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FREDERICK GEORGE DONNAN*

1870—1956

Frederick George Donnan was born in Colombo, Ceylon, 5 September 1870, the second son of six children of William Donnan, a merchant of Belfast, North Ireland, and his wife, whose maiden name was Jane Ross Ternley Liggate, both parents being natives of Northern Ireland, to which Donnan returned at the age of three. Of the family of six, two brothers and four sisters, only his two sisters Jane and Nora play a great part in our story, with his gracious mother, a remarkable, kindly, witty lady who, throughout her eighty years, taught one how her distinguished son came by his remarkable qualities. His two sisters Jane and Leonore (Nora) shared in his life, the one, Jane, as his secretary in University College days, before, during and after World War I, the other keeping house for her bachelor brother throughout thirty-eight years of her life.

When nine years old, the young Donnan lost his left eye in a game which he was playing with a boy of about his own age, where, in a housing development, the two were playing with freshly mixed mortar as "snowballs," one of which caught Donnan in the left eye. Immediate removal of the eye became necessary and, for a time, it was feared he might lose the other. However, as his mother once remarked, "after the accident to his eye he never looked back."

There were school years in the Belfast Royal Academy from 1880–1889 where his main interests were mathematics and physical science. In the last three years of his school days, he defrayed much of the cost of his schooling by gaining "Exhibitions" in total value about £100. He got his laboratory training initially, not in the Academy, but in evening schools at Hollywood, North Ireland. His teacher was one Mr. Adam Speers to whom Donnan was always grateful, from whom he derived his scientific enthusiasm. As a silver medallist from the evening school, he entered Queen's College, Belfast, in 1889. In 1890, 1891 and 1892 with the award of science scholarships and with first place in Ireland in the First Class Exhibition competition in 1890, 1891 and in physics *and* chemistry in 1892 he was able to finance much of his student years. He graduated B.A. in 1894 with first place and a graduate studentship of £300, in chemistry and physics. The M.A. in 1897 brought him a Junior Fellowship of £400 for four years and a post as Assistant Examiner. To chemistry, mathematics and physics during those years he added training in English Literature, Latin, Logic and Philosophy. An 1851 Exhibition Research Scholarship in 1893 made it possible to go to Germany, to the University of Leipzig for a year's study under Wislicenus. He transferred to Ostwald's laboratory in the same university and his orientation towards physical chemistry was thereby secured. He achieved a Ph.D., *magna cum laude*, for a thesis on the relation between ionization and light absorption by violuric acid alone or mixed with other acids. The Donnan colorimeter was a by-product of this research. In 1896–97 he transferred to the laboratory of J. H. van't Hoff in Berlin. Here he studied vapor pressures of saturated aqueous solutions of single and double salts pertinent to van't Hoff's studies of oceanic salt deposits.

A year of quiet study at home in 1897–8, reading deeply in physical chemistry produced four papers on (1) Lord Rayleigh's proof of van't Hoff's osmotic theorem, (2 and 3) the Thompson and Hall Effects in a binary electrolyte and (4) on the isothermal pressure surface in the case of two single salts and one double salt.

Donnan was ready for his active scientific life which began with a studentship in Ramsay's laboratory in University College, London, in 1898. In the next three years, there were papers on soap solutions, on the rates of effusion of the rare gases, and two theoretical papers on colloidal solutions.

* This memoir is compiled from personal recollections over a period of fifty years, from Donnan's own Personal Record deposited with the Royal Society of London, as utilized by one of his earliest co-workers in Liverpool University, F. A. Freeth, who, with the assistance of numerous pupils and friends, compiled his Biographical Memoir for the Royal Society of London in 1957.

In 1901, his 31st year, he obtained his first academic post, as assistant lecturer in Ramsay's laboratory at a salary of £100 per annum. A year later he was assistant professor in the same laboratory; one year later we find him Lecturer on Organic Chemistry at the Royal College of Science in Dublin. Fortunately, in the year 1904, the Sir John Brunner Chair of Physical Chemistry, the first such Chair in Britain, was established in the University of Liverpool. In addition, the Muspratt Laboratory of Physical Chemistry was built in Liverpool. Donnan was the supervisor of its construction and its Director from 1906 to 1913. From 1906 as a freshman, to 1912 as a graduate student, I lived through these golden years in Liverpool. In 1912 I went, for a year, to Arrhenius in Sweden and a year later, at Donnan's emphatic insistence, to Max Bodenstein in Hannover, to become the second student to work on chain reactions, in this case with alpha-particles as the chain initiator. It was through Donnan that I obtained the opportunity of those two years as 1851 Exhibitioner, an appointment which twenty years earlier had taken Donnan to Leipzig and thereby determined his future career and his dominant influence in Physical Chemistry in Britain, from 1904 till his retirement in 1937 from the Chair at University College, London. There he was the successor to Sir William Ramsay, as Professor of General Chemistry.

