

OBITUARY NOTICES.

AUGUSTUS GEORGE VERNON HARCOURT.*

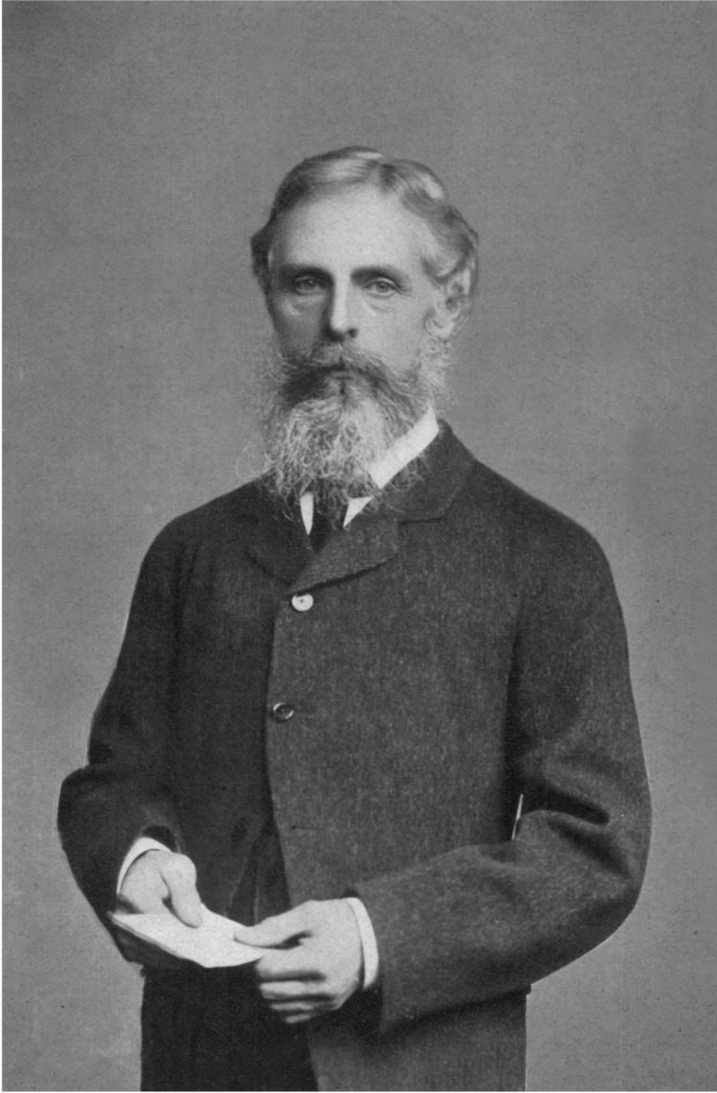
BORN DECEMBER 24TH, 1834; DIED AUGUST 23RD, 1919.

By the death of A. G. Vernon Harcourt in his eighty-fifth year, there passed away a chemical teacher endeared to many generations of Oxford students, a singularly skilful experimenter, and a pioneer in the new domain of physical chemistry. He was one of the first who planned experiments to follow the course of a chemical change, to measure the velocity of a reaction, and to study the conditions that determine it; he rebelled against the idea that chemists had to concern themselves only with the preparation of new substances and the elucidation of their properties—for him the interesting thing was *how* the change happened, not what was the result.

Augustus George Vernon Harcourt was the elder son of Admiral F. E. Vernon Harcourt and of Marcia, sister of the first Lord Tollemache, and grandson of the Archbishop of York. He was born December 24th, 1834, and died August 23rd, 1919. He was educated on the old classical lines at Cheam and at Harrow, and entered Balliol College, Oxford, in 1854.

It was at Balliol, under Henry Smith, that he laid the foundation of his chemical career. Harcourt, in his reminiscences of the Oxford Museum and its Founders, has told us how, when Salvin's buildings at Balliol were constructed early in the "fifties," two cellars were appropriated to the study of chemistry; and to provide a teacher, Henry Smith, ablest of Oxford men, was deputed by the College to take some lessons in the subject. He went for a few months to Dr. Hofmann at the College of Chemistry. Montgomerie, Hertford Scholar in 1854, and Harcourt were his first pupils. The classical atmosphere of the College cellar is brought out in one of Harcourt's reminiscences: "Once a stick of phosphorus took fire on the bench; Montgomerie was for pouring water over it, which might have caused a dangerous scattering of the fiercely burning liquid; Henry Smith stopped him, and extinguished the blaze by pouring over it a little sand, remarking in his soft tones—'*Pulveris exigui jactu compressa quiescet.*'"

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A. V. Harcourt.

[To face p. 1628 *Trans.*

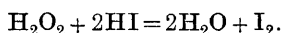
When Brodie, a pupil of Bunsen, came to Oxford as Professor of Chemistry, the Balliol cellars were placed at his disposal, and Harcourt became first his pupil and then his assistant. At Balliol, Brodie began working on the acid peroxides, and afterwards on the oxidation of graphite, and then turned to the systematic study of the alkaline peroxides, the reducing action of which he was the first to explain—incidentally supplying a strong *chemical* argument in favour of the diatomic nature of oxygen gas. In 1858, Brodie migrated to the chemical department of the New Museum, and took Harcourt—still an undergraduate—with him as lecture assistant. A year later, after gaining a First Class in the School of Natural Science, Harcourt was appointed Demonstrator in the Students' laboratory, known from its prototype as the "Glastonbury Kitchen"—and among his first pupils was the Prince of Wales, afterwards King Edward VII.

Under Brodie, at the New Museum, Harcourt began his researches with the exact determination of the oxygen absorbed by the metals potassium and sodium—allowing air to enter slowly into a flask containing the pure liquid metal heated in an atmosphere of nitrogen. In this first paper one can see that it is the initiation and progress of the oxidation that interest him. "Soon after the dry air has begun to mix with the nitrogen, the grey film which covers the molten metal changes to a deep blue; the surface gradually becomes roughened by little wrinkles and projections, and a moment arrives when a single spluttering spark appears at one point and a dust of white oxide rises. . . . At the point where the spark appears the blue crust becomes white, and this change passes in a moment over its whole extent."

In 1859 Harcourt was elected Lee's reader in chemistry and a senior student of Christ Church, but it was not until some years after his appointment that he began his work in the Lee's Laboratory. Meanwhile he had started those researches on the rate of chemical change which—in conjunction with those of Berthelot in France and those of Guldberg in Norway—were to establish on a quantitative basis Berthollet's law of mass action. In the interpretation of his results Harcourt was associated with William Esson, whose special mission in Oxford seemed to be—as the writer knew him—to illuminate mathematically the obscure records of chemical velocities. Harcourt and Esson first studied the reaction between oxalic acid and potassium permanganate in acid solution. They found that the rate of change varied with the amount of manganous sulphate formed, and that the reaction was probably *nil* in the complete absence of manganous salt; but, once started, the velocity would increase to a maximum and then fall off—the

curve representing the course of the change having a point of contrary flexure. They liken their curves to those obtained by Bunsen and Roscoe in the course of photochemical induction—thus suggesting that the “inductive period” in the union of hydrogen and chlorine was due to the action of another substance, a suggestion which finally was proved to be correct.

