OBITUARY NOTICES.

MAX BERGMANN.

1886—1944.

MAX BERGMANN was born in Fürth, Bavaria, on the 12th February, 1886, and died in the Mount Sinai Hospital, New York, after an illness lasting some months, on the 7th November, 1944. He leaves a widow and a son and daughter.

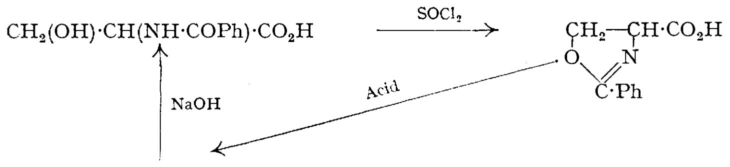
Bergmann took his first degree at the University of Munich in 1907; from there he proceeded to Berlin, where he took the Ph.D. degree in 1911, in the same year becoming assistant to Emil Fischer. He worked with Fischer until the latter's death in 1919, and in 1920 was appointed Privat-Dozent in the University of Berlin; at the same time he became Assistant Director and Head of the Department of Chemistry of the Kaiser Wilhelm Institut für Faserstoff-forschung. In 1921 he was appointed Director of the Kaiser Wilhelm Institut für Lederforschung in Dresden and was given the title of Professor in the Technische Hochschule of that city. The value of his work in leather research was recognised by the Presidency of the International Society of Leather Chemists which he held from 1928 to 1933.

Bergmann held his post at Dresden until 1934, when the pressure of political events in Germany made the continuation of his scientific career there impossible. He therefore sought refuge in the United States where, in common with many others of his exiled fellow countrymen, he received a generous welcome. Shortly after his arrival he was made an Associate-Member of the Rockefeller Institute for Medical Research and in 1937 he became a Member; this position he held until his death. For the last three years of his life he had largely abandoned his normal research work in order to devote himself to problems of military importance.

In reviewing Bergmann's scientific career it is convenient to trace its development from the period when he worked with Emil Fischer who was his teacher and who exercised a lasting influence upon him.

No part of the great work of Emil Fischer in organic chemistry has proved to be of more importance than his contribution to knowledge of amino-acids. The hypothesis that the peptide bond is the fundamental linkage in the protein molecule which owed so much to his work, after some vicissitudes, holds its own twenty-five years after his death. On the foundation of Fischer's work there has been built up a great structure of knowledge concerning the chemistry of amino-acids; not only have unexpected and highly interesting chemical properties of these compounds been revealed, but development of methods of synthesis of the amino-acids themselves and of peptides derived from them has made possible the detailed study and classification of the proteolytic enzymes. An outstanding part in this development has been played by Fischer's pupil, Max Bergmann.

The first important contribution to amino-acid chemistry made by Bergmann rested on his observation of the formation of oxazolines by the action of thionyl chloride on 1-acylamido-2-hydroxy-compounds, followed by the acid decomposition of the oxazoline to give the amino-*O*-acyl derivative corresponding to the starting material. This was first (Bergmann, Brand, and Weinmann, *Z. physiol. Chem.*, 1932, **131**, 1) observed in the case of β-hydroxy-γ-benzamidobutyric acid and the work was later extended to *N*-benzoylserine (Bergmann and Miekeley, *ibid.*, 1924, **140**, 128); under the same conditions this gave 2-phenyloxazoline-4-carboxylic acid (I), which on treatment with acid yielded *O*-benzoylserine; the latter in turn reverted in alkaline solution to *N*-benzoylserine.



(I.)

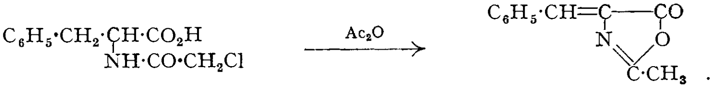
Arising out of these experiments on acyl migration, a study was made (Bergmann, Miekeley, and Kann, *ibid.*, 1925, **146**, 247) of the action of thionyl chloride on glycyl- and alanyl-serine; it was found that the normal anhydride was not formed but that two molecules of water were lost to give a diketopiperazine (II) which on hydrolysis yielded pyruvic acid and glycine or alanine; on the other hand reduction of the diketopiperazine

$$\mathrm{R{\cdot}CH(NH_2){\cdot}CO{\cdot}NH{\cdot}\underset{CH_2{\cdot}OH}{CH}{\cdot}CO_2H} \xrightarrow{-2H_2O} \begin{array}{l}\mathrm{CO{-}NH{-}C{=}CH_2}\\ \mathrm{R{\cdot}CH{-}NH{-}CO}\end{array}$$

(II.)

from alanyl-serine (II; R = CH_3) gave normal alanine anhydride; Bergmann remarks in this paper on the interest attaching to such easy chemical interconversions of alanine, serine and pyruvic acid, substances known to be metabolically related.

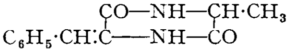
In such transformations of alanine into serine or pyruvic acid the key position would be occupied by dehydro-alanine (α-aminoacrylic acid or α-iminopropionic acid) and it therefore became of interest to study the formation and properties in general of derivatives of dehydrogenated amino-acids. Bergmann discovered (Bergmann and Stern, *Annalen*, 1926, **448**, 20) that the dehydrogenation of α-amino-acids could be readily effected by the action of acetic anhydride on their halogenoacyl derivatives. Thus, treatment of *N*-chloroacetylphenylalanine with acetic anhydride led directly to an oxazolone (2-methyl-4-benzylideneoxazolone; III) identical with that obtained by condensing benzaldehyde with acetylglycine and from which *N*-acetamidocinnamic acid could be obtained. This was shown to be a general reaction, tyrosine behaving similarly, and α-bromopropionylalanine with acetic anhydride giving an oxazolone which on hydrolysis yielded pyruvic acid. Pyruvic acid was also obtained from α-*N*-chloroacetylasparagine, in this case presumably through the intermediate stage of oxaloacetic acid (Bergmann, Kann, and Miekeley, *Annalen*, 1926, **449**, 135).


