

OBITUARY NOTICES.

FREDERICK AUGUSTUS ABEL.

BORN JULY 17TH, 1827; DIED SEPTEMBER 6TH, 1902.

THE sudden death of Sir Frederick Abel on September 6, 1902, at his residence, Whitehall Court, London, S.W., at the age of seventy-five years, removed from the English scientific societies one of their most distinguished and energetic representatives. Almost every branch of Technical Science had been enriched by his labours, and he became in turn the active official head of many important organisations during the latter part of the last century.

Born in London on July 17th, 1827, eldest son of the late J. L. Abel, of Kennington, a music master of German descent (whose father is said to have been Court Miniature Painter to the Grand Duke of Mecklenburg Schwerin), the subject of this memoir enjoyed the advantage of home training in two languages, his mother being English. At the age of fourteen he went to Hamburg on a visit to his uncle, A. T. Abel, a mineralogist and pupil of Berzelius, and probably to this circumstance may be ascribed his leaning towards scientific pursuits. Electing to become a chemist, young Abel commenced his studies in 1844 under Dr. Ryan at the Royal Polytechnic Institution; but, not finding this course of instruction acceptable, he changed over in the following year (October 1845) to the newly-founded Royal College of Chemistry, which, starting on the approved Giessen system with a pupil of the illustrious Liebig as the Professor, offered greater advantages. Abel was one of the twenty-six original students who began work in the temporary laboratories at George Street, Hanover Square, and migrated with the Professor, Dr. A. W. Hofmann, a year later, into the specially-erected buildings in Oxford Street, of which the foundation-stone had been laid by the Prince Consort in June 1846. So apt was he as a pupil that he was speedily elected an assistant, having for colleagues E. C. Nicholson, T. H. Rowney, and C. L. Bloxam, and being joined later by Dr. David S. Price, fresh from Professor Erdmann's laboratory at Leipzig. Here he spent five more years, teaching in the laboratory and doing some original work on his own account. He likewise assisted the Professor in some of his important

early researches, *e.g.* "Volatile Organic Bases." Abel was elected a Fellow of the Chemical Society of London in 1848, and read the following papers at meetings of that body:—

1847. F. A. Abel. "Products of the Oxidation of Cumol by Nitric Acid."
 1848. Abel and Rowney. } "Mineral Waters of Cheltenham."
 } "Water from Artesian Wells, Trafalgar Square."
 1849. Abel and Nicholson. "On Strychnine."

In 1851, Abel left the College to become Demonstrator of Chemistry at St. Bartholomew's Hospital under Dr. John Stenhouse; and when, two years later, the post of Lecturer on Chemistry at the Royal Military Academy, Woolwich, became vacant by the retirement of Michael Faraday (who had held it since 1829), Abel applied for it and was duly elected. This was the turning-point in his career, and marked the commencement of a long period of active service at Woolwich as the Scientific Adviser to the War Office, almost immediately [View Article Online](#) resulting in his definite appointment as Chemist of the War Department, with official residence at Woolwich Arsenal, about the year 1854, when all the Government resources were being strained to their utmost in preparation for the great Russian war. At this time also his scientific reputation and influence were doubtless strengthened by the joint publication of a *Handbook of Chemistry* by Abel and Bloxam, with a Preface by Dr. A. W. Hofmann (724 pages), issued from the well-known press of John Churchill, London, in 1854.* This quickly ran through two editions, but when later a third was required, Abel, "not having leisure to devote to its preparation," as stated in the Preface, the work was reproduced in a somewhat different form by Charles L. Bloxam alone.

To enumerate the activities of the thirty-four years (1854–1888) during which Sir Frederick Abel retained his position at Woolwich Arsenal is no light task, inasmuch as it covers a period of great reforms in the Army and alterations of military equipment. The cast-iron ordnance and bronze field guns were superseded, breech-loading arms of greater precision were introduced, and new percussion fuses provided; also torpedoes, submarine mining, and blasting materials—even the black gunpowder in common use had to be changed—all demanding careful study and innumerable experiments.

The Navy also underwent a crucial change from the time-honoured "wooden walls" to iron ships and armour-plating. Chilled shot and

* The prime motive for the appearance of this work was the want of a suitable text-book to put into the hands of the cadets studying at the Royal Military Academy, who would find the Waltham Abbey processes for the purification of saltpetre and manufacture of gunpowder fully described, together with other details of professional interest.

steel shells were introduced, and then began the interminable contest between means of attack and defence. Trials were constantly made in Woolwich Marshes and at Shoeburyness of new schemes and constructions, all of which were supervised by military committees, on which Sir Frederick Abel invariably found a place.

As juror or British representative he was sent to do duty at the Paris and Vienna Electrical Exhibitions of 1881 and 1883; also he was Chief of the Executive of the International Inventions and Music Exhibition held in London in 1885; Member of the Ordnance Select Committee; of the Royal Commission on Accidents in Coal Mines; Expert for Petroleum Legislation, Submarine Defences, and Smokeless Powders; and until cut off by death he was for many years President of the Explosives Committee.

The lamentable accident at Messrs. Prentice's Stowmarket factory brought to light a hitherto unsuspected property of gun-cotton, showing that even in the form of moist pulp, and under water, it could be fired by detonation or extreme compression. Working on this basis, and with the happy collaboration of one of his assistants, Edwin O. Brown (who devised and carried out a special series of experiments, for which he was rewarded by the Government), Abel was driven to the conclusion that his first opinion as to the cause of the Stowmarket disaster would have to be modified; and as a final outcome of this inquiry most important results followed, which were immediately put to practical use in submarine and torpedo warfare. Then, again, as to the old form of gunpowder, working with Sir Andrew Noble on grains of enormous size, "pebble powder," it was found that the rapidity of ignition and pressure under which it was fired, exerted a vast influence upon the expansive force generated, and that even the products of combustion were variable under these different conditions. The powder had therefore to be specially prepared when the huge chambers of the 81-ton gun required to be supplied with ammunition, charges of "prism powder" being the result.

From 1868 to 1875, Abel devoted much of his time to the investigation of gun-cotton, publishing his results in the *Philosophical Transactions* of the Royal Society, and delivering lectures on special points at the Royal Institution, London, and Royal Artillery Institution, Woolwich. He was elected President of the Chemical Society for 1875-7, and during the tenure of this office he invited the Fellows to Woolwich on March 14, 1876, to witness a series of practical demonstrations in the Royal Arsenal. About four hundred members attended, and they were favoured with an ever-memorable programme of great scientific interest. Two rounds were fired from the 81-ton gun, called at that time "The Woolwich Infant." A grand series of gun-cotton experiments were displayed, showing the extraordinary difference in the

destructive effects according to the mode of ignition and confinement of the charges—sometimes burning slowly away or, if detonated, exploding with terrific violence. Torpedoes were launched in the Military Canal; the 40-ton steam-forging hammer was set in action, and the whole of the workshops and gun factories were open for inspection.

In September 1877, Abel was President of Section B (Chemistry) at the Plymouth meeting of the British Association; in 1881 and 1882, President of the Institute of Chemistry. The following year, 1883, he succeeded Sir Henry Roscoe as President of the Society of Chemical Industry, served at the Vienna Exhibition, as already mentioned, and was knighted. Then we find him busy on "Dangerous Dusts," Steel Testing, Nitro-Glycerine and Cordite, and helping the cause of Technical Education whilst on the governing body of the City and Guilds of London Institute and as Prime Warden of the Goldsmiths' Company; filling up his time by serving as Chairman of the Society of Arts, and President of the Institution of Electrical Engineers; Member of the Board of Managers, Royal Institution, and of the Council of the Royal Academy of Music. He was also Chairman of the British Committee in promotion of the Hofmann Testimonial, 1888, which added a considerable sum—about £270—to the International Fund.

Another subject upon which Sir F. A. Abel was consulted took the form of a reference touching the safety of Petroleum for storage and use as an illuminant in domestic lamps. In 1868, investigations led to the adoption of an Open-Test apparatus with the limit of 100° F. as "flash point"; but it was found later that more precise results could be obtained by the use of Abel's Close-Test apparatus and substitution of 73° F. (instead of 100°). This standard was legalised in 1879, and has ever since been adopted.

Somewhat akin to the above was an experimental inquiry undertaken at the request of the Home Office, 1880, into the question of Colliery Explosions and the influence of Coal-dust as one of the causes. The report was presented in June 1881, and went to show that the finely-divided particles suspended in air were a source of danger similar to that occasionally experienced in flour-mills. A lecture was delivered at the Royal Institution in April 1882 on "Dangerous Dusts," in which, after reviewing the Reports of Faraday and Lyell, 1845; Rankin and Macadam, 1872 (referring to the lamentable accident at the Tradeston Flour Mills, Glasgow, when several persons were killed), and to the later report of Marreco and Morison on Coal-dust dangers at Seaham Colliery, Durham, Sir Frederick Abel described his own experimental results, and pointed to the fact that, although a mixture of two or three per cent. of fire-damp with air was not itself inflammable, it became explosive, or "a carrier of flame," as

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soon as the particles of coal-dust were diffused through such an atmosphere, as the consequence, for instance, of using the ordinary gunpowder-blast for dislodging masses of coal. The merits of the quicklime system of mining, and of the dynamite and water-blast were discussed.

In 1883, Sir F. A. Abel was elected an Honorary Member of the Institution of Mechanical Engineers, in recognition of his having undertaken for their Research Committee on the Hardening of Steel a series of experiments on the condition in which the carbon exists in that metal. The isolation of the carbide, Fe_3C , believed to be dissolved throughout the steel, was held to be a step to the elucidation of this subject; but it remained for the late Sir W. Roberts-Austen to put the finishing touch to this inquiry by attacking the problem from the physical side. The subject of steel, and the influence of small additions of other metallic elements, such as manganese, nickel, cobalt, chromium, and aluminium, was referred to at Leeds in 1890, when Sir Frederick Abel was President of the British Association for the Advancement of Science, and again in the following year, when he was President of the Iron and Steel Institute. [View Article Online](#)

It had been decided to commemorate the Jubilee of Her Majesty Queen Victoria's reign by the erection of a grand edifice at South Kensington, which was to be devoted to a permanent exhibition of the natural products and articles of commerce obtainable from India and the British Colonies. The Museum was to be a centre of inquiry and conference between merchants and manufacturers of the Empire. Imperfectly-known substances were to be brought to their proper uses and turned to profitable account; some ores and drugs might require to be analysed, or made the subject of research, for which a trained scientific staff and suitable laboratories were provided. Sir Frederick Abel was appointed the Organising Secretary, and for fourteen years he devoted himself to this work (1887 to 1901), ceasing from his labours only when the perfected scheme was placed under the direction of the Board of Trade, and part of the surplus buildings devoted to the needs of the London University.

Blest with good health and indomitable perseverance, Abel succeeded in accomplishing an amount of work—and that of a nature sometimes attended with personal risk—which would have appalled many a scientific professor placed in similar circumstances. It is not surprising that honours fell fast upon him both by Royal patronage and University preferment. He was made a Companion of the Bath in 1877, and promoted to Knight Commander of this Order in 1891; knighted in 1883, and made a Baronet in 1893 (after the opening of the Imperial Institute), while in 1901 he was created a Knight Grand Cross of the Victorian Order. Oxford conferred its D.C.L. in 1883,

and Cambridge its D.Sc. in 1888. He held the Albert, the Royal, and the Telford Medals, also the Bessemer Gold Medal, 1897. As already stated, he was made successively President of many of the learned Societies and Honorary Life Member of others.

Sir Frederick Abel was one of the six Past Presidents of the Chemical Society, "who had accomplished their Jubilee as Fellows," in whose honour a Banquet was given in London on November 11, 1898, at the Whitehall Rooms. There were to have been seven, but Lord Playfair died while the preliminary arrangements were being made, and the Festival was consequently postponed from an earlier date (June 9th). Of these six or seven distinguished men only Professor Odling survives. The chair was taken by Professor Sir James Dewar, and an illustrious company assembled, including Dr. H. T. Böttlinger, Professor W. Ostwald, Lord Lister, P.R.S., Lord Chief Justice Alverstone, several statesmen and heads of scientific departments, together with about two hundred and fifty Fellows of the Chemical Society.

Socially, the late Sir F. A. Abel was doubly acceptable on account of his splendid musical talents. Not a vocalist himself, he was ever ready to play the accompaniments, and even train a band of singers, besides giving exquisite performances on the grand pianoforte at many of the earlier dinners and festivities of the Chemical Societies. To hear his rendering of "William Tell," "Oberon," "Der Freischütz," "Tannhäuser," and other choice operatic selections, generally played without music score, was always a great artistic treat.

As to Clubs, he was a member of the Athenæum, the Savage, and the Garrick, and in former times one of the prominent members of "The Bees"—a small fraternity of chemical students (chiefly Hofmann's pupils) to whose meetings Abel used to take his zither.

Sir Frederick was twice married, but died a widower without children. The Baronetcy is therefore extinct.

J. SPILLER.

LOBRY DE BRUYN.

BORN JANUARY 1ST, 1857; DIED JULY 27TH, 1904.

At the early age of forty-seven the name of one of the youngest of the Honorary Foreign Members of the Chemical Society disappears from the list. Scarcely had his election been completed, in May last, than he was seized with illness which ended fatally on July 27.

Cornelis Adriaan Lobry van Troostenburg de Bruyn was born on January 1, 1857, at Leeuwarden, where his father, Nicholaas Lobry van Troostenburg de Bruyn, was a physician in practice. The boy was in



L. H. ...

due time sent to the high school of the town (Hoogere Burger School), and subsequently for a year to the Gymnasium. In 1875 he entered the University of Leiden, and in 1883, while acting as assistant to Professor Franchimont, he produced his dissertation and obtained his doctorate. The subject of this thesis was the interaction of the three dinitrobenzenes with potassium cyanide in alcoholic solution, an investigation to which he several times returned, and of the results of which he published a *résumé* so recently as the spring of 1904 (*Rec. Trav. chim. Pays-Bas*, 23, 39).

About this time De Bruyn went to Paris and worked for a few months in the laboratory of Wurtz, and in that of Friedel, returning to Leiden in 1884, where he remained until the following year. Having been appointed Chemist to the Government Department of Marine, his official duties naturally brought before his notice new problems, especially those connected with the manufacture and properties of explosives, and to this work he devoted much attention during eleven years. During this period he began the study of methyl and ethyl alcohols in the character of solvents, which led him on to the isolation of hydroxylamine and of hydrazine. Neither of these bases had up to this time been obtained in a free state, owing probably to the use of water as the solvent. De Bruyn found that hydroxylamine hydrochloride dissolves in about six times its weight of absolute methyl alcohol, and that when mixed with the calculated quantity of sodium methoxide, also dissolved in methyl alcohol, sodium chloride is precipitated, and a solution of hydroxylamine is obtained. From this the alcohol may be distilled off under reduced pressure. It was soon found that hydroxylamine is not a gas, as had been previously supposed, but a crystalline solid which, although very explosive, can be distilled under a low pressure. This isolation of hydroxylamine was accomplished in 1891. Hydrazine, discovered by Curtius in 1887, was known in the form of hydrate, from which, however, it had been found impossible to remove the elements of water. De Bruyn succeeded in 1894 in applying the method adopted for the isolation of hydroxylamine. The hydrochloride boiled with a methyl-alcoholic solution of sodium methoxide and then fractionated under reduced pressure gave solutions containing as much as 92 per cent. of hydrazine. The dehydration was completed by contact with barium oxide. The free base, originally described as a gas, was found to be a liquid at common temperatures, although freezing into a solid which melts at 1.4° , and in the liquid state having nearly the same density as its hydrate $N_2H_4 \cdot H_2O$, a remarkably stable substance which boils constantly at 118.5° . The whole of the physical constants of hydrazine were determined by De Bruyn, and are described in a memoir published in 1896 (*Rec. Trav. chim.*, 15, 174).