Seeking for a less complicated reaction, Harcourt found that in dilute solutions hydrogen peroxide decomposed hydrogen iodide with velocities that could be easily followed, and the amount of change could be accurately ascertained. The method of carrying out the experiment in a stream of carbon dioxide, and the device by which the iodine liberated was reconverted into iodide by the successive additions of exactly equal drops of concentrated thio-sulphate, show Harcourt at his best as an experimenter. The time-intervals between the successive appearances of the iodine proved that the velocity of the change varied directly with the quantities of each of the reacting substances—when the other conditions were kept constant. The rates found, however, do not prove that the change is necessarily a termolecular one as Harcourt supposed :



The change most probably takes place in two stages, each of which is bimolecular; but, one stage being much faster than the other, the observed rates follow the simple law. In studying the effect of temperature on the rate of this reaction, Harcourt and Esson arrived at a zero of chemical action in wonderful agreement with the absolute zero calculated from physical data.

Harcourt was so strongly convinced that chemical change followed mechanical laws that his laboratory became a centre where the experiments of Bunsen and his school on “chemical induction” and “sprungweise” explosions were repeated and criticised.

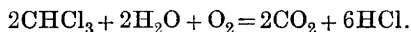
Though one of the pioneers of physical chemistry, Harcourt remained a sceptic towards the new theories of solution and ionisation, and the word “dissociation” was anathema to him. In his last address as President of the Chemical Society in 1897, he maintained that the distinction between dissociation and decomposition was absurd. “A journey,” he declared, “is the same journey, whether I go with a return ticket or whether I cannot return by the same route.”

Of the painstaking character of Harcourt's demonstrations, of his insistence on neatness and cleanliness, of the patience and personal trouble he took with each beginner, generations of old Christ Church men can speak with grateful appreciation. The

minutiæ of manipulation appealed to him, but they were only means to attack the largest problems; for him no defect was too small to remedy, no authority was too great to question. Through the inspiration of his example and teaching, Oxford, no less than English chemistry, has been intellectually quickened.

In applied chemistry Harcourt was chiefly drawn to questions dealing with the purification and testing of coal-gas, he having been appointed in 1872 one of the three Metropolitan Gas Referees whose duty it is to prescribe the mode of testing the London gas and, subject to the various Acts of Parliament, to fix the limits of impurity allowed. One of his early researches on coal-gas was his attempt to purify the gas from sulphur compounds by means which he devised for converting the carbon disulphide into hydrogen sulphide. Harcourt's "sulphur test" came into wide use, but its application on a large scale for the purification of coal-gas has only recently been carried out successfully by Dr. Charles Carpenter at the South Metropolitan Gas Works. Perhaps the most signal improvement in the testing of gas effected by Harcourt was the introduction of the Pentane Lamp as the official standard of light in place of the variable spermaceti candle. His original one-candle lamp has been replaced by the more convenient 10-candle Pentane lamp, and this has been largely adopted as the measure of illuminating power, not only for gas, but for other illuminants.

Another very useful investigation which occupied much of his time between 1899 and 1911 was concerned with the administration of chloroform as an anæsthetic. Already in the former year he had devised a ready means for determining the percentage of chloroform vapour, mixed with air, by converting the chloroform into carbon dioxide and hydrogen chloride in contact with a red-hot platinum wire in presence of steam and of water to absorb the hydrogen chloride:



When the Council of the British Medical Association in 1901 appointed an expert committee to investigate the methods in use for administering chloroform, to study its quantitative determination, and "to determine if possible what is the minimum dose which would secure anæsthesia for operations and at the same time not endanger life," they gave their committee power to co-opt two outside members—of whom Harcourt was their first choice.

After much patient labour he devised an "inhaler," which his colleagues described as "possessing the advantages of simplicity, exactness, and portability." The Committee adopted it in their experiments, and in their final Report state that it appears to be well adapted for universal employment.

Of recognition by learned societies and of devoted service rendered to them Harcourt could claim a large share. Elected to the Royal Society in 1863, he served on the Council 1878—80. In conjunction with Esson, he published four memoirs in the *Philosophical Transactions*, in the third of which, the Bakerian Lecture for 1895, the observations are given indicating that all chemical action would cease at -272.6° .

Admitted to the Chemical Society in 1859, he served as one of its Secretaries for eight years, 1865—73, and was elected President in 1895. In 1910 he was one of the five Past-Presidents whose jubilee as Fellows was celebrated by the Society.

As became the nephew of one of the founders of the British Association—Rev. W. Vernon Harcourt—he early took an interest in its meetings and made many contributions to the Chemical Section, of which he was President in 1875. A few years later he was elected one of the General Secretaries of the Association, an office he held for fourteen years with conspicuous tact. He was an honorary Doctor of Oxford, McGill, and Durham Universities.

In 1872 Harcourt married Rachel Mary, daughter of Mr. H. A. Bruce, at that time Home Secretary in Mr. Gladstone's first administration, and afterwards Lord Aberdare. Of his happy family life at Cowley Grange, the home he built for himself on the banks of the Cherwell, many of his old Oxford pupils and friends can tell; and perhaps no more picturesque spot could have been chosen for the evening of his days than St. Clare, near Ryde, the property he inherited, with its fine cedars and beautiful lawns falling from terrace to terrace down to the waters of Spithead. Even in the sunny Isle of Wight people spoke of the roses of St. Clare—that pleasantest corner of the world of which he would quote when bidding one to an Easter or an autumn visit:

*“ Ver ubi longum tepidasque praebet
Juppiter brumas.”*

Both at Oxford and St. Clare, Harcourt displayed extraordinary activity in games. Without being an athlete, he was naturally fond of all sports and outdoor exercises, and, once interested in a game, he took infinite trouble to improve. Many of his pupils found, to their surprise, that their white-haired tutor could give them lessons in other things besides chemistry.

His knowledge of the classics, especially of poetry, and a memory which remained excellent till quite late in life, made him apt at quotation and ready in rejoinder. He was a really good critic of style. Singularly lucid as a writer, he set his pupils an example

of precision and clearness, which some, it must be admitted sorrowfully, could not reach, though they tried to follow it.

His life was a full and happy one; he followed the path he had chosen, with never a thought for profit or self-advancement. If he had an ambition, it was the desire to serve others, and to feel that he was loved by his friends.