(III.)

The reactivity of the oxazolone group opens up possibilities of peptide synthesis with its aid. These were explored by Bergmann in an interesting paper (Bergmann, Stern, and Witte, *ibid.*, p. 277) in which he showed *inter alia* that 2-methyl-4-benzylideneoxazolone would condense with glutamic acid to give the acetamidocinnamoyl derivative of the latter; reduction of the product gave a mixture of acetyl-*l*-(−) and -*d*-(+)phenylalanyl-*l*-(+)glutamic acids which could be separated. In this paper also is described the preparation of oxazolones with saturated groups in the 4-position (*e.g.*, 2-methyl-4-benzyloxazolone by the action of acetic anhydride on phenylalanine); these were shown to be more reactive than the corresponding unsaturated compounds.

The oxazolone method was used (Bergmann and Miekeley, *ibid.*, 1927, **458**, 40) to pursue further the question of intermolecular dehydrogenations of amino-acids; thus, by condensation of 2-methyl-4-benzylideneoxazolone with serine and reduction followed by dehydration of the product, a diketopiperazine (II; R = $C_6H_5{\cdot}CH_2$) was obtained which was an anhydride of phenylalanylaminoacrylic acid; in alkaline solution a shift of the double bond occurred to give the anhydride of α-acetamidocinnamoylalanine (IV). Similarly, it was later shown that the dehydrophenylalanyl residue could, under certain conditions, dehydrogenate aspartic acid (Bergmann and Ensslin, *Z. physiol. Chem.*, 1928, **174**, 76).

A study of acylated amino-acids led to results of particular interest in the case of arginine. Bergmann found (Bergmann and Köster, *Z. physiol. Chem.*, 1926, **159**, 179) that the action of excess of acetic anhydride on this amino-acid gave a triacetyl anhydroarginine which, with water, yielded diacetyl urea and α-acetamidopiperidone, the latter in turn giving ornithine by hydrolysis; if the anhydride (V), instead of being decomposed with water, were brought into reaction with glycine ester the product split into the piperidone and the ester of diacetylglycocyamine; similarly, reaction of the anhydride with sarcosine led to creatine (Bergmann and Zervas, *Z. physiol. Chem.*, 1928, **172**, 277; **173**, 80). In all these experiments the ornithine isolated was racemic; the racemisation was ascribed to intermediate oxazolone formation under the influence of the acetic anhydride, and this racemising effect of excess acetic anhydride on amino-acids was later shown to be a general phenomenon (Bergmann and Zervas, *Biochem. Z.*, 1929, **203**, 280).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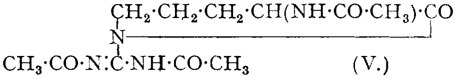

(V.)

In 1932 Bergmann (Bergmann and Zervas, *Ber.*, 1932, **65**, 1192) made what was perhaps his greatest synthetical contribution by the development of the so-called "carbobenzoxy" method of peptide synthesis. This rests on the facts that benzyl chloroformate reacts readily with all amino-acids or their esters to give *N*-carbobenzyloxy-derivatives which can be converted into the acid chlorides or acid azides and brought into reaction with other amino-acids; moreover, the carbobenzyloxy-residue can be removed from the acylated peptides so formed by catalytic reduction under the mildest conditions. This discovery immediately opened an easy route to large numbers of peptides containing optically active amino-acids which had hitherto been difficult or impossible of access. The introduction by other workers of alternative methods of reductive elimination of the carbobenzyloxy-residue has extended the usefulness of the method to sulphur-containing amino-acids, so that it is now of almost universal application in the field of peptide synthesis.

Bergmann himself employed the new technique mostly for the purpose of synthesising peptides which offered special features of interest as substrates for the study of enzyme action. The general question of the factors determining specificity among proteolytic enzymes had already attracted Bergmann, and his interest in it was doubtless stimulated by the discovery (Bergmann and Schleich, *Z. physiol. Chem.*, 1932, **205**, 65) of an enzyme in the kidney specifically capable of hydrolysing the dehydropeptides to which reference has been made above. From the time when he left Germany his efforts were largely directed towards the study of enzyme specificity, and the series of papers on this subject which has come from his laboratory at the Rockefeller Institute forms an impressive contribution.

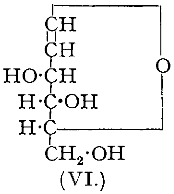
Attention was first turned to dipeptidase, and a detailed study of the action of this enzyme on synthetic substrates was made in which considerable attention was paid to stereochemical factors affecting the enzymic action (Bergmann, Zervas, Fruton, Schneider, and Schleich, *J. Biol. Chem.*, 1935, **109**, 325).

From dipeptidase Bergman passed to the study of papain, the nature of the activity of which seems to have exercised a great attraction on his mind. At the time when he took up the work the plant enzymes papain, bromelin and ficin, as also the similar enzymes ("cathepsins") which occur in the cells of animal tissues were regarded as proteinases and it was not thought that they were capable of attacking simple substrates. Bergmann was able to show that, in fact, papain can split a number of amino-acid amides and simple peptides and that its hydrolytic action is independent of the presence of free ionising groups in the substrate; the same was found to be generally true of the cathepsins of animal tissues, from which it appeared that this group of enzymes had a much wider range of activity than the proteolytic enzymes of the alimentary tract. Justice cannot be done here to the large amount of detailed work on the specificity of papain and related enzymes which was carried out by Bergmann and his collaborators, among whom may be specially mentioned J. S. Fruton, but reference may be made to his study of the activation of papain which led him to doubt the oxidation–reduction theory of this process, and of syntheses accomplished with the aid of the enzymes. Such enzymic syntheses, for instance of an anilide from an acylated amino-acid, take an asymmetric course involving only the *l*-isomeride; the method has indeed been employed as a practical means of resolving two *dl*-amino-acids (Fruton, Irving, and Bergmann, *J. Biol. Chem.*, 1940, **133**, 703; Behrens, Doherty, and Bergmann, *ibid.*, 1940, **136**, 61).

Bergmann's studies of enzymic specificity extended also to amino- and carboxy-peptidases, to chymotrypsin and to pepsin; he made the outstanding discovery that certain simple synthetic substrates were susceptible to attack by the latter enzyme. In two recent review articles Bergmann summarised his views on the classification and action of proteolytic enzymes; although some of his conclusions may not stand the test of time, yet he undoubtedly effected a very great clarification of a complex subject (Bergmann and Fruton, *Advances in Enzymology*, 1941, **1**, 63; Bergmann, *ibid.*, 1942, **2**, 49. In these two articles will be found a full bibliography of the work on specificity of proteolytic enzymes).

Another matter which attracted much of Bergmann's attention during the latter part of his career was the structure of the protein molecule. He approached this subject from an analytical point of view, devoting considerable time to the development of methods for the quantitative isolation of amino-acids. His first attempts were based on the use of complex acids which gave sparingly soluble salts of individual amino-acids; on the basis of analytical results obtained in this way he developed in collaboration with Niemann the so-called periodicity theory of protein structure, according to which the total number of amino-acid residues in the protein molecule may be expressed by the formula $2^n \times 3^m$, where n and m are whole numbers, and the number of residues of any individual amino-acid by $2^{n_1} \times 3^{m_1}$, where n_1 and m_1 may be 0 or a whole number. This attractively simple hypothesis appeared to be borne out by the first few cases studied, but later work by others threw doubt on its general validity; it is probable that Bergmann himself came to feel that the analytical basis for the theory was not sufficiently secure, and that this influenced him in pursuing further and making valuable contributions to the difficult problem of the quantitative isolation of individual amino-acids from hydrolysates of proteins. In the meantime, whatever the ultimate fate of the periodicity hypothesis, it has performed a valuable function in the stimulation of thought and of experimental work on the general problem of protein structure.

The work on amino-acids and proteins which has been described represents Bergmann's chief scientific interest which was maintained throughout his career. It must not be forgotten, however, that for a number of years he was Director of an institute for leather research, and there exist a large number of papers under his name dealing with practical aspects of this problem; no attempt to review these papers is made in this Notice. Reference is desirable, however, to two notable contributions which he made in the field of carbohydrate chemistry. In a paper published with Fischer (Fischer, Bergmann, and Schotte, *Ber.*, 1920, **53**, 510) after the death of the latter the correct constitution (VI) was assigned to the substance obtained by Fischer and Zach by reduction of acetobromoglucose and named " glucal " under the erroneous impression that it contained an aldehyde group. In confirmation of the new constitution proposed, Bergmann (Bergmann and Schotte, *Ber.*, 1921, **54**, 440) established the position of the double bond by the isolation of arabinose after oxidation of triacetylglucal with ozone followed by hydrolysis. In a further series of papers the constitutions of various transformation products of glucal were established.


(VI.)

Bergmann's second main achievement in carbohydrate chemistry was the preparation (Bergmann, Zervas, and Silberkweit, *Ber.*, 1931, **64**, 2436), by acetolysis of chitin, of a crystalline octa-acetylchitobiose, and the presentation of satisfactory evidence that the glucosamine residues in this, and hence in the parent chitin, were linked in the 1 : 4-positions. In connection with this work he synthesised various simple peptides of glucosamine (Bergmann and Zervas, *Ber.*, 1931, **64**, 975; 1932, **65**, 1201) and made a detailed study of the deamination of glucosaminic acid (Bergmann, Zervas, and Silberkweit, *Ber.*, 1931, **64**, 2428).

In this Notice no attempt has been made to give a comprehensive account of Bergmann's work; the writer has selected only those aspects of it which seem to him to be the most important. It is hoped, however, that enough has been said to indicate that Bergmann was much more than a worthy upholder of the Emil Fischer tradition. There is a continuity of thought and an originality of outlook in his work, particularly in the amino-acid–protein–enzyme field, which are the marks of a powerful mind, and that he possessed such a mind was indeed evident to all who were personally acquainted with him. It is noteworthy that his output of scientific work was scarcely affected by the upheaval which in middle life forced him to leave his country; this is a reflection of his overwhelming absorption in his chosen work, an absorption which at times excluded all other interests. He has his reward in that his achievement will stand as one of the major contributions to organic chemistry.

C. R. HARINGTON.

MARY BOYLE.

1874—1944.

Mary Boyle was a student at the Royal College of Science for two years (1899—1901), during which period she took the full three-year course in Chemistry, and received the Frank Hatton Prize, awarded to the student heading the list in the final examination. She took the B.Sc. (London) after a year (1901—1902) as a student at Royal Holloway College, where she remained as Assistant Lecturer and Lecturer until **1933**. She was awarded the D.Sc. in **1910**, the subject of her research being the iodosulphonic acids of benzene; her work on this group, which involved the isolation and orientation of many related nitro- and amino-sulphonic acids, was published in the *Journal* between **1910** and **1919**, and remains the principal work on the subject.

Dr. Boyle was a lucid and accurate lecturer on Organic Chemistry, and though in the latter part of her career she did little research, her interest in investigation never flagged, and she kept herself well informed on modern developments; she was very successful as a teacher of practical technique, being herself an excellent manipulator.

