followed by a stream of other writings dealing with the characteristics and transformations of these series, and with their applications to several well-known functions of importance in mathematical physics. This group of discoveries has enriched the region of mathematics in which Stirling was the pioneer two centuries ago, and where the methods of approximation are reduced to a precise science. These include the method of 'steepest descent', and any account of asymptotic series to-day must be based to a great extent upon Watson's discoveries.

About that time many of the ablest pure mathematicians were trying to sum a difficult oscillating series involving Bessel and Legendre functions, which had presented itself in the theory of the diffraction of wireless waves round the earth. Watson solved the problem by a new method (1918), and went on to study the more difficult case of the transmission of electric waves when it was assumed that the earth is surrounded by a concentric conducting layer, as suggested by Heaviside. Watson's powerful analysis made possible a great advance in the physical theory.

Another example of his capacity for providing a brilliant solution of a problem which had been attempted by many of his predecessors is furnished by his paper on the Rogers-Ramanujan identities. Following this came his work on general transforms in which he solved a problem which many celebrated mathematicians had attempted without success. This is probably Watson's greatest achievement, and ranks as one of the most important contributions to the subject made in recent years. In addition it has had the great merit of inspiring a large amount of work by other mathematicians. Among the more notable papers of the next years were those on "Generating Functions of Class-Numbers", on Ramanujan's continued fraction, and one that gave the proof of Ramanujan's assertion about the number 691 which occurs in 'almost all' the terms of a certain infinite product when expressed as a series. The series of papers on singular moduli, during the period 1932-36, are deservedly celebrated.

His great book on Bessel functions is perhaps the most impressive single work that has ever been written on the analysis of functions. In collaborating with Prof. E. T. Whittaker in the second and later editions of "Modern Analysis", he has shown the same breadth and power and has influenced the course of higher analytical mathematical teaching throughout the world.

Hughes Medal

The Hughes Medal is awarded to Prof. John Turton Randall, Wheatstone professor of physics at King's College, University of London, in recognition of his distinguished contributions to applied physics, and especially of his development of the magnetron.

In 1940 Prof. Randall, while working in the laboratory of Prof. M. L. Oliphant, at Birmingham, agreed to join Dr. H. A. H. Boot in an endeavour to utilize the magnetron principle for the production of electromagnetic waves of frequency greater than 3,000 Mc./sec. Previous work in the laboratory had shown that satisfactory circuits for these wavelengths must be an integral part of the internal structure of the valve itself. Randall and Boot together put forward the suggestions that such a circuit, for a multi-segment magnetron, should consist of a revolver-like arrangement of holes, spaced evenly about a circle, each hole communicating by means of a slot with a central cavity in which the

cathode was mounted. The first trials with demountable valves using tungsten cathodes were immediately successful, and it was shown that the suggested form of valve can generate continuously oscillations of the required wave-length.

With the assistance of S. M. Duke, Randall and Boot were able to develop methods of construction of the magnetron which enabled oxide-coated cathodes to be used, and which therefore gave high powers when the valve was subjected to pulsed operation. Empirical investigation fixed the best coupling arrangement by which the power could be fed into an external circuit. Careful investigation of the operation of a valve showed that it was subject to sudden changes of wave-length, a condition which limited its applicability to Service equipment. This difficulty was overcome by the 'strapping' methods developed by Dr. J. Sayers.

There is little doubt that the magnetron valve was the prime factor in the improvements made in radar during the War, and Randall deserves a very large share of the credit for this development.

He contributed also to the problem of crystal detection of centimetre waves.

Randall's studies of fluorescence and phosphorescence were of a high standard, and his careful and painstaking experimental work did much to establish on a firm basis the theories of semi-conductors developed by Wilson and others, and especially the assumptions about the existence of 'electron traps'. His work on practicable phosphors has been of importance in the development of fluorescent lamps, and of the screens of cathode-ray tubes.

Randall has also made contributions to the X-ray investigation of the structures of glasses and of liquids, and he developed satisfactory forms of oxide cathodes for the fluorescent lamps.

