezing point of mercury. Hence it can

[10] See Routh's "Rigid Dynamics," Chapter VII., where references will be found relating to the history of the controversy.

readily be deduced that the value T on the new scale will be given by the formula :—

$$T = \left(\frac{\sqrt{F + 40} - \sqrt{72}}{\sqrt{252} - \sqrt{72}} \times 180 \right) + 32.$$

where F is the temperature on the Fahrenheit scale. Mr. Arthur Adamson finds that this formula agrees with the numbers calculated by Dalton.

We now know that the scale proposed by Dalton is untenable, and in the Appendix of the 1827 edition of Part I., Vol. II. of the "New System" he admits that it is so in the light of the researches of Dulong and Petit on the expansion of mercury.

Sheet 23.

Eleven thermometers are shown each 17 inches long, the spherical bulbs are blackened and so also is the lower part of the stems to a common level. The graduations on the thermometers are :—

No. 1.	Right side 1, 2, 3, 4, 5, 6, 7				
	Left side $1^2, 2^2, 3^2, 4^2, 5^2, 6^2, 7^2$				
,, 2.	Earthenware (1)	in 10° spaces from	36	to	106
,, 3.	Earthenware (2)	,, ,, ,, ,,	40	to	110
,, 4.	Glass	,, ,, ,, ,,	41½	to	111½
,, 5.	Iron	,, ,, ,, ,,	42½	to	112½
,, 6.	Tinned Iron ...	,, ,, ,, ,,	42½	to	112½
,, 7.	Copper ...	,, ,, ,, ,,	45½	to	115½
,, 8.	Brass	,, ,, ,, ,,	46	to	116
,, 9.	Pewter	,, ,, ,, ,,	46	to	116
,, 10.	Lead	,, ,, ,, ,,	49½	to	119½
,, 11.	No graduations.				

Sheet 24.

(19″ × 33″.) This is marked by Dalton :—"Water therm." On the left-hand of the sheet two thermometers are shown. On one there is a scale against which Dalton has written:—"Reformed graduations as the square of the temperature," and against the other, "Graduations of water therm. to correspond with common scale of mercurial thermometer." These show graduations from 42° to 212°. On the middle of the sheet these scales are again drawn on a larger scale, with only seven graduations. On the right is hand-printed:—

Water Therm.
Lowest Point.

In Earth-Ware	38
Stone-W.	40
Glass	$41\frac{1}{2}$
Iron	$42\frac{1}{2}$
Copper	$45\frac{1}{2}$
Brass	46
Pewter	46
Lead	$49\frac{1}{2}$
Zinc	(no number)

These numbers correspond nearly with those on p. 31 of Part I. of the "New System."

On the bottom of the diagram the following numbers are tabulated:—

	6°	16°	26°	38°	48°	56°	66°	76°	86°		
$\frac{9}{2}$	$\frac{7}{2}$	$\frac{5}{2}$	$\frac{3}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{2}$	$\frac{5}{2}$	$\frac{7}{2}$	$\frac{9}{2}$	real exp. glass, etc.
11	9	7	5	3	1	1	3	5	7	appar. exp.

which further illustrate Dalton's experiments on the maximum density of water. He concluded that this greatest density is at or near 36° of the old scale, and 37° or 38° of the new scale.

Sheet 25.

This is drawn on rough paper and is 8 feet long and 7 inches wide, formed of three slips of paper pasted together. It is labelled "Water Therm." and shows a long thermometer with a large spherical bulb. This and part of the stem up to 42° are shaded to represent the water. The remainder is graduated in steps of ten degrees, 52°, 62°, etc., up to 212°, the distances between these divisions are gradually increased, showing the increasing rate of expansion of the water.

Sheet 26.

Labelled "Old and New Scales, 32° to 212°." A diagram 27 inches long and 6 inches wide, showing adjacent scales marked in steps of 10 degrees.

Sheets 27 to 29.

These diagrams were used to make clear the difference between temperature and capacity for heat. No. 27 (20″ × 33″) shows two vessels of different capacity connected by a stopcock. In No. 28 (17″ × 21″) there are three independent vessels of different sizes filled to the same level with a liquid. No. 29 (19″ × 14″) is a hydrostatic analogy relating to the "method of mixtures" used in calorimetry.

Sheet 30.

A diagram 41in. long and only 4in. wide. It is weighted at the bottom by a piece of lead so that it will hang vertically. It shows graphically the relative expansion of:—

1.	Glass, etc.	$\frac{1}{400}$	=	25.
2.	Lead, etc.	$\frac{1}{116}$	=	86.
3.	Mercury	$\frac{1}{55}$	=	180.
4.	Water	$\frac{1}{22}$	=	465.

5.	Salt Water	$\frac{1}{20}$	=	500.
6.	Sul. and Mur. Acid ...	$\frac{1}{17}$	=	600.
7.	Ether, oil Turp.	$\frac{1}{14}$	=	700.
8.	Oils	$\frac{1}{12 \cdot 5}$	=	800.
9.	Alcohol, Nit. Aci. ...	$\frac{1}{9}$	=	1100.
10.	Air	$\frac{3}{8}$	=	3750.

The above is printed by hand on the chart, and the right-hand numbers, after dividing by 100, are used to show graphically the expansion. Thus air is represented by 37·5 inches, alcohol by 11 inches and so on. In each case it is the coefficient for cubical expansion from 32°F. to 212°F. that is represented by the fractional numbers. If these be compared with the Table on p. 44 of the 1808 edition of Part I. of the "New System" it will be found that they all agree with the figures given in the Table, with the exception of mercury, which is given as high as $\frac{1}{50}$. The value $\frac{1}{55}$ is nearer the $\frac{1}{55 \cdot 5}$ which Dalton quotes from the experiments of Dulong and Petit, given in the 1827 edition of Part First of Vol. II. of the "New System." It hence seems probable that the diagram No. 30 was made after 1819, when the experiments of Dulong and Petit were published.

Sheets 31 and 32.

These diagrams are very similar to that given in Plate 2, Part I. of the "New System," but better adapted for lecture use. They both show logarithmic curves representing Dalton's law for the increase of vapour pressure with temperature. In the case of No. 31 a diagram is added which shows a barometer tube containing mercury with water on the surface of the mercury. The tube has a heating jacket surrounding its upper part, whilst the lower part is bent and graduated for pressure measurements. No. 31 (22″ × 33″) relates to water only, but in No. 32 ($19'' \times 32''$) the values for ether are also shown. Dalton's law may be given in the form :—

$$\log p = A + B\theta$$

where p is the pressure, A and B constants, and θ the absolute temperature. Modern experiments have shown that

$$\log p = A + \frac{B}{\theta}$$

more nearly expresses the law for water.

Sheets 34 and 35.

These are smaller diagrams ($19'' \times 24''$) and have no lettering. They were used by Dalton in his earlier lectures, when dealing with the steam engine. No. 35 explains the method of Savary (1698) for raising water by suction into a vacuum produced by the condensation. In the diagram a safety valve is shown which was not applied by Savary, but invented in 1717.

No. 36 is Newcomen's engine (1705-7). The diagram shows the method of injection into the cylinder, but no safety valve or method of feeding the boiler is represented.

Sheet 36.

($20'' \times 15''$.) Leslie's experiment on the reflection of heat. In the focus of one concave mirror is placed a bottle of hot water; in the focus of a second concave mirror is an air thermometer.

OPTICS.

Sheet 37.

($13'' \times 19''$.) Shows (1) a parallel beam and a diverging beam of light, (2) the reflection of a parallel beam from a plane mirror, (3) the refraction of a parallel beam in passing through a prism, and (4) the diffraction of a parallel beam when passing through a small opening.

Sheet 38.

($9\frac{1}{2}'' \times 17\frac{1}{2}''$.) Probably used to illustrate the law of inverse squares. It consists of four blackened squares having the relative areas of 1 : 4 : 9 : 16. White lines are used to divide the larger squares into areas equal to the smallest square.

Sheets 39 and 40.

The first is a small diagram ($16'' \times 10''$) showing the method of the formation of the image of an object (a Latin cross) by a plane mirror. The second is like the last but larger ($21'' \times 16''$).

Sheet 41.

($17'' \times 21''$.) Two plane mirrors lettered A and B are inclined at an angle of 30°. Between them are two objects, a **x** and a ●. The multiplication of the images of these objects is represented, there being eleven images of each. Dalton has marked the manner of the formation of each image. Thus one of the images of the **x** is marked

"1 *b* by *a* by *b* by *a* by *b*",

a and *b* referring to the mirrors A and B.

Sheet 42.

($21\frac{1}{2}'' \times 17\frac{1}{2}''$.) Multiplication of the images of a candle flame by a single plane mirror, due to the reflection from the front and back surfaces of the looking glass. The formation of seven images is represented.

Sheet 43.

A small diagram ($16'' \times 10''$) probably for use in small lecture classes. It shows the formation of images of Latin crosses (1) by a concave mirror giving an inverted magnified real image, (2) by a concave mirror giving an erect magnified virtual image, and (3) by a convex mirror giving an erect, diminished and virtual image. Dalton has written "object" and "image" against the crosses. On the back of the diagram he has written "optical schemes."

Sheet 44.

A larger diagram (21″ × 16½″) showing the production of images by curved mirrors. Two cases are drawn, the formation of an erect magnified virtual image by a concave mirror, and the formation of an erect diminished virtual image by a convex mirror. Each mirror has the same focal length, and the size of the object in front of the convex mirror is made equal to the image in the concave mirror, and since their distances from the mirrors are also equal, one diagram is the reverse of the other.

Sheet 46.

(21½″ × 17½″.) Two diagrams, the upper one representing the experiment of Newton. Light from the sun passes through a hole and falls on an equilateral glass prism which produces a spectrum. The lower diagram explains the well-known experiment, which Dalton showed in his lectures, of a coin placed in a vessel in such a position that the coin cannot be seen until water is poured into the vessel.

Sheet 47.

(17½″ × 10½″.) Illustrates the use of a Wollaston's prism as a Camera Lucida. The diagram shows the two reflections from the faces of the quadrilateral figure that are essential to prevent a reversed image.

Sheet 48.

($20\frac{1}{2}'' \times 16\frac{1}{2}''$.) This has four diagrams :—

(1) The concentration of a parallel beam by a double convex lens to its principal focus.

(2) The method of use of a double convex lens as a magnifying glass.

(3) The formation of an inverted magnified real image by a double convex lens.

(4) The formation of an image by a double concave lens.

Sheet 49.

($21'' \times 17''$.) The upper diagram explains the compound microscope. Three convex lenses are used to produce a magnification of an insect. The lower diagram relates to the solar microscope. Sunlight is reflected by a mirror and concentrated by a large convex lens on an insect. With the aid of a small convex lens of short focal length an enlarged image of the insect is produced.

Sheet 50.

($21\frac{1}{2}'' \times 17\frac{1}{2}''$.) This has five diagrams, explaining the optical principles of :—

(1) The Gregorian reflecting telescope.

(2) The common refracting telescope with erecting lenses.

(3) The refracting astronomical telescope with four lenses.

(4) A telescope with two convex lenses.

(5) The opera glass.

Sheets 51 and 52.

The first is a small diagram ($10'' \times 8''$) showing how an inverted image is produced on the retina of the eye. The other sheet ($21'' \times 17''$) shows the previous figure to a larger size, and has in addition three views of the eye with the pupil contracted, of normal size, and dilated.

Sheets 53 and 54.

(8″ × 10½″ and 17″ × 20½″.) These are in illustration of what Dalton has called the "optical principle" used in the "Essays" in connection with the Propositions concerning the Aurora Borealis, where he says "for it is known to every one, that celestial objects, and objects at a distance in the air, as the sun, moon, stars, meteors, etc., all appear at the same distance, though nothing can be more disproportionate than their real distances."

ACOUSTICS.

Sheet 55.

(22″ × 18″.) The transverse vibrations of strings showing the production of the fundamental note and harmonics. This is an enlarged drawing of one on a half-sheet of notepaper, found among Dalton's papers, on which he has written "Young's Theory of Harmonic Tones."

Sheets 56, 57 and 58.

The first is a small diagram (8″ × 13″) on which Dalton has carefully drawn seven organ pipes producing fundamental and harmonic tones, and has marked the position of the nodes and anti-nodes. He has also represented the condition of the air of the sound-wave by spirals whose diameter is gradually varied. Three relate to open and three to closed pipes. A pitch-pipe is also shown, which is provided with a piston for altering the length of the tube. No. 57 (16½″ × 13″) gives the first six cases. No. 58 (27″ × 19″) includes the pitch-pipe, four closed pipes and three open pipes.

ELECTRICITY.

Sheets 59 and 60.

No. 59 is a small diagram (3″ × 23″) illustrating Davy's explanation of electrolysis. It shows 6 "atoms" of water, the oxygen being indicated by ○ and the hydrogen by ⊙. The upper part of the diagram shows the position of the atoms when not connected with a battery, and the lower part shows the liberation of the gases at the electrodes when the current passes. This diagram is probably taken from a paper on "Theories of the Excitement of Galvanic Electricity" by William Henry (see *Memoirs*, **2**, p. 311, 1813). No. 60 is a larger diagram (21″ × 17″) like 59 without showing any electrodes.

METEOROLOGY.

Sheets 61, 62, 63 and 64.

These relate to the Theory of Rain, which Dalton adopted and extended,[11] that was first given by Hutton.[12] The latter had pointed out that the quantity of vapour capable of entering the air increases at a greater rate than the temperature. Hence it may be concluded that when two volumes of air at different temperatures are mixed together, each being previously saturated, a precipitation must ensue, in consequence of the mean temperature not being able to support the mean quantity of vapour.

No. 61 (21″ × 17″) is headed "Theory of Rain," and shows a curve plotted connecting the pressure of saturated water vapour and its temperature. Dalton has written on the diagram the numbers used :—

[11] See Dalton's observations on the barometer, thermometer, and rain at Manchester, from 1794 to 1813 inclusive. *Memoirs* (2nd Series), **3**, p. 483, 1819.

[12] "The Theory of Rain," by J. Hutton. *Trans. Roy. Soc. Edin.*, Vol. I., p. 41, 1788; Vol. II., p. 39, 1790.

New Scale.		Inches of Water.		Differences.
12°	=	1·523		
22	=	2·010	...	·487
32	=	2·652	...	·642
42	=	3·5	...	·848
52	=	4·618	...	1·118
62	=	6·094	...	1·476
72	=	8·041	...	1·947
82	=	10·61	...	2·569
92	=	14·	...	3·390

The curve shown is convex towards the horizontal line of temperatures.

No. 62. (27″ × 19″.) Like the previous diagram but the Fahrenheit scale is used. The departure of the curve from a straight line connecting the freezing and boiling points is much less marked than in No 61.

No. 63 is like No. 61 but larger (32″ × 22″). A straight line connecting the 30° and 90° points shows that at 60° the amount of water that must be precipitated when the temperature falls from 90° to 60° is considerable.

No. 64. A still larger diagram (41″ × 34″) like the last one but designed for a large lecture room. Straight lines are drawn connecting the 30° to 80°, the 30° to 50°, and the 60° to 80° points.

Sheet 65.

(27″ × 19″.) This has been intended by Dalton to explain Proposition III. of the "Mathematical Propositions necessary for illustrating and confirming those concerning the Aurora Borealis" (see "Meteorological Essays," p. 154, 1834). It shows a series of cylindrical beams equal and parallel to each other, all in a plane perpendicular to the horizon, and at equal distances from the horizon. These beams Dalton demonstrates will appear to an observer like a series of arches of a special shape. The diagram has not been completed.

Sheets 66 and 67.

Relate to the cause of the long-continued and irregular sound of thunder. About the year 1808 or 1809 (see "Meteorological Essays," 2nd Edition, Appendix, p. 202), it occurred to Dalton that if he could assume an electric discharge to be made instantly from one cloud to another, the distance apart of the clouds being say 12-14 miles, then the sound will be first heard from the nearest point, then from equidistant points and then from the furthest points. He gave this explanation at the Royal Institution lectures in 1810. No. 66 is a small (20″ × 17″) diagram that has been carefully made and painted. A cottage with a lightning conductor, a tree and a man are depicted. The suggestion has been made that this was drawn and coloured for Dalton by some artist friend. No. 67 is a much larger diagram (43″ × 27″), and is a rough copy of 66. The explanation of the diagram is given on p. 203 of the "Essays." The clouds between which the lightning passes are supposed to be 14 miles apart. On the last page (p. 244) Dalton says that he has been informed that the above explanation was previously given by Boscovich. The name should have been Beccaria.[13]

Sheets 68 and 69.

The first of these (16″ × 20″) shows the gradual diminution of the density of the atmosphere as the height increases by the aid of a distribution of black dots. These are close together at the bottom of the diagram and the number in a given space is made to decrease gradually. In No. 69 (19″ × 27″) the decrease of density is shown by horizontal lines, these are close together at the bottom of the diagram and are drawn further

[13] Lettere dell' elettricismo artificiale e naturale. Turin, 1753. See "History of Electricity," by Joseph Priestley, 4th Edition, 1775.

apart with increasing height. This diagram also shows a logarithmic curve.

Sheet 70.

(20″ × 30″.) A rough map of Great Britain showing an isogonic line. This is drawn through London, and the declination when read off by a protractor is 20° W.

Sheet 71.

(17″ × 20″.) A diagram explaining the theory of the winds.

ASTRONOMY.

Sheet 72.

(22″ × 32″.) This diagram is repeatedly referred to by Dalton in his Lecture Notes on Astronomy. In Lecture 8, April 17th, 1820, his rough notes give :—

"Gravitation explained—Earth, Diagram.

—Attraction of each particle of matter is inversely as the square of the distance.

—Force of Gravity at the Earth's surface Max.

—Force above, inversely as square of distance from centre.

—Force below—directly as distance from centre."

The diagram (22″ × 32″) represents the earth attracting a weight of 1 at the surface of the earth and balances a weight of 4 placed at distance 2 from the centre of the earth. The weights are placed in the pans of a balance having short and long suspensions. The attraction at distance 2 is marked $\frac{1}{4}$, and at distance 3, $\frac{1}{9}$.

Sheets 73 and 74.

(20″ × 16″ and 22″ × 18″.) These Dalton used to explain Kepler's 1st Law, which he states as :—"A body revolving round any centre of force describes equal areas in equal times."

Sheet 75.

($22'' \times 17\frac{1}{2}''$.) Kepler's 2nd Law. Dalton's statement of the law is:—"If several bodies revolve around a common centre of force, and if the *squares* of the Periodic Times are as the *cubes* of the distance, then the central attraction decreases as the square of the distance increases." The diagram refers to the cases of the Earth and Mars, which have relative distances of 2 and $3\frac{1}{6}$, and periodic times of 1 and 2 respectively, hence

$$\frac{2^3}{3\frac{1}{6}^3} \text{ should be equal to } \frac{1}{2^2}$$

and this is found to be approximately the case.

Sheet 76.

($17'' \times 21\frac{1}{2}''$.) Shows that the orbits of the planets are ellipses, the sun being in one focus.

Sheets 77 and 78.

($21'' \times 17''$.) The first explains the production of shadows by a body in the path of the sun's rays. The second one explains lunar and solar eclipses.

Sheet 79.

($21'' \times 17\frac{1}{2}''$.) Explains the transit of Venus.

From Dalton's notes:—

"1639. Horrox of Toxteth predicted the transit of Venus—communicated it to Crabtree of Broughton. They both saw it, the first time that ever was seen—this extra. youth died in the 22nd year of his age."

Sheet 80.

A circular diagram, 17″ diam. This represents the size of the sun, the relative sizes of the planets are shown within the circle.

Sheet 81.

(29″ × 21″.) Explains the production of tides.

Sheet 82.

(17″ × 5½″.) Shows a beam of light from the sun falling on a surface placed at right angles to the beam, and the spreading of the beam when it falls on a horizontal surface.

Sheet 83.

(21″ × 17½″.) This is designed to explain the relation between latitude and the sun's altitude.

Sheet 84.

(8″ × 8″.) Represents the projection of a sphere with meridians and circles of latitude.

[Sheets 10, 33, 45, and nine others remain unclassified.]

Manchester Memoirs, Vol. lix. (1915), *No.* **12**.

Part III.

The Lecture Sheets Illustrating the Atomic Theory.

By HUBERT FRANK COWARD, D.Sc.,

AND

ARTHUR HARDEN, D.Sc., Ph.D., F.R.S.