Apart from chemistry, Dr. Boyle's chief interests were music, photography, and bridge, in all of which she was expert. Her joyful appreciation of all good music, her excellence as a solo pianist and as a ready and sensitive accompanist, helped greatly to establish and maintain the musical tradition of the College. In all her activities she showed an almost unlimited aptitude for co-operation, and the influence of her personality, of which the outstanding characteristics were high principles, tolerance, and on occasion, fun and high spirits, extended over a wide variety of students, to their lasting advantage.

On her retirement in **1933** Dr. Boyle settled in Leeds near her family, and the contact with younger generations which had been so essential a feature of her life at College, was maintained through her numerous nieces and nephews and their children. She found many ways of serving the community; for several years she was Treasurer of the Leeds and District Nursing Association; from the beginning of the war she was Treasurer of the Lady Mayoress's Welfare Committee and a Visitor for the Soldiers', Sailors', and Airmen's Families Association. To within a few days of her death she lived a full, happy, and useful life. She will be remembered with affection and gratitude by many.

T. S. Moore.
M. A. Whiteley.

JOHN JACOB FOX.

1874—1944.

John Jacob Fox, eldest son of the late Mark and Hannah Fox, was born on 12th April, 1874. He entered Government Service in 1896 and after attending a course at the Royal College of Science was a chemist at the Government Laboratory from 1904. He became Superintending Chemist in 1920, Deputy Government Chemist in 1929, and Government Chemist in 1936, occupying this position until his death on 28th November, 1944.

The present writer made the acquaintance of Fox in 1899 or 1900. After taking a chemistry course at the Royal College of Science, he joined classes at East London Technical (now Queen Mary) College with a view to keeping up his chemical work. The Royal College has always insisted on accurate practical work, and Fox, like many others, had profited thereby. As he was not cramming for a degree and had a genuine interest in scientific knowledge for its own sake, it was obviously desirable to get him on to some original work, and the results of his first research were communicated to the Chemical Society (Hewitt and Fox, J., 1901, **79**, 49). In this paper it was shown that benzeneazosalicylic acid yields benzeneazonitrosalicylic acid ($CO_2H : OH : NO_2 : N_2Ph = 1 : 2 : 3 : 5$) when warmed with dilute nitric acid but gives the known *p*-nitrobenzeneazosalicylic acid (Meldola, J., 1885, **47**, 666) on nitration in concentrated sulphuric acid.

In a further paper by the same authors (J., 1908, **93**, 333) the question of the constitution of the salts formed by *p*-hydroxyazo-compounds with acids was discussed; these were formulated as oxonium salts of the quinone-hydrazone form, since substitution in presence of strong acids takes place in the non-phenolic nucleus, whilst the light absorptions of parent azophenols and their alkyl ethers in presence of strong acids are very similar.

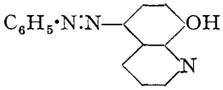
The above-named authors also published two papers on acridine derivatives (J., 1904, **85**, 529; 1905, **87**, 1058) which resulted in the preparation of an anhydro-base from the carbinol pseudo-base corresponding to the (acridinium) methiodide derived from benzoflavine.

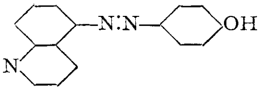
Fox continued to work at hydroxyazo-compounds and obtained some noteworthy results.

Having observed that methyl-orange was useless as an indicator in presence of warm dilute nitric acid, he examined the reaction between these two substances (*Ber.*, 1908, **41**, 1989) and found that the products isolated were dinitro*mono*methylaniline and diazosulphanilic acid. The elimination of a methyl group is consistent with a quinonoid structure of a nitrate in which the methyl-orange functions as a base in virtue of its dimethylamino-group.

After measuring the dissociation constants of 8-hydroxyquinoline (J., 1910, **97**, 1110) and showing that the compound was a weaker base than aniline and a weaker acid than phenol, Fox coupled the substance with diazotised aniline to give (I) and prepared an isomeric hydroxyazo-compound by diazotisation of 5-aminoquinoline and coupling it with phenol to give (II). Both compounds give monohydrochlorides with ease, and the second gives a relatively stable dihydrochloride, whilst the dihydrochloride of the isomeride loses one molecule of hydrogen chloride on exposure to the air. Another peculiarity of the arylazo-8-hydroxyquinolines is their resistance to acylation, even under drastic conditions.

(I.)





(II.)

The absorption spectra (ultra-violet and visible) of amino- and hydroxy-azobenzene and the alkyl ethers of the latter compound have been measured and given rise to much discussion with regard to their bearing on the choice of azoid or quinonoid structure. As it was desirable to add an examination of thiol derivatives, preparation of substances of the type C_6H_5·N:N·C_6H_4·SR (R = H or alkyl) was undertaken, but the isolation of benzeneazophenylmercaptan in a pure state proved impossible (Fox and F. G. Pope, J., 1912, **101**, 1498). The methyl and ethyl mercaptols were obtained, however, by diazotising aniline, converting it into a xanthic ester (see Leuckart, *J. pr. Chem.*, 1890, **42**, 187), hydrolysing this with alkali, and treating it with an excess of alkyl iodide without attempting to isolate the thiol. These mercaptols gave hydrochlorides (1HCl) which lost their acid in moist air, yielding hydrates ($\frac{1}{2}H_2O$). Attempts at adding alkyl halides were unsuccessful. The absorption spectrum of the methyl mercaptol is of interest, being of the same type as the spectra of benzeneazophenetole and aminoazobenzene but intermediate with regard to the maximum frequency.

Fox and Pope subsequently measured the absorption spectra of phenylmercaptan in alcohol, with and without sodium ethoxide, and of diphenyl sulphide and disulphide in alcohol. A well-marked absorption band was only obtained with the sodium salt of phenylmercaptan (J., 1913, **103**, 1263).