Few men have been so completely happy in their work or lived so much in the lives of their students. The writer, whose good fortune it was to fall under his influence at Oxford, gratefully acknowledges that he owes his career to Harcourt's affectionate interest and to his example.

H. B. D.

LUCIUS TRANT O'SHEA.

BORN MARCH 29TH, 1858; DIED APRIL 18TH, 1920.

LUCIUS TRANT O'SHEA, the eldest son of Major R. P. O'Shea, was born in 1858. He was proud of being the grandson of Sir Lucius Curtis, admiral, and still more proud that he was descended from the distinguished admiral Lord Rodney.

He was educated at the Manchester Grammar School, and completed his chemical training under Roscoe at Owens College. Afterwards he acted as private assistant to C. Schorlemmer, and took part in the research on the constitution of aurine.

Later he was chemist in an explosives factory, where he gained experience which was valuable to him in after-life.

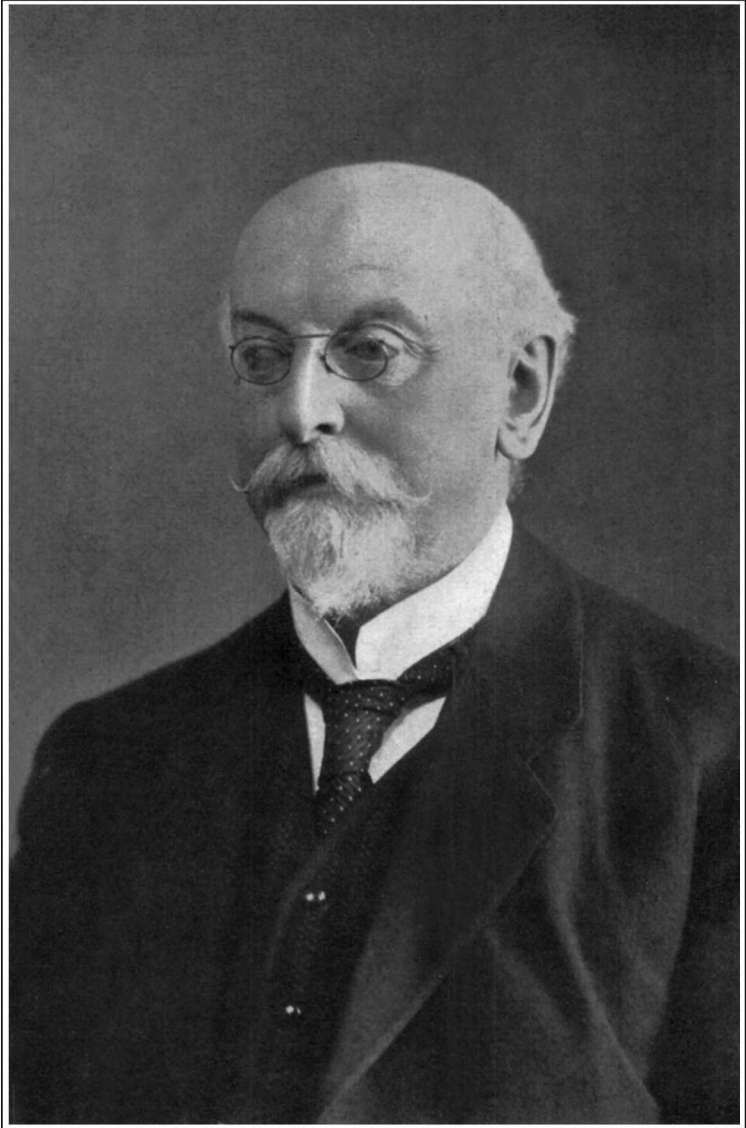
When Firth College, Sheffield, was opened, Thomas Carnelley was appointed Professor of Chemistry and Physics. He selected O'Shea as his assistant lecturer and demonstrator in chemistry in 1881. Later O'Shea held the post of lecturer in mining chemistry, and in 1907 he was appointed Professor of Applied Chemistry in the University of Sheffield. He remained faithful to the college and its allied institutions to the day of his death, which took place suddenly on April 18th, 1920, a period of thirty-nine years.

O'Shea was a B.Sc. of London and an M.Sc. of Sheffield. For a time he was an abstractor for this *Journal*. His genial nature and courteous demeanour won the regard and esteem of all who knew him. Children adored him, and the success of a children's party was ensured by his presence.

For several years his energies were devoted to imparting a

knowledge of chemistry and physics to the deputies (*in futuro*) in the coal-mining districts of Derbyshire and the neighbourhood of Sheffield. This was probably his most valuable work in the early days of Sheffield University College. The results of this teaching are embodied in an exceedingly useful book, "Elementary Chemistry for Coal Mining Students," published in 1911, which was specially intended for students who had little or no preliminary knowledge of chemistry. O'Shea's most important contributions to pure chemistry are papers on the "Constitution of Bleaching Powder" and on the "Preparation of Pure Iron," which are to be found in the pages of this *Journal* and in the *Journal* of the Society of Chemical Industry. He also made a number of contributions on the applications of Chemistry to mining problems, especially in connexion with explosions in coal mines, mining explosives, the by-products of coking, coal-washing, etc. These are to be found for the most part in the *Transactions* of the Institution of Mining Engineers.

His work in connexion with mining brought him into intimate contact with a large number of prominent mining engineers, by whom his admirable qualities were fully appreciated. In 1905 he was elected Secretary of the Midland Institute of Mining, Civil, and Mechanical Engineers. In 1908 the Institution of Mining Engineers, which had for many years had its headquarters at Newcastle-on-Tyne, decided to move these to London; simultaneously, the Institution was in many respects reorganised, and, the general secretary having died in the previous year, it was decided after much deliberation to offer the honorary secretaryship to Professor O'Shea, which the latter accepted, and he was duly appointed to the post on September 2nd, 1908, with an assistant secretary in London to attend to the routine work. It must be understood that this honorary secretaryship was anything but a sinecure, as the reorganisation of a complex society like the Institution of Mining Engineers demanded much hard work and involved a mass of correspondence; what was, however, needed more than anything to ensure the success of the altered conditions was the power to reconcile various conflicting interests, and in this the tact, geniality and shrewdness of O'Shea proved invaluable. He continued to hold the post of honorary secretary until the time of his death, and discharged all the duties of that post in a thoroughly admirable manner; during his tenure of the office he did much to strengthen and consolidate the Institution of Mining Engineers and to maintain the *Transactions*, for the editorship of which he was responsible, at the highest possible standard.



[To face p. 1633 *Trans.*

O'Shea was a keen volunteer, and took an active part in raising a company of the 1st West York R.E. Volunteers. In the Boer War he went out to South Africa in command of a detachment of this company. This experience of active service led to his being placed in command of the University O.T.C. contingent, which was formed in 1911, a position he retained for eight years.