(*Read May 11th, 1915. Received for publication May 31st, 1915.*)

Towards the end of the eighteenth century and during the early part of the nineteenth, John Dalton delivered courses of lectures on Natural Philosophy in Kendal, Manchester, London, Edinburgh and Glasgow, and other places.[14] During his development of the atomic theory, from about 1803 onwards, Dalton's lectures dealt more and more with chemistry, and were illustrated by chemical experiments and by sheets of diagrams which he prepared with considerable care. Recently some 150 of these lecture sheets were found in the rooms of the Society, and of these the 53 which illustrate the atomic theory are described in the present Memoir.

While no new view of the origin of the atomic theory has been disclosed by them, they nevertheless present some highly interesting points to the student of the history of science. In general they show that Dalton made much more use of his symbols in oral explanations of the theory than in his published works or even in his laboratory note-books. Thus, besides two tables of atomic weights and symbols, some 34 of the sheets

[14] For a list of these, see Part I.

represent the composition of "compound atoms" of the most diverse inorganic and organic compounds.

Very little of Dalton's published work deals with organic compounds. The sheets show, however, that he used his atomic symbols for picturing the constitution of the commoner compounds of vegetable and animal origin, probably for exhibition during courses of lectures on pharmaceutical chemistry. The symbols were not put together in a haphazard fashion; for example, Dalton introduced a "vegetable atom," composed of one atom each of carbon, hydrogen and oxygen, as a constituent of such different substances as citric acid, sugar and wood. This conception of the radical marks an intermediate stage between Lavoisier's idea and the later theories of compound radicals. Dalton also clearly expressed by his symbols the conception of isomerism, as shown by sheet 23 (reverse), reproduced in *Plate VII.*, where the compound atoms of two different substances are represented by "ultimate atoms," the same in nature and number but differently arranged.

Surprise has been expressed that Dalton could not bring himself to adopt Berzelius' system of chemical nomenclature. These diagrams, especially those dealing with organic chemistry, render Dalton's attitude towards Berzelius' system much more intelligible; for his symbolic expression of the *constitution* of substances is much simpler than that of Berzelius. It may indeed be said that while modern chemistry has adopted the symbols of Berzelius, it has used them much in the Daltonian fashion.

Dalton's formulæ for organic compounds are, however, very different from those now accepted.

One of the two sheets of atomic weights seems to have been the second ever presented to the public. It was prepared, together with several of the other sheets, for the lecture course delivered in Edinburgh and in Glasgow in the spring of 1807.

Two of the sheets, numbered 34 and 35, represent reacting quantities by formulæ, almost in the manner of a modern chemical equation.

A minor point which has come to light in the course of the study of Dalton's note-books in connection with the diagrams, is a tri-dimensional formula for oxamide. (Laboratory Note-book xi., p. 372, March, 1834.) Oxamide was supposed to consist of one atom each of carbon, hydrogen, oxygen and nitrogen, and these are figured in the form of a tetrahedron, so that each atom is similarly placed, in contact with the other three.

Sheet 1.

Plate III.

"ELEMENTS."

Several of the figures have been altered from those originally inserted. Some of these alterations are visible in the reproduction, the others can only be observed in the original. Most of the figures have been enlarged since they were first inserted The corrections detected are:

Sulphur, from 12 to 13.

Magnesia, originally 20, as shown in the plate, was later covered with a slip of paper holding the figure 17. At some later time the slip became detached, but the ink stain from the superposed slip is plainly visible.

Lime, from 23 to 24.

Iron was originally 40, then altered to 38, and finally covered with a slip of paper bearing the number 50. This slip has been detached in order to disclose the figures underneath, and is now shown in the reproduction alongside the figures which it covered.

Lead, from 95 to 90.

Silver, which now appears to be 190, was originally 100. The 1 has at some time been covered and a tail given to the first 0 to make it a 9. Some fibres of the fragment of paper which had been pasted over the 1 still adhere to the sheet.

Gold, originally 140, was altered to 90. A slip of paper pasted over the 1 is lost but has left the faint outline of one corner, as shown by the small difference of tint in the colour of the sheet in that region.

Platina was 100, then altered to 90 in the same way as the figure for silver. Fibre left by the covering slip is readily noticed on the sheet.

The date of the original preparation of this sheet can be determined when the figures and symbols on it are compared with those in Dalton's published works and especially with those in his manuscript note-books. In the first place it is evidently a very early list, although quite different from the first published one, which was appended to the paper "On the Absorption of Gases by Water," published in 1805 (*Memoirs* 6, 287). It contains, however, the names of the same twenty elements (so-called) as the first part of the first volume of his "New System of Chemical Philosophy," published in 1808. Certain differences between the figures and symbols of the sheet and the corresponding ones of the book are apparent, and by comparison with others prove that the sheet was the earlier of the two. Thus the symbols for lime, magnesia and gold were not the same as those in the book, and the atomic weights of sulphur and iron are certainly earlier than those of the book.

The published figures, therefore, point to the date of the sheet as between 1805 and 1808. The atomic weights found in the set of laboratory note-books kept by Dalton and now preserved in the Society's library, were next compared with those of the sheet, and were found to point to its date as lying between October, 1806, and July, 1807. Whilst the figures for oxygen, azote, sulphur and phosphorus show that the sheet was not produced before 1805 or 1806, the most significant figure is that for iron, which at the first appearance of this sheet was 40. Now, in September, 1806, Dalton put the atomic weight of iron as 29 or 58; on October 22nd of the same year it became 40, but in July, 1807, was again altered to 50, and did not again become 40 so far as can be discovered. The other atomic weights are all in accord with the date ascribed, with the exception of two: the figure for carbon is 5·4[15] on the sheet, a value not found in the published works or laboratory books until 1810 ("New System," I., ii.); for mercury the atomic weight on the sheet is 167, a figure which appears first in 1808 ("New System," I., i.) where it replaces the 166 of July, 1807, and October, 1806.

The latter difficulty is probably of no significance, since the difference is only of one unit in the large value 166 to 167. The former difficulty—the atomic weight of carbon being 5·4 when in contemporary lists it appears as 5—was removed as the result of an enquiry as to the reason for the compilation of this sheet of atomic weights. It seemed reasonable to expect that this was drawn up for use during some important lecture, and it was therefore no surprise to find that Dalton gave courses of lectures in Edinburgh and Glasgow in April, 1807. The notes for these lectures, which are also among the relics in the Society's library, contain worked out several atomic weights, together with reference to a "scheme" (apparently the present sheet). The atomic weight of carbon

[15] Without doubt the figure in the first decimal place belonged to the original compilation of the sheet.

calculated from the composition of carbonic acid is therein put 5·4. Evidently Dalton about this period generally used whole numbers for his atomic weights; on this one occasion he showed more confidence than usual in the analytical figures from which he had deduced this atomic weight. An illustration of his attitude of mind at the time is to be found in the third laboratory note-book, page 76 (*circa* 1809), where he writes, in reference to the atomic weight of nitrogen, "From the above observations it seems probable that the true ratio of hydrogen to azote in ammonia is nearly 1 to 5, or perhaps 1 to $4\frac{3}{4}$; but as an integer is more easily remembered, we shall prefer the ratio 1 to 5 till a more accurate one can be ascertained."

There seems therefore to be little doubt that this sheet was prepared at the latter end of 1806 or early in 1807 for illustrating the lectures in Scotland in April, 1807. It is therefore the second publicly presented list, so far as is known. It was probably prepared by Dalton's own hand.

The atomic weights from Dalton's note-books and publications of this period, starting from the earliest found (in 1803) are collected for comparison in Table I.

Sheet 2.

Plate IV.

This table of atomic symbols and weights is much later than the previous one and is not very different from the corresponding list of elements in Volume II. of the "New System" (1827). The symbols are represented in the book by the full names of the elements. The following comparison shows those details where differences between the two lists are found:

TABLE I.

	The Lecture Sheet (Plate I).	6.9.1803. Note-book i., 248.	19.9.1803. Note-book i., 258.	— 9.1803. Note-book i., 260.	— 3.1804. Note-book i., 381-2.	14.9.1804. Note-book ii., 107.	1805. Mem. 6, 287.	14.8.1806. Note-book ii., 284.	23.8.1806. Note-book ii., 282.	16.9.1806. Note-book ii., 247.	— 9.1806. Note-book ii., 255.	22.10.1806. Note-book ii., 256.	Spring, 1807. Notes for lectures in Edinburgh and Glasgow.	— 7.1807. Note-book ii., 421.	1808. "New System" I., i.	1810. "New System" I., ii.	2.5.1815. Note-book vi., 227.	1827. "New System" II.
Hydrogen ...	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Oxygen	7	5·66	5·66	5 5	[5·5]	5·5	5·5	7	7	7	...	7	7	...	7	7	...	7
Azote	5	4	4	4	...	4·2	4·2	5	5	5	...	5	5	...	5	5	...	5 ± or 10?
Carbon	5·4	4·5	4·4	...	...	[4·3]	4·3	5	5	5	...	5	5·4	...	5	5·4	...	5·4
Sulphur	12	17	14·4	...	...	[14·4]	14·4	22	22 −	12	...	12	...	...	13	13	...	13, or 14
Phosphorus ...	9	...	7·2	...	...	...	7·2	9⅓	9 +	...	...	9⅓	...	...	9	9	...	9
Potash	42	...	...	...	...	...	...	18?	22 +	42	...	42	42	...	42	42	...	...
Soda	28	...	...	...	...	...	...	28	26, 28	28	...	28	28	...	28	28	...	28
Lime	23	...	...	...	...	...	...	22	22, 10?	23	...	23	23	...	23	24	...	24
Magnesia	20	...	...	...	...	...	...	20?	20 ±	20	...	20	20	...	20	17	...	17
Strontian	46	...	...	...	...	...	...	38 } 42 }	44?	46	...	46	46	...	46	46	...	46
Barytes	68	...	...	...	...	...	...	76?	48	68	...	68	68	...	68	68	...	68
Alumine	...	...	...	...	...	...	...	(11), 36?	30, 40, 60	...	...	11?	...	...	...	15	...	20
Gold	140	...	...	...	105	...	...	140	...	...	140-150	...	...	...	140	140?	90 } 45 }	60 ±
Platina	100	...	...	...	...	...	...	...	...	...	90-100	...	...	...	100	100?	90	73
Silver	100	...	...	...	105	...	...	63	...	115	100 ±	100 ±	...	100	100	100	90	90
Mercury	167	...	...	...	105	...	...	133 } 112 }	...	...	...	166	...	166	167	167	167	167 or } 84 }
Copper	56	...	...	...	44	...	...	56	...	...	...	56	...	56	56	56	56	56 or } 28 }
Iron	40	...	...	...	16	...	...	19? } 38? }	33? } 66 }	29 or } 58 }	...	40	...	50	38	50	50 } 25 }	25
Tin	...	...	...	...	22	...	...	36	...	...	70	...	...	50-60	...	50	52	52
Lead	95	...	...	...	105	...	...	63	...	106 } 90 }	...	95	...	95	95	95	90	90
Zinc	56	...	...	...	22	...	...	50 +	...	52	...	56	...	56	56	56	29	29
Bismuth	...	...	...	...	22	...	...	60	...	...	117 ±	...	...	62	...	68?	62	62
Antimony ...	...	...	...	...	...	...	...	...	...	...	32-44	...	...	37? 50? } 40 }	...	40	40	40
Arsenic	...	...	...	...	...	...	...	25 } 50 } ?	...	...	40-48	...	...	42?	...	42?	21	21
Manganese ...	...	...	...	...	16	...	...	56	...	...	58?	...	...	63	...	40?	25	25