The results obtained by Fox in his work on azo-compounds are consistent with an azoid formulation of the free amino- or hydroxy-derivatives, whilst their salts with strong acids are derived from quinone-hydrazones. In those days links were single or double as the case might be, the electron had not made its appearance in organic chemistry, and " resonance " was unheard of. But even if two " canonical " structures should be taken into account in the case of benzeneazophenol and related compounds it would be necessary to admit that the hydroxyazo- was overwhelmingly more important than the quinonehydrazone formulation.

Besides the work Fox was carrying out at East London College, certain organic problems were examined at the Government Laboratory. The possibility of titrating boric acid with alkali in presence of an excess of mannitol raised the question of whether it would be possible to isolate a mannitoboric acid. This was accomplished by boiling mannitol and boric acid in alcohol and crystallisation; in this way tufts of prisms were obtained which melted sharply at 89·5°. Complete analysis and molecular-weight determination agreed with the formula $C_6H_{15}O_8B$, and silver, calcium, and barium salts were prepared (Fox and Gauge, J., 1911, **99**, 1075).

The appointment of Sir James Dobbie as Government Chemist led to more organic research work at Clement's Inn; in this Fox collaborated. Two papers appeared on the absorption spectra of alkaloids (Dobbie and Fox, J., 1913, **103**, 1193; 1914, **105**, 1639) as well as one on mediaeval wax seals (J., 1914, **105**, 795).

By the action of sodium on 2 : 2′-dibromodiphenyl, a hydrocarbon was obtained which was taken to be diphenylene (m. p. 74·5—75°), since it reverts to dibromodiphenyl on treatment with bromine (Dobbie, Fox, and Gauge, J., 1911, **99**, 1615; 1913, **103**, 36). Later investigators have failed to confirm this reaction, but Lothrop (*J. Amer. Chem. Soc.*, 1941, **63**, 1187) has obtained a hydrocarbon, $C_{12}H_8$, m. p. 110°, by distilling 2 : 2′-dibromo- (or better, di-iodo-)diphenyl with cuprous oxide; this result has been confirmed by Wilson Baker and his co-workers, and the question of the existence of diphenylene has been treated at some length in the last Tilden lecture (this vol., p. 265).

Fox was more interested in the application of physical methods to the solution of chemical problems than in purely organic work, and Dobbie and Fox applied ultra-violet spectroscopy to the question of the complexity of elements in the gaseous state. Sulphur was examined (*Proc. Roy. Soc.*, 1919, *A*, **95**, 484) as it was known to consist of S_2 molecules between 860° and 1040° (Deville and Troost) whilst at lower temperatures the vapour density increases and approaches that required for S_8 (Biltz; Bleier and Kohn). It might be supposed that the complex molecules dissociated into the S_2 molecules and that intermediate densities were merely due to equilibrium between S_8 and $4S_2$. Howe and Hammer (*J. Amer. Chem. Soc.*, 1898, **20**, 757) found that sulphur vapour first darkened in colour and then became lighter again as the temperature was raised, and Dobbie and Fox found that the absorption in the visible spectrum spread towards the red on heating to 650° and then receded again on further heating. This is incompatible with continuous dissociation from S_8 to S_2; between these extremes there must be molecules of different absorbing power, and S_3 was suggested as a possibility.

A second paper dealing with the absorption spectra of selenium, tellurium, mercury, zinc, cadmium, phosphorus, arsenic and antimony (*ibid.*, 1920, *A*, **98**, 147) showed that the maximum absorption of selenium vapour occurs near 650°, whilst in the case of tellurium the maximum absorption is reached near 1250° after which there is a slight diminution at 1350°. Mercury, zinc and cadmium showed no general absorption up to $\lambda = 3100$; with phosphorus, arsenic and antimony the absorption was progressive with increasing temperature.

The absorption spectra of the halogens (*ibid.*, 1921, *A*, **99**, 456) showed maxima in the case of bromine and iodine as the temperature was raised; for this an explanation is suggested (*ibid.*, p. 460).

Sir Robert Robertson succeeded Sir J. J. Dobbie at the Government Laboratory, and instead of the ultra-violet the infra-red now engaged attention; for this there was a specific reason. " For a projected investigation on the rate of decomposition of an explosive gas, arsenic hydride, it became necessary to know its absorption in the region of the infra-red. . . . Interest in the absorption spectrum of arsenic hydride led to the exploration of the same region for phosphine and ammonia." Considerable experimental difficulties were experienced, partly on account of the laboratory being situated near traffic and electric stations; these were overcome, and the results were recorded in a series of papers [Robertson, Fox, and (in part) E. S. Hiscocks, *Proc. Roy. Soc.*, 1928, *A*, **120**, 128, 149, 161, 189]. These deal with (i) the apparatus (prism spectrometer) employed, (ii) the calibration of the spectrometer and the preparation of the three hydrides in a pure condition, (iii) the infra-red absorption spectra of the latter, and (iv) discussion of the absorption bands. Where possible, the bands were resolved and their fine structure described (P, Q, and R branches), the results being used to calculate moments of inertia and radii of gyration. The authors were in favour of a tetrahedral (not plane) configuration in each case, but note that Watson found only small electric moment in the case of arsine.

This infra-red work was followed a few years later by the monumental paper on " Two Types of Diamond " (Sir R. Robertson, J. J. Fox, and A. E. Martin, *Phil. Trans.*, 1934, **232**, 463—535). A number of diamonds supplied by Professor W. T. Gordon were examined with regard to infra-red absorption and, of these, all gave a large band at 8 μ with one exception. The ultra-violet spectrum was then explored, and it was found that the exceptional diamond was transparent to $\lambda = 2250$ whilst all the others were opaque beyond $\lambda = 3000$. With regard to the water-whiteness, density, refractive index, dielectric constant and Raman frequency, the two sets agreed, but it was noted that the transparent diamond was made up of a large number of parallel laminæ and it was more nearly isotropic when examined by polarised light. *X*-Ray examination was at first inconclusive, but it was subsequently found that there was some difference.