In this year he was appointed to succeed Gunning as Professor in the

University of Amsterdam, having declined the position of State Chemist offered to him in 1895 by the Government of the Transvaal. In this connection it may be mentioned that in 1901 a chair was offered to De Bruyn in the University of Vienna, an invitation which, however flattering, did not disturb his devotion to the work which lay before him in his own fatherland. His duties in Amsterdam included the instruction of pharmaceutical students as well as students of pure chemistry, but over all he exercised the same stimulating and inspiring influence which carried them forward, and to which many of those, especially who are applying their chemistry to the purposes of the profession of medicine, will have reason to look back with thankfulness.

In the inaugural address delivered on assuming his professorial duties De Bruyn announced his intention of studying the phenomena which are attributed to atomic rearrangement, and in the pursuit of these inquiries he gradually turned in his later years to problems of physical chemistry. The sort of questions with which he occupied himself are indicated clearly by the titles of some of his most recent papers. *View Article Online* carry the Solvent with them in Electrolysis?"* This question cannot be studied by using purely aqueous solutions, but it can be done by means of solutions of an electrolyte, say, in mixtures of water and methyl alcohol. Then if one of the ions carried with it one of the solvents, this would be found out by the difference in the proportion of the two solvents at the cathode and the anode both by comparing them with each other and with the original solution. Experiments made with silver nitrate led to the conclusion that under the circumstances of the experiments no such transference of the solvent occurred. Another, "On the Variations of Concentration of Solutions and the Crystallisation of Dissolved Substances under the Influence of Centrifugal Force,"† led to a very remarkable result. With the object of determining whether gravitation was competent to effect any separation of a solid from the liquid in which it was dissolved, Gay-Lussac had long ago placed in the cellars of the Observatory at Paris, where the temperature is practically constant, a tube, two metres long, containing a solution of salt, and after a time determined the concentration of the top and bottom layers of solution. The result was negative, as the force of gravity was insufficient to bring about any change which could be experimentally recognised. Quite recently (1895), Bredig,‡ making use of centrifugal force, succeeded in partially separating two gases, hydrogen and hydrogen iodide, which have very different molecular weights. Bredig made use of a sealed glass tube, having a tap in the middle, each arm being 21 cm. long and filled with the mixture. Having whirled the tube

* *K. Akademie Wetenschappen te Amsterdam*, August 1903.

† *Rec. Trav. chim.*, 1904, **23**, 218.

‡ *Zeit. physikal. Chem.*, 17, 459.

about 2400 turns a minute for $1\frac{1}{2}$ to 3 hours, the apparatus was stopped and the tap closed. On analysing the contents of the two arms of the tube a difference of about 3 per cent. was observed. De Bruyn, in concert with R. P. van Calcar, submitted solutions of various salts and of sugar in water to centrifugal action in an apparatus devised so as to permit of the removal of small quantities of liquid at different distances from the centre during the process of centrifugation. When a saturated solution of Glauber's salt was employed, so great was the concentration towards the periphery of the whirling drum that about $\frac{3}{8}$ ths of the dissolved salt separated in the solid crystalline state, having a liquid in the middle which contained only 5.54 per cent. of anhydrous sodium sulphate!

No mention has been made of De Bruyn's work in connection with carbohydrates. The first communication jointly with Franchimont on the amino-derivatives of the sugars was the outcome of his use of methyl alcohol as a solvent. The further study of these compounds, pursued with van Leent, and later with Alberda van Ekenstein, [View Article Online](#) director of the Government sugar laboratory, resulted from his discovery of the transformations of the sugars under the influence of alkalis, and were continued appropriately in connection with his duties as scientific adviser to the Minister of Finance. But no department of chemistry escaped his notice, and the variety and extent of his experimental labours can only be estimated after inspecting such a complete list of his published memoirs as will appear in the completed volumes of the Royal Society Catalogue.

In 1884, De Bruyn married Maria Simon Thomas, daughter of H. E. Simon Thomas, Professor of Obstetrics and Gynæcology in Leiden. He leaves two sons and two daughters. Though personally known to but few English chemists, his great services to science have been fully recognised in this country, and his recent election as an Honorary Foreign Member of the Chemical Society may be regarded as an expression of the appreciation of his English colleagues. As to his personal qualities, we may well believe the statement of his friends, Professor Cohen and Dr. Blanksma,* that his only fault was his too great modesty. In the words of one who knew him best, "he was like all really good men, a very kind father and husband, of that calm Dutch temperament which is never out of tune." Peace be to his ashes! Though the march of science must go forward, his comrades cannot but feel that the world has lost in Lobry de Bruyn an active and successful leader and a good man.

W. A. TILDEN.

* *Chemisch Weekblad*, 1, 985.

EDWARD FRANKLAND.

BORN JANUARY 18TH, 1825; DIED AUGUST 9TH, 1899.

IN his autobiography, which has recently been printed for private circulation, Frankland tells us that he had been to seven schools by the time he reached the age of seven years. In the eighth school, near Lancaster, he remained until he was twelve, and it was here that he began to take an interest in science and consult books at the Mechanics' Institute; here he made a voltaic pile and decomposed water and joined with his school-fellows in the making of fireworks and other experiments. From the age of twelve to fifteen he attended the Lancaster Free Grammar School. As he wished to enter the medical profession, his stepfather, acting on advice given by others, apprenticed him to a druggist for six years, in the belief that this would lead to the desired end. For the first two years of this apprenticeship he was the junior and had to do laborious and dirty work without holidays; in the third and fourth years he had one week's holiday in each year, and the fifth and sixth years were less trying. During his apprenticeship, Dr. James Johnson invited Frankland and some other druggists' apprentices to make use of a laboratory and small lecture-room which he had fitted up in a cottage, where they performed many chemical experiments and made rough analyses of waters.

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In his twenty-first year, Frankland left Lancaster and went to London, where he was introduced to Dr. Lyon Playfair and commenced working in his laboratory in October 1845, under the direction of the assistant, Mr. Ransome. At the end of six months, Playfair appointed him lecture-assistant in the Civil Engineering College, Putney.

Kolbe was then assistant in Playfair's laboratory, and he and Frankland undertook an investigation suggested by the theory of Berzelius that acetic acid is a conjugate compound of methyl and oxalic acid, and on April 19, 1847, they read a paper at the Chemical Society "On the Chemical Constitution of Metacetic (Propionic) Acid, and some other Bodies related to it," which was published in *Chem. Soc. Mem.*, 1845—1848, 3, 386—391. They suspected that the nitriles, some of which had been prepared by other chemists, were in reality cyanides, and they prepared pure ethyl cyanide and acted on it with boiling solution of caustic potash, and obtained potassium propionate with evolution of ammonia.

In May 1847, Frankland went with Kolbe to Marburg and worked for three months in Bunsen's laboratory. Here they completed the work on the preparation of organic acids from the alkyl cyanides and

published a complete account of their researches in the *Annalen*, 1848, 65, 288—304, under the title "Ueber die chemische Constitution der Säuren der Reihe $(C_2H_2)_nO_4$ und der unter dem Namen 'nitrile' bekannten Verbindungen." In this paper (April 15, 1848) they describe the use of the inverted condenser for digestions. They also attempted to isolate ethyl by the action of potassium on ethyl cyanide, when they obtained a gas having the composition of methyl; this gas, when acted on by chlorine, gave a compound which they supposed to be an isomeride of ethyl chloride. In the residue left after the evolution of the gas, they found the new base, cyanethine, of which they prepared the nitrate and platinichloride.

In the combustion of these compounds with oxide of copper, they employed a stream of oxygen evolved from potassium perchlorate placed in the posterior end of the combustion tube (*Quart. Journ. Chem. Soc.*, 1849, 1, 60—74. Read February 7, 1848).

In August 1847, Frankland went to Queenwood College to teach chemistry, geology, and botany. It was here that his experiments on the isolation of the alcohol radicles* were commenced on April 10, 1848, in the attempt to remove the oxygen from ether by the action of potassium, but which yielded only hydrogen from the presence of water or of alcohol. On April 18, he prepared ethyl iodide for further experiments, this compound not having been hitherto used in chemical research. On April 21, he tried the action of potassium on ethyl iodide; no change took place in the cold, but when the iodide was heated near its boiling point, gas was evolved; this experiment was lost in consequence of the entry of water into the tube. On April 26, potassium and ethyl iodide were heated together in a sealed tube in an oil-bath; on opening the tube, a gas escaped which was found to be a mixture of methyl and hydrogen. Frankland appears to have been one of the first chemists to use sealed tubes in chemical research, and he tells us that, when he was working in Liebig's laboratory in 1849, Hofmann paid him a visit to learn the way of making these tubes and took a number of them back to London with him. On May 18, during the analysis of another quantity of the gas, the eudiometer exploded. In August, in attempting to prepare the radicle formyl by the action of potassium on chloroform, several serious explosions occurred, but apparently no important result was obtained.

He then returned to the isolation of ethyl, and on July 28, 1848, he sealed up a mixture of ethyl iodide and zinc in a glass tube and heated the tube to 300° F.; no action appeared to occur, but at 400° the zinc began to be slowly converted into iodide and the liquid ceased to boil.

In October 1848, Frankland, accompanied by Tyndall, went to Marburg and worked in Bunsen's laboratory. Here he isolated

* It should be noted that Frankland always spelt this word "radical."

chromium by electrolysis, but he does not appear to have published any account of its properties, which differed somewhat from those of the metal obtained by other processes. On February 18, 1849, he opened the tube in which, on July 28, 1848, he had heated the mixture of zinc and ethyl iodide. The tube was opened under water and some of the contents came in contact with the water, producing a violent effervescence. The gas was found to consist of ethyl mixed with methyl and ethylene. On March 2, he placed ethyl iodide and zinc in a tube from which the air was removed before sealing; after heating, the evolved gas was found to be a mixture of ethyl, methyl, and ethylene. When the sealed tubes were opened, a large quantity of gas rushed out, leaving a small quantity of volatile liquid in the tube; the vapour of this liquid was shown to be pure ethyl. The homogeneity and density of the gas were determined by observation of its rate of diffusion, this being the first application of this method. He endeavoured to combine ethyl with chlorine, bromine, and other substances, but without success. He also studied the action of zinc on ethyl iodide in the presence of water, and found that ethyl hydride was evolved. The results of this investigation were sent to the Chemical Society on June 17, 1849, and published in the *Quart. Journ. Chem. Soc.*, 1850, 2, 263—296, under the title "On the Isolation of the Organic Radicles." On March 15 and 16, 1849, the action of ethyl iodide on other metals was tried, and tin was found to be acted on with considerable ease. The results of all these experiments were included in the thesis for the Ph.D. degree, which was granted on June 30, 1849, Frankland being the first Englishman to graduate at Marburg.

Experiments were next made with zinc and methyl iodide, when zinc methyl was discovered with all its surprising properties. This compound and zinc ethyl were described in a paper on a new series of organic bodies containing metals and phosphorus (*Quart. Journ. Chem. Soc.*, 1850, 2, 297—299), and read on November 5, 1849.

In the autumn of 1849, Frankland went to Giessen and worked with Liebig until Christmas; here he experimented on the action of amyl iodide on zinc and obtained, in addition to amyl and zinc amyl, the compounds amyl hydride and amylenes, which were previously unknown. This research was described at the Chemical Society on February 18, 1850, and published under the title "Researches on the Organic Radicles; Part II, Amyl" (*Quart. Journ. Chem. Soc.*, 1851, 3, 30—52). A section at the end of this paper refers to the constitution of alcohols, ethers, and the ammonia bases.

At Christmas, he went to Berlin with the intention of working in Rose's laboratory, but before the laboratory was opened he was offered the Professorship of Chemistry at Putney College in succession to Playfair and entered on his duties in the beginning of the year

1850. After organising the laboratory he tried the action of sunlight on ethyl iodide and found that, in the presence of mercury, mixtures of ethyl, ethyl hydride, and ethylene were formed. The paper on the action of solar light on ethyl iodide was read on November 4, 1850 (*Quart. Journ. Chem. Soc.*, 1851, **3**, 322—347). The paper concludes with a discussion of the isomerism of methyl and ethyl hydrides and a reply to some criticisms by Hofmann. While at Putney the experiments on the action of light on ethyl iodide in the presence of various metals were commenced and particular attention was paid to the effect produced by tin.

In January 1851, Frankland was appointed Professor of Chemistry at Owens College, Manchester, on its foundation, and immediately afterwards was married to Sophie Fick. The College was opened early in March, and a temporary laboratory was fitted up in a vacant house while the permanent laboratory and lecture-room were being built. These were completed and occupied in October 1851, and were, at that time, the most conveniently arranged in the country. [View Article Online](#) The research on the action of metals on ethyl iodide in the presence of light was completed and the results brought before the Royal Society under the title "On a New Series of Organic Bodies containing Metals" on May 10, 1852 (*Phil. Trans.*, 1852, **142**, 417—444). In this paper are described the organo-tin compounds obtained from the stannethyl iodide, SnEt_2I_2 , the product of the action of light on tin and ethyl iodide. This was believed to be a conjugate compound of tin and ethyl iodide, and as in these compounds the metal was supposed to retain its combining power unaltered, it was expected that the stannethyl iodide would combine with an additional quantity of a negative element. Cacodyl was at that time considered to be a conjugate compound, and, as it was capable of combining with chlorine and oxygen, the same property was looked for in the case of the tin compound and also of zinc methyl. The failure to effect these combinations threw new light on the combining powers of the elements, and this research was the starting point of the theory of atomicity or valency, which has had such an important influence on the progress of modern chemistry. The first of the organic compounds containing mercury, mercuric methiodide, was also described in this paper.

At Manchester, Frankland's attention was naturally drawn to technical chemistry, and he delivered a course of lectures on this subject at Owens College extending over two years. He also gave courses of lectures on Technological Chemistry at the Royal Institution in 1853 and 1857. In the *Memoirs of the Manchester Literary and Philosophical Society*, 2nd Series, **10**, 71—119 (January 13, 1852), he published a long paper, "Contributions to the Knowledge of the Manufacture of Gas," containing an investigation of White's hydro-

carbon process, which consisted in injecting water-gas into the retorts in which coal was being distilled.