	"New System," II.	Sheet.
Azote	5±, or 10? ...	5
Sulphur	13, or 14 ...	14
Gold	60± ...	56—63
Mercury	167, or 84? ...	167
Copper	56, or 28? ...	56
Tellurium ...	29, or 58? ...	28?—57?
Chromium ...	32 ...	25? 32? 39? 46?
Calcium	17? ...	Not represented.
Strontium ...	39 ...	Not represented.
Barium ...	61 ...	Not represented.
Osmium ...	Neither name nor weight. ...	Symbol only, no weight.

It appears that the doubts entertained about the atomic weights of azote, sulphur, mercury and copper, at the time of compilation of the "New System," did not exist when the sheet was compiled; but on the other hand that the reverse is the case for chromium. The comparison of these figures therefore gives no clue as to which of the two lists is the earlier. It seems probable however that the sheet was made earlier than 1827, since calcium, strontium and barium find their place as elements in the book. The only apparent indication to the contrary is the presence of the element osmium on the sheet and not in the list in the book; but Dalton was quite aware of the existence of this element long before 1827, for an account of it appears in the "New System," I., p. 255. The reason that it did not appear in the list of elements in the book is that Dalton had no data for determining its atomic weight.

Sheet 3.

Plate VI.

Alternative formulæ for (*a*) water, (*b*) ammonia.

In the Edinburgh and Glasgow lecture notes (1807) Dalton refers to this or a similar diagram immediately after a discussion of the composition of water and ammonia: "See small scheme of three modes." In the famous chapter "On chemical synthesis" in the "New System," I., i, 211—216 (1808), is found the following rule which led Dalton to choose the binary formulæ for these two compounds: "When only one combination of two bodies can be obtained, it must be presumed to be a *binary* one, unless some cause appear to the contrary." No "cause to the contrary" was ever admitted by Dalton for these formulæ.

Sheet 4.

Plate VI.

Alternative formulæ for the oxides of carbon.

Dalton chose the latter two formulæ to represent carbonic oxide and carbonic acid. A discussion of this question is found in the "New System," I., ii, 368—371.

Sheet 5.

Plate V.

"ATOMS OF ELASTIC FLUIDS."

These are represented as surrounded by atmospheres of heat of different sizes. They express Dalton's conception, at one time, of the composition and size of the atom of:

1. Hydrogen.
2. Hydrogen sulphide.
3. Nitrous oxide.
4. Carbon dioxide.
5. Water.
6. Hydrochloric acid ("Muriatic acid").
7. Methane ("Carburetted hydrogen from stagnant water").
8. Carbon monoxide.
9. Nitric oxide ("Nitrous gas").
10. Ammonia.
11. Nitric acid.
12. Alcohol.
13. Oxygen.
14. Nitrogen.
15. Ether.
16. Ethylene ("Olefiant gas").

This diagram obviously belongs to the very early days of the atomic theory, when to Dalton the atmosphere of heat around the atoms was still the fresh and vivid conception which had played so important a part in the physical origin of the atomic theory. The original sheet shows plainly that the formula for hydrogen sulphide (No. 2) is on a slip which has been pasted over an earlier formula representing that compound by a central sulphur atom surrounded by three atoms of hydrogen. The new formula was adopted in 1809 (Third laboratory note-book, page 185). The older one has been found in 1808 ("New System," I., i.), in 1807 (Edinburgh and Glasgow lecture-notes), and once as an alternative formula in 1806 (Laboratory note-book ii., p. 245, September, 1806). Before 1806 Dalton gave only the formulæ SH_2 and SH_4. The original compilation of the sheet therefore belongs to the period 1806 to 1809.

Another formula of interest is that for muriatic acid, which is represented as HO_3, a view held by Dalton in the "New System," I., ii. (1810).

Very interesting is the representation of methane, ethylene, ether and alcohol as hydrocarbons: CH_2, CH, C_2H, and C_3H respectively. This is exactly the idea Dalton held at the time of the Edinburgh and Glasgow lectures (1807), as shown in the Mss. notes. It seems most likely that the table was prepared to illustrate those lectures, and is the actual "scheme" mentioned in the lecture notes for reference during the lectures.

A further point of interest is the difference between the mode of presentment in this early diagram and that employed in the "New System," I., ii. (1810). In the latter case (Plates 7 and 8) the atoms are represented by squares, each containing 16 rays representing the atmosphere of caloric.

In the early diagram the first eight atoms have nearly the same diameter and the others follow in order of decreasing size. Slight differences exist between the values employed in this diagram and those given in the note-books and in the "New System," as is seen from the following list :

No. of figure in Diagram.	Diameter of the Atom.			
	On Diagram.	Note-book i., 258, 19 Sep., 1803. (Calculated to hydrogen unity)	Note-book ii., 107, 14 Sep., 1804.	"New System," I. ii., 560. 1810.
1	1	1	1	1·000
2	1	1·143	—	1·00
3	1	0·971	0·952	0·947
4	1	1·048	1·00	1 00
5	1	1·009	0·976	—
6	1	—	—	1·12
7	1	—	1·00	1·00
8	1	1·05 +	0·993	1·020
9	0·95	0·981	0·958	0·980
10	0·95	0·971	0·965	0·909
11	0·85	0·905	0·854	—
12	0·87	—	0·911	—
13	0·80	0·810	0·787	0·794
14	0·78	0·762	0·758	0·747
15	0·75	0·667	0·652	—
16	0·80	0·952	0·809	0·81

Sheet 6.

Plate VI.

Formula, inscribed "Nitrous oxide, 13·9."

The atomic weights used were N=4·2, O=5·5. A reference to Table I. shows that these are later than September, 1803, and earlier than August, 1806. They actually appear in 1804 and 1805. The diagram is therefore of earlier date than the older of the atomic weight lists.

Sheet 7.

Plate VI.

Formula, inscribed "Carbonic acid, 15·3."

The atomic weights used were C=4·3, O=5·5. These belong to the same period as the atomic weights of the previous formula.

Sheet 8.

A similar formula for carbonic acid.

Sheet 9.

Plate VI.

Formula, inscribed "Carburetted hydrogen from stag. water, 6·3."

This again requires C=4·3 and is therefore of the same period as the formulæ for nitrous oxide and carbonic acid.

Sheet 10.

Plate VI.

Same formula as above for methane, together with a diagram apparently representing 3 atoms of hydrogen around a carbon atom.

The exact use Dalton made of this sheet is not clear.

Sheet 11.

Plate VI.

Formula, inscribed "Ether, 10·4."

This requires C=4·7, a value which we have not found elsewhere. The representation of ether as a hydrocarbon, C_2H, appears in the note-books of 1803 and 1805, and with doubt expressed in 1807.

Sheet 12.

Five oxides of nitrogen, represented as compounds of one atom of nitrogen with one, two, three, four and five atoms of oxygen respectively. It is improbable that Dalton himself ever adopted these formulæ for the oxides of nitrogen. The sheet was perhaps used to illustrate some contemporary views on the subject (*e.g.* T. Thomson, *Ann. Phil.* 1814, **3**, 135, gives a list containing four of these oxides), or possibly even those of W. Higgins, "A Comparative View of the Phlogistic and Antiphlogistic Hypotheses," 132—5, 1789.

Sheet 13.

Five oxides of nitrogen, with names, as follows:

1 atom	nitrogen +	1	atom oxygen.	...	"Nitrous gas."
2 atoms	,,	1	,,	,,	...	"Nitrous oxide."
1 atom	,,	2	atoms	,,	...	"Nitrous acid."
2 atoms	,,	3	,,	,,	...	"Subnitrous acid."
2 ,,	,,	5	,,	,,	...	"Nitric acid."

This represents Dalton's view at the time of the publication of the second volume of the "New System" (1827). The same list is found in his paper in Thomson's *Ann. Phil.* 1817, **9**, 186, and is much different from that expressing his opinions in 1810. The note-books (vi, 20, 40) show that the change in view occurred mainly in September or October, 1814.

Sheet 14

Names and formulæ for some acids, with their weights.

In the modern symbols these are as follows :

CO_2	Carbonic acid	...	...	19
SO_3	Sulphuric acid	...	...	34
NO_2	Nitric acid	...	...	19
NO_3	Oxynitric acid	...	...	26
N_2O_3	Nitrous acid	...	...	31
HO_3	Muriatic acid	...	...	22
HO_4	Oxymuriatic acid	...	...	29
PO_2	Phosphoric acid	...	...	23
$C_2H_2O_2$	Acetic acid ...	...	...	26

On the back of this sheet are the words, in Dalton's handwriting, "Old Chemical." The formulæ, names and weights correspond closely with those of 1810 ("New System," I., ii.), but are much different from those of 1827 ("New System," II., i.). The last line, relating to acetic acid, has been attached to the rest of the sheet by paste.

Sheet 15.

Symbols for sulphur, oxygen and hydrogen, and formulæ for some compounds formed by their union.

Using modern symbols, the list becomes :

SO	Sulphurous oxide.
SO_2	Sulphurous acid.
SO_3	Sulphuric acid.
HS	Sulphuretted hydrogen.

The first of these was supposed by Dalton to be produced as a bluish white substance, in admixture with yellow sulphur, when sulphurous acid and sulphuretted hydrogen are brought together. (See "New System," I., ii., 383 *et seq.*) It has proved to be in fact "milk of sulphur."

Sheet 16.

Formulæ and names for the following compounds of phosphorus :—

PO	Phosphorous acid.
P_2O	Subphosphorous acid.
PO_2	Phosphoric acid.
PH	Phosphuretted hydrogen.

These are later than 1810, for in that year phosphorous acid was represented as P_2O_2 (" New System," I., i., plate 5), and subphosphorous acid was unknown.

Sheet 17.

Formulæ, only, for the sulphate, carbonate and oxide of barium.

Sheet 18.

Formulæ, only, for the oxides and sulphides of gold, mercury, iron, lead and arsenic, described in "New System," II.

Sheet 19.

Formulæ, only, for some compounds formed of two or more of the elements lead, arsenic, iron, sulphur, oxygen and hydrogen.

Sheet 20.

Formulæ for prussic acid [HC_2N_2], cyanogen [CN], ferrous oxide [FeO] and potash [KO].

Sheet 21.

Formula, with inscription " Acetic acid wt. 26 [? 25]."

Acetic acid is represented by symbols equivalent to $C_2H_2O_2$.

Sheet 22.

Same formula as on sheet 21.

This representation of acetic acid first appeared in 1806, in Note-book ii., 262. It appeared also in 1811 and in 1823; other formulæ were also used during this period.

Sheet 23.

On one side of this sheet are formulæ for ether and alcohol, which with modern symbols become C_4H_5O and C_2H_3O. They are inscribed:

Ether.	wt. 34.
Oxy.	45·5
Carb.	35
Hyd$^{n.}$	19·5
	100

Alcohol.	wt. 21.
Oxy.	33·7
Carb.	52
Hyd$^{n.}$	14·3
	100

These formulæ are evidently more recent than those on sheet 5, where these compounds are represented as C H and C_3H respectively. Dalton considered quite a number of different formulæ for these compounds between 1805 and 1810; they were mostly deduced from explosion experiments with the vapours of these substances. It is not until 1819 that some formulæ nearly like those of this sheet are found in the note-books (Note-book vii., 447). In lecture note-books dated 1824 and 1827 the molecular compositions are recognised as equivalent to C_4H_5O and C_2H O, and expressed as

1 atom water and 4 atoms olefiant gas, for ether, and *1 atom water and 2 atoms olefiant gas*, for alcohol. These formulæ would have contained the same numbers of atoms of each of the elements as the modern formulæ, had Dalton used double atomic weights for oxygen and carbon.

Sheet 23 (reverse side).

Plate VII.

The atoms C_2H_2ON are arranged in two different ways to represent albumen and gelatine respectively, and under them is written :—

Expt. Albumen.	Theory.	Expt. Gelatine.
53 Carbone	44 Carbone	48 Carbone
27 Water	32 Water	31 Water
20 Ammon.	24 Ammonia	21 Ammon.
100	100	100

These formulæ are truly isomeric. It is also interesting to note the little respect Dalton shows for the analytical results, since he is satisfied that there is sufficient accordance between the experimental figures and the calculated ones.

The origin of these figures is found by reference to the Laboratory Note-book iv., p. 59, which shows Gay Lussac's analytical figures for albumen and gelatine as nearly the above, viz. :—

Albumen.			Gay Lussac.	Gelatine.			Gay Lussac.
1 oxy.	7	23·3	23·9	1 oxy.	7	28¼	27·2
3 carb.	16·2	52·6	52·9	2 carb.	10·8	43½	47·9
2 hyd.	2	6·6	7·5	2 hyd.	2	8	7·9
1 azote	5	16·5	15·7	1 azote	5	20¼	17
	30·2	100	100			100	100
or 1 Am.				1 Am.			
1 Water.				1 Wat.			
3 Carbone.				2 Carb.			

The formula for albumen in the Note-book is different from that of gelatine by possessing one atom of carbon more. The date in the Note-book is October, 1811.

Sheet 24.

Plate VII.

The formulæ for four organic acids, inscribed "oxalic," "citric," "acetic," "tartaric." Oxalic acid is represented as C_2O_3, a compound of CO and CO_2. Acetic acid is CHO, and citric and tartaric acids are represented as each having a central atom of oxygen, surrounded in the case of citric acid with three of these CHO groups symmetrically placed; in the case of tartaric acid with four of these CHO groups. In 1811 Dalton had the idea of an important part played by the CHO group, which he called the "vegetable atom" (Note-book iv., 56), with a weight 13·4. This idea might have been fruitful at the time: with modern atomic weights the grouping would have become CH_2O, which, as formaldehyde, seems to play a most important part in natural organic syntheses. Dalton published very little of his organic chemical work, however; indeed, it extended only occasionally beyond analyses of a few organic acids and their salts.

An exact reproduction of the formulæ for citric and tartaric acids has been found once only, in a note-book entitled, "Salts, Oxides, Sulphurets," which contains a laborious compilation of the composition by weight and the atomic composition of many of the compounds of metals. This note-book received additions during many years, and was probably intended to form a basis of volume II. of the "New System," not only the published part but also another projected part dealing with the salts of the metals. The formulæ of citric acid and tartaric acid in the note-book and on the sheet probably belong to the period 1810 to 1815. The formulæ for acetic acid and oxalic acid occur frequently during many years, together with some others suggested but soon discarded.

Sheet 25.

Oxalic acid, again represented by symbols equivalent to C_2O_3. On the back: "2 atoms with 90° asunder both oxygen and charcoal." "1 atom oxygen with 1 hole."

Sheet 26.

Citric acid, represented as CHO. On the back: "60° asunder." This formulation has been found in the laboratory notes of 1841, and at the end of the pamphlet "A New and Easy Method of Analysing Sugar," a product of Dalton's last years, date about 1840.

Sheet 27.

"Acetic acid," erased.

"5 carbone 37
4 wat. 48."

Formula representing this acid by a central *carbon* atom with four "vegetable atoms" symmetrically disposed around it. This formulation for acetic acid is described at the end of the pamphlet, "A New and Easy Method of Analysing Sugar."

Sheet 28.

"Tartaric acid," erased, and replaced by "acetic acid."

Formula representing a central *carbon* atom with five "vegetable atoms" symmetrically disposed around it. On the back:

"$\frac{360}{5} = 72°$ asunder."

"each peg . . . . rest is obvious."

Tartaric acid is represented in the pamphlet mentioned above as similarly constituted, but with six vegetable atoms.

Sheets 25 to 28 seem to belong to the same period and were found together, apart from all the other sheets described here.

Sheet 29.

Formulæ equivalent to CHO (acetic acid, or "vegetable atom") and $C_4H_3O_3$, the latter being a central carbon atom surrounded by three "vegetable atoms." This may represent one of the acids above mentioned, or possibly the atom of sugar, or of wood. Dalton represented sugar on various occasions as a central carbon atom with 5, 8, and 12 "vegetable atoms" around it.

Sheet 30.

Formula, entitled "indigo." Equivalent to C_8H_2ON. In his paper on the "Nature and Properties of Indigo" (*Mem.*, 1824, **9**, 427) Dalton arrived at this composition from Crum's analysis, with Dalton's own atomic weights.

Sheet 31.

Formula, entitled "oil etc." and described:

		Gay Lussac.	
"Carb.	77·7	77·2	"Olive oil and probably Spermaceti oil."
Oxy.	9·2	9·4	
Hyd.	13·1	13·4"	"Constitution 1 atom Carbonic oxide. 10 atoms olefiant gas."

This constitution is found in the Laboratory Notebook iv., p. 58 (1811). Earlier suggested formulæ are to to found, but are different from that of this sheet.

Sheet 32.

The atoms C_3H_2ON arranged as a molecule. Below is written in Dalton's handwriting:

"Carb.	...	53·66
Oxyg.	...	23·16
Azote	...	16·56
Hyd$^{r.}$	...	6·62
		100

Gay Lussac.	Carb.	Oxy.	Azot.	Hyd$^{r.}$
Fibrin ...	53·36	19·87	19·93	7·02
Albumen ...	52·88	23·87	15·71	7·54
Cheese ...	59·78	11·41	21·38	7·43
Gelatine ...	47·88	27·21	17	7·91"

Further, a formula equivalent to C_2O is written below, and entitled "Tan. 18."

These analyses are also quoted in Note-book iv., 58 and 59, but the four bodies are therein supposed to have the following atomic constitutions:

	Carbon.	Oxygen.	Nitrogen.	Hydrogen.
Fibrin ...	4	1	2	3
Albumen ...	3	1	1	2
Cheese ...	7	1	3	5
Gelatine ...	2	1	1	2

The formula for "tan" has been found in a lecture note-book on Pharmaceutical Chemistry, dated 1824, and in lecture-notes of 1827, and on the sheet of "atomic symbols" prepared to illustrate a lecture at the Manchester Mechanics' Institution in 1835.

Sheet 33.

Formula equivalent to $C_3H_2O_2$, with inscription "Wood."

	Gay Lussac.		Theory.
Carbone	52	...	50½
Oxygene	42	...	43¼
Hydrogen	6	...	6¼
	100		100

The same formulation is found in Laboratory Notebook iv., 57 (1811), with Gay Lussac's figures for comparison.

Chemical Reactions represented by Formulæ.

Sheet 34.

Plate VII.

Reduction of a mercuric salt to a mercurous salt. Above the line is represented a mercuric salt ("A" is frequently used in the note-books to designate generically an acid). Below the line are represented two molecules of the corresponding mercurous salt formed from the mercuric compound by interaction with an atom of mercury.

This sheet may well have been prepared to illustrate the Edinburgh and Glasgow lectures of 1807, in the notes for which appears the following:

" Muriat Mercury	1 A + 1 protoxide M (black)
Oxymuriat M. or Corros. subl.	2 A + 1 deutoxid M (red)

hence the reason why crude Merc. & cor. sub. produce calomel or muriate of M."

Sheet 35.

Plate VII.

The combustion of methane. Represented by the formula for methane above the line, and below the line formulæ for one molecule of carbonic acid and two molecules of water.

These two diagrams are almost chemical equations. Dalton has not employed equations to any great extent; one of the earliest is in the first laboratory note-book, page 278, August, 1804, and is reproduced in Roscoe and Harden's "New View of the Origin of Dalton's Atomic Theory," p. 63.