Other specimens of transparent diamonds were obtained later, and the two types subjected to a comparison of physical properties. One of the most remarkable of these was the photo-electric conductivity; the majority of the diamonds were only feebly conductive, even when high voltages were applied, but the transparent variety gave measurable currents with small applied potentials or even with none at all. The activation was produced with light of $\lambda = 2300$ and it persists for a considerable time if the diamond be kept in the dark. But if light of $\lambda = 2400$—5000 be applied, the conductivity is for a time greatly increased, but the larger part of this photo-conductivity rapidly disappears.

A later paper (*Proc. Roy. Soc.*, 1936, *A*, **157**, 579) extends these observations, emission as well as absorption spectra being measured, and a comparison made with graphite. The way in which Kirchoff's law is obeyed, even down to fine structure, is remarkable.

The infra-red absorption spectra (region 3 μ) of a number of organic compounds were examined by Fox and Martin (*ibid.*, 1938, *A*, **167**, 257), and the results used for calculating the force constants of various C–H and C–C linkages. These were afterwards correlated with heats of rupture of linkages and internuclear separation of the atoms concerned (J., 1938, 2106). Two curves are given in this paper; one compares internuclear distance with heat of rupture, the second gives the relation between bond order and heat of rupture. A smooth curve drawn through the points for acetylene (bond order 3), ethylene (2), and hydrocarbons (1) finishes at the origin (bond order 0) as it should. The bond orders for graphite and benzene are marked on the curve at 1·45 and 1·62 respectively, agreeing with the calculated values found by Penney (*Proc. Roy. Soc.*, 1937, *A*, **158**, 306).

In a further paper (J., 1939, 884) the same authors derive a potential function which they compare with the Morse function

$$U = D[\mathrm{e}^{-2ax} - 2\mathrm{e}^{-ax}]$$

Utilising some results obtained by Sutherland, they are able to write

$$U/D = [\mathrm{e}^{-6\cdot 44(r/r_e - 1)} - 2\mathrm{e}^{-3\cdot 22(r/r_e - 1)}]$$

and plotting U/D against r/r_e they obtain a type of Morse curve which applies to *all* carbon-to-carbon linkages.

One other paper (Fox and Martin, J., **1939**, **318**) on infra-red spectra in the **3** μ region of naphthalene, α- and β-methylnaphthalenes, quinoline and *iso*quinoline shows how the results may be of use analytically. Similar methods seem to be making progress in America at the present time.

Fox took a scientific interest in analytical problems, one of his earliest independent researches describing the separation of cadmium from zinc as sulphide in the presence of trichloroacetic acid (J., **1907**, **91**, 964).

The problem of the solubility of lead sulphate in solutions of alkaline acetates then engaged his attention. He first showed that a solution of lead sulphate in 3N-ammonium acetate deposits crystals of the composition $Pb(NH_4)_2(SO_4)_2$ (Proc., 1907, 23, 200). Further information was gained by measuring the solubility of lead sulphate in concentrated solutions of sodium and potassium acetates (J., 1909, **95**, 878). One reason for using these two acetates was the fact that lead sulphate is not dissolved by solutions of the corresponding sulphates whilst it dissolves comparatively easily in ammonium sulphate. Experiments at 25° showed that the solubility increased more rapidly than the concentration of acetate, as might be expected, and the interesting fact was established that when potassium acetate was used, the solid phase contained the double sulphate $PbK_2(SO_4)_2$, no sulphate ions being found in solution. With sodium acetate, sulphate as well as lead acetate went into solution and the solid phase consisted of lead sulphate. Fox remarks that the absence of sulphates in the equilibrium solutions in the case of potassium acetate confirms the supposition that the solubility of lead sulphate is due to the formation of non-ionised lead acetate (Noyes, *Amer. Chem. J.*, **1905**, **27**, **747**).

The work at the Government Laboratory is, of necessity, largely of an analytical character, and this often engaged Fox's attention. He was an adept at improving methods both as regards processes and apparatus, and some of this analytical work has been published. Reference may be made to papers on the analysis of cresols (with M. F. Barker, *J. Soc. Chem. Ind.*, 1917, **36**, 842T; 1918, **37**, 265T; 1920, **39**, 169T); aluminium alloys (with E. W. Skelton and F. R. Ennos, *ibid.*, 1918, **37**, 328) in which separations from Pb, Mn, Si, Cu, Sn, Fe, Zn (high or low %), Mg and Ni are given; cobalt blues, their nature, preparation, uses and analysis (*J. Oil Colour Chem. Assoc.*, 1926, **9**, 304); zinc chromes (with B. A. Ellis and J. F. Hirst, *ibid.*, 1928, **11**, 194; with J. L. Buchan, *ibid.*, p. 198; further work by A. G. Francis, C. O. Harvey and J. L. Buchan); recent analytical methods (*ibid.*, 1929, **12**, 38) and recent work on analytical problems (*Oil and Col. Trade J.*, 1937, **91**, 993, 995). Other papers deal with stone decay (with T. W. Harrison, *J. Soc. Chem. Ind.*, 1925, **44**, 145T) and sulphur in flue gases (with L. G. Groves, *ibid.*, 1932, **51**, 7T).