During the investigations on the isolation of the organic radicles and the organo-metallic bodies, frequent analyses of gases were necessary, and this led to the publication in June 1853, in conjunction with Mr. W. J. Ward, of the paper on an improved apparatus for the analysis of gases (*Quart. Journ. Chem. Soc.*, 1854, **6**, 197—205). This apparatus, which was an improvement on that of Regnault and Reiset, is the parent of many other forms of gas analysis apparatus which have since been devised.

The study of the manufacture of coal gas and its illuminating power gave rise to the invention of an improved gas burner, described in *Ure's Dictionary*, 7th edition, vol. 2, p. 562. In this burner, the air supplied to the flame passes between the chimney and the surrounding globe before passing to the flame. In this manner both air and gas are heated before coming in contact, and the amount of light produced is increased 67 per cent. This burner was the precursor of those of Siemens, Grimston and Bower, and Wenham. A similar burner appears to have been devised as early as 1840, for Sir John Robison, in the *Edinburgh Philosophical Journal*, **28**, p. 299, states that such a burner was "proposed in Paris and much praised in London," but he says that it offers no advantage over a proper regulation of gas in an argand burner.

During the time that Frankland was at Manchester he published three more papers containing results of the researches on organo-metallic bodies. The first was on zinc ethyl, read February 9, 1855 (*Phil. Trans.*, 1855, **145**, 259—275); it contains a description of the iron digester in which sealed tubes were heated in water, so that the external pressure of the steam supported the walls of the tubes against the internal pressure of the contents; the copper digester for the preparation of zinc ethyl on a large scale is also described. The paper contains an account of the preparation and properties of zinc ethyl, and of the precautions necessary in manipulating this compound. The second research was "On a New Series of Organic Acids containing Nitrogen" (*Phil. Trans.*, 1857, **147**, 59—78; June 19, 1856). This deals with the action of nitric oxide on zinc ethyl and the products obtained from this reaction. And the third paper was on a new series of compounds derived from ammonia and its analogues, and published in the *Proc. Roy. Soc.*, 1856—1857, **8**, 502—506 (received June 18, 1857). This communication contains an account of the action of zinc ethyl on ammonia, aniline, diethylamine, oxamide, and acetamide, resulting in the replacement of hydrogen in these compounds by zinc.

On July 20, 1857, Frankland was appointed Lecturer on Chemistry

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at St. Bartholomew's Hospital, and entered on his duties on October 1, in succession to Dr. Stenhouse, who had resigned in consequence of ill health. In 1859, he became Lecturer on Chemistry and Physics at Addiscombe, and on May 4, 1863, he succeeded Faraday as Fullerian Professor of Chemistry at the Royal Institution. He held these three appointments simultaneously during more than a year, for he retired from St. Bartholomew's on July 12, 1864, and shortly afterwards the Military College was abolished.

The work at St. Bartholomew's left more time for research than was available at Owens College, and the investigations of the organo-metallic bodies progressed, a note on sodium ethyl and potassium ethyl being published in 1858, and the Bakerian lecture entitled "Researches on Organo-metallic Bodies" being delivered at the Royal Society in 1859. Sodium and potassium ethyl were discovered by Mr. Wanklyn, and in the note above mentioned (*Proc. Roy. Soc.*, 1857—1859, 9, 345—347) Frankland explains his failure to obtain these compounds by the action of sodium and potassium on ethyl iodide in his earlier experiments. Although action takes place between these substances, the products are merely metallic iodides and a mixture of ethylene and ethyl iodide. This was found to be due to the fact that sodium ethyl and ethyl iodide mutually decompose one another at the common temperature with formation of sodium iodide and a mixture of ethyl hydride and ethylene.

The Bakerian lecture (*Phil. Trans.*, 1860, 149, 401) deals with further investigations on the tin, mercury, and zinc compounds. Pure stannic ethyl, SnEt_4 , was obtained by the action of zinc ethyl on stannic ethyl iodide, SnEt_2I_2 , and it was found to be incapable of further combination, showing that in this compound the combining powers of the tin are quite satisfied. Iodine, however, acts on it, replacing some of the ethyl by iodine. By the action of hydrochloric acid, stannic triethyl chloride, SnEt_3Cl , is formed with evolution of ethyl hydride. Stannic diethiodide, by the action of zinc methyl, gave stannic diethiodimethide, which, under the influence of iodine, gave distannic tetraethiodide, $\text{Sn}_2\text{Et}_4\text{I}_2$, with separation of methyl iodide. Attempts were made to produce mercuric ethomethide by the action of zinc ethyl on mercuric methiodide, HgMeI , but without success, the products being mercuric ethide, zinc methyl, and zinc iodide. Mercuric methochloride, when acted on by zinc ethyl, gave a product the composition of which approached that of mercuric ethomethide, but by distillation it appeared to separate into mercuric ethide and mercuric methide. Attempts to produce zinc ethomethide were also unsuccessful. The preparation of pure zinc methyl on a large scale by the action of an ethereal solution of methyl iodide in the copper digester resulted in

the formation of a molecular compound of zinc methyl with ether, and when methyl ether was substituted for ethyl ether an analogous compound was produced.

While Frankland was at St. Bartholomew's, he became acquainted with Baldwin Francis Duppa, who had been a student of Hofmann's, and went to St. Bartholomew's to learn gas analysis. They soon became associated in original research, and the first paper they published appears to be a short one on boric ethide (*Proc. Roy. Soc.*, 1860, 10, 568—570), presented to the Royal Society on July 7, 1860. The compound was prepared by the action of zinc ethyl on ethyl borate; this paper was merely a preliminary communication, the detailed description of these researches being published in 1862. On June 7, 1860, Frankland gave a lecture to the Chemical Society on organo-metallic bodies. It is published in the *Journal*, 1861, 13, 177—235, and describes the work done up to that period.

About this time he undertook some experiments in physical chemistry. A short note dated November 7, 1861, was published in the *Phil. Mag.*, 1861, 22, 472—473, on the blue band in the lithium spectrum, which had not been observed by Bunsen and Kirchhoff, and which he showed was due to increase of temperature.

On the 20th and 21st of August 1859, Frankland and Tyndall ascended Mont Blanc for the purpose of making scientific experiments. They made preparations for remaining a week upon the mountain, and started with a large party of 26 porters, to carry provisions and instruments, and 3 guides. On the night of the 20th they slept at the Grands Mulets, and on the 21st they slept in a tent about 12 feet below the summit of the ridge. Most of the porters having returned to Chamounix, the party, consisting of 11 persons, was the first to pass the night on the summit of Mont Blanc. On the following morning, Tyndall erected a post to which maximum and minimum thermometers were fixed, and also made some observations on solar radiation, while Frankland collected some air for analysis and also determined the rate of combustion of six stearin candles. He found that the loss of weight of each candle was 9·2 grams per hour, while at Chamounix he had found that 9·4 grams per hour were consumed, showing that the rate of combustion at the two different levels was practically the same. The party returned to Chamounix on the same day. The analysis of the air from Mont Blanc was described in a paper read to the Chemical Society on February 2, 1860, and published in the *Journal*, 1860, 13, 22—30.

The experiments on the rate of combustion of candles on the summit of Mont Blanc led to a long experimental investigation on the influence of atmospheric pressure upon some of the phenomena of combustion, an account of which was read before the Royal Society on

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June 20, 1861, and is printed in the *Phil. Trans.*, 1862, 151, 629—653. It was not found practicable to determine experimentally the quantity of candle burnt in air at different pressures, for the observations were seriously interfered with by the heating of the enclosing apparatus; in the only experiment recorded, the quantity of stearin consumed in air at a pressure of 9 inches was more than 15 per cent. greater than that burnt at the ordinary pressure. It had been observed by Quartermaster Mitchell that time-fuses used at high altitudes burnt for a longer time than those used at sea level; experiments were tried by connecting a time-fuse to an iron tube in which the atmospheric pressure could be reduced, and the results fully confirmed those obtained by Mitchell, the rapid removal of the gases produced by the combustion of the gunpowder apparently cooling the next layer of the combustible and thus retarding the action. It was found that the rate of combustion of the fuse was reduced one-thirtieth for each diminution of one inch of the barometric pressure.

Experiments were tried on the amount of light produced by the combustion of candles in air of reduced pressure, but the results were not satisfactory owing to the irregularity of the combustion. An apparatus was constructed by means of which the light of a gas flame burning 0.65 cubic feet an hour could be compared with a similar flame burning the same quantity of gas in an enclosed space through which a current of air at reduced pressure was passing. The pressures varied from 6.6 inches to the ordinary barometric pressure, and it was found that the curve representing the amount of light produced is practically a straight line between 30 inches and 14 inches pressure, there being a diminution of approximately 5.1 per cent. of the luminosity at 30 inches for each reduction of 1 inch of pressure. Below 14 inches pressure, the diminution of light proceeds at a less rapid rate. Experiments were also made on the increase of luminosity on increasing the pressure. Difficulties were encountered at this stage, for all ordinary combustibles give smoky flames on a comparatively slight increase of pressure. A lamp containing amyl alcohol was used from the ordinary pressure to about 2 atmospheres; at a slightly higher pressure, the flame began to smoke. The increase of light obeyed approximately the same law as was found to represent the change of luminosity under reduced pressure. A lamp supplied with a mixture of five parts of common alcohol with one of amyl alcohol could be used up to a pressure of 4 atmospheres, but the luminosity increased much more quickly than calculated by the law.

On May 22, 1862, Frankland read a paper before the Royal Society on "A New Series of Organic Compounds containing Boron" (*Phil. Trans.*, 1863, 152, 167—183). In this paper he recapitulates the work previously published in conjunction with Duppa and describes the preparation of

boric ethide, BEt_3 , the action of hydrochloric acid on it with formation of boric diethochloride, BEt_2Cl , and the compound with ammonia, $\text{NH}_3, \text{BEt}_3$. Boric ethide by action of oxygen gives boric ethodiethylate, $\text{BEt}(\text{EtO})_2$, which is decomposed by water into alcohol and boric ethodihydrate, $\text{BEt}(\text{HO})_2$. He proves that the action of zinc ethyl on boric ether is not the simple removal of oxygen, as suggested by Kekulé, but is the replacement of the ethoxyl by ethyl, for, when boric ether is acted on by zinc methyl, the gaseous boric methide, BMe_3 , is formed, the ethoxyl of the ether being replaced by methyl. Boric methide, like the ethide, forms a volatile compound with ammonia, and combines also with the hydrates of the alkali and alkaline earth metals.

On May 20, 1862, there appeared in the *Journal of Gas Lighting* a paper by Frankland "On the Igniting Point of Coal Gas," which was reprinted in the *Journ. Chem. Soc.*, 1863, 1, 398—403. He determined the inflaming point of the principal constituents of coal gas, and found that the vapour of carbon disulphide inflames at about 150° , hydrogen at the temperature of an iron rod heated to redness in daylight, carbonic oxide at a higher temperature, marsh gas and olefiant gas at still higher temperatures. A mixture of carbonic oxide with 3 per cent. of carbon disulphide vapour inflamed at about 175° , and a mixture of hydrogen and 3 per cent. of carbon disulphide vapour at 215° . The inflaming point of olefiant gas was not lowered by admixture of carbon disulphide, and the presence of a small quantity of olefiant gas very much raised the inflaming points of mixtures of carbonic oxide with carbon disulphide vapour and of hydrogen with the same vapour. Marsh gas was not inflamed by sparks from flint and steel, although such sparks easily inflame hydrogen and coal gas. He points out that Davy lamps must be used very cautiously in mixtures of air and coal gas.

About this time, Frankland's attention was occupied by the synthesis of organic compounds by the use of zinc ethyl, and on January 15, 1863, a paper was read before the Royal Society on the synthesis of leucic acid (*Proc. Roy. Soc.*, 1862—1863, 12, 396—398). When zinc ethyl and ethyl oxalate are mixed, an energetic action takes place; if the product is mixed with water and distilled, a liquid passes over of the same composition as that of the ethyl salt of leucic acid, an acid obtained by Strecker by the action of nitrous acid on leucin. The ethereal salt is the result of replacing one atom of oxygen in ethyl oxalate by two semi-molecules of ethyl, and was called ethyl diethoxalate. In conjunction with Duppa, Frankland afterwards found that leucic acid is isomeric, but not identical, with diethoxalic acid. This was the first member of the lactic series which was obtained artificially, and its discovery led to a series of investigations by Frankland and Duppa on the acids of the

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lactic and acrylic series. In a series of notes presented to the Royal Society, the authors recorded the progress of their work. These papers were entitled "Notes of Researches on the Acids of the Lactic Series." No. 1 is "On the Action of Zinc upon a Mixture of Iodide and Oxalate of Methyl" (*Proc. Roy. Soc.*, 1864, **13**, 140—142). No. 2, "Action of Zinc upon a Mixture of Iodide of Ethyl and Oxalate of Methyl" [1864] (*Proc. Roy. Soc.*, 1865, **14**, 17—19). No. 3, "Action of Zinc Ethyl on Ethylic Leucate" (*Proc. Roy. Soc.*, 1865, **14**, 79—83). No. 4, "Action of Zinc upon Oxalic Ether and the Iodides of Methyl and Ethyl mixed in Atomic Proportions" (*Proc. Roy. Soc.*, 1865, **14**, 83—86). No. 5, "Action of Zinc upon a Mixture of Ethyl Oxalate and Amyl Iodide" (*Proc. Roy. Soc.*, 1865, **14**, 191—198). These papers were read between February 18, 1864, and April 27, 1865.

On June 15, 1865, the authors read a paper at the Chemical Society entitled "Transformation of the Lactic into the Acrylic Series of Acids" (*Journ. Chem. Soc.*, 1865, **13**, 133—156), in which they showed that the ethereal salts of the acids of the lactic series, which they had produced by synthesis, were transformed by the action of phosphorous chloride into ethereal salts of acids of the acrylic series, and that the acids of the acrylic series obtained from these esters when heated with caustic potash gave two acids of the acetic series. From the results obtained, the constitution of the acids of the acrylic or oleic series obtained artificially, and that of some of the natural oleic acids, was determined.

The joint authors read a paper before the Royal Society on April 27, 1865, "Notes of Synthetical Researches on Ethers. No. 1. Synthesis of Butyric and Caproic Ethers from Acetic Ether" (*Proc. Roy. Soc.*, 1865, **14**, 198—204), and on July 13 they forwarded another paper, which was read on November 16, 1865, "Synthetical Researches upon Ethers. 1. Synthesis of Ethers from Acetic Ether" (*Proc. Roy. Soc.*, 1865, **14**, 458—464, and *Phil. Trans.*, 1866, **156**, 37—72). In these papers, they describe the results of the consecutive action of sodium and ethyl and methyl iodides on ethyl acetate, by which they obtained butyric and caproic ethers, sodic and disodic acetic ethers, the carboketonic ethers, and the ketones prepared from them. This paper concludes with theoretical considerations on the constitution and chemical relations of the ethereal salts and ketones derived from the duplication of the molecule of ethyl acetate, and on the constitution of the fatty acids, in which it is shown that the fatty acids may be regarded as containing the negative group CO(OH) united to a positive radicle, either hydrogen or methyl, or methyl with one or more atoms of the hydrogen replaced by other positive groups. It is also pointed out for the first time how numerous are the isomeric modifications of the fatty acids which are possible by varying the constitution of the positive radicle.