Apparatus for gas analysis.

Sheet 36.

A Volta eudiometer with wires to form the spark gap.
Also, a cylinder, apparently to hold the eudiometer tube.
Also, a graduated tube, with the lower open end enlarged, for collecting and measuring gases and treating them with reagents.

The Volta eudiometer is described in "New System," I, i, 274. It was frequently employed by Dalton in his investigations on gases.

Three Diagrams representing Speculations on the Nature of Solutions of Gases in Water:

Sheet 37.

"Air in Water." Two diagrams, closely represented by the carefully drawn Plate 3 in *Mem.*, 1805, 6.

Under one diagram are the words "Oxygenous, Nitrous, etc., $\frac{1}{27}$ Density," and under the other "Azotic, hydrogenous, etc., $\frac{1}{64}$ Density."

Sheet 38.

Two diagrams, similar to those on sheet 37. Inscribed "Hidrogenous, Azotic, and Carbonic oxide Gasses" and "Olefiant Gas in Water."

Sheet 39.

Two diagrams, similar to the above, inscribed

"Oxigenous, Nitrous and Carburetted Hidrogen Gasses."

[FIG.]

"Oxigenous gas, etc., in water."

N.B. Distance of the true atmosphere only $\frac{1}{3}$ of what it ought to be.

"Carbonic Acid, Sulphuretted Hidrogen, and Nitrous Oxide."

[FIG.]

"Carbonic Acid Gas, etc., in Water."

Sheets 38 and 39 are very early ; the spellings "hidrogenous" and "hidrogen" and "gasses" were discarded by Dalton before 1803.

Fourteen Diagrams representing the Arrangements of Atoms, in some cases with Atmospheres of Heat surrounding them.

Sheet 40.

Four atoms with their atmospheres of heat in contact. Each atom with its atmosphere occupies a square.

Sheet 41.

Plate VIII.

Four atoms with their atmospheres of heat.

Sheet 42.

Atmosphere of heat around two sets of four atoms.

Sheet 43.

Plate VIII.

The mutual repulsion of the atmospheres of heat round two atoms, represented to show a diminishing repulsion with increasing distance. This diagram may be the one referred to by Dalton in the note-book of the Birmingham lectures of 1817, as follows :—

> "Repulsion of atoms inversely as the Distance.
> Fact that condensation is as pressure—1. Tube expt.
> 2. Diagram * * * * * * * "

Sheet 44.

Inscribed "Fluids"—(*a*) "elastic," (*b*) "inelastic."

(*a*) Represents gaseous atoms with their atmospheres of heat.

(*b*) Represents the closely packed atoms of a liquid or solid, without atmospheres of heat.

Sheet 45.

"Atoms" of steam repellent by virtue of their atmospheres of heat, above the close-packed atoms of water without heat.

Sheet 46.

Plate VIII.

"Heat in an atmosphere and in a vacuum."

A reference to "heat in a vacuum" is found in Dalton's "New System," I., i., 73 (1808): ". . . . interstitial heat amongst the small globular molecules of air, . . . [which] scarcely can be said to belong to them, because it is equally found in a vacuum or space devoid of air, as is proved by the increase of temperature upon admitting air into a vacuum."

Sheet 47.

Six atoms, four of one size, two of another, with their atmospheres of heat. These are figured similarly in "New System," I., ii., Plate 7.

Sheet 48.

In three equal areas are disposed atoms of hydrogen, nitrous oxide and carbonic acid. A similar diagram is in "New System," I., ii., Plate 7, but whereas in the book equal numbers of atoms of all three gases are present, in the sheet the numbers are in the ratio 9 : 7 : 7.

Sheet 49.

Entitled "Compound Atmosphere." There is a uniform distribution of "atoms" of nitrogen, oxygen, water and carbonic acid, much as in the plate accompanying the memoir "On the Constitution of Mixed Gases" read in 1801 (*Mem.*, 1802, **5**, ii., Plate 8). On this sheet the atoms are, in number,

315 of nitrogen
81 of oxygen
9 of aqueous vapour
7 of carbonic acid.

There is here a closer approach to the relative numbers of molecules of the constituent gases of the atmosphere, than in the memoir. The carbonic acid figure is too high, and the sheet was therefore compiled before Dalton's determination of the proportion of this gas in the atmosphere (*Mem.*, 1805, **6**, 244. Paper read in 1802). The date of the diagram is therefore probably 1801 or 1802.

Sheet 50.

Fourteen atoms of nitric oxide are arranged regularly within a rectangle; in rectangles each exactly half the size are arranged separately fifteen atoms of nitrogen and fifteen of oxygen.

Sheet 51.

Spheres arranged as in "New System," I., i., Plate 3, figs. 1 and 2, to illustrate the arrangement of atoms of water and ice. The sheet differs from the figures in the plate only in the numbers of spheres, not in their arrangement.

Sheet 52.

Figures very like those of "New System," I., i., Plate 3, figs. 3, 4, 5, 6.

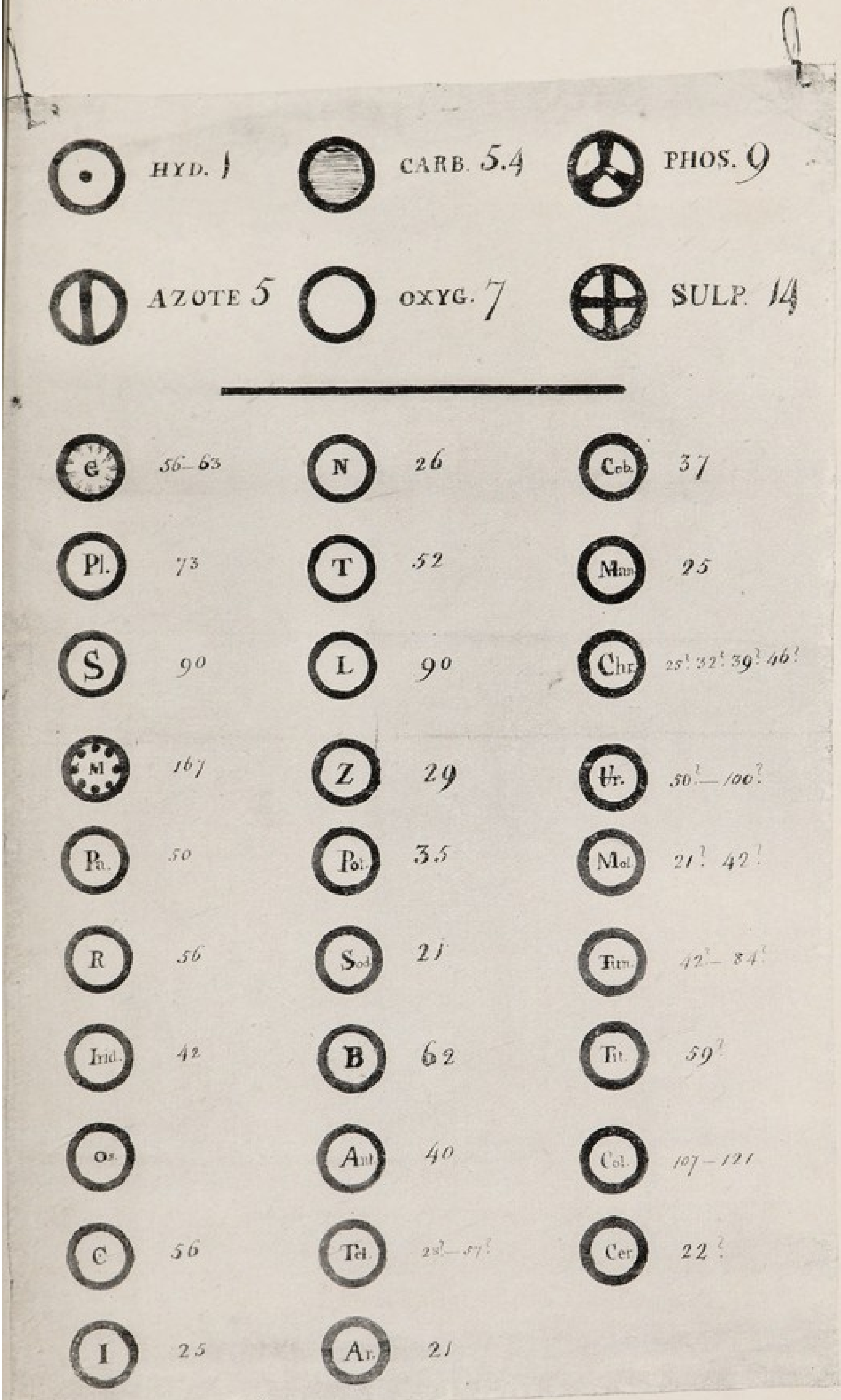
Sheet 53.

Plate VIII.

Figure similar to that of fig. 6 in the previous arrangement, which represents the hexagonal form of snow crystals as the result of the packing of atoms. One important difference exists : on the sheet, half the circles represent hydrogen atoms, half represent oxygen atoms ; in the book all the atoms are alike, and apparently each small circle represents an "atom" of water.