Donnan's researches covered a wide range of subjects. In the early days in University College, London, it was he who brought the Ostwald-Arrhenius school of physical chemistry into the orbit of Ramsay's essentially inorganic chemical approach. He was a Charter Member of the Faraday Society in 1903 and its President, 1924–26. He lived long enough to greet the Society with the other living founder member Sir James Swinburne at the Golden Jubilee of the Society in 1953. Their combined ages at that time was well over 170 years. The catholicity of his research interests is indicated by researches with E. C. C. Baly on surface energies and densities of liquefied gases, with Katharine Alice Burke on the velocity of reaction of silver nitrate with alkyl halides, with Le-Rossignol on a "quinquemolecular" reaction between potassium ferricyanide and potassium iodide, with Henry Bassett on the color of cobalt, iron and copper salts from the standpoint of electroaffinity.

The Liverpool years, from 1904 to 1913, were characterized by his excursions into the area of colloid chemistry, with the crowning achievement, his paper on Membrane Equilibria, published in the *Zeitschrift für Elektrochemie*, **17**, 572 (1911), in the year of his election to Fellowship in the Royal Society of London. The problem concerned a solution of an electrolyte consisting of two diffusible ions separated by a membrane from another salt with a non-diffusible ion. Donnan showed that, at equilibrium, the distribution of the diffusible ions will be unequal on the two sides of the membrane. He gave a thermodynamic proof of the equilibrium condition and, with this, students experimentally verified the solution. Donnan and Harris worked with a non-diffusible ion R′ where NaR was Congo Red. Allmand used the ferrocyanide ion as R′ and copper ferrocyanide as the membrane. The leather chemists, Procter and Wilson, showed the applicability of the theory to the swelling of gelatine in electrolytes. The presence of a membrane is not necessary if there is constraint on ionic movement. Loeb, in the Rockefeller Institute, summarized the applicability of the theory to protein solutions in presence of electrolytes ("Proteins and the Theory of Colloidal Behaviour," 1922). Changes in membrane potentials, osmotic pressure, and viscosities of protein and protein solutions caused by the addition of electrolytes all obeyed the Donnan formulation. Loeb emphasized that it gave "a quantitative, mathematical, and rationalistic explanation of the curves expressing the influence of hydrogen ion concentration, valency of ions and concentration of electrolytes on colloidal behaviour." Loeb was enthusiastic about the theory as early as 1915 since he made a flattering offer of employment to the writer, introduced to him by Dr. J. H. Northrup in 1915, largely, one must suppose, to a pupil of Donnan and Arrhenius rather than for any special competence to work in the Rockefeller Institute of Medical Research in New York.

Those years in Liverpool, 1904–1913, are characterized by the international character of the Muspratt Laboratory. It was a miniature of Leipzig under Ostwald: F. D. Farrow and C. N. Stubbs from New Zealand, T. Thorvaldson, who spent forty subsequent years in the University of Saskatchewan, E. B. R. Prideaux, who went to India, H. Rai, with J. T. Barker, T. W. A. Shaw, H. E. Potts and A. S. White as the local contingent. The topics studied ranged from Portland cement, calorimetry of hydrated salts, studies of efficiency in alkali-chlorine cells, emulsification of hydrocarbon oils, solubility of oxygen in silver and the consequent blistering, solubilities of cuprous oxide in aqueous ammonia solutions, Gibbs' theory of interfacial concentration at air-water interfaces, the bleaching of animal fats and oils, emulsions and emulsifications. It was an appetizing fare for the young undergraduates observing their elders. My only work under Donnan was concerned with an unexplored area of Donnan's researches with Katharine Burke, the influence of nitric acid on the kinetics of silver nitrate–alkyl iodide interaction. It was my good fortune to carry through these measurements during the advanced undergraduate laboratory course in physical chemistry. I exchanged the tedium of routine exercises in conductivity, transport numbers and electromotive forces for the excitement of the unknown. It was my first taste of research. When the time came for post-graduate years I chose to work, not with Donnan, but with his pupil, Henry Bassett, and in the general area of inorganic chemistry. Donnan remained during these years a wise, kind counsellor and friend. There was afternoon tea, each day, for all the research men in the whole laboratory, and it was in these minutes that Donnan's dynamic character, his wide range of experience revealed itself to us. One dim memory of those teas is the occasion when Mendeleeff visited the laboratory. His presence took us back over the years to the Periodic Law of 1869. There were many other

distinguished visitors, for Donnan, more than most Britishers, was an extensive traveller, a leader in international scientific co-operation.

In May 1914, just prior to World War I, I was privileged to see a letter from Haber to Donnan suggesting that London University might consider the award of its D.Sc. degree to Le Rossignol for his contributions to ammonia synthesis, since it was now clear that this synthetic process would shortly go into technical production at Oppau in Germany. During World War I, Donnan became the focal point of the regeneration of British chemical industry that the first Great War demanded. Lord Moulton depended heavily on Donnan's advice and through him Donnan learned to know and respect a Texas chemical engineer, K. B. Quinan, loaned to the British Government by the Cape Explosives Company in South Africa to design, build and operate the contact sulfuric acid plants that explosives demanded. It was a Donnan–Moulton–Quinan trio who formulated the program of research on ammonia synthesis that a mounting submarine warfare appeared to demand of Britain, amid all the other demands of scientific effort. It was from this research program, with less than a dozen trained young scientists, in the basement of the University College laboratories, that there emerged the know-how for the platinum gauze oxidation conversion of ammonia-air mixtures to oxides of nitrogen for nitric acid production, for the water-gas conversion process of hydrogen manufacture and ultimately for the large scale production of synthetic ammonia at Billingham-on-Tees.

As soon as the war was ended Donnan took up the threads of international co-operation again. In this, he was ably assisted by his Dutch colleague, Ernst Cohen. It was these who organized the first International Meeting of Chemists after 1914–18. It was they who were largely responsible for bringing their German colleagues back into international scientific intercourse. The tragedy of this effort came in the closing years of World War II when Ernst Cohen fell victim to the anti-Semitic hates of Hitler and his group. Donnan's travels took him far afield, to Holland in 1922, to the U. S. A. in 1923–24 and again in 1929, to South America (Chile) in the same decade, to Scandinavia and frequently to meetings of the Bunsen Gesellschaft in Germany. It was only out of his intimate knowledge of conditions in Germany in the early '30s, that, with F. A. Freeth, arrangements were made for Simon, London, Teller, Peierls, Freundlich, and others to come to Britain. Polanyi had already been offered his Manchester position, von Neumann and Wigner had accepted appointments to Princeton University. Few of the younger generation of first-rank scientists were left in Germany as Hitler pursued his frenzied way.

Donnan retired from his professorship at University College, London, in 1937. He lived nearby in Woburn Square with his mother and two sisters. As the bombing of London became worse he decided to move to Hartlip, Sittingbourne, Kent. To his home in the countryside he brought his wonderful collection of museum-piece furniture. He was fortunate, for his London home was destroyed twelve hours after the household was transferred to Kent.

Donnan had stayed twice in our homes in Princeton, once in the 1923–24 visit and the second time at the opening of the Frick Chemical Laboratory in 1929. He gave the first lecture in the Laboratory after its formal opening and received an honorary degree from Princeton on that occasion. There were at least ten other honorary degrees including those from Johns Hopkins and Oberlin in this country, from his Alma Mater in Belfast, Liverpool, Durham, Athens, Coimbra and the National University of Ireland. He was an honorary member of many societies including the American Chemical Society in the west, the National Institute of Science in India and the Indian Academy of Science at Bangalore in the east, with a dozen others in between from Uppsala to Roumania, across Europe.

For one other reason the indebtedness of American scientists to Donnan is very great. He was the Editor with A. Haas of "The Commentary on the Scientific Writings of J. Willard Gibbs, Volume I, Thermodynamics," published by Yale University Press, New Haven, U. S. A. As F. A. Freeth remarked of this task: it was "this very heavy and exacting work (which) took much of his spare time from 1928 to 1936. He was at it night after night until the small hours of the morning. Owing to various causes practically all the work fell on him."

Is it not passing strange that America's genius of the mid-nineteenth century required for his annotation one who "read deeply into the literature of physical chemistry" in the solitude of his own home in Northern Ireland?

The last memories of my wife and myself stem from our last visit to his home at Hartlip, the day before we returned to U. S. A. in September 1953. He had graced the Golden Jubilee of the Faraday Society in April of that year and was our guest at the celebrations in the Royal Institution, surrounded by beloved students and friends. Sir Charles Goodeve and Professor W. E. Garner of Bristol were among his special students and friends in the University College years. For just over three years longer he lived quietly in his country home with his two sisters who shared his content almost to the very end. Leonora died in May 1956. Jane died three days before her famous brother, and they were cremated together. The words written by John Tyndall of Michael Faraday can well be repeated of one who helped to enshrine Faraday's name in the Society which, more than any other, is the exemplar of physico-chemical scientific institutions:

> "Not half his greatness was incorporated in his science, for science could not reveal the bravery and delicacy of his heart."

HUGH TAYLOR