In August 1865, Frankland had intended accompanying his brother-in-law, Professor Fick, and Professor Wislicenus in their expedition to the Faulhorn, where they intended to institute some experiments on the origin of muscular power. The weather was unpropitious and Frankland had to leave Geneva, where he was waiting for his colleagues; they, however, carried out the experiments a fortnight later in his absence. The method adopted was to climb the mountain after having abstained for about 18 hours from albuminoid food, and by the determination of the amount of urea excreted they hoped to obtain evidence that the work performed resulted from the oxidation of muscle. It was found, however, that the measured work far exceeded that which could have been performed by the oxidation of the muscle and that the energy must therefore have been partly supplied by the non-nitrogenous food that they had consumed.

Frankland undertook to determine the amount of heat produced by the combustion of various food materials and the experiments were carried out by means of Lewis Thompson's calorimeter, the organic substances being burnt under water by means of a mixture of potassium chlorate and potassium nitrate. From the quantity of energy produced by the combustion of the food, it was shown that the source of the muscular power was not the muscle that was wasted, but the carbon and hydrogen of the food that was oxidised in the body, and thus served as fuel, the muscle acting merely as the machine which rendered the energy available. The results of this research were published in a paper in the *Philosophical Magazine*, 1866, 32, 182—199. Frankland also gave a lecture on the subject at the Royal Institution on Friday evening, June 8, 1866.

Meanwhile the organo-metallic bodies were not neglected, for on November 19, 1863, Frankland and Duppa read a paper before the Chemical Society "On a New Method of producing the Mercury Compounds of the Alcohol Radicles" (*Journ. Chem. Soc.*, 1863, 1, 415—425), in which they showed that when the iodides of methyl, ethyl, and amyl, mixed with a small quantity of ethyl acetate, are brought into contact with sodium amalgam at the ordinary temperature, the corresponding mercury compounds are formed; and on December 3, 1863, another paper was read at the Chemical Society "On a New Reaction for the Production of the Zinc Compounds of the Alcohol Radicles" (*Journ. Chem. Soc.*, 1864, 2, 29—36), describing the action of zinc on mercuric methide, ethide, and amyliide, by which the zinc methyl, zinc ethyl, and zinc amyl were readily obtained in a state of purity.

On February 14, 1866, the authors sent to the Royal Society a paper on "Researches on Acids of the Lactic Series. No. 1. Synthesis of Acids of the Lactic Series," which was read on March 1, 1866 (*Proc. Roy.*

Soc., 1867, 15, 25—28; *Phil. Trans.*, 1866, 156, 309—360). This paper includes the results of the five notes read between February 18, 1864, and April 27, 1865, entering more fully into the subject and giving analyses of the products. In the theoretical considerations which conclude this paper, they propose the name of oxatyl for the compound radicle CO(OH), it being the radicle of which oxalic acid is the isolated molecule. They show that this radicle exists in almost all organic acids and that it is to this radicle that these compounds owe their acidity, hence the expression "An organic acid containing *n*-semimolecules of oxatyl is *n*-basic." Thus, they consider lactic acid to be a monobasic acid, a matter which had been previously much contested. They divide the lactic acids into eight classes and explain the reasons for this classification. In a note they advise chemists to use Crum Brown's graphic formulæ, a recommendation which has been almost universally followed, and by means of such formulæ they explain the isomerism in the lactic series. They also deal with the proximate analysis of the acids of the lactic series by which they ascertain the presence of the various radicles in the acids.

In September 1866, Frankland communicated to the Chemical Society "Contributions to the Notation of Organic and Inorganic Compounds" (*Journ. Chem. Soc.*, 1866, 4, 372—395). The study of organic compounds and the elucidation of their constitution by means of graphic formulæ led him to devise a system of symbolic notation which would represent the same ideas as were conveyed by the graphic formulæ. By employing symbols to represent compound radicles, as Ho for (OH), Ko for (OK), Bao" for (O₂Ba), Me for (CH₃), &c., and constructing the formula of a compound by placing the symbol of the binding or grouping element (printed in thick type) before the symbols of the elements and compound radicles to which it is combined, and by using a bracket to show that the elements whose symbols are next to the bracket are directly combined, it is possible to represent the constitution of compounds whether inorganic or organic.

Thus, ammoniac chloride and nitrate are represented by NH₄Cl, NO₃Amo. Sulphuric acid, the sulphates of potassium and barium by SO₂H₂, SO₂Ko₂, SO₂Bao". Ferric sulphate by S₃O₆Fe₂o^{vi}. Alcohol

and acetic acid by $\left\{ \begin{array}{l} \text{CH}_3 \\ \text{CH}_2\text{Ho} \end{array} \right\}$, $\left\{ \begin{array}{l} \text{CH}_3 \\ \text{COHo} \end{array} \right\}$. Lactic acid by $\left\{ \begin{array}{l} \text{CMeHHo} \\ \text{COHo} \end{array} \right\}$,

and tartaric acid by $\left\{ \begin{array}{l} \text{COHo} \\ \text{CHHo} \\ \text{CHHo} \\ \text{COHo} \end{array} \right\}$, &c. It is obvious that these formulæ

can be at once transformed into graphic formulæ if required.

On January 17, 1867, Frankland and Duppa read a paper before the Chemical Society on "Synthetical Researches on Ethers. No. 2.

Action of Sodium and Isopropyl Iodide upon Ethylic Acetate" (*Journ. Chem. Soc.*, 1867, **5**, 102—116). The results of this action were found to be quite analogous to those obtained with the other iodides.

During the time that Frankland was at the Royal Institution, he was engaged in professional work which brought him in contact with many problems of an economic nature. Thus, in 1859, when the condition of the Thames in London became very offensive, he and Dr. Hofmann were requested by the Metropolitan Board of Works to examine various proposals which had been made for the deodorisation of sewage, and when, in 1865, he succeeded Dr. A. W. Hofmann as Professor of Chemistry at the Royal School of Mines, he continued the reports on the monthly analyses of the metropolitan waters which had been commenced a short time previously at the Royal College of Chemistry. He became much interested in the water supply of towns and he read a paper before the Chemical Society on March 15, 1866, on "The Water Supply of the Metropolis during the Year 1865—1866" (*Journ. Chem. Soc.*, 1866, **4**, 239—248). This led him to investigate the methods in use for the analysis of water, and on January 16, 1868, he delivered a lecture before the Chemical Society "On the Analysis of Potable Waters" (*Journ. Chem. Soc.*, 1868, **6**, 77—108). In this lecture, the investigations on water analysis, made in conjunction with Dr. H. E. Armstrong, are fully dealt with, and descriptions are given of the processes which they suggest for a more trustworthy analysis of waters. The organic carbon and nitrogen are determined by combustion of the solid residue from the water with lead chromate and oxide of copper, the combustion being carried out in a tube previously exhausted by a Sprengel pump, and from which the resulting carbon dioxide and nitrogen are removed by the same pump and the gases measured. The manipulations necessary for this process and for the determination of nitrogen in the state of ammonia and of nitrates and nitrites are given in detail and the objections to other methods are stated. This paper was succeeded by another "On a Simple Apparatus for determining the Gases Incident to Water Analysis" (*Journ. Chem. Soc.*, 1868, **6**, 109—120). This is a simplification of the gas analysis apparatus previously described in 1853.

In 1868, Frankland was appointed a member of the Royal Commission to inquire into the Best Means of preventing the Pollution of Rivers. A laboratory was fitted up in Victoria Street, Westminster, in which a large amount of experimental work was carried on under the supervision of the late Mr. W. Thorp. The work was continued until 1874, and six voluminous reports were issued by the Commission during this period.

In March 1867, Frankland gave, at the Royal Institution, a course of lectures on coal gas, in which he stated that some experiments had

led him to doubt the correctness of Sir Humphry Davy's theory that the light of gas and candle flames is due to the incandescence of solid particles in the flames, and in a paper read before the Royal Society on June 11, 1868, "On the Combustion of Hydrogen and Carbonic Oxide in Oxygen under Great Pressure" (*Proc. Roy. Soc.*, 1868, 16, 419—422), he shows that there are many luminous flames which cannot possibly contain solid matter, such as those produced by the combustion of arsenic and phosphorus in oxygen, the temperature produced by the combustion being more than sufficient to retain the products of combustion in the gaseous condition. He attributes the luminosity to the incandescence of the dense vapours present in the flame. A jet of hydrogen one inch long gives very little light when burnt in oxygen at the ordinary pressure, but when the pressure is raised to 10 atmospheres a white flame is produced, which is sufficiently bright to enable one to read a newspaper at the distance of two feet from the flame, and the spectrum of the flame is continuous from red to violet. The spectrum of carbonic oxide burning in oxygen at a pressure of fourteen atmospheres is very brilliant and quite continuous. When sparks from an induction coil are passed through hydrogen, oxygen, chlorine, and sulphurous anhydride, the brilliancy of the sparks increases with increase of density of the gas. On June 12, 1868, a lecture was given on this subject at the Royal Institution (*Proc. Roy. Inst.*, 1869, 6, 419—423).

About 1868, Mr. J. Norman Lockyer was working at the Royal College of Chemistry, and three short papers were published by the joint authors in 1869. The first was read at the Royal Society on February 11, 1869, "Preliminary Note of Researches on Gaseous Spectra in relation to the Physical Constitution of the Sun" (*Proc. Roy. Soc.*, 1869, 17, 288—291). They found that the line seen near *D* in the spectrum of the chromosphere, afterwards known as the helium line, was not due to hydrogen, that the widening of the green line *F* at the lower portion of the chromosphere was due to increase of pressure, and that the gas at the upper portion of the chromosphere must be in a state of excessive tenuity. They also suggest that the photosphere of the sun does not consist of solid or liquid matter, but of gas of sufficient density and temperature to produce a continuous spectrum. The second note was read on June 10, 1869, "Researches on Gaseous Spectra in relation to the Physical Condition of the Sun, Stars, and Nebulæ. Second Note" (*Proc. Roy. Soc.*, 1869, 17, 453—454), and deals principally with the spectra of hydrogen and nitrogen, which are each reduced to single lines in the green when the temperature is reduced. The third note, with the same title, was communicated on July 14, 1869 (*Proc. Roy. Soc.*, 1870, 18, 79—80); it deals principally with the spectrum of magnesium, some of the lines in which are

shorter than others, both when magnesium is projected into the chromosphere and when sparks are produced between poles of magnesium.

On February 2, 1871, Frankland read a paper before the Chemical Society on "The Development of Fungi in Potable Waters" (*Journ. Chem. Soc.*, 1871, 9, 66—76). This refers to the test for purity of potable water suggested in the previous year by Mr. Heisch, which consisted in dissolving in the water a small quantity of pure sugar and keeping the solution for some days in a warm place: if the water was contaminated, a fungus was found to be produced. Frankland tried many experiments with this test, and found that the presence of a phosphate was necessary for the growth of the fungus, whatever the source from which the water was obtained.

On February 17, 1876, another lecture was delivered at the Chemical Society "On Some Points in the Analysis of Potable Waters" (*Journ. Chem. Soc.*, 1876, i, 825—851), giving the results of eight years' experience of the methods described in 1868, together with further details of manipulation. The term "previous sewage contamination," which had been adversely criticised, was defended. The variations in the condition of the London waters are shown by diagrams, and objections are raised to other methods of water analysis in vogue at that period.

In 1876, Frankland returned to the study of the organo-boron compounds, and on June 15 he read before the Royal Society a paper on organo-boron compounds (*Proc. Roy. Soc.*, 1877, 25, 165—168). He gave another method of preparing boric ethide by passing the vapour of boric chloride into zinc ethyl. By the action of two molecules of boric ethylate on one of zinc ethyl, he obtained diboric ethopentylate, a liquid boiling at about 112° and distilling unchanged. This has the composition of a compound of boric ethylate with boric etho-diethylate, and it appears to dissociate into these compounds when volatilised, for the vapour density is only one-half of the theoretical. It probably contains two atoms of pentad boron united together by two bonds of each, forming a hexad group, with which one semimolecule of ethyl and five of ethoxyl are combined. Ammonia-boric methide, previously discovered, may have a similar constitution, the pentad nitrogen and boron being united by two bonds of each, and the hexad group combined with three atoms of hydrogen and three semimolecules of methyl. Boric diethethylate, boric diethohydrate, and boric ethethylate-hydrate are also described in this paper.

The foregoing account by no means includes all the papers that Frankland published, but it contains the most important, almost all of them containing discoveries which have had a great influence on the progress of science; many of the remaining papers are continuations of the work done in earlier years.

Frankland was an excellent manipulator; his early researches required such careful experiment, and were, of course, carried out without the help of others, that he acquired great facility in manipulation. Even after circumstances had placed at his disposal the assistance of students and other co-workers, he still continued to do a large amount of work with his own hands. He took great care in experimentally illustrating his lectures and devised a large number of striking experiments, many of which are still used by lecturers, but their origin has been forgotten. His retiring character was so marked that even those who were in frequent contact with him heard very little from his lips of what he had previously accomplished, and it was only from his published work that they learnt the extent of his early successes. He was always kind, considerate, and helpful to his students and assistants.

Sir Edward Frankland in his autobiography tells us that in his youngest days he was very fond of books of travel, but that he had not any opportunity of going beyond a short distance from home until, at the age of 17, he spent a week in Cumberland and Westmoreland. In 1845 he came from Lancaster to London, in 1847 he went to Marburg, crossing from Dover to Ostend, and by the Rhine to Mayence, and on to Frankfort and Marburg. Tyndall and he went to Paris to spend their summer vacation in 1848, and he was there during the revolution at the end of June, living in one of the most disturbed districts. In October 1848 he again went to Marburg, and the next year to Giessen, and in the beginning of 1850 he was for a short time in Berlin. After his marriage he went to Cassel in 1852, and in 1855 he took a cottage at Windermere, where he and his family resided during the vacations; here he had a small yacht, and later he kept a yacht at Cowes. His mountaineering in Switzerland gave rise, as we have seen, to investigations on combustion under different pressures, as well as to papers and lectures on the glacial epoch, thermometric observations, and experiments on solar radiation. In 1863 he paid his first visit to Norway, to which country he became much attached and where he died. He also went to Spain and Algiers. He attended the meeting of the British Association at Montreal in 1884, and afterwards went to the Yellowstone Park and Chicago. In 1886 he went to the Riviera, Naples, Vesuvius, and Capri. He was in Berlin in 1890. This very meagre account of his travels will, however, show that his early predilections for travel were continued during his whole life.

While living at Haverstock Hill, between 1857 and 1870, Frankland took a great interest in gardening; he also at that time ground and silvered a 7-inch glass speculum and fitted it in a telescope, which he used for astronomical purposes, making drawings of the moon and

planets. From 1870 to 1880 he resided in Lancaster Gate, and in the latter year he moved to the Yews, Reigate. Here he had a fine observatory. He lighted the house by electricity, supervising the working and making some of the fittings himself. This led to his investigations of the action of secondary batteries, described in a paper sent to the Royal Society on February 21, 1883, entitled "Contributions to the Chemistry of Storage Batteries" (*Proc. Roy. Soc.*, 1883, 35, 67—70). He also took much interest in his gardens and hot-houses.

Frankland was elected a Fellow of the Chemical Society on December 20, 1847. He served on the Council in 1850—1851 and again in 1858—1859; he was Foreign Secretary from 1861—1868, Vice-President in 1860, 1868, and 1870, and President from 1871—1873. By a curious oversight, his connection with the Chemical Society is not mentioned on the title page of his collected papers, entitled "Experimental Researches in Pure, Applied and Physical Chemistry," published in 1887. He was one of the founders and the first President of the Institute of Chemistry from 1877 to 1880, and afterwards a Vice-President and Censor. He was elected Fellow of the Royal Society on June 2, 1853, and served on the Council in 1857—1859; 1865—1867; 1875—1877, and 1886—1888. He was Foreign Secretary from 1895 until his death. He was awarded a Royal Medal in 1857 and the Copley Medal in 1894. He was also a member of many of the foreign learned societies and academies. He received the honorary degree of D.C.L. of Oxford in 1870, and the LL.D. of Edinburgh in 1884. On the occasion of the Diamond Jubilee of Queen Victoria in 1897 he was created K.C.B.

Frankland was twice married, first to Fräulein Sophie Fick, on February 27, 1851, who died at Davos on January 7, 1874. His second wife was Miss Ellen Frances Grenside, whom he married on May 11, 1875. She died in January, 1899, after a long illness.

He left two sons and two daughters by his first wife, and two daughters by his second. His elder son is a remarkable mathematician, the younger is the well-known Professor of Chemistry at the University of Birmingham. Of recent years, Sir Edward Frankland went almost annually to Norway, where he spent much of his time in fishing, although during the last few years of his life he devoted his time spent in his cottage at Golaa in Gudbrandsdalen to literary work. He died there, after ten days' illness, on August 9, 1899.

HERBERT McLEOD.

JOHN HALL GLADSTONE.

BORN MARCH 7TH, 1827; DIED OCTOBER 6TH, 1902.

FOR many generations the ancestors of John Hall Gladstone lived in the town of Kelso in Roxburghshire, where they carried on the business of damask weavers. But in the early part of the nineteenth century the cottage hand-loom was being superseded, and John Gladstone was driven to seek his fortune in London. Here in February 1816 he entered the drapery establishment of Mr. Cook, in Cheapside, in the humble position of shop-boy; but he soon rose to be traveller and buyer, and in 1824 was taken into partnership. He then married a young cousin, Alison Hall, whose father had a drapery business in Bishopsgate Street, and in due time three sons were born to them. John Hall, the eldest, was born at 7, Chatham Place West, Hackney, and was baptised at Albion (Presbyterian) Chapel, Moorfields. The three brothers were educated entirely at home under tutors, and from very early days all showed a strong inclination toward natural science. In 1842 the father, John Gladstone, retired from business, and soon afterwards the family spent upwards of a year in travelling on the Continent. Part of this time was passed in Italy with their old friends Mr. and Mrs. Tilt and their daughter May, who in 1852 became the eldest son's wife.

From early years John Hall Gladstone had shown strong religious tendencies, and when, at the age of seventeen, the question of his future career came to be discussed, he wished to enter the Christian ministry. From this course he was dissuaded both by his father and by Mr. Tilt, and in December 1844 he entered University College as a student. Here he attended Graham's lectures on chemistry and worked in his private laboratory, and here he prepared his earliest contributions to scientific literature. His first paper, containing an "Analysis of Sand from St. Michael's Bay, Normandy," was read at a meeting of the Chemical Society on November 16, 1846, when he was but nineteen years of age. On June 7 in the following year a more important communication, on "Gun Cotton and Xyloidine," showed that, although so young, he possessed the qualifications necessary for serious scientific investigation, and a gold medal for original research was awarded him by the College. Later in the same year he went to Giessen to work under Liebig, returning in April 1848 with the degree of Doctor of Philosophy. The subject of his dissertation can only be conjectured, but it is probable that the paper on the "Artificial Formation of Urea from Fulminic Acid" (*Quart. Journ. Chem. Soc.*, 1, 228), which appears in Liebig's *Annalen* for 1848, contains the results of the work under-

taken with a view to graduation. But although Gladstone had thus formally adopted the pursuit of science as his career, he continued throughout his life to take an active part in religious work. In Clapham his parents were members of the Rev. James Hill's Congregational Church, and here he taught in the Sunday School, beside conducting services in a Mission Room at White Square. Later on he held a Bible Class for young men on Sunday afternoons, and until the end of his life he was intimately connected with the work of the Young Men's Christian Association. For many years he was the chief organiser of the Sunday afternoon devotional meeting held annually at the meeting of the British Association. In 1850 he was appointed Lecturer in Chemistry to St. Thomas's Hospital, a post which he held for two years, and in 1853, at the age of 26, he was elected into the Royal Society. After the death of his father-in-law in 1861 there was no necessity for Dr. Gladstone to earn money; but he was now so well known, both as a scientific man and a philanthropist, that he had no difficulty in filling his days with useful work. In 1864 he had the deep misfortune to lose his wife and their eldest daughter and only son. This, however, seems to have been followed by only temporary suspense of activity, social and scientific.

In 1863-4 and again in 1866-8 he served on the Council of the Royal Society, and having been a member of the Royal Commission on Lighthouses, Buoys, and Beacons from 1859 to 1862, he became a member of the Gun Cotton Committee in 1864-8.

In politics Gladstone was a Liberal, and on more than one occasion he was tempted to enter Parliament. In 1868 he unsuccessfully contested the borough of York. In 1869 he married Margaret, daughter of the late Rev. Dr. David King, and niece of Lord Kelvin. This lady died in 1870, leaving one daughter.

From 1874-7, Gladstone held the Fullerian Professorship of Chemistry at the Royal Institution, and was first President of the Physical Society, of which he was one of the founders. He was President of the Chemical Society from 1877-9, and in 1898 he was one of the six past Presidents of that Society who had been Fellows for upwards of fifty years, and in whose honour a banquet was given under the chairmanship of the President, Professor Dewar.

Gladstone will be long remembered for his services to education, especially in connection with the introduction of the rudiments of science into the curriculum of Elementary Schools. From 1873 to 1894 he was a member of the London School Board, for three years he was Vice-Chairman of the Board, and for many years he was Chairman of the Books and Apparatus Sub-Committee. He was also for several years, and up to the time of his death, an Almoner of Christ's Hospital, and took much interest in the arrange-

ments for the improved teaching of experimental science in the new buildings at Horsham. Dr. Gladstone was an expert phonographer, having learned the art so early as 1846, and he made use of it for note-taking as a student and for general purposes of composition throughout his life. This led him when a member of the School Board to institute inquiries into the methods of teaching reading, and as a result he came to the conclusion that a reform in English spelling was very desirable. He was successful in 1876 in inducing the School Board to pass by a large majority a resolution in favour of a change, a memorial was subsequently presented to the Committee of Council on Education, and in 1879 the Spelling Reform Association was constituted. Although phonetic spelling was not adopted, much good was accomplished in the abolition of the old-fashioned spelling-books, and to Dr. Gladstone's efforts in urging the importance of shorthand is mainly due the teaching of this art which has been so widely adopted.

Dr. Gladstone was very fond of London, and although from childhood he had taken much interest in natural history, and although he often praised the country, not unfrequently in verse, he seems never to have wished to live out of the metropolis. It only remains to be mentioned that he spoke French readily, and frequently attended the summer meetings of the Association Française pour l'Avancement des Sciences, and was also at one or two meetings of the Swiss Association.

In recognition of his services to education he was elected an Honorary Fellow of the College of Preceptors. He also received the degree Sc.D. at the celebration of the Tercentenary of Trinity College, Dublin, in 1892, and the Davy Medal from the Royal Society in 1897.

In 1880 he became a member of the Company of Wheelwrights, and as a liveryman took part in the last year of his life in the election of the Lord Mayor, at the Guildhall, on Michaelmas Day. On the day of his death, October 6, 1902, he presided in the afternoon at a meeting of the Christian Evidence Society, and, after walking part of the way home, he went into his study, and was found lifeless there as the result of failure of the heart. He was buried the following Friday in Kensal Green Cemetery.

As an investigator in pure chemistry and in physical chemistry Gladstone accomplished a prodigious amount of work. Beside 140 papers standing under his own name alone, there are no fewer than 78 written in collaboration with other workers, as follows: with Sir David Brewster 1, with Rev. T. P. Dale 5, with George Gladstone 7, with J. D. Holmes 2, with Alfred Tribe 41, with Walter Hibbert 20, and with Dr. W. H. Perkin 2. This fertility is partly explained in his speech at the banquet in 1898, for having ample means at his command he was always able to keep in his laboratory a trained

assistant whose work could proceed in his absence. He was a scientific amateur in the best sense of the word.

Some of the subjects in what may be called pure chemistry to which Gladstone's attention was in his early years directed have already been mentioned. Others which deserve notice were the production and properties of phosphamide and similar compounds, begun at Liebig's suggestion and revised ten years later; an inquiry into the composition of the so-called iodide of nitrogen (1852), in which the author's results seemed to justify the adoption of the formula previously given to the compound by Bineau, viz. NHI_2 . Not only had this subject been previously much investigated with results which were not concordant, but from that time onward the question remained unsettled until 1899, when the formula $\text{N}_2\text{H}_8\text{I}_3$, which had been proposed by Bunsen half a century before, was established by Chattaway.

A more important inquiry is embodied in the paper, which appears in the *Philosophical Transactions* for 1855, on "Circumstances modifying the Action of Chemical Affinity." Here, after giving the history of ideas relating to chemical affinity from Bergman down to Berthollet and onwards, the author proceeds to examine the question, arising out of the researches of Bunsen and Debus, whether when two substances act on each other an increase in the quantity of one of them leads to a corresponding increase in the amount of chemical change observed, and whether such change occurs continuously, or *per saltum*, in atomic proportions. In the work of Bunsen on the products of the explosion of carbonic oxide and hydrogen with various proportions of oxygen the resultant carbon dioxide and water are incapable of acting on each other, and in Debus's experiments on the precipitation of mixed barium and calcium chlorides by a carbonate the precipitated earthy carbonates are removed from the reach of further chemical action. In Gladstone's experiments, on the other hand, the products of the interchange as well as the unaltered residue of the original materials remain in the field.

The most interesting results were obtained by observation of the changes of colour which occur in the formation of the red ferric thiocyanate by bringing together in aqueous solution various ferric salts and an alkaline thiocyanate in different proportions. The principal conclusions arrived at are briefly as follows:—

When two or more binary compounds are mixed under such circumstances that all the products are free to act and react, each positive element combines with each negative element in constant proportions, which are independent of the manner in which the elements were originally combined and which are not merely the resultant of the action of the various affinities concerned, but are dependent also on the mass of each of the substances in the mixture.

An alteration in the mass of any one of the binary compounds present alters the amount of every one of the other binary compounds, and that in a regularly progressive ratio, sudden transitions only occurring where a substance is present which is capable of combining with another in more than one proportion. The theory of Berthollet is thus confirmed. The phenomena which present themselves when precipitation, volatilisation, or crystallisation occurs are different because one of the substances is removed from the field of action. Hence there is a fundamental error in all conclusions as to what compounds exist in a solution, drawn from such empirical rules as that "the strongest base combines with the strongest acid." This paper was justly considered so important that it was reprinted in full in the Quarterly Journal of the Chemical Society, vol. 9. The same volume contains another paper directly contributed to the Chemical Society, entitled "Some Experiments illustrative of the Reciprocal Decomposition of Salts," which is devoted to a discussion of some apparent exceptions to the law quoted above and disposes of them all. A further contribution to the same subject occurs in vol. 11, on the "Chemical Action of Water on Soluble Salts." The concluding sentence, which declares that "the actual state of a dissolved salt is beyond the expression of any of our formulæ," is not far from a true representation of the state of knowledge on this subject at the present time.

There is no doubt, however, that optical phenomena and the properties of elements and compounds in relation to light formed the subjects which possessed the greatest fascination for Gladstone. This comes out quite early in his career, and in a variety of forms. Thus in 1854 he lectured at the Royal Institution on "Chromatic Phenomena exhibited by Transmitted Light." In 1855 there were "Notes on some substances which exhibit the Phenomena of Fluorescence," in the *Edinburgh New Philosophical Journal*, and in 1856 on "Some Dichromatic Phenomena among Solutions," at the meeting of the British Association. In 1858 he drew attention to the use of the prism in qualitative analysis (*Quart. Journ. Chem. Soc.*, 10, 79), and discovered the remarkable lines in the absorption spectrum of didymium, a substance long afterwards resolved by Auer von Welsbach into the two elements known as praseo- and neo-dymium. A little later he studied the absorption spectrum of the atmosphere, and found that the lines of Fraunhofer varied according to the time of day, and that the change must be due to some constituents of the earth's atmosphere. In this research he was joined by Sir David Brewster, and together they produced a paper on the lines of the solar spectrum which appears in the *Phil. Trans.*, for 1860.

But the most important work of Gladstone's in this direction was undoubtedly the long series of observations on the refraction and

dispersion of liquids. This apparently originated with a study of the "Influence of Temperature on the Refraction of Light," undertaken in concert with the Rev. T. P. Dale (*Phil. Trans.*, 1858). This was followed by the important "Researches on the Refraction, Dispersion, and Sensitiveness of Liquids," in the *Phil. Trans.* for 1863.

Representing the refractive index by μ , the expression $\mu - 1$ is termed by the authors the refractive energy of the substance, and this multiplied by the volume or divided by the density, d , gives the specific refractive energy, $\frac{\mu - 1}{d}$. The refractive power of liquids is, like

some other physical properties, additive in character, and every liquid has a specific refractive energy composed of the specific refractive energies of its component elements more or less modified by the manner of combination. The specific refractive energy being almost independent of temperature, solution, or even chemical combination, the product of this value multiplied by the molecular weight gives the molecular refractive energy from which refraction equivalents for the elements may be deduced. These refraction equivalents calculated from the refractive energy of different compounds come out nearly but not quite identical, the mean value for potassium, for example, derived from observations on the chloride, cyanide, thiocyanate, and hydroxide is 8.2, while the ethylate, formate, acetate, and tartrate give a mean value 7.8. With such constants the molecular refractive powers of compounds can be calculated, and are generally found to agree very well with those deduced from direct observation of the same compounds. In some cases, carbon and nitrogen for example, the element exhibits more than one atomic refraction, which appears to be connected with its mode of combination. This part of the subject has been pursued for many years by Professor J. W. Brühl, but to Gladstone's laborious observations we owe practically all our knowledge of refractive equivalents.

Another memorable series of researches commenced about 1872, in conjunction with his assistant Alfred Tribe, resulted in the discovery of the copper-zinc couple, and its application to the production of the organo-zinc compounds and to other purposes. The couple has long since found its way into every laboratory in the world, and as a reducing agent has met with applications not only in connection with carbon compounds but for many purposes in analysis.

Notwithstanding or perhaps in consequence of Gladstone's activity as an experimenter, an occupation which almost necessarily leads to the writing of many papers, he did not produce many books. In 1872 he brought out a Biography of Faraday, with whom he had been on terms of close friendship. In 1883 a series of papers on the "Chemistry of the Secondary Batteries of Planté and Faure" were collected into a



little volume published by Macmillan. A small work on "Spelling Reform from an Educational Point of View" was also published by Macmillan in 1878. It will readily be understood from what has already been stated that a large number of pamphlets, papers, and magazine articles on social, educational, and religious subjects also came from his pen.

Personally Gladstone was one of the most kindly and genial of men, with an old-fashioned but never-failing courtesy of manner. It was characteristic of him that when called upon to speak, even in a scientific meeting, he almost invariably addressed his audience as "Friends!" Eager in the pursuit of knowledge and anxious for its diffusion, he divided the long years of an active and useful life between the search after truth and the promotion of the social, moral, and intellectual improvement of his fellow-men. His memory is secure in the respectful admiration of his contemporaries, and by future generations his name will be remembered as one of those who helped to lay the foundations of modern physical chemistry.

W. A. TILDEN.

WLADIMIR WASSILJEWITSCH MARKOWNIKOFF.

BORN DECEMBER 22ND, 1838; DIED FEBRUARY 11TH, 1904.

WLADIMIR WASSILJEWITSCH MARKOWNIKOFF was born on December 22 (N.S.), 1838, in the neighbourhood of Nischnij Nowgorod. Here he attended the preparatory school; and, after passing through the "Gymnasium," entered in 1856 the University of Kazan as a "Cameralia" student. In this university he took his doctor's degree in 1861. About this time he first came in contact with the striking personality of Butlerow, who attracted him strongly; and who, having recently returned from Germany and France charged to the full with the new doctrines of molecular structure, was lecturing and demonstrating enthusiastically on these subjects. In 1862, having completed his course of study, he was appointed Assistant in the department of Inorganic Chemistry. He married in the following year.

In 1865, Markownikoff was sent abroad by the Russian Government to pursue his studies for two years. He went first to Heidelberg, where he attended the lectures of Kopp, Kirchoff, and Erlenmeyer, working in Erlenmeyer's laboratory: thence he proceeded to Berlin, to study with Baeyer, and finally to Kolbe, in Leipzig, where he spent most of his leave. Here, in 1866, he made his

researches on the first isomeric acid of the fatty series, which he discovered, namely, *isobutyric acid* and its derivatives. After his return to Kazan he published (1869) his paper, "Ueber die reciproke Beeinflussung der Atome im Molecule." The work described in this memoir, and the ideas contained in it, he always regarded as his most valuable contribution to chemical science. Its importance was pointed out long subsequently by Michael (*J. pr. Ch.*, 1899, [ii], 60, 288). Soon after this Markownikoff became Professor in Kazan, and, on the transference of Butlerow to St. Petersburg, Director of the laboratory. This post he held for four years. In 1871, he and five colleagues resigned for political reasons. Markownikoff, however, immediately received an invitation to occupy the chair of chemistry in the University of Odessa, the Russian universities having at that time the power of making appointments in that way. Here he remained until 1873, when he was called to the University of Moscow. In this stimulating position he found ample scope for a very active mind, and here he produced the greater number of his researches. With much effort he surmounted many very serious difficulties in the building of his new laboratory (1884—6).

Here Markownikoff began his long and laborious investigation of Caucasian petroleum, which occupied him during the last decade of his life. In 1893, a serious misfortune befel him, for he was dismissed from his post without reason assigned, and deprived of his emoluments and official residence. Nevertheless, he continued to work on indefatigably in his own house, assisted by his faithful servant Mikhailo, who had become wonderfully expert in fractional distillation. He died quite unexpectedly, in the midst of his labours, while engaged in preparing some of his results for publication. An apoplectic seizure ended his life in a few hours.

Markownikoff was a conscientious man of science, ever setting exactitude, earnestness, and honour above the ambitions of the moment and the vanities of the self-seeker. In his political opinions he was, to his own severe loss, an outspoken patriot. As a delegate of the Red Cross, he took an active part in the work of disinfection in the Russian Army during the 1878—9 campaign. His numerous pupils, not a few of whom occupy important scientific and technical positions, will long and sincerely lament their distinguished master.

Markownikoff was elected a Foreign Member of the Chemical Society on January 20, 1898, and on February 25, 1901, received the congratulations of the Council on the fortieth anniversary of his doctorate. He was the author of sixty-two papers, and of several separately published memoirs, the most important of which related to Caucasian petroleum (in which work he was associated

with Ogloblin), army disinfecting practice, the plague in Russia, modern chemistry, and chemical industry in Russia.

The investigation of Caucasian petroleum led to the discovery that this substance contains as principal constituents a series of hydrocarbons of peculiar character, to which Markownikoff gave the general name naphthene. They somewhat resemble paraffins in yielding no addition compounds, and by Markownikoff himself were supposed to consist of the hydrides of benzenoid hydrocarbons, a view which is now generally accepted. The lower fractions of this petroleum also contain benzene and a number of its homologues. These discoveries, with the observation of the relation of the expansion coefficient to specific gravity, and of the extraordinary tenacity with which the higher paraffins hold the gaseous ones, even at elevated temperatures, are all matters of great importance to the petroleum industry and its scientific consideration.

Markownikoff also discovered a C_6 glycerol, and made a study of suberone, from which he obtained a monohydric alcohol called suberol, as well as the oxime and a base formed by its reduction. From suberyl iodide by reduction, a saturated hydrocarbon, suberane, C_7H_{14} (heptamethylene), is formed, which is readily converted into the heptanaphthene present in Caucasian petroleum. Papers on many other subjects, such as the pyrotartaric acids, on dichlorohydrin, and on Bulgarian rose-oil, testify to his activity and wide interests.

Markownikoff's association with Kolbe and Erlenmeyer early led him to speculate very deeply on questions of isomerism and allied subjects; ideas of this kind are found in most of his work, and consciously dominated all his scientific thought. There is, as usual in such cases, some difficulty in accurately determining the true share of the teacher and the student. The theoretical results (1869) on which he laid chief stress as his most important contribution to chemical science have already been mentioned. A very clear statement of them, in his own words, will be found in the *Comptes rendus*, 1875, 81, 668—671. They are at first comprised in two rules:

(1) "Lorsqu' à un hydrocarbure non saturé, renfermant des atomes de carbone inégalement hydrogénés, s'ajoute un acide haloidhydrique, l'élément électronégatif se fixe sur le carbone le moins hydrogéné."

(2) "Pour le cas de l'addition des hydracides aux molécules saturées, contenant un élément négatif fixé à celui de ces carbones qui est doublement lié, je me suis permis de donner comme une règle que l'atome de l'élément négatif d'un hydracide se place à côté de son pareil qui s'y trouvait déjà."

Subsequent consideration, and a note of warning from Henry,

induced him to reconsider these rules. For it is clear that the results of chemical change are as much affected by conditions as the process itself, and so must be the molecular structure. Hence the two rules are combined together into the following more perfect expression :

“Lorsqu’ à une molécule non saturée C_nH_mX s’ajoute un autre système moléculaire YZ à une température basse, l’élément ou le groupe le plus négatif Y se combine avec l’atome de carbone le moins hydrogéné, ou avec celui qui était déjà en liaison directe avec quelqu’élément négatif ; mais, à des températures comparativement plus hautes, c’est l’élément Z qui se fixe sur le carbone le moins hydrogéné, c’est-à-dire que, pour les mêmes substances, la réaction prend une marche tout à fait opposée à la première.”

One sees how much and how long the matter remained in the mind of its author, and how characteristic these “rules” are of his mental atmosphere. Although we cannot assign to Markownikoff a position in the first rank of original thinkers and discoverers, his name will always be associated with unremitting industry, honesty of purpose, and integrity of record.

EDMUND J. MILLS.

LYON PLAYFAIR.

BORN MAY 21ST, 1818; DIED MAY 29TH, 1898.

By the death of Lord Playfair the Society lost its Senior Past President, and the last survivor of the seventy-five who had founded the Society in 1841. Such a time must come in the history of every society such as ours, but it can only rarely happen that such a passing away from our midst occurs in circumstances so pathetic as with us. The Society had hoped to entertain at a banquet, on June 9th, 1898, no fewer than seven of its Past Presidents who had been on the roll of its Fellows for half a century ; but this hope was destined to be blighted by the somewhat sudden death of Lord Playfair on May 29th.

Born at Meerut, in Bengal, on May 21st, 1818, Lyon Playfair was of pure Scottish parentage, his mother having been a Miss Janet Ross, of Edinburgh, whilst his father, Dr. George Playfair, Chief Inspector-General of Hospitals in Bengal, was the eldest son of James Playfair, Principal of the United Colleges of St. Leonard and St. Salvator, in St. Andrews. To this old University city of St. Andrews Lyon and his elder brother George were sent home in 1820 to be educated, first under a governess, then at the parish

school, of which he always spoke highly, then at the Grammar School, where he was taught "Latin, and nothing but Latin." At the age of fourteen he was sent to the University, and whilst there at this early age, both he and his brother gave indications of the lines with which they were to be more or less identified in after life; being found fault with by their mother for spending so much time in the kitchen one day, it was found that George was boiling a sparrow in order to obtain its skeleton, whilst Lyon was endeavouring to prepare sugar from beetroot.

After a short time spent in the office of his merchant-uncle, James Playfair, in Glasgow, we find him, in 1835, commencing his medical studies, and as chemistry was already his favourite pursuit, he preferred to study under Thomas Graham at the Andersonian College rather than at Glasgow University. Two of his fellow-students at this time were destined to become famous, but in very different ways; one was David Livingstone, the African explorer and missionary, and the other James Young, the founder of the paraffin industry in this country. When Graham left Glasgow to become Professor of Chemistry in University College, London, Playfair went to Edinburgh in order to complete his medical education. Illness, however, compelled him to discontinue the study of medicine, so his father advised him to look to India for a career as others of his family had done. In his nineteenth year we find him, therefore, once more in India, and again trying a mercantile career. His final choice, however, was about to be made, for in 1838, when Graham appointed him his private assistant, he gave up commerce for the pursuit of science. In 1839, Graham recommended him to go to Giessen to study under Liebig, and whilst there he published his first scientific paper "On a New Fat Acid from the Butter of Nutmegs"; this acid he named myristic acid.

Liebig was at this time writing his "Agricultural Chemistry," and arranged with Playfair to translate it into English, and this was done almost simultaneously with the German. As Liebig himself was unable to come over to the meeting of the British Association in Glasgow in 1840, Playfair (who had been appointed one of the Secretaries to the Chemical Section), along with Ettling, Will, and Varrentrapp, came to the meeting, and brought Liebig's views prominently forward.

In 1841 he became chemical manager of the Primrose Calico Printing Works at Clitheroe, and there obtained experience which was to be of the highest value to him in later years. Becoming Honorary Professor of Chemistry in the Royal Institution in Manchester, he soon had more pupils than he could accommodate, and had amongst the visitors at his lectures the veteran John Dalton. The offer of

the Professorship of Chemistry at Toronto led to his being induced by the Prime Minister of that day, Sir Robert Peel, to remain in this country, and in 1845 he was appointed Chemist to the Geological Survey. He began his work as such in a small laboratory in Duke Street, Westminster, where he continued his well-known researches (which he had begun in Manchester), along with Joule, on the atomic volumes of salts; and here he carried out his research resulting in the discovery of the nitroprussides. It was here, also, he had two assistants, Kolbe and Frankland, who were later to be well known to fame.

Fired as he was by the spirit of Liebig's teaching and by his own enthusiasm to carry on research in chemistry for its own sake, and imbued as he was with the great importance of a thorough training in the laboratory for all students who were to do useful work in chemistry, Playfair was not to be allowed to do much along any of these lines. His eminently practical mind and very varied experience marked him out to those in authority as pre-eminently fitted to carry out, on a large scale, the investigation of various problems which were prominently before the public at this time. For example, he was appointed a member of the Royal Commission of 1843 to inquire into the health of towns, and as he was at this time still in Manchester, he took as his district the County of Lancashire; and from the ardent way in which he threw himself into this work, he was before long recognised as a leader in all matters relating to the improvement of the public health. This work was followed by his being asked by the Government to report on the state of Buckingham Palace and of Eton College. Then the Board of Trade wanted a report on graveyards, and analyses of all the water supplies to towns; the Admiralty wanted advice as to what were the best coals for steam navigation. This involved an investigation of the composition of the various kinds of coal, their calorific values, and their evaporative powers under actual steam boilers. An investigation along with De La Beche, on a disastrous explosion in a coal-mine at Jarrow, led to his carrying out the analyses of a large number of samples of "fire-damp." The next important Royal Commission of which he was a member, and one which led to many far-reaching changes politically, was that on the potato disease and famine in Ireland in 1845.

One very important and famous research, undertaken along with Bunsen, in 1844, at the instance of the British Association, was that on the chemical operation of blast furnaces in the manufacture of iron. The investigations were carried out near Alfreton, in Derbyshire, on blast furnaces belonging to Mr. Oakes, of Riddings, whose youngest daughter Playfair married two years later.

In 1848 he was elected a Fellow of the Royal Society, and in the same year we find him in Paris, acting as correspondent to the *Daily News* during the exciting week in June.

Evidence had all along been growing stronger and more conclusive that Playfair's greatest sphere of usefulness lay mainly in the practical application of science to the numerous requirements of the nation, and in 1850 he became associated with what was to be, in many respects, the chief work of his lifetime. Sir Robert Peel had seen much of him in connection with the numerous Royal Commissions of which he had been a member, and with the various scientific and other inquiries he had carried out for the Government and other public bodies. He discovered that Playfair was essentially a practical man and a man of action, who was endowed with an unusual degree of tact, clear-headedness, and knowledge of the world; these, combined with his enthusiasm, enabled him to surmount and triumph over difficulties which would have proved too much for most men. It was the possession of these qualities rather than his knowledge of science in general, or of chemistry in particular, which marked him out as the man for the part he was to play in the organisation of the Great Exhibition of 1851. There can be no doubt that Playfair's experience in commercial affairs and his knowledge of the aims and the difficulties of business men generally were of the utmost value in thoroughly interesting manufacturers of all kinds of products, and in bringing home to them the advantages which would accrue to them through the success of the Exhibition. Until Playfair appeared on the scene they seem to have been, if not actively hostile, at least quite apathetic as a body towards the Exhibition and its aims. How great a success the Exhibition was everyone knows now, and instead of being a financial failure it ended with the handsome profit of £186,000. It may fairly be claimed for Playfair that had it not been for his energy, tact, and business capacity it would have been far otherwise. From the Exhibition to the investment of the profits derived therefrom, and then to his travels on the Continent, inspecting methods of education, especially with regard to the organisation and methods of imparting technical instruction there, to his lectures on Technical Education, and then on to the institution of the Science and Art Department, and the foundation of what is now the Victoria and Albert Museum, the sequence is natural and easily understood. One appointment which particularly interests us is his election, in 1857, as President of the Chemical Society, in succession to Professor W. Allen Miller, and it was peculiarly fitting that it was during his tenure of office that the Society migrated from its rooms

in Cavendish Square to its first set of rooms in Burlington House, which were in the north-east corner. It was during his second year of office that Playfair was appointed to the Professorship of Chemistry in the University of Edinburgh. This he held for ten years, setting to work at once to organise and develop the teaching of practical chemistry especially. Successful as he was in this it was only by the generous expenditure of much of his professorial income that he was able to convert the rooms at his disposal into really useful laboratories for teaching. He left his impress not only on the teaching of chemistry, both in the laboratory and by the clearness of his lectures, but also by the system of stimulating earnest work amongst the students throughout all the university classes by the method of awarding university medals and other prizes in each class. The institution of degrees in science was also very largely due to his initiative and influence.