Valuable service to the country in training officers was accomplished during the Great War.

O'Shea leaves a widow and one daughter.

W. C. W. AND H. L.

JAMES EMERSON REYNOLDS.*

BORN JANUARY 8TH, 1844; DIED FEBRUARY 17TH, 1920.

JAMES EMERSON REYNOLDS was born at Booterstown, Co. Dublin, on January 8th, 1844. He was the son of Dr. James Reynolds, a medical practitioner at Booterstown, a man of some literary ability and the author of one or two plays which had a certain measure of success. His mother, originally a Miss Campbell, was English. He was named after his great uncle, a Captain Emerson, of the Royal Navy.

Emerson Reynolds, as he was usually called, was intended for the medical profession, and in early youth became an assistant to his father. In 1865 he qualified as a licentiate of the Edinburgh College of Physicians and Surgeons, and afterwards practised for a short time in Dublin; but on his father's death he definitely abandoned medicine, and, following a strong inclination, devoted himself solely to chemistry. At Booterstown he had fitted up a small laboratory, and tried his hand at research work from the outset.

He was not a student of Trinity College, and never attended a systematic course of instruction either in theoretical or practical chemistry. In fact, he was wholly self-taught. His first paper, "On the Oleaginous Matter formed on dissolving different kinds of Iron in Dilute Acids," appeared in the *Chemical News* for 1861, when its author was, presumably, only seventeen years of age. In the same year, and in the same volume, appeared a second paper, "On a New Process for Photographic Printing." These were followed, next year, by a communication to the same journal on

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the "Oxalates of Iron," and in 1863 by no fewer than five contributions, partly to the *Chemical News* and partly to the *Journal of the Royal Dublin Society*. Their various subjects—"On the Economical Preparation of Sulphocyanide of Ammonium" (*Chem. News*, 1863, **8**, 14), "On the Numerical Nomenclature of Spectral Lines" (*idem*, p. 59), "On the Detection of Hyposulphite of Soda" (*idem*, p. 283), "Wood Spirit and its Detection" (*J. Roy. Dubl. Soc.*, 1863, **4**, 126), "Note on Pure Methylic Alcohol" (*idem*, p. 131)—if of no special merit or great originality, are, at least, remarkable as the work of a self-taught youth, wholly unguided, and with very limited means. They serve to show the range of his activities and the assiduity with which he followed the developments of contemporary science. Spectrum analysis was only in its infancy in 1863. Reynolds' practical interest in the subject was probably quickened by the popular lectures of the late Sir Henry Roscoe and Sir William Huggins to the Royal Dublin Society, and, as subsequent papers show, he maintained this interest to the end of his days. His early work was carried on under considerable difficulties, and as it was probably regarded as an interruption to his medical studies, it is doubtful if it received much encouragement at home. It was not until 1867, when he became keeper of minerals at the National Museum in Dublin, that he had access to a fairly equipped chemical laboratory. The subject-matter of many of his papers from 1868 onwards—for example, formation of dendrites, manganese ores, phosphoric acid in minerals, classification of silicates, notes on Irish rutile and the feldspars, boron minerals, mineralogical tables, etc., etc.—may be said to have had their origin in this appointment; and it was probably due to the interest thus created in the chemistry of silicon, which he laboured to show was conceivably co-extensive with that of carbon, that we owe his many papers on the silicic acids, silicon haloids, and on silico-organic compounds, which he continued to publish, from time to time, down to his last paper in 1913.

To this early work belongs his discovery of the colloidal derivative of mercury and acetone (*Proc. Roy. Soc.*, 1871, **19**, 431), which originated from his experiments on wood-spirit. It was the first colloidal derivative of mercury to be made known. The neutral solution of the compound $(C_3H_6O_2)_3HgO$, prepared by dialysis, was used with success by the late Sir Charles Ball as an antiseptic dressing in surgery where no ordinary mercurial solution could be used.

In 1868 he became analyst to the Royal Dublin Society, and two years later was appointed Professor of Chemistry at the Royal College of Surgeons, Dublin. He held both these positions until

his election, in 1875, to the Chair of Chemistry at Trinity College, Dublin, as successor to Dr. James Apjohn. At this period Reynolds had a considerable practice as a consultant and public analyst. He was interested in subjects relating to medical chemistry and hygiene, and had collaborated in the production of a "Manual of Public Health for Ireland." He was responsible for the analytical examination of the Vartry water as supplied to Dublin, and had laboured, like many before and since, at the perennial question of the utilisation of Irish peat.

On his appointment to Trinity College, Reynolds devoted himself, almost exclusively, to the duties of his chair. He was a good lecturer and an excellent teacher, somewhat precise in manner and diction, and too strict a disciplinarian to be generally popular with the type of student he had to teach; but he always commanded the respect of his pupils, who could appreciate the care and thought he spent on his lectures. They were always admirably illustrated by experiments, for he spared no pains in acquiring or devising suitable and striking demonstrations. If an experiment failed, which rarely happened, he insisted on its successful repetition on the next occasion. He was scrupulously careful that his teaching should be abreast of contemporary knowledge. He early perceived the significance and value of the doctrine of Periodicity, and his course of instruction was arranged in conformity with it. His theoretical conceptions of the basic principle of the Law, afterwards expanded by Sir William Crookes, and his graphic and glyptic representations of it, are well known to teachers of chemistry. He was among the first to attempt to settle the true position of the element glucinum in the periodic series, and to establish its valency and atomic weight. It is true that the experimental proof he was able to adduce was not wholly convincing, as the metal which he had himself prepared was far from pure, and the foreign matter present necessitated a very uncertain correction. It was only subsequently established that the specific heat of glucinum, as in the case of other elements of low atomic weight, varied very rapidly with the temperature, and that it was only at comparatively high temperatures that the value of its atomic heat approximated to that demanded by Dulong and Petit's law—a fact which accounted for the discrepant conclusions of previous and subsequent workers. Nevertheless, Reynolds' prevision of the true place of glucinum in the periodic series turned out to be correct, and there is no further doubt on the subject.

Reynolds was one of the first to introduce quantitative work into the early training of the student of chemistry, thereby familiarising him experimentally with the relation between atomic weights,

equivalents, valency, etc. His "Experimental Chemistry for Junior Students," in which he developed this system, was a distinctly original work, and has had a considerable measure of success in school teaching. As his own staff was very limited, much of his time during the session was spent in doing demonstrator's work in the laboratory. In this way he acquired practical experience of the working of his system, which he incorporated in subsequent editions of his book. Indeed, he gave so much of his time and energies to his professorial duties that steady, uninterrupted research work had to be relegated to the vacations.