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ELECTROMETRIC ANALYSIS

A JOINT meeting of the Physical Methods Group of the Society of Public Analysts and other Analytical Chemists, the Cardiff and District Section of the Royal Institute of Chemistry and the South Wales Section of the Society of Chemical Industry was held at University College, Cathays Park, Cardiff, on October 11, when three papers were read on "Electrometric Analysis".

In discussing the improvements to pH-measuring apparatus for use with the glass electrode, Mr. A. D. Elmsly Lauchlan pointed out that if the glass electrode is to be robust, its resistance will be very high, and accurate results can only be obtained if the valve is arranged to have a high grid resistance, such as 10^{13} ohms, and the lead from the electrode to the valve is well screened and carefully insulated; a leakage of 10^9 ohms can produce errors of about 8-9 per cent. The use of modern insulating materials, however, has raised the insulation to such a level as to make error from this source negligible. Small four-electrode valves are now used instead of the large special electrometer types, and an instrument was shown in which these improvements have been carried out.

Some manufacturers in the United States have adopted the electronic detector, the so-called 'magic eye', in place of the usual galvanometer; but possibly on account of its slightly lower sensitivity and the difficulty in noticing small changes in the shadow at

the balance point, it has not been used on pH meters in Great Britain. The expansion of automatic recording and controlling of pH has been largely due to such improvements as have been made in manually operated instruments, rather than to any particular feature of the recorder itself.

Improvements in the glass electrode due to the use of pure materials free from aluminium oxide have enabled theoretical results to be obtained over a wide range of pH. Such electrodes are thick and strong, and can be made as small as 2.5 mm. in diameter; they are useful for micro-tests and for medical and dental work.

Further improvements have resulted in the production of a glass electrode for use in the alkaline range up to pH 14; the sodium ion error of a 1 *N* solution at pH 12 is zero with the new electrode, whereas for the usual type it is about 0.6 pH. The accuracy of such an electrode was about 0.02 pH. Examples of various types of glass electrode were shown.

The latest types of electro-titration apparatus are much neater and smaller than the prototypes, and here again the galvanometer or the 'magic eye' is employed as the detector of the equivalence point. The slightly lower sensitivity of the 'magic eye' is of less importance, as much larger potential changes are encountered. The instruments are battery- or mains-operated, depending on the detector used, and there is little to choose between them in a matter of convenience. Both types were suitable for all the usual acid-alkali and potentiometric titrations, and a demonstration of the latter was given showing the large deflexion at the equivalence point with one drop of a dilute solution. These instruments are especially convenient for the 'dead stop' end-point method, which is rapidly finding new fields.

The applications of the electro-titration apparatus were discussed more fully by Mr. R. J. Carter, who dealt with acid-alkali, precipitation and oxidation-reduction types in general, and with the Karl Fischer method of determining small amounts of water in some detail. Electrometric methods for acid-alkali titrations are particularly suitable where feebly dissociated acids and bases give poor end-points; accurate results can nearly always be obtained by noting the change of sign of the second differential when the E.M.F. is plotted against the volume of the reagent used. Titrations can also be carried out in non-aqueous media made conducting by the addition of lithium chloride, or by using a mixed solvent such as benzene and isopropyl alcohol with 1 per cent of water. The solvent must permit sufficient ionization of acidic materials of dissociation constants greater than 10^{-7} in water.

A method for determining the saponification number of fats and oils, which avoids the need for a blank titration, was described. The titration curve obtained, after saponifying the oil, by titrating with acid shows two breaks; the acid added in the portion between the two inflexion points on the curve is the amount required to liberate the free fatty acid, and this is equivalent to the saponification number of the oil.

A series of graphs giving the types of titration curves obtained with various non-aqueous solvents was shown, indicating that by a choice of a suitable solvent it is easy to distinguish between acids the *pK_a* (aqueous) values of which are very close together.

In many potentiometric titrations, particularly those involving the use of silver, there is a danger that the liquid from the reference cell may leak out

and contaminate the test solution. This difficulty is neatly overcome by the use of the glass electrode as reference cell, provided the hydrogen ion activity of the solution does not change appreciably.