The present writer has to thank Dr. A. G. Francis, Deputy (Acting) Government Chemist for details of Fox's official career, of which Dr. Francis gave an account in *Nature* (1945, **155**, 13) and *The Analyst* (1945, **70**, 1). Fox was at first in the Crown Contracts Department but was soon chosen by Sir Edward Thorpe to assist in the work of the Departmental Committee set up to investigate the possibility of finding substitutes for white lead to avoid the dangers of plumbism. When war broke out in 1914, much extra work was thrown on the Government Laboratory, and Fox devised rapid methods for the analysis of ferrous and non-ferrous alloys, whilst his wide knowledge enabled him to advise Departments on many matters.

The passing of The Safeguarding of Industries Act led to Fox organising a section dealing with the work entailed. " It was largely owing to his encyclopædic knowledge of organic chemistry and his sound judgment that the administration of the Act proceeded smoothly " (Dr. Francis, *Analyst, loc. cit.*).

The causes of the decay of buildings (Fox and Harrison, *J. Soc. Chem. Ind.*, 1925, **44**, 145T), drainage from tarred roads into rivers (Fox and Gauge, *ibid.*, 1920, **39**, 260T; 1922, **41**, 173T), the cleaning and restoration of wall paintings (Chapter House, Westminster, and the Orangery, Hampton Court) and bituminous filling compounds for electrical apparatus (*Proc. World Petroleum Congr.*, 1933, **2**, 595) also claimed his attention. The duties on silk, rayon and hydrocarbon oils necessitated the organisation of sections of the laboratory.

Fox had a lively interest in the claims of industry, and the present writer has had proof of the appreciation this evinced in conversation with technical men. One remarked, " he wouldn't just send you a letter but came round and talked over the matter." He was Chairman of the Road Tar Research Committee and of the Committee on Physico-chemical Problems of the Building Research Board.

Fox had matriculated at some time at London University but did not take the Intermediate Science examination (at East London College) until 1906 or 1907. This was followed by the B.Sc. " by research " (1908) and the D.Sc. (1910). His interest in Queen Mary College never flagged; he was made a Fellow in 1937, was Past President of the Old Students' Association (1922), and was one of its Honorary Auditors at the time of his death. There is a small circle of old students which meets (in peace time) three or four times a year, and Fox attended the informal dinners regularly.

In his younger days he frequently spent his leave from the Government Laboratory working at East London College, generally from morning to late evening. His energy was great, his work exact and his judgment sound. If he had two dislikes, they were experimental inaccuracy and sloppy thinking. Despite all the calls on his time, he was always ready to give help or advice to those who needed it; a lovable as well as a respected man.

Fox joined the Chemical Society in 1907, served on the Council 1922—1925, 1935—1938, 1941—1944, and contributed to the *Annual Reports* (Analytical Section) for ten years (1925—1934).

He joined the Institute of Chemistry in 1916 and was President, 1940—1942. He had been Chairman of the Oil and Colour Chemists' Association and of the London Section of the Society of Chemical Industry, on the Council of which he served.

He received the O.B.E. in 1920, the C.B. in 1938, was elected F.R.S. in 1943, and was knighted in 1944.

In 1899 he married Amelia, daughter of Charles and Elizabeth Boas; she survives him with a son (now in India with the R.A.F.) and a daughter (Mrs. Diffley). They have the sincere sympathy of their many friends.

J. T. HEWITT.

RONALD WILLIAM HAMILTON O'DONNELL.

1913—1944.

RONALD WILLIAM HAMILTON O'DONNELL was born in Aigburth, Liverpool, on August 7th, 1913, and was educated at the Alsop High School in that city, matriculating with distinction in mathematics at the early age of thirteen. Proceeding to the University of Liverpool, he graduated in the Honours School of Chemistry in 1934. A period of three years, at the end of which he received his Doctorate in Philosophy, was then spent in the Organic Chemical Research Laboratories, where, under the direction of Professor A. Robertson, he undertook research on the chemistry of natural products. The results of this work, published in the *Journal*, include contributions to the chemistry of rotenone and its derivatives and of picrotoxinin.

Whilst at the University, he took a very active part in student affairs, especially in all matters concerned with the University Chemical Society. One of his great hobbies was amateur theatricals, and he showed considerable talent as a producer. The Annual Concerts of the University Chemical Society were, under his direction, especially memorable affairs. He was elected President of that Society in 1937.

Leaving the University in 1937, O'Donnell obtained an appointment in the Research Laboratories of Messrs. Imperial Chemical Industries (General Chemicals) Limited, at Widnes, where he was quickly promoted to the position of an Assistant Research Manager. Unfortunately, early in 1941, ill-health made it necessary for him to spend some twenty months in a sanatorium. Responding to treatment, he then took up an appointment with Messrs. Plant Protection Limited, Jeallots Hill, but the following winter, a recurrence of his previous complaint led him to undergo further treatment at Axbridge, Somerset, where he died on July 16th, 1944.

The courage and fortitude with which O'Donnell battled against ill-health over a number of years, especially during his last illness, when owing to geographical reasons visitors were very few, remain after his passing a lasting inspiration and example to his many friends.

W. N. Howell.

FORSYTH JAMES WILSON.

1880—1944.

Forsyth James Wilson died suddenly on October 18th, 1944, whilst still actively engaged with his duties in The Royal Technical College, Glasgow. With his passing the chemical societies and the teaching profession have lost an enthusiastic member.

Born at Moffat in 1880, Wilson graduated with distinction from Edinburgh University and thereafter proceeded to Leipzig University, from which he obtained the degree of Ph.D. in 1905, and finally in 1910 he was awarded the degree of D.Sc. of Edinburgh University.

While in Leipzig, Wilson came under the influence of Hantzsch, Stobbe, and others, and organic chemistry became his chief interest.