Probably the best known of Reynolds' contributions to organic chemistry is his discovery of thiourea. As already stated, one of his earliest contributions from the little laboratory he had established when a boy in his father's house at Booterstown was concerned with ammonium sulphocyanide. On heating this salt to a few degrees above its melting point, dissolving the product in water, and allowing the concentrated solution to stand, he obtained a substance crystallising in silky needles, the true nature of which for a time escaped him, but which he eventually characterised as an isomeride of sulphocyanogen, under which title he communicated a short paper to the *Journal* of the Royal Dublin Society. A further account appeared in the *Journal* of the Chemical Society for 1869, and was quickly re-published in various Continental periodicals. It is not often that a young man of twenty-three hits on so remarkable a discovery, and particularly one which had baffled the skill of men like Liebig and Hofmann. It at once established Reynolds' position as one of the most promising of the younger Irish chemists, and no doubt contributed greatly to his subsequent professional success. Thiourea, or thiocarbamide, as it was indifferently termed for a time, proved to be an exceedingly reactive substance, and the preparation of its derivatives and congeners, and the elucidation of their constitution, have been pre-eminently associated with the chemical laboratory of Trinity College, Dublin.

Reynolds vacated his chair in Dublin in 1903, and took up his residence in London. He continued to pursue his experimental work at the Davy-Faraday laboratory, and ultimately fitted up a small laboratory in his house. His last published communication, "On the Synthesis of a Silicalcyanide and of a Felspar," appeared in the *Proceedings* of the Royal Society in 1913. In previous papers he had given descriptions of organic compounds containing the silicocyanogen group, SiN, proving the marked affinity of silicon for tervalent nitrogen. In his last paper he gave an account of the synthesis of a silicon compound of aluminium and calcium—a

calcium silicalcyanide, CaSi_2Al_2 , analogous to CaC_2N_2 , yielding, on oxidation, a substance of the composition of anorthite, $\text{CaAl}_2\text{Si}_2\text{O}_8$, with the properties of the naturally occurring mineral. The keeper of the minerals of 1867 was, up to the last, faithful to the conceptions which had dominated nearly half a century's intellectual activity.

Reynolds joined the Chemical Society in 1873, and became a Vice-President in 1881—1884, in 1889—1892, and again in 1897—1900. In 1901—1903 he served as President. In the first of his presidential addresses he discussed, with his characteristic lucidity of exposition, the development of a subject to which he had given much thought, and with which he had been associated since the early eighties, namely, the Periodic Law. In the following year he dealt with some pressing questions of inorganic research—inorganic isomerism and the so-called inorganic ferments, in which he gave a highly suggestive summary of many problems which have since occupied the attention of many workers, and some of which have proved to be of great technical importance. He was elected into the Royal Society in 1880, served on the Council, 1900—1902, and was a Vice-President in 1901—1902. He was an original member of the Society of Chemical Industry, of which he became President in 1891, presiding over the only Annual Meeting of the Society held in Ireland. He presided over the chemical section of the British Association at the Nottingham meeting in 1893.

In 1875 he married Janet Elizabeth, the daughter of Prebendary Finlayson, of Christchurch Cathedral, Dublin, who survives him. During his later years his eyesight, never very good, gradually failed, but his mental power was active to the last. He had a serious accident in the autumn of 1919, fracturing a rib; this was followed by a slight stroke, from which he never wholly recovered. He died very suddenly on February 17th, 1920, at his residence in Kensington.

T. E. THORPE.

WATSON SMITH.

BORN JUNE 16TH, 1845; DIED MAY 1ST, 1920.

WATSON SMITH, who died on May 1st, 1920, was the son of the Rev. Watson Smith, and was born at Stroud in 1845. His early training in chemistry he received under Sir Henry Roscoe at Owens College, Manchester, which he entered in 1862, and had

amongst his fellow-students Sir Edward Thorpe and the late G. I. Snelus, who also commenced their chemical studies in the same year. His chemical education was continued at Heidelberg, and later on pursued at Zurich. Here Watson Smith came under the influence of Professor Lunge, and this undoubtedly proved an important factor in directing his subsequent career. After some years spent in industry, he was appointed Lecturer in Technological Chemistry in Owens College, a position he retained until 1889, and on leaving Manchester to reside in London, he became for a period the Professor of Applied Chemistry at University College. Shortly after his appointment at Owens College, the Society of Chemical Industry was founded, in 1881, and in this movement he took an active part. Of the *Journal* of this Society he became the first editor, a post he held for thirty-two years. The recognised position which this *Journal* has attained is in the main due to the care and direction it received from Watson Smith, and surely this success may be counted amongst the most important contributions to the advancement of chemistry made by him. Something of this success is to be credited to our own *Journal*, for it was as an abstractor, in fact, one of the first, that Watson Smith acquired an experience which he later turned to such useful account.

By his investigations, either alone or in collaboration with others, he contributed to various departments of chemistry, both pure and applied. In this connexion, his researches on "Diphenyl," "*iso*Dinaphthyl," "The Exhaustive Chlorination of Certain Hydrocarbons," and "Pentathionic Acid" may be cited. The chemistry of coal and of coal-tar has been materially advanced by his researches, and as far back as 1883 he directed attention to the importance of the full utilisation of coal, insisting on the necessity for the adoption of the practice of coking in retort ovens, with the recovery of the ammonia and other of the valuable by-products formed. It must have been a source of gratification to him to have seen the fruition of his advocacy, by the widespread adoption in recent years, of these methods of coking.

He was elected a Fellow of this Society in 1866, so that at the time of his death he had already passed his jubilee as a Fellow. He was an original Fellow of the Institute of Chemistry, and for two periods (1883—1887, 1888—1892) acted as an examiner for the Institute.

In music and musical composition Watson Smith found his recreation, and was a skilful executant on the piano.

He was twice married, and is survived by his second wife and children of the first marriage.

P. P. B.

ALFRED WERNER.

BORN DECEMBER 12TH, 1866; DIED NOVEMBER 15TH, 1919.

THE originator of the co-ordination theory of valency and chemical constitution was born in Mulhouse in modest circumstances, his father being a factory inspector who, with the assistance of his mother (née Teché), also cultivated a small holding.

Pocket-money was scarce, and young Werner, who had already in his early school days manifested a great liking for chemistry, undertook such humble tasks as chopping wood for the neighbours in order to procure a few additional centimes wherewith to buy scientific books and chemical materials and apparatus. At eighteen years of age, having fitted up a laboratory in a barn on his father's homestead, he submitted to Professor Noeltig the manuscript of his earliest chemical investigation, with the naïve inquiry as to how long it would take to become a professor. A sympathetic appreciation of the work, with a guarded reply to his question, confirmed Werner in his enthusiasm for chemistry, so that when a year later he joined the army at Karlsruhe as a one-year volunteer, he seized this opportunity of commencing his studies at the technical high school.