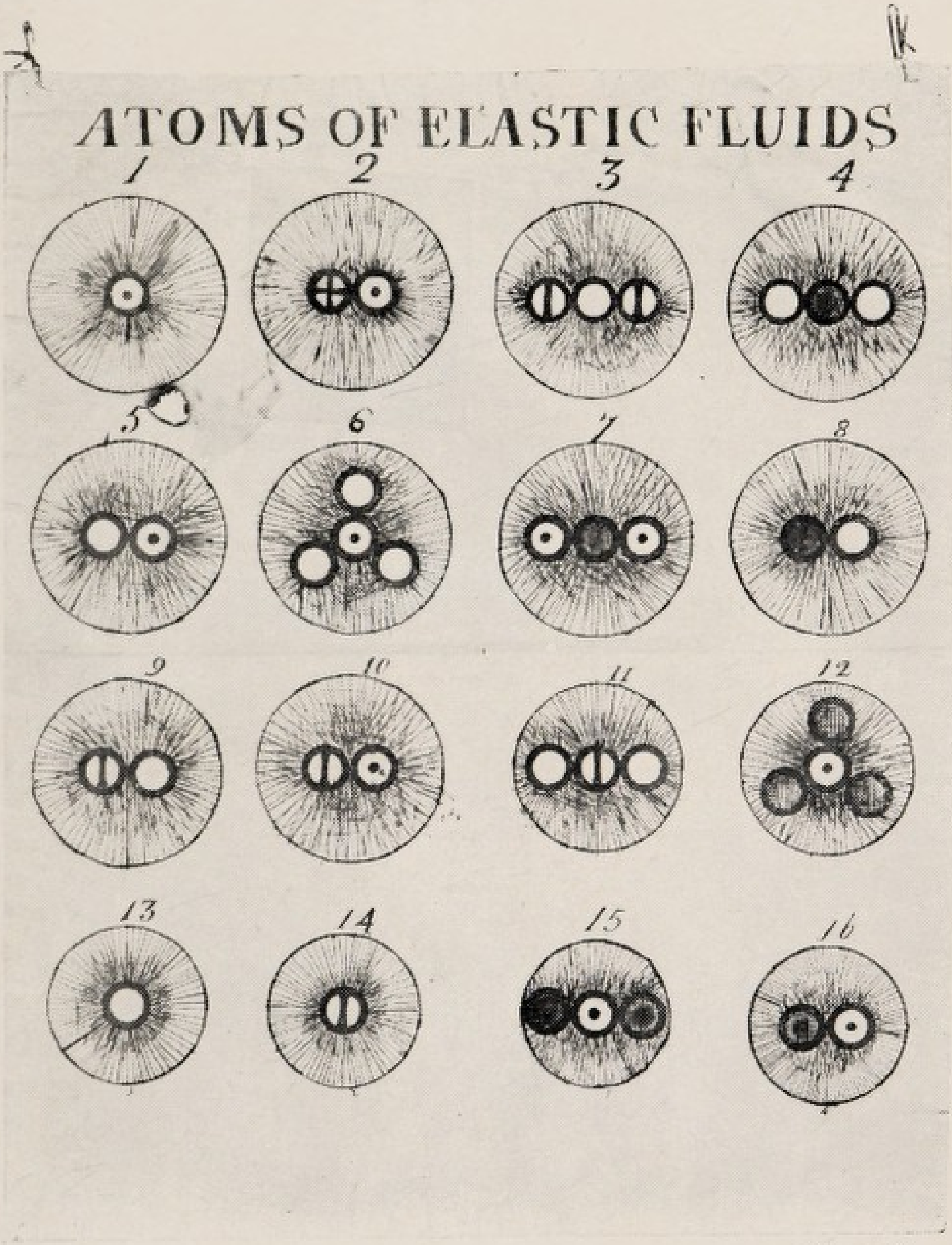
19″ × 26½″.

SHEET I.


HYD. 1
CARB. 5.4
PHOS. 9
AZOTE 5
OXYG. 7
SULP. 14
G
56–63
N
26
Cob.
37
Pl.
73
T
52
Man
25
S
90
L
90
Chr.
25? 32? 39? 46?
M
167
Z
29
Ur.
50?—100?
Pa.
50
Pot.
35
Mol.
21? 42?
R
56
Sod
21
Tun.
42?—84?
Irid.
42
B
62
Tit.
59?
Os.
Ant
40
Col.
107—121
C
56
Tel.
28?—57?
Cer
22?
I
25
Ar.
21

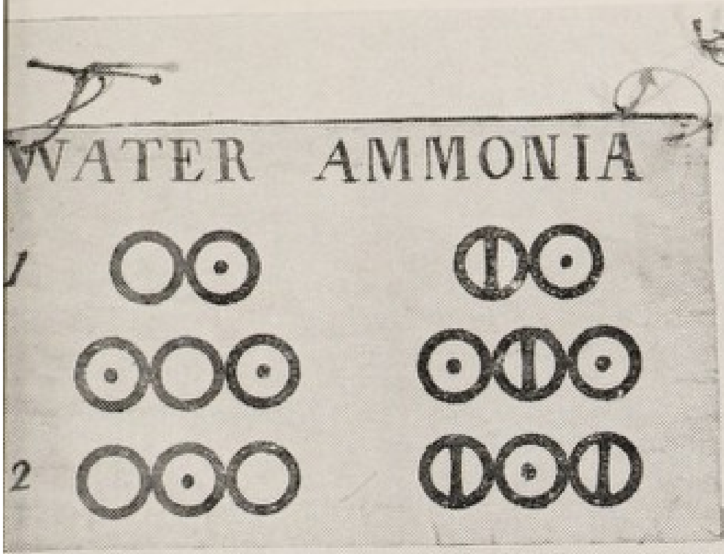
21″ × 33″.

SHEET 2.



19″ × 23½″.

SHEET 5.



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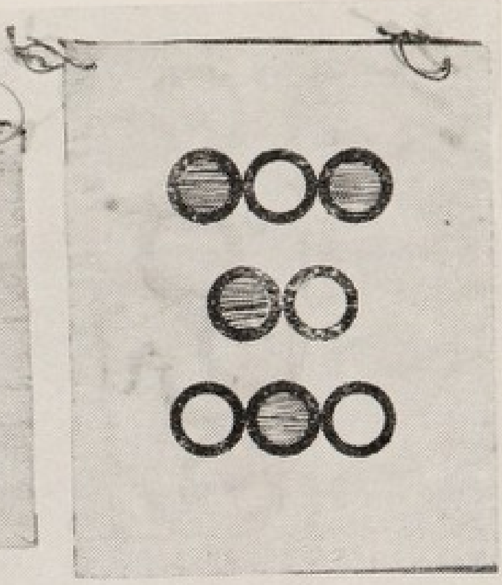

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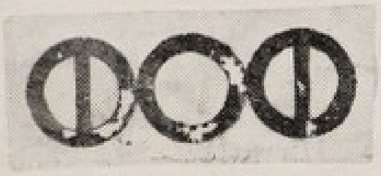
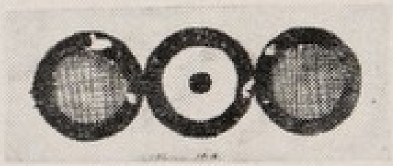


Sheet 6

Sheet 9

Sheet 7



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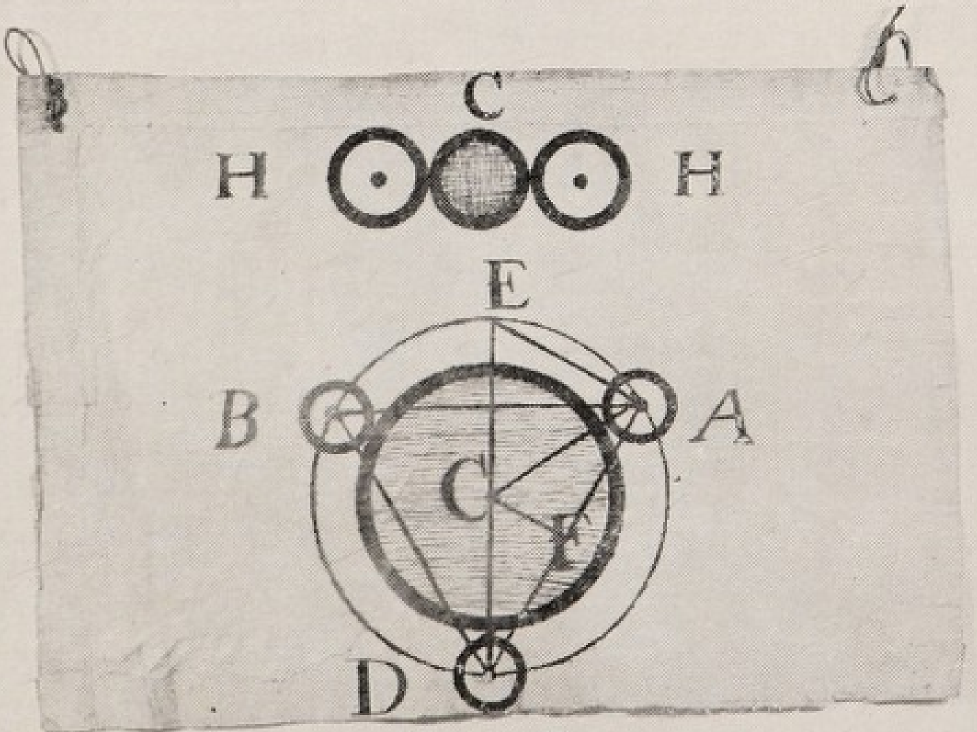

Sheet 10

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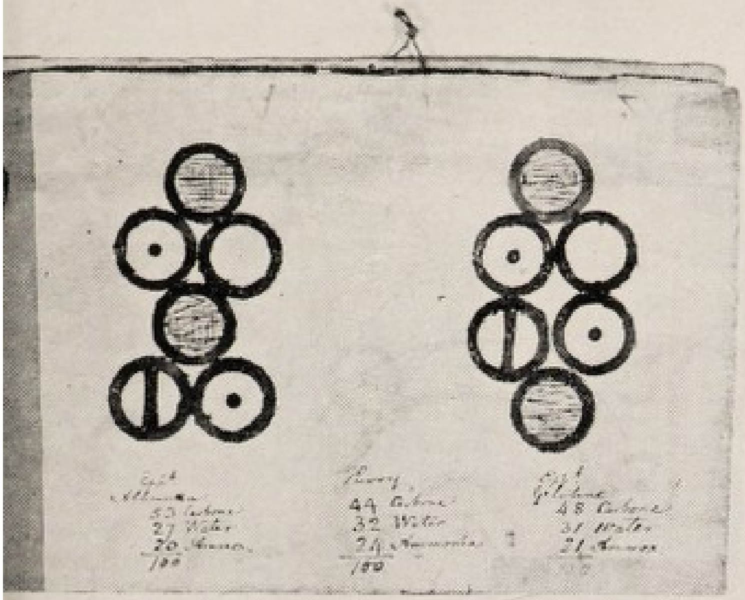
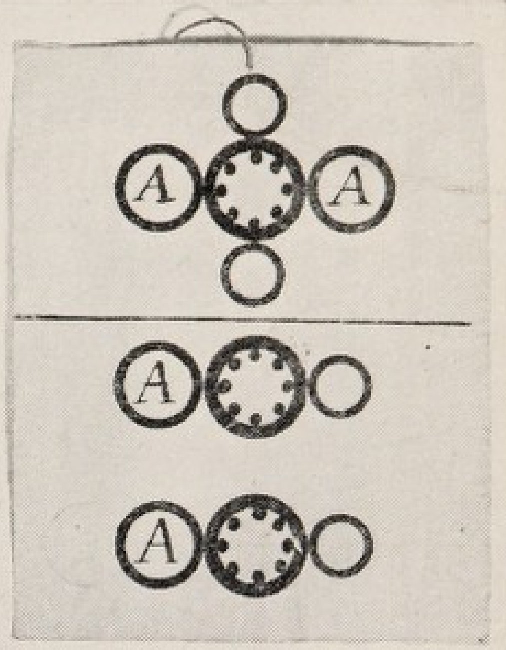