When, in 1868, members of Parliament were allocated to the Scottish Universities, Playfair was chosen the first member for the Universities of Edinburgh and St. Andrews, a seat which he retained for seventeen years. This was somewhat remarkable, because, himself a pronounced Liberal in politics, he represented what is, and has always been, a well-marked Conservative constituency. This was due to several causes, chiefly, no doubt, to his universally recognised services to the cause and progress of sound education throughout the country, but also in no small measure to his popularity as a Professor in the University, who was brought into contact with large classes of students. But in 1885, recognising that his services were being more and more claimed as a member of the Liberal party, he withdrew his candidature for the representation of the Universities, and was elected member for South Leeds, which constituency he continued to represent until 1892, when, on the recommendation of Mr. Gladstone, he was elevated to the peerage under the style of Baron Playfair of St. Andrews. In 1883 he was appointed a Knight Commander of the Bath, and in 1895 he received the Order of the Grand Cross of the Bath.

Amongst other important work which he was chiefly instrumental in carrying out for the country, although not of especial interest to Fellows of the Chemical Society, were the introduction of halfpenny post-cards, the remodelling of the Civil Service, known as "The Playfair Scheme," his work on the Cattle Plague Commission, and in organising the jury department of the 1862 Exhibition. His tenure of the office of Postmaster-General in 1873 was too short for him to leave much of his mark there, for after three months' work the Liberal Government went out of office.

It need hardly be pointed out that his work on these various

schemes could not always tend to the increase of his popularity, for some were very strenuously opposed, but everyone admitted the honesty of purpose pervading all, however much they differed from him.

The record of original papers standing in Playfair's own name in the Royal Society's catalogue contains the names of twenty-seven papers, of which that on the nitroprussides is perhaps the most important. Other papers which have left their mark on the progress of science were those with Bunsen on the chemistry of blast furnaces, with Joule on the atomic volume of salts, and with J. A. Wanklyn on a method of determining vapour densities at temperatures below the boiling points of the substances.

The amount of original work, however, which Playfair carried out at one time and another cannot be estimated by a record such as that just given, for the numerous investigations on which he was almost continually engaged embodied an enormous amount of work really original in the strictest sense, and demanding scientific qualities of the highest order.

Playfair was three times married, first in 1846, as previously mentioned, to Miss Margaret Oakes, daughter of Mr. Oakes, of Riddings House, near Alfreton, then in 1857 to Miss J. A. Millington, and thirdly, in October, 1878, to Miss Edith Russell, of Boston, U.S.A., now Lady Playfair, who survives him, along with his only son, George James, Lord Playfair, and two daughters.

A. SCOTT.

ALEXANDER WILLIAM WILLIAMSON.

BORN MAY 1ST, 1824; DIED MAY 6TH, 1904.

ALEXANDER WILLIAM WILLIAMSON was born at Wandsworth on May 1, 1824. His father, Alexander Williamson, who came to London from Elgin as a boy, married, in 1820, Antonia, daughter of William McAndrew, a Scotchman settled in London as a merchant, and of his wife Antonia (born Sykes), an English lady. Mr. Williamson had three children: Antonia Helen, born in 1822, Alexander William, and a second son, James, who died in childhood. Antonia married a Mr. Clark, and died, a widow, several years before her brother. She combined admirable accomplishments with much force of character and intellectual independence with great kindness of heart. She was untiring in acts of well-considered and persevering benevolence. Although this lady's career forms no part

of the subject of this notice, her qualities of heart and mind are not without interest as throwing an indirect light on the moral and intellectual characteristics of the home in which she and her illustrious brother grew up.

As a child, and throughout his boyhood, young Williamson had very delicate health. The weakness showed itself most obviously in affections of the eyes, the consequence being that his parents, as well as the medical men they consulted, were misled as to the nature of the complaint. Local treatment was adopted, but it only aggravated the evil, and it was not until he was about sixteen that it was fully recognised that what was needed was to let the eyes alone and build up the general health. Eventually, he grew up to vigorous manhood, but the right eye was permanently useless, and the left arm had very little power. It was in spite of these serious physical disadvantages that all his work was accomplished.

Between 1825 and 1831, Mrs. Williamson and her children spent much time at Brighton, where Mr. Williamson, at that time a clerk in the East India House, paid them frequent visits, notwithstanding the somewhat long coach-journey each way which such visits involved in those days. Subsequently, Mr. Williamson bought a house in Wright's Lane, Kensington, with a large garden, now built over. While living here the young Williamsons were much in the company of James Mill's children. John Stuart, the eldest, being older than the future chemist by eighteen years, to say nothing of his abnormally early intellectual development, can hardly have been much of a companion for the sickly boy. Mill was Mr. Williamson's superior officer at the East India House, and it is not an unnatural supposition that it was their common employment there that brought them acquainted. However this may be, the fact that Mr. Williamson was for many years on intimate terms with Mill and came to share, to a great extent, his opinions on religious, social, and educational questions, cannot have been without influence on his son's mental development, seeing that he was thus brought into contact with the innermost circle of the Utilitarians. Another result of this intimacy was that Mr. Williamson became one of the strenuous band of educational pioneers and reformers who, in 1826, founded the University of London, afterwards University College, London, the institution with which his son was destined to be so long and closely connected.

In or about 1840, Mr. Williamson retired from the India House on a pension. He soon afterwards gave up his house at Kensington, and he and his family removed to the Continent, and lived for several years chiefly in France and Germany.

In 1840, young Williamson was entered as a student of the

University of Heidelberg. His father's idea was that he should study medicine, and with this view he attended Leopold Gmelin's lectures on chemistry and those of Tiedemann on anatomy. Very soon, however, he announced his intention of becoming a chemist, an announcement which was by no means favourably received by his father, to whom the only idea which it conveyed was associated with the vision of a shop window with bright lights shining through corpulent blue and yellow bottles. However, the young student was eventually able to explain the real nature of his ambition and to get his father's sanction to the course of study he proposed. In this he was aided by Prof. Gmelin, who, although at first inclined to think the lame arm and the loss of sight of one eye were enough to make a chemical career impossible, was so much impressed by the zeal and intelligence of his pupil that he told his parents he would certainly be a chemist.

In the years of which we are speaking, Giessen was the centre of chemical activity, in a sense that no other place ever was either before or since. The Giessen Laboratory was the first ever built specially for the reception of students, and Liebig's activity and genius and wonderful power of communicating his own enthusiasm to his pupils were creating a new era in chemical training and investigation. Thither Williamson went in April, 1844, and he remained there for two years, living in the house of Prof. Hillebrand, the professor of philosophy. In his first semester, besides working at chemistry, he attended Bischoff's lectures on physiology. In writing to his father, he speaks of the "clear and impressive" style of these lectures, which were delivered at seven o'clock in the morning, and says, "I get up every morning regularly before six without being called." He seems to have been somewhat disappointed with the first lecture he heard from Liebig, finding it "rather tedious from the extreme elementary manner in which he treated it," and he was "not remarkably pleased with his delivery." His stay at Giessen seems to have been marked by great industry: he was enthusiastically interested in his work, and allowed himself no distraction beyond such exercise, chiefly walking, as he felt to be needful for his health. Now and then he took part in a "picnic," and very occasionally he mentions having been at a dance. He was impressed by the earnestness of his fellow-students in the laboratory, and speaks of them as being "a superior class from the generality of Heidelberg students, being come here from all quarters of the globe for scientific purposes and devoting themselves to nothing else." He continues, "the chemists are, accordingly, the principal people here, and are generally much respected." Among Englishmen who were at Giessen in Williamson's time were Hodges,

Blyth, Walter Crum, Brodie, and Sheridan Muspratt. Anderson (of Glasgow) immediately preceded him as an inmate with Prof. Hillebrand.

His work at Giessen resulted in the publication by Williamson of his first contributions to science, namely, "On the Decomposition of Oxides and Salts by Chlorine," "On Ozone," and "On the Blue Compounds of Cyanogen and Iron," which all appeared in the Memoirs and Proceedings of the Chemical Society. The materials for a note "On the Constitution of C₆H₆," published after he left Giessen, were also accumulated there.

In connection with the immense number of investigators whom Liebig trained, and the almost countless researches that issued from his laboratory, it is of some interest to note, as an indication that these results were not attained by hurrying his pupils on prematurely to original work, before they had been thoroughly drilled in routine operations, that when Williamson, a little more than a month after his arrival at Giessen, proposed to examine the lower oxides of iodine, Liebig told him it was a hopeless task, and recommended him to do some ash analyses instead.

A subject which seems to have occupied much of Williamson's thought during his first year at Giessen was the theory of galvanism, which, as set forth by Gmelin, he considered "particularly imperfect, defective, and forced." He thought out and put on paper "a system which seems to me much more simple and natural." In writing to his parents he repeatedly refers to electrical experiments with which he was engaged, and in April, 1845, he speaks of a paper on electricity which he submitted to Liebig, whose reception of it was much more favourable than he had expected, "for it was the theory of Humphry Davy which I had ventured to attack." With Williamson's concurrence, Liebig submitted the paper to Buff. Williamson speaks of Buff as "one who considers as indubitable the fundamental principles which I deny," and he is amusingly warlike in speaking of the advantage he expects to derive from Buff's criticism: "My theory will thus undergo from one personally friendly to me the searching criticism to which it would otherwise first be exposed from the public, and I shall thus be enabled before publication to become better acquainted with the defence of my opponents from a preliminary skirmish. I shall obtain an idea of the method of warfare to be pursued, and shall accordingly be able to arrange and dispose my forces more advantageously for the battle than would otherwise be possible." It does not appear that this paper to which, for the time at least, Williamson attached so much importance was ever published. It is not impossible that Liebig's favourable reception of it indicated rather friendship for the author

and a general high opinion of his powers than agreement with the special views therein set forth. Without apparently committing himself on the scientific question involved, he praised the writer's language and style, and expressed surprise that he should be "able to write in such a manner in German."

Williamson was naturally highly gratified that, in the course of their interview about the electricity paper, Liebig proposed to him that he should take the degree of Doctor of Philosophy, and records, in reference to the particular form of the degree suggested, that "it is an honour which, as I hear, Liebig has as yet conferred only on two persons." The degree seems to have been actually conferred in August.

After the summer of 1845, Williamson suspended for a time his chemical studies in order to devote himself to mathematics and physics. He worked at the former under Zamminer, and at the latter with Buff, who accorded him special facilities and gave him access to the Physical Cabinet. This apparently was what Williamson meant when he said he was allowed "the use of an institution to which no student in Giessen has as yet been allowed access, being only intended for the use of lecturers." At the same time he attended, five times a week, Hillebrand's lectures on "Literaturgeschichte"; these were given in the evening, and "profitably filled up an hour which would probably otherwise be turned to little account."

In the summer of 1846 he went to Paris, and stayed there for three years. His chief occupation during this time was the study of advanced mathematics. John Stuart Mill had recommended Auguste Comte to Mr. Williamson, senior, as the first man in Europe for completing a scientific education, and during his residence in Paris Williamson was Comte's pupil. He had a regular mathematical lesson three times a week, and very often spent his evenings at Comte's house with him and his disciples. His long and intimate association, during the impressionable years of early manhood, with such a man as Comte cannot have been without influence on his subsequent mental characteristics, and it is possible that such an influence may be traced in a certain fondness for generalities that Williamson sometimes showed, and in occasional turns of phraseology.

Notwithstanding his mathematical studies, his mind was still occupied with chemistry. He set up a laboratory in his house in Paris (8 Rue des Francs Bourgeois), and among the results of his work succeeded in producing urea and carbonic acid by the direct oxidation of an amide. These experiments were embodied in a paper which he read to the Italian Scientific Congress at Venice in

1847. He speaks also of having been "engaged in an extensive research, whose object is to elucidate some obscure, though fundamental, chemical phenomena, my views on which were suggested and gradually developed by my former studies." At about the same time he says he intends to "go on with a research on the laws of chemical action." It is perhaps not unlikely that these investigations, which do not seem ever to have been published, may have referred to the views on the interchange of atoms among neighbouring molecules, to which he gave emphatic expression a year or two later.

Early in 1849, Graham made Williamson's acquaintance in Paris, and encouraged him to become a candidate for the professorship of analytical and practical chemistry in University College, London, which was then vacant through the death of its first holder, George Fownes. He applied and was appointed, and entered on his duties in the following October.

At the beginning of his first college session, Williamson read himself in by delivering a public introductory lecture to the courses of the Faculty of Arts and Laws. Of this lecture it is perhaps not unfair to say that the best part of it was the title, "Development of Difference the Basis of Unity." The discourse itself is disappointing, and mostly consists of somewhat obvious generalities set forth with a philosophical air, but coming to no definite point. Graham kindly congratulated the lecturer on his musical voice.

Williamson's first few years at University College constituted a period of remarkable activity and productiveness. The first session of all produced his memorable paper on etherification, and it was soon followed by valuable papers from his pupils: among the earliest, Duffy on stearine and Wills on heptylic alcohol. The session 1853—1854 was particularly fruitful, and furnished no less than six experimental papers by himself and his pupils. At this time he was a splendid teacher, always in the laboratory, going from one student to another, arousing and maintaining their interest in their work, and ready to discuss with them any point on which they sought his help. Now and then, when Graham was obliged to be absent, Williamson would lecture on general chemistry in his stead, and these occasions were always hailed with delight by some of the students to whom he seemed to bring out new points of interest in the best-worn subjects by the freshness of his treatment and the new light he would throw on them. In the laboratory, he abounded in new devices. If there was a traditionally established way of conducting a given operation, this was to him rather a reason for trying a new plan than for doing it in the old way. His new methods were perhaps not always important improvements, but

they at least had the effect of preventing his pupils from falling into a stereotyped routine and thinking that because a thing had been done in one way before it could never be done in any other. He would never admit that an experimental difficulty was insurmountable: "If you know clearly," he would say, "what you want to do, there is always a way of doing it." Kekulé, Odling, and Brodie were constant visitors, and in the talk of these men in Williamson's little room at the end of the laboratory the seed was planted of much of the chemical theory of the day.