In later years he recalled with pleasure the circumstance that he was frequently posted as sentry before the palace wherein dwelt the Princess Victoria, afterwards Queen of Sweden, whose court he subsequently attended as Nobel prizewinner.

In 1886 Werner proceeded to Zurich, and continued his studies in the Federal Polytechnic under Professors Lunge, Hantzsch, and Treadwell. Three years later, having obtained his diploma as technical chemist, he became assistant to Lunge, at the same time working for his doctorate, under Hantzsch's guidance, on the spatial arrangement of atoms in nitrogenous compounds. In this research, which proved to be of exceptional importance, the young chemist displayed remarkable powers as an observer and original thinker.

After a short stay in Paris with Berthelot, he returned to Zurich, where his independently published memoirs on the theory of affinity and valency, and on the constitution of inorganic compounds, speedily led to his appointment, at the age of twenty-seven, as Extraordinary Professor in the University, and two years later as Ordinary Professor in succession to Victor Merz.

During these early years the Zurich laboratories were of very primitive type, and consisted largely of cellars and basements so

insufficiently lighted and ventilated that they received the ominous name of "catacombs." Yet, in spite of these material drawbacks, the master's inspiring personality attracted each year a larger band of enthusiastic students. In 1905 the Cantonal authorities acceded to the professor's strongly expressed request for more adequate accommodation, and, with the completion of the new laboratories in 1909, Werner at length became provided with an installation worthy of the epoch-making researches to which he devoted the remainder of his life.

Werner's capacity for work was prodigious: always the first to arrive at the Institute, he was frequently the last to leave it. His publications reached a total of 169, and 200 dissertations were produced by his pupils, of whom he sometimes had as many as twenty-five working simultaneously under his personal guidance. But in spite of the strenuous existence which these activities entailed, Werner, who was of a jovial disposition, found time for conviviality and for such social recreations as card-games, billiards, and chess. He delighted in bringing together under his hospitable roof his colleagues and past and present students, and of these festive gatherings he was the life and soul.

Werner had a comparatively short career of meteoric brilliancy, and the transcendent quality of his work brought him rapid recognition from scientific contemporaries throughout the world. The Swiss universities granted honorary degrees and learned societies in all lands bestowed various honorific distinctions. He was elected an Honorary and Foreign Member of the Chemical Society in 1913, and in the same year the Nobel Prize came as a culminating honour. These gratifying marks of appreciation made, however, no difference to his naturally modest demeanour, and served only to stimulate him to further efforts and more arduous toil.

In 1915, while at the pinnacle of his fame, the first insidious symptoms of his fatal malady (arteriosclerosis) declared themselves, and then followed four tragic years of increasing suffering and infirmity until death brought respite and release.

Although the time for accomplishment was short, Werner's life-work is not to be regarded as incomplete or unfinished. The coordination theory, which, with creative genius and prophetic insight, he had conceived as a young investigator, was before his death extended logically to its remotest consequences, and was subjected in his laboratory to the most rigid and exhaustive proofs.

Werner's success is a triumph of the inductive method of reasoning. His ideas were inborn and swiftly engendered, but he spared himself no pains to confirm these preconceptions by reference to cognate facts, or, if these were lacking, by crucial laboratory tests.

His prevision was so exact and well focussed that in the great majority of cases it was confirmed by experiment. These repeated verifications rendered Werner rather impatient of controversy, and he paid little attention to views which differed from his own; but although he felt sure that his hypotheses were correct, yet he was open-minded enough to believe that his theory was only a stepping-stone to a more comprehensive generalisation of chemical phenomena.

Though somewhat autocratic as director of research, he was, however, geniality personified to all students who sought his advice, and as a teacher his enthusiasm for his subject was contagious. An English pupil describes his lectures on inorganic chemistry and the periodic classification as "a perfect joy." His classical treatise, "Neuere Anschauungen auf dem Gebiete der anorganische Chemie," the work of several years, is a remarkable testimony to the encyclopædic character of his knowledge and comprehensive grasp of inorganic chemistry.

ORGANIC RESEARCHES.

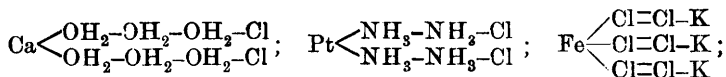
For several years after his promotion to the university chair, Werner divided his attention between the inorganic and organic sections of chemistry, with an ever-increasing bias towards the former. His earliest memoir, published jointly with Hantzsch, contains their celebrated hypothesis of the stereochemical configuration of the oximes. Werner followed up this idea by further researches on oximes and allied compounds, and this work on the structure of doubly linked carbon-nitrogen compounds is to be regarded as his most important contribution to organic chemistry.

Considerable attention was devoted in the Zurich school to the study of phenanthrene derivatives, which are of interest on account of their relationship to certain natural products, and Werner's discovery of xanthonium salts, together with his researches on pyronium salts, are notable contributions to our knowledge of oxonium compounds.

INORGANIC RESEARCHES.

In 1891, when Werner first propounded his views on chemical affinity and valency, Kekulé's theory of constant or fixed valency, which had proved of fundamental importance in the development of organic chemistry, was more or less accepted as the guiding principle in explaining the constitution of inorganic compounds. In this respect it was not helpful, and sufficient evidence had already accumulated to show that a theory of variable valency was more in accord with known facts. Werner discarded the idea of

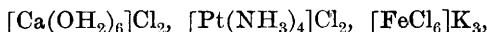
constant valency with a fixed number of valency units of equivalent strength operating in certain definite directions, and assumed that the chemical affinity of an element was distributed uniformly over the surface of its spherical atom in such a manner that, according to the circumstances attending chemical combination, this affinity could be divided up in a great variety of ways into few or many valency units of varying intensities. This new viewpoint of chemical affinity had its effect even in organic chemistry, where it was utilised in elucidating certain facts of aromatic substitution and of stereochemical change. But a longer stride was taken in 1893 by the publication of a dissertation on the constitution of inorganic compounds, wherein Werner expounded more explicitly his new theory of variable valency. At that time, hydrated and ammoniated simple salts, and also double salts, were formulated either as "molecular" compounds, $\text{CaCl}_2 \cdot 6\text{H}_2\text{O}$, $\text{PtCl}_2 \cdot 4\text{NH}_3$, $\text{FeCl}_3 \cdot 3\text{KCl}$, or as open-chain complexes,



but neither of these methods of representation gave any clear explanation of the properties of these substances.

Co-ordination Number.