Examples were given of the titration of two ions in solution in the presence of each other, such as hydrogen sulphide and thiophenol, by titrating with *N*/10 alcoholic silver nitrate in *N*/10 alcoholic sodium acetate, a procedure comparable with the estimation of mercaptans in petroleum. Graphs were also shown of titration curves of the simultaneous determination of iodide and chloride, and of thiocyanate and chloride.

The oxidation-reduction titration by ferrous ammonium sulphate of the nitrate ion, formed by the decomposition of nitroguanidine with concentrated sulphuric acid, and its possible application to the estimation of nitrourea, were mentioned, together with the determination of fluorine in organic compounds with cerous nitrate, as interesting extensions of older methods.

Polarization end-points, discussed in principle in the third paper, were shown to have applications to already existing methods, such as the determination of dissolved oxygen in water and of ascorbic acid by means of 2,6-dichlorophenol indophenol. The method offers greater sensitivity than the starch indicator and is also capable of high accuracy in coloured solutions.

Perhaps the most outstanding use to which the method has been placed is the determination of small amounts of water by means of the Karl Fischer reagent, used for the determination of moistures. The material of which the water content is to be determined is mixed with a solution of iodine in pyridine saturated with sulphur dioxide; the water in the sample allows some of the iodine and sulphur dioxide to react, and the excess iodine is found by back titration with methanol containing a known quantity of water. The complete removal of the iodine at the end-point allows the cathode to become polarized and the galvanometer needle returns to zero. By the use of a higher polarizing E.M.F. of 1–2 volts instead of the more usual 15–20 millivolts, it has been found possible to make a direct titration, when the end-point is given by the excess iodine depolarizing the cathode and causing the galvanometer needle to be deflected.

From the amount of literature on the subject, the method appears to have almost unlimited applications, such as the estimation of organic radicals, carbonyl compounds by reaction with hydroxylamine hydrochloride, the hydration of salts, and the analysis of mixtures of primary and secondary amines.

It was a pity that Dr. D. P. Evans's paper on polarization end-points could not be given in full, owing to the lateness of the hour, as this subject is well worth careful study by those interested in improving existing titrations and also in finding new volumetric methods. A brief description was presented of the principle of the polarization end-point, which was first given proper recognition by Foulk and Bowden in the United States; the method is particularly attractive as the ease of determining the equivalence point is much greater than with the potentiometric methods, the attainment of equilibrium being almost instantaneous.

When two noble metal electrodes are immersed in a solution and are connected to a source of E.M.F. less than the maximum back E.M.F. developed by the system, a current will flow for a short time until

small quantities of oxygen and hydrogen have been deposited on the anode and cathode. The back E.M.F. developed then reduces the current to an extremely small value, so that a galvanometer connected in series with the electrodes almost immediately shows no deflexion, or at the most only a small displacement of the needle. The subsequent addition of a substance capable of depolarizing one of the electrodes gives rise to a deflexion on the galvanometer.

In order to demonstrate the method, a titration of $N/500$ sodium thiosulphate with iodine was shown. With the electrodes immersed in the solution of thiosulphate and connected to a source of E.M.F. of 15–20 millivolts, the galvanometer showed zero deflexion since the back E.M.F. of the cell is due to the polarization of the cathode; the anode remains depolarized by the reducing action of the thiosulphate. The addition of small quantities of iodine causes a temporary displacement of the galvanometer needle as the iodine partially depolarizes the cathode; but the hydrogen, which has been removed, is quickly replaced, and the needle returns to zero until an excess of iodine keeps the cathode depolarized and reduces the back E.M.F., so that the galvanometer needle is steadily deflected by the current flowing.

An inversion of the above titration allows the current to flow until the thiosulphate removes all the iodine and allows the back E.M.F. to rise, bringing the current and therefore the galvanometer needle to zero; hence the term 'dead stop' end-point.

In practice, it is considered better to adopt the former scheme whereby the electrodes remain polarized until the equivalence point, as there is not the same danger of over-running the end-point.