On returning to this country he undertook research in dyes with Professor A. G. Green at Leeds, and in 1906 was appointed chief assistant to Professor G. G. Henderson in the Royal Technical College, Glasgow. This appointment he held until the outbreak of war in 1914, when he volunteered for service and obtained a commission in the 17th Battalion of the H.L.I. He was on active service from 1915, first as instructor in gas defence, and finally, until the armistice, as Chemical Adviser to the 11th Army Corps. In the latter capacity he was overseas for a large part of the time and did some valuable work in connection with gas warfare.

On being demobilised, he returned to the Royal Technical College, and on the transference of Professor G. G. Henderson to the University of Glasgow, was appointed to the chair of Inorganic and Analytical Chemistry. This appointment he held until the resignation of Professor I. M. Heilbron from the chair of Organic Chemistry, when Wilson, whose heart had always been in organic chemistry, asked to be transferred to that chair.

With the death of Professor R. M. Caven, who had succeeded Wilson in the chair of Inorganic and Analytical Chemistry, the two chairs were united in the Freeland Chair of Chemistry, and Wilson received the appointment which he held until his death. He took a keen interest in the activities of the various chemical societies, seldom missed a local meeting, and served on the Councils of the Chemical Society, the Society of Chemical Industry, and the Royal Institute of Chemistry.

Wilson was a lucid teacher and a keen research worker and did much to stimulate the interest of these students working under him. Many are the men whom he has guided into the right paths both in chemical research and in industry. It is a tribute to his personality that these students, no matter how far from their native land their appointments took them, remembered Professor Wilson, kept in touch with him by letter, and never failed to visit him on their return to Glasgow.

Wilson was unmarried, but his home, which he shared with a much-loved sister who predeceased him by only a few months, was a centre of hospitality for his friends and colleagues. He had a great love of Scottish scenery and his vacations were mostly spent in exploring the Highlands or the Southern Uplands. Nothing gave him greater pleasure on these occasions than the hours he spent with his maps planning each day's itinerary. As a record of his ramblings he had a collection of very beautiful photographs, especially of the Cairngorms, where it was his wish that his ashes should be strewn. He will be long remembered by his staff in the Royal Technical College for his kindness, consideration, and his unfailing courtesy to each member.

Wilson was a regular contributor to the *Journal of the Chemical Society* and published over fifty original papers, mostly in this journal. He was joint author, with Professor Heilbron, of a small book "Chemical Theory and Calculations," a book written whilst the authors were fellow assistants on the staff of the Chemistry Department of the Royal Technical College and at a time when they felt the need for such a volume in the course of their teaching.

Wilson's first interest was in stereoisomerism and polymorphism in unsaturated ketones, doubtless stimulated by his work with Stobbe when studying for his doctorate in Leipzig.

Various papers appear in this connection, for example, ketones of the type of benzaldehydedeoxybenzoin (with Stobbe, *Annalen*, 1910; J., 1910). In 1911 he started, along with Heilbron, a series of experiments on the properties of semicarbazones (J., 1911—1912). In this work the authors found that the semicarbazones of phenyl styryl ketone exist in several modifications. They investigated the absorption spectra of these in alcoholic solution, with and without sodium ethoxide, and concluded that phenyl styryl ketone yields four stereoisomeric semicarbazones, two stable under ordinary conditions and two existing in alkaline solution. This work was continued upon a simple aliphatic ketone, namely, mesityl oxide, and again stereoisomerism was observed in the semicarbazones. The research on semicarbazones was further extended to the action of heat on the compounds of phenyl styryl ketone and the preparation of the corresponding phenylsemicarbazones (J., **1913**). This line of research was still in progress at the outbreak of war in 1914, and a note on the action of hydrogen chloride on semicarbazones, the conclusions from which were not cleared up, terminated the series of publications.

With the end of hostilities, and the return of Wilson to academic life, his interest was still in semicarbazones, and in 1922 he published (with Hopper and Crawford) a paper on the action of amines on semicarbazones and the preparation of an optically active semicarbazide in which are described the preparation and properties of *d*-α-phenylethylsemicarbazide, giving a rotation of $[\alpha]_{\mathrm{D}}^{12\cdot 2^{\circ}}$ 66° in aqueous solution.

Attention was directed in the same year to reactions of thiosemicarbazones (with Burns). In most of his research Wilson's interest centred round hydrazine derivatives, and in 1923 a paper was published on derivatives of semioxamazide (with Pickering). Between 1924 and 1927 there were several publications on the action of hydrazines and amines on semicarbazones (with Sutherland, with Baird, and with Crawford).

An important paper on the resolution of benzoin next appeared and both the *d*- and the *l*-form were isolated (with Hopper, J., **1928**). Benzoin was again resolved by a different method using *l*-δ-menthylsemicarbazide (with Crawford, J., **1934**). In the course of this work it was found that acetic acid, besides acting as a buffering agent to reduce acidity in condensation of semicarbazide hydrochlorides and ketones, acted as a catalyst in semicarbazone formation. A further resolution was accomplished by using *d*- and *l*-δ-(α-phenylpropyl)semicarbazides (with Little and McLean, J., **1940**).

Numerous papers on a variety of subjects were published from time to time. About ten years ago Wilson became interested in chemotherapy and his research from then until his death was mainly on that subject. A series of papers were published on the preparation and therapeutic properties of anil and styryl derivatives of acridine and styryl derivatives of quinoline (with Sutherland and Glen; with Sutherland and Sharp, J., **1936**, **1938**, **1939**, **1943**). Wilson was engaged on this research at the time of his death, a section being almost ready for publication.

Throughout his long association with the Chemistry Department of the Royal Technical College, and in spite of the heavy toll administrative work took on his time, Wilson never lost his enthusiasm for research, and inspired those with whom he worked with the same spirit.

It has been the privilege of the writer to collaborate with Professor Wilson in much of his later research and she therefore takes this opportunity to pay tribute to a kind and inspiring teacher and friend.

M. M. J. SUTHERLAND.