Williamson's great achievement was, of course, the theory of etherification. This was first published in a paper read before the British Association at Edinburgh on August 3, 1850, and afterwards printed in the *Philosophical Magazine*, 1850, [iii], 37, 350—356. A further publication with more details was made two years later in the *Quarterly Journal of the Chemical Society*. His leading idea in undertaking the research, of which these papers were the outcome, was, starting from common alcohol, to climb up to higher terms of the homologous series. With this view, he dissolved metallic potassium in absolute alcohol, thus replacing one-sixth of the hydrogen in alcohol by potassium, and then substituted ethyl for the potassium by acting on the potassium compound with ethyl iodide. The resulting product was a substance of the anticipated composition, but to his surprise, instead of being a new alcohol, it was nothing more than common ether. The explanation which Williamson himself gave of this result now seems so obvious that it requires some effort to see that an explanation was needed, but at the time it marked a step of immense theoretical importance.

Up to the date with which we are concerned, the prevailing ideas of chemical constitution were still largely influenced by the notion of binary combination which grew up when the only compounds that were at all familiarly known were metallic salts. These were regarded as secondary compounds formed by the union of two primary compounds, a metallic oxide and an (anhydrous) acid. So-called double salts were looked on as tertiary compounds formed by the combination of two secondary compounds. Hydrated acids and bases were supposed actually to contain water, which might be an unavoidable, but was a non-essential, constituent: caustic potash was KO, Aq ($\text{O} = 8$); sulphuric acid was SO_3, Aq . In the same order of ideas, ether was looked on as oxide of ethyl, $\text{C}_2\text{H}_5\text{O}$, and alcohol as the hydrated oxide, $\text{C}_2\text{H}_5\text{O}, \text{HO}$. It is true that Laurent and Gerhardt had advocated the view that the molecules of these substances must both contain the same quantity of oxygen, namely, one atom of twice the commonly accepted mass; but their arguments, which were to a great extent founded on considerations of

molecular volumes in the state of vapour, were not as yet widely accepted. What Williamson did was, in the first place, to show what was the true genetic relation between ether and alcohol, and to prove, by a process which came as near to an absolute demonstration as is possible in relation to any question of chemical constitution, that the formation of ether from alcohol is due, not to the loss of the elements of water, but to the substitution of the group or radicle C_2H_5 in place of an atom of hydrogen; that the molecules of water, alcohol, and ether all contain the same quantity of oxygen; and that these three substances form a true series in which the relation of the middle term, alcohol, to either of the extremes is the same as that of the other extreme term to it.

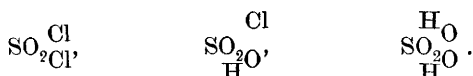
He showed, in the second place, that in the ordinary process of etherification of alcohol by sulphuric acid there is an interchange of the group C_2H_5 for hydrogen between the alcohol and the acid, first in one direction and then in the other, and he maintained that this is only a particular example of what goes on in liquids in all cases—that, in fact, the molecules of a liquid are not structures permanently composed of the same individual atoms, but that they are constantly decomposed and reproduced by interchanging atoms with other molecules. If the interchanging molecules are similar, the results of the exchange of atoms are similar to the original molecules; but if molecules of different kinds are present, the interchange gives rise to new combinations: to take the simplest kind of case, an exchange of atoms between molecules of the composition AB and molecules CD gives rise to molecules AD and CB, which, in their turn, reproduce AB and CD. There are thus at any instant molecules of four different kinds in presence of each other, instead of only two, and the apparently constant composition of a finite portion of the mixture results from the number of transformations which take place in one direction in each element of time being sensibly equal to the number taking place in the opposite direction.

A few years later, Clausius was led from a different point of view to similar conclusions, and, as is well known, his views have been developed and applied to the explanation of a great variety of phenomena by Arrhenius and others.

In 1851, the year after the first publication of his paper on etherification, Williamson published a paper "On the Constitution of Salts," in which he worked out further and applied to a great variety of cases the idea already employed in the former paper when he represented the molecules of water, alcohol, and ether as constituted on the same model: $\frac{H}{H}O$, $\frac{C_2H_5}{H}O$, $\frac{C_2H_5}{C_2H_5}O$. The keynote of the present paper was given in the following sentences: "I believe that throughout inorganic chemistry, and for the best-known

organic compounds, one single type will be found sufficient; it is that of water, represented as containing 2 atoms of hydrogen to 1 of oxygen, thus $\frac{\text{H}}{\text{H}}\text{O}$. In many cases, a multiple of this formula must be used, and we shall presently see how we thereby get an explanation of the difference between monobasic and bibasic acids" The idea of the *water-type* set forth in this paper was immediately adopted by Gerhardt, Odling, Kekulé, and many of the younger chemists of the time. The then recent discovery of ethylamine by Wurtz, and Hofman's discovery of diethylamine and triethylamine and the corresponding derivatives of aniline, had made chemists familiar with the idea of the existence of a considerable number of compounds the properties and constitution of which were best understood by regarding them as being built up on the same type as ammonia. Williamson pointed out that the mutual relations of a still larger class of substances could be elucidated by considering them as constituted on the type of water. The idea has since become so familiar that no further illustration is required in this place.

In 1854 he communicated to the Royal Society a note on the action of pentachloride of phosphorus on sulphuric acid, the chief result of which was a chloro-hydrate of sulphuryl, intermediate between chloride of sulphuryl and sulphuric acid, as shown by the formulæ :



Williamson laid stress on the formation of this substance as indicating the bibasic character of sulphuric acid which was not at that time by any means generally recognised. This substance is further of theoretical interest as the first example of the class of compounds recognised as being derived from a *mixed type*. This mode of formulation was afterwards very much employed by Kekulé and others especially to represent the mutual relationship of organic compounds.

The most fundamental point of chemical theory that was under discussion during the years we have been speaking of was the atomic weight of oxygen, or, what was in effect the same thing, whether a molecule of water contained one or two atoms of hydrogen. No question of chemical constitution could be raised which did not directly or indirectly involve this point, and it may be fairly said that no chemist made a more effective contribution towards the decision of the controversy, in the way that has long been universally admitted, than did Williamson by the facts and arguments brought forward in papers we have been considering.

In 1855 Graham resigned the Chair of Chemistry in University College on being appointed Master of the Mint, and Williamson was appointed to succeed him, while still retaining his previous Chair of Analytical and Practical Chemistry. He continued to hold both appointments until 1887, when he retired from the College. He entered upon his extended duties with great energy, spending much labour and money on the preparation and illustration of his lectures, and he induced his former pupil, Dr. (now Sir Henry) Roscoe, to help him by taking for the first session the office of lecture-assistant.

A few words more may be said here about his work at University College. As a teacher he was clear and impressive, and, although in a miscellaneous class largely composed of medical students there were naturally always a good many whose attendance was only perfunctory, those who wanted to learn never found him dull or uninteresting. In the later years especially his time was much in demand by outside scientific bodies—as the Chemical and Royal Societies, the British Association, the Society of Telegraph Engineers (now Institution of Electrical Engineers), of which he was one of the founders, the University of London, and many other organisations, permanent or temporary, besides numberless meetings and committees concerned with the work of the College itself. In the latter connection, his clearness of view and directness in advocating what he considered the wise and right course gave him great influence with his colleagues and the Council. He took a leading part in promoting many important reforms and improvements in the work and organisation of the College, as, for example, the establishment of a Faculty of Science and the introduction of laboratory work for engineering students, thus helping to inaugurate a new system of engineering education, which was soon adopted in every engineering school of the country. He was also one of the foremost in promoting the institution of degrees in science in the University of London. He acted as an examiner for the University for two periods of five years, and was a member of the Senate from 1874.

A natural result of such occupations was that, in the later years of his professorship, he was obliged to entrust the detailed supervision of his laboratory more and more to the care of assistants.

The idea of interchange of atoms between molecules in contact with each other, to which Williamson gave expression in his paper on etherification, long interested him. In the autumn of 1856 he began a series of experiments with the view of investigating the conditions that influenced the rate of change in a particular case. The plan of the first experiments was to expose weighed quantities of

ethyl chloride to prolonged contact with aqueous solutions of silver nitrate of known concentrations at a fixed temperature, and to observe the quantities of silver chloride formed in measured times. During the preparation of ethyl chloride for these experiments, which, however, were never completed, he was severely cut and burned about the face by an explosion, but, fortunately, was not permanently injured.

Soon after 1860 he became much interested in practical applications of science, and for several years he had sanguine hopes of effecting important improvements in the steam engine by the use of steam under very high pressure. A few years later, he bought a piece of land and put up buildings near Willesden Junction, intending to carry on there various chemical processes on a manufacturing scale. He was greatly impressed by the enormous possibilities offered by Siemens's regenerative furnace, and this led to his taking an active part in the Landore Siemens Steel Company.

In conjunction with Dr. W. J. Russell, he devised a process for the analysis of gases, in which the methods of allowing for changes of pressure and temperature were greatly simplified. The general idea was to place close to the tube containing the gas to be measured, so as to be at the same temperature, a second tube containing a constant quantity of air at a pressure somewhat less than that of the atmosphere, and, in making a measurement, first, by raising or lowering this tube, to bring the mercury in it to a fixed mark and so the air to a fixed volume; then to raise or lower the measuring tube so as to bring the mercury in it to the same level as that in the air-tube. It is easy to see that this artifice does away with the necessity for knowing the actual temperature or pressure of the gas to be measured; for, remembering that, for a given sensibly perfect gas, the quantity

$$\frac{pv}{273+t} = \text{constant} \times \text{mass of the gas,}$$

it will be seen that, the volume of the fixed quantity of air being made the same at each observation, the ratio $p/(273+t)$ is constant, and applies to the gas under examination as well as to the air; consequently, the mass of the gas is proportional to its volume.

Another suggestion connected with chemical calculations relating to gases which he persistently advocated was to define "one volume" of a gas as meaning 11.19 litres at 0° and under a pressure of 76 cm. mercury, this being the volume under the conditions named of 1 gram of hydrogen, or of an equivalent quantity of any other nearly perfect gas. However useful such a convention might be, it be-

comes unnecessary if it is kept in mind that, for 1 gram of any nearly perfect gas, the value of the quantity

$$\frac{pv}{273+t} = 3094 \frac{\text{mass in grams}}{1 \text{ gram-equivalent}}$$

in *all* circumstances, if t is temperature centigrade, v volume in c.c., and p pressure in centimetres of mercury. This is the one numerical datum relating to gases that it is useful for a chemist to remember.

In 1865 Williamson published, through the Clarendon Press, an elementary text-book under the title "Chemistry for Students," a work which has passed through several editions. The aim of the book is thus described in the preface: "This little book is intended to supply to students of chemistry an outline of the most interesting and useful facts pertaining to the science, and of the most important ideas that have been got from a study of those facts.

"The method of exposition differs from that which is adopted in most other treatises of Chemistry; for I describe and compare individual facts, so as to lead the mind of the reader towards general principles, instead of stating general principles first and then proceeding to illustrate them by details."

During the composition of this book he was led to consider carefully various current questions of chemical terminology, and, besides embodying his conclusions in his text, he made them the subject of a paper communicated to the Chemical Society. The points chiefly insisted on in this paper were the systematic use of such names as sodic chloride, argentic nitrate, hydro-potassic sulphate, hydro-disodic phosphate, methylic acetate, and the like, instead of chloride of sodium, &c., and, secondly, the application of the name *acid* to such substances as CO_2 , SO_3 , N_2O_5 He called H_2SO_4 hydric sulphate, HNO_3 hydric nitrate or simply sulphate, nitrate, &c.

By the recommendation of Mr. (now Sir Augustus) Prevost, who was a member of the Council of University College, London, five young Japanese noblemen were put under Williamson's care by Mr. Matheson, of the firm of Jardine, Matheson and Co. This was in November, 1863, at the very beginning of the intercourse between Japan and European science. These young men left their own country at the risk of their lives and some of them under assumed names; they came to England to make a systematic study of European science and civilisation, and they could hardly have met with more kindly and judicious guidance and supervision than they received from Williamson. Three of them, of whom the well-known Marquis Ito was one, lived in his house, one of them for nearly four years, and all on returning to Japan attained positions of influence

and importance. Two or three years later, Prince Satsuma sent over sixteen more young men to study under Williamson's direction; among these were Mori Arinori, afterwards Japanese Minister in Paris and London successively; Yoshida, who became Envoy Extraordinary to Washington; and Sameshima, who died in Paris as Chargé d'Affaires.

In many respects, Williamson was admirably qualified to exercise a beneficial influence on the band of earnest young inquirers who were put under his care. He combined strength and decision of character with sound judgment and much kindness of feeling, and his standard of personal conduct and honour was uniformly high, while his familiarity with the life of France and Germany, and with many of the leading men of those countries, gave him a wide outlook and a freedom from mere insular prejudices.

After his retirement from his Professorship in 1887, Williamson went to live at Hindhead, near Haslemere, where he built himself a house and interested himself in farming. He only rarely came to London to take part in scientific gatherings, but he continued for several years to attend to the duties of his office as Chief Gas Examiner to the Board of Trade.

This notice cannot be concluded better than by quoting from *Nature* (May 12, 1904) a few lines in which Dr. T. E. Thorpe sketches some of the leading points of Williamson's mind and character:

"Like most original thinkers, he was somewhat tenacious of opinions, and apt to be dogmatic in their utterance. His beliefs were too hardly won to be lightly discarded. But although at times impatient of contradiction, he had too strong a regard for truth, was too sincere and broad-minded a man to persist in any opinion if its unreasonableness was made clear to him. Like Carlyle, his philosophy was largely swayed by his emotions, and, like Carlyle's, his judgments on men and things were apt to be tinged by the mood of the moment—a fact which may serve to account for seeming inconsistencies in their expression.

"He had a high sense of duty, and of the responsibilities of his position as a representative man of science. Although, like many strong men, fond of power, he was in no sense a self-seeking man, and was contemptuous of the artifices by which smaller and more ambitious men seek to gain preferment."

Williamson married, in 1855, Emma, third daughter of Thomas Hewitt Key, F.R.S., Headmaster of University College School and Professor of Comparative Grammar in University College. He leaves a son, Dr. Oliver Key Williamson, and a daughter, who is married to Dr. A. H. Fison.

He was President of the Chemical Section of the British Association at the meeting at Newcastle in 1863, and again at the Jubilee Meeting at York in 1881; he was President of the Association at the Bradford meeting in 1873, and General Treasurer from 1874 to 1891.

He was elected a Fellow of the Royal Society in 1855, and served three times on the Council; he received a Royal Medal in 1862, and was Foreign Secretary from 1873 to 1889.

He joined the Chemical Society in 1848, and was President from 1863 to 1865, and again from 1869 to 1871. He was a Corresponding Member of the Academy of Sciences, Paris, a member of the Berlin Academy, and received honorary distinctions from many other learned bodies, British and foreign.

He died at his house, High Pitfold, Hindhead, on May 6th, 1904.

G. CAREY FOSTER.