When working with dilute solutions such as $N/500$, an error can arise due to an insufficiency of iodide ions to depolarize the anode, so that the accidental current passing with the addition of each drop of iodine added to the thiosulphate results in polarization of the anode and, therefore, an increase in the back E.M.F. An excess of iodine must then be added to reverse the galvanometer deflexion. This error can amount to 0.16 ml. on 1 ml. of $N/500$ iodine; but by the simple expedient of adding 5 ml. of 10 per cent potassium iodide solution, results repeatable to 0.01 ml. of $N/500$ iodine can be obtained, an accuracy far beyond the capabilities of the starch indicator.

In the discussion which followed these papers, the relative merits of the galvanometer and the 'magic eye' as the detector in pH meters were reviewed; it was stated that while it was possible to detect changes of 2–3 millivolts on the 'magic eye', the galvanometer was considered to be rather better as changes of 1 millivolt could be noted. The mention of standard half-cells for electro-titrations brought forward the interesting application of the glass electrode for such a purpose where changes in pH do not take place. When such a condition could not always be obtained, it was possible to have a glass electrode made specially insensitive to pH changes.

After hearing the papers, it was clear that electro-metric analysis should not and need not be considered as a special means to be used when others fail; suitable apparatus and well-tested methods are now available, which together can help the analyst to obtain more quickly even more accurate results. The papers presented at the meeting will be published in due course in the *Analyst*.

A. D. ELMSLY LAUCHLAN

VENEREAL DISEASES IN GREAT BRITAIN

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RELIABLE information about the incidence of venereal diseases in Britain is still lacking. This is particularly the case with gonorrhoea, where many patients, especially since the sulphonamide era, seek private treatment. Since 1931, when clinics began to record numbers of 'new' syphilis infections (of less than one year's duration), it has been possible to get a fairly accurate idea of the trend in this disease.

The increase in syphilis in the First World War was offset in the two decades that followed by the use of drugs of the arsphenamine series. For gonorrhoea there were, until comparatively recently, no comparable remedies, and the figures for this disease remained unchanged between the Wars.

The Second World War brought a marked increase in venereal diseases, but the use of sulphonamides for gonorrhoea, and, more recently, of penicillin for both gonorrhoea and syphilis, has kept the situation from degenerating to the state reached in 1918.

The incidence of early syphilis contracted in Britain declined by more than 46 per cent between 1931 and 1939, rose sharply then to reach a peak about 1943 and then started to decline slowly. An increase in 1945 suggests the importation of disease from abroad. The rate per 10,000 of population was: in 1931, 2.28; 1939, 1.21; 1943, 2.34; 1944, 2.26; 1945, 2.60.

So far as can be ascertained the increase in gonorrhoea was less than that in syphilis, and reached its peak in 1942, when it was probably about 86 per cent higher than in 1939. By 1944 it had declined to about 35 per cent higher than in 1939, but this decline was entirely accounted for by males, the rate in females actually increasing in 1944.

In 1942 the Government, in co-operation with the Central Council for Health Education, began a campaign to combat the spread of venereal diseases. Radio broadcasts, films, newspaper and magazine advertisements, posters and pictorial exhibitions were employed. Surveys suggested that the campaign was approved and understood by the public.

The introduction of Defence Regulation 33B in 1942 was the first departure from the practice of treating venereal disease on an entirely voluntary basis. The Regulation was aimed at the habitual spreader of disease and provides that any person named as a source of infection by two or more patients may be compelled to undergo examination by a special practitioner and to receive any necessary treatment until pronounced "free from venereal disease in a communicable form". Only a few thousands of cases have been thus brought under control, but even so the effort has been of importance.

There has also been increasing use of social workers by treatment centres to trace contacts and do follow-up work.

Since 1939, forty-one new treatment centres have been opened, and existing centres have held additional sessions. There was close co-operation between the civilian and the Forces venereal diseases services¹.

Specially qualified general practitioners have been appointed, especially in rural areas, to treat patients with venereal diseases, and the increased facilities ensure, so far as possible, that no patient need travel more than ten miles for treatment.

JAMES MARSHALL

¹ *Nature*, 151, 46 (1943).