Sheet 23
-reverse-



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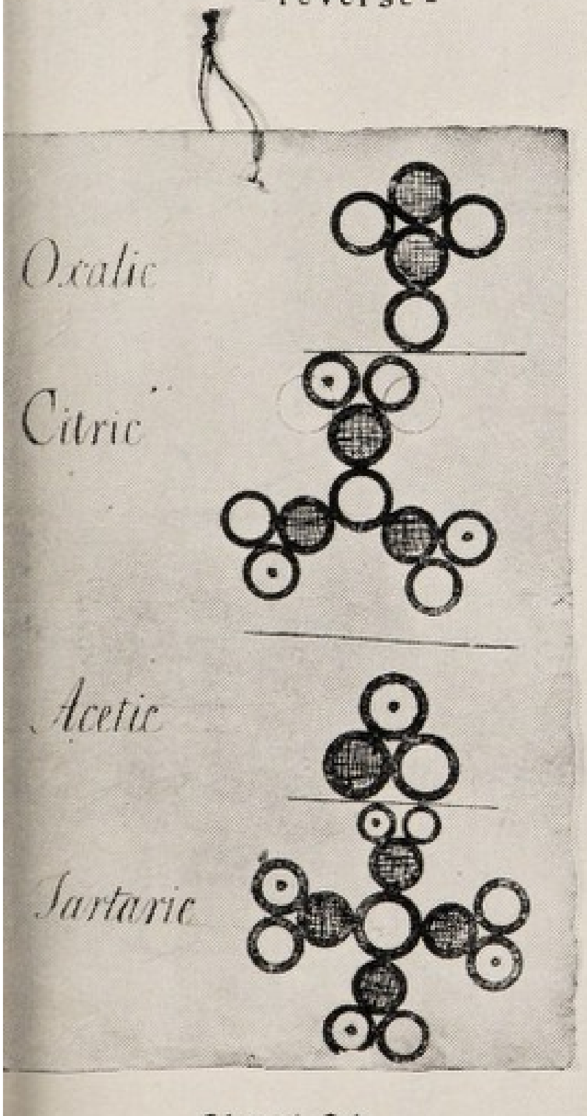

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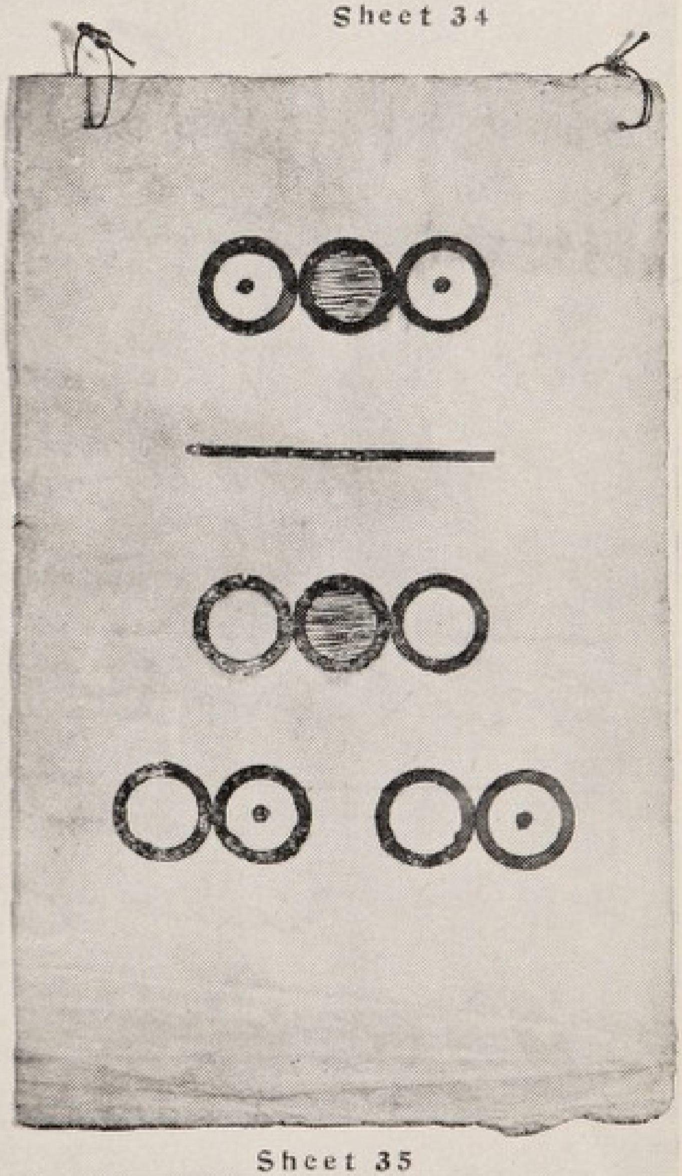

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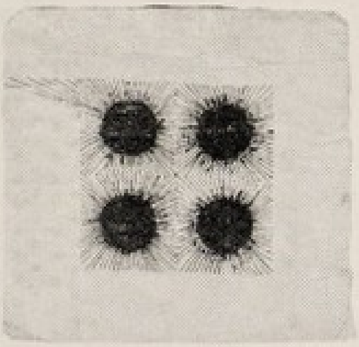

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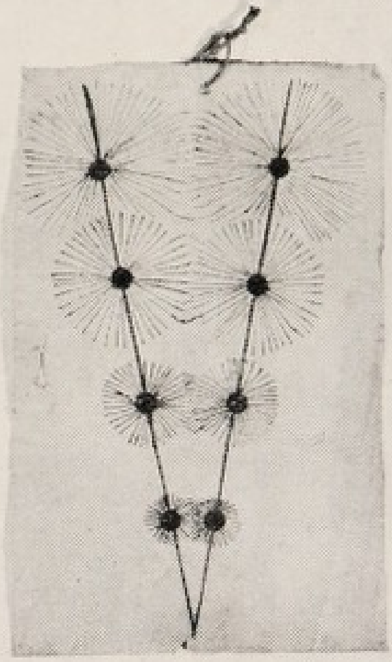

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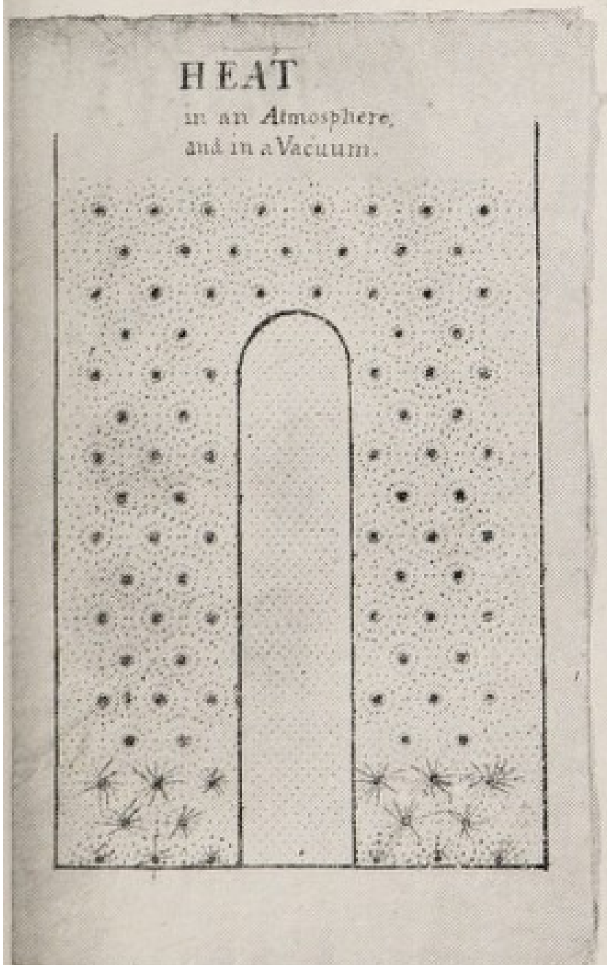

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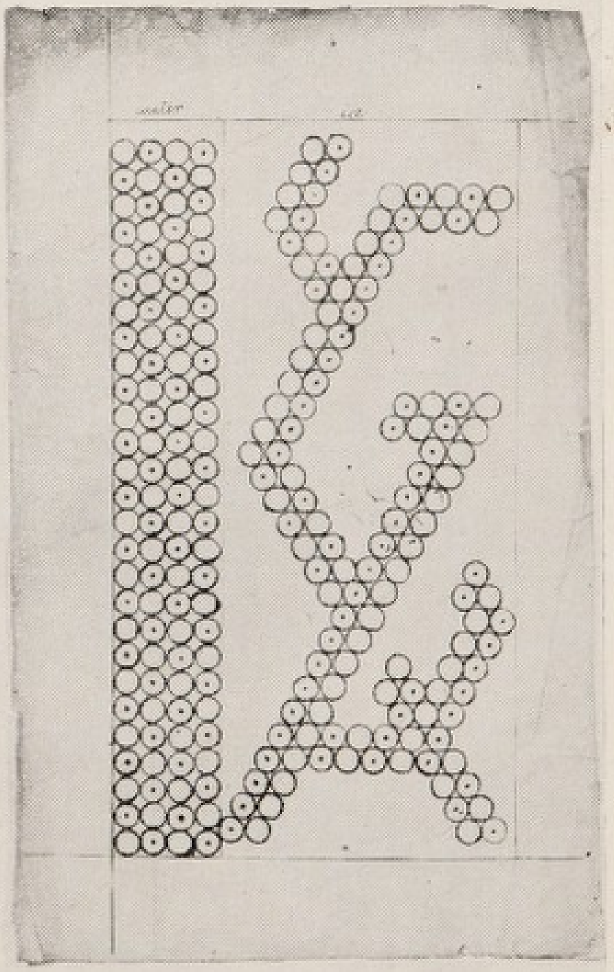

Sheet 53

Scale one-fifth.