In opposition to these unsatisfactory formulations, Werner put forward his "co-ordination formulæ," according to which the associating units, OH_2 , NH_3 , or KCl , are grouped round a central atom, which is usually metallic. The maximum number of these groups which can find a place in the co-ordination sphere immediately surrounding the central atom is termed the "co-ordination number." The associating units implicated in a stable co-ordination complex have no ionic properties, but outside this inner or first sphere there may be ionisable radicles, as shown in the following co-ordination formulæ:



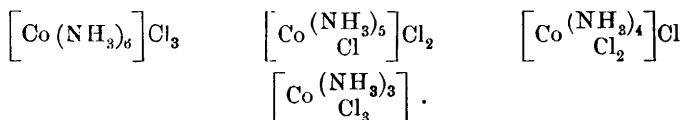
where the co-ordination complexes or first spheres are included in square brackets.

The co-ordination complex can be produced either by the addition of elementary or compound radicles, as in the combination of platinic chloride and potassium chloride, or by the assimilation into this inner co-ordination sphere of a number of complete molecules, as in the interaction of ammonia and cobaltic chloride. The products $[\text{PtCl}_6]\text{K}_2$ and $[\text{Co}(\text{NH}_3)_6]\text{Cl}_3$ are typical respectively of two great general classes of co-ordination compounds.

Residual Affinity—Supplementary Valency.

The effective force in these combinations is the residual affinity or supplementary (auxiliary or secondary) valency of the central atom, which, although not powerful enough to attract further atoms or radicles having integral valencies, is nevertheless sufficiently intense to combine with another molecule possessing a similar degree of unsaturation.

The co-ordination complex may, however, be built up partly by the agency of principal valency and partly by that of supplementary valency, as shown in the following series, where cobalt is consistently trivalent:

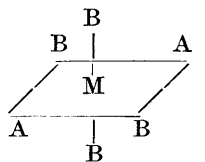
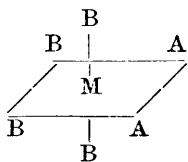


The gradual introduction of chlorine into the complex is accompanied by a diminution in the electrical conductivity of the compound; the fourth member, which contains all the chlorine in the inner sphere, is practically a non-electrolyte.

In the majority of cases, the co-ordination number is six, but with carbon, boron, glucinum, and bivalent platinum it is four, and it increases to eight for molybdenum, tungsten, and a few other elements.

Geometrical Isomerism.

The frequent recurrence of the co-ordination number six suggested a definite spatial grouping of the associating units. Three arrangements present themselves: the hexagon, the triangular prism, and the regular octahedron. If either of the first two arrangements be assumed, a co-ordination complex of the type $[\text{MA}_2\text{B}_4]$ should exist in three isomeric forms, corresponding with the three di-substituted isomerides of the hexagonal and prismatic constitutions of benzene, but if the associating groups A_2B_4 are situated at the vertices of a regular octahedron, then only two stereoisomerides are possible:

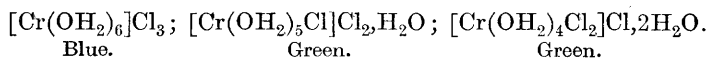


Many compounds of this type were examined, of which no fewer than twenty-seven series contained cobalt as central atom, and in every case only two stereoisomerides were detected. In most instances the stereochemical configuration of each isomeride was established by taking advantage of the fact that, as in organic chemistry, only the *cis*-position lends itself readily to ring formation.

Inorganic and Co-ordination Isomerism.

The demonstration of several other types of inorganic isomerism furnished additional confirmation of the co-ordination theory and of the important part played by the co-ordination complex.

Hydrate isomerism was shown in the following series of salts, which differed considerably in physical and chemical properties:



Several other more complicated cases of hydrate isomerism were discovered by Werner and his collaborators.

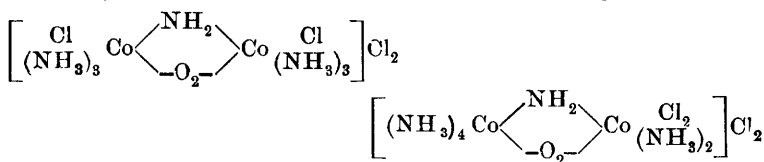
Ionisation isomerism was exemplified by such examples as the following pair, containing, respectively, nitrite and chlorine ions:



Salt isomerism, arising from the circumstance that the nitrite and thiocyanate groups often present in the co-ordination complexes can each exist in two differently constituted forms, is exemplified by the following compounds, where "en" represents ethylenediamine, a molecule of which often replaces two molecules of ammonia, thus occupying two positions in the co-ordination complex:



Co-ordination position isomerism is possible owing to the fact that associating units maintain a definite spatial orientation, even in highly complex structures, such as the following:

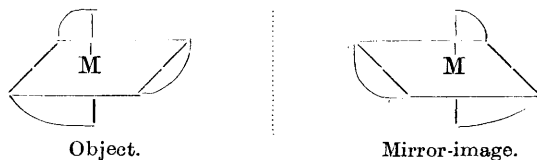


Many other series of a highly complicated character containing two or more metallic atoms were examined by Werner and his

pupils, and shown to conform to the fundamental principles of the co-ordination theory.

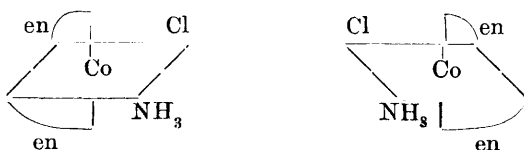
The culminating point in these researches was reached with the discovery of optical isomerism among co-ordination compounds.

Octahedral Enantiomorphism.



Geometrical isomerides of the *cis*-series having the general formulæ $[MA_2en_2]X$ and co-ordination compounds of the type $[Men_3]X_3$ containing, respectively, two and three molecules of ethylenediamine should each exist in two optically active enantiomorphous forms corresponding with the foregoing general formulæ, in which the central atom is surrounded by a complex consisting of at least two ethylenediamine molecules or similar caliper-like groups.

After many disappointments, the resolution of 1:2-chloroammino-diethylenediamine cobaltic chloride, $\left[\begin{array}{c} NH_3 \\ Cl \end{array} Co en_2 \right] Cl_2$, was accomplished in 1911 with the aid of *d*-bromocamphorsulphonic acid.



This striking confirmation of Werner's views of the configuration of co-ordination compounds was speedily followed by other analogous resolutions, and optically active compounds of octahedral symmetry are now known containing cobalt, chromium, iron, iridium, platinum, rhodium, and ruthenium as central metallic atoms.

Considerable ingenuity was displayed in the selection of these co-ordination compounds, and, out of the many examined, two may be mentioned as being of outstanding interest. The well-known blue double potassium chromium oxalate, $[Cr(C_2O_4)_3]K_3$, and the remarkable red additive compound of ferrous bromide and $\alpha\alpha$ -dipyridyl, $[Fe(Dip)_3]Br_2$, were successfully resolved, and thus shown to possess octahedral symmetry.

More than forty series of these compounds of octahedral symmetry have been shown to exist in optically active forms, so that the spatial configuration of the co-ordination complex with six associating units is now as firmly established as that of the asymmetric tetrahedral carbon atom.

Werner's activities did not, however, abate even with this complete and crowning demonstration. The search for further evidence was extended in all directions. The polynuclear complexes with two cobalt atoms, which should, in accordance with the theory, display remarkable optical properties, were put to the test, and found to confirm Werner's theoretical anticipations in every particular. Among these may be cited the case of the

following complex salt, $\left[\text{en}_2 \text{Co} \cdot \begin{array}{c} \text{NO}_2 \\ \text{NH}_2 \end{array} \cdot \text{Co en}_2 \right] \text{X}_4$, which was shown to exist in four modifications: two optically active forms, a racemic form, and an optically inactive form, due to internal compensation. Accordingly, these four varieties of the substance furnish a complete analogy to the four tartaric acids. This binuclear co-ordination compound illustrates also an important corollary of the co-ordination theory, the smoothing out and equalisation of the difference between principal and supplementary valencies (ionogenic and non-ionogenic valencies) within the co-ordination complex. The existence of an internally compensated analogue of mesotartaric acid shows that the bridging groups NO_2 and NH_2 , although originally attracted into the co-ordination complex partly by principal and partly by supplementary valency, are now similarly associated with each of the two cobalt atoms.

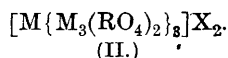
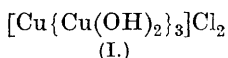
The optically active co-ordinated compounds hitherto considered contain carbon present in the ethylenediamine or $\alpha\alpha$ -dipyridyl molecules or in oxalate complexes. In order, however, to remove any lurking suspicion that carbon may, after all, be even a contributory cause of the optical activity in these substances, Werner (1914) resolved a purely inorganic compound entirely free from carbon. In this substance the basic cobaltic complex, $[\text{Co}(\text{NH}_3)_4(\text{OH})_2]\text{X}$, took the place of ethylenediamine, and three molecules were co-ordinated with cobaltic bromide. The resulting complex bromide, $\left[\text{Co} \left\{ \begin{array}{c} \text{OH} \\ \text{OH} \end{array} \right\} \text{Co}(\text{NH}_3)_4 \right]_3 \text{Br}_6 \cdot 2\text{H}_2\text{O}$, was resolved successfully through the bromocamphor- π -sulphonates into optically active components, thus proving beyond all doubt that this form of optical isomerism is not due to the presence of any special element or group of elements, but is simply a geometrical property of the octahedral co-ordination complex.

Applications of the Co-ordination Theory.

Numerous resolutions of octahedral racemoid substances, made with the aid of organic optically active compounds, tartaric acid, camphorsulphonic acid, bromocamphorsulphonic acid, nitrocamphor, and the alkaloids, placed Werner in possession of many optically active products of octahedral symmetry. These new reagents were promptly applied to refractory racemoid substances of tetrahedral symmetry and, in the resolution of *s*-dimethylsuccinic acid with the aid of the optically active triethylenediamine cobaltic bromides, $[\text{Co } 3\text{en}]\text{Br}_3$, Werner (1913) repaid the debt he owed to Pasteur.

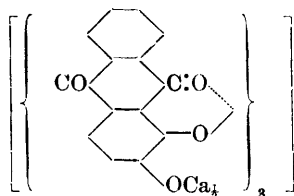
The acceptance of Werner's theory by other investigators has led to the study of co-ordination compounds of very diverse types. Among these are several which have already proved useful in chemical analysis, such as the metallic derivatives of dimethylglyoxime, benzildioxime, dicyanodiamidine, nitroso- β -naphthol, and phenylnitrosohydroxylamine (cupferron).

The theory offers a valid explanation of the constitution of many complex minerals, for instance, atacamite (I) and its analogues, and the members of the apatite group (II), where $\text{M} = \text{Ca}$ or Pb ,

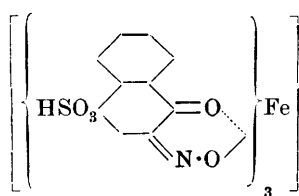


$\text{R} = \text{P}$, As or V , and $\text{X} = \text{F}$ or Cl , may be formulated as co-ordinated compounds. In this connexion, it should be mentioned that the co-ordination theory has widened considerably, and, at the same time, rendered more precise our conceptions of isomorphism.

An extension of the theory to which Werner paid considerable attention was its general explanation of the mechanism of adjective dyeing with metallic mordants. The resulting highly-coloured lakes, to which the tinctorial effect is due, have the characteristic properties of internally co-ordinated complexes: insolubility, exceptional colour, chemical inertness, and an inhibition of the ordinary analytical properties of the metallic atom. It is impossible to summarise this rapidly growing section of co-ordination chemistry, but two typical examples may be formulated.



Alizarin-red.



Naphthol-green G.

At least one important metallurgical industry—the production of pure nickel—may, in the light of this theory, be regarded as being dependent on the singular properties of a co-ordination complex, nickel carbonyl.

Werner's generalisation has all the attributes of a scientific theory of first-rate importance. It is in close accordance with known facts, which it explains and summarises in a logical and comprehensive manner. It endows its exponents with the gift of prophesy, and many far-reaching predictions based on its simple hypotheses have been subsequently verified by direct experiment.

By birth Werner was an Alsatian subject of the second French Empire, but with the annexation of his native province by Germany in 1871, his nationality became changed, and, as already narrated, he served in the German army. His early studies in Zurich imbued him, at an impressionable age, however, with a love for the democratic institutions of Switzerland. The call to a Swiss chair of chemistry strengthened this bond, and in 1895, the year of his marriage to a lady of Zurich (Fräulein Emma Giesker), Werner became by naturalisation a citizen of the Swiss Confederation. Thenceforward he became wholeheartedly a Swiss, remaining attached to Zurich and loyal to his adopted fatherland in spite of gratifying invitations to Vienna and to Würzburg. He spoke German intentionally with a Swiss accent, and took great pride in displaying a colloquial knowledge of the local *patois*. Werner's deliberate change of nationality was for him a happy choice, for while neighbouring empires were tottering to their fall in a turmoil of war and social unrest, the alpine republic gave to her illustrious adherent one of the greatest of earthly blessings, peace: for the fulfilment of his life's work and in his closing years.

The writer's best thanks are extended to Professors Fierz, Karrer, and Staudinger, and to Mr. C. W. Bailey, for their kind assistance in the compilation of this memoir.

G. T. MORGAN.
