W. E. Garner.

WILLIAM EDWARD GARNER

1889-1960

Professor W. E. Garner died on 4 March 1960 at his home at Westbury-on-Trym, Bristol, where he had lived for over thirty years.

Garner was born at Hugglescote, Leicestershire, on 12 May 1889, the eldest son in a family of three sons and a daughter. His younger brothers also attained distinction in the scientific world: Sir Harry Garner, after notable achievements in the field of aircraft research and development, became Chief Scientist to the Ministry of Supply, and F. H. Garner was for many years until his retirement in 1960 Professor of Chemical Engineering in the University of Birmingham.

After attending Market Bosworth Grammar School (1902-1907) Garner went to Birmingham University (1908-1913). He was awarded an 1851 Exhibition in 1913 and proceeded to the University of Göttingen to work with Professor Gustav Tammann. Garner's research at Göttingen was curtailed by the outbreak of the First World War and he only managed to get out of Germany in time. In the University of Birmingham he carried out research under Professor P. F. Frankland and it is interesting to recall that he began his scientific life as an organic chemist—his first publications being on the preparation of oximes, amines and the reactions of thionyl chloride with lactic acid and ethyl lactate. It was undoubtedly his year at Göttingen which influenced much of his subsequent research. Tammann—who held the Chair of Inorganic Chemistry—was then surging ahead with his fundamental investigations on the internal pressure of solutions, equilibria between crystalline and liquid states, particularly melting and nucleation, and crystallization of inorganic and organic liquids and metals, and he had gathered around him some twenty to thirty research workers from all parts of the world. In this atmosphere Garner met many distinguished European physical chemists and was in close contact with the development of the new and growing branch of chemistry—known as physical chemistry.

On his return to England in 1914 he joined the scientific staff of Woolwich Arsenal where he carried out some outstanding research work with Sir Robert Robertson on the calorimetry of high explosives. Garner's experience at Woolwich (1915-1918) was later to be invaluable to him when he became an adviser to the Ordnance Factories, and later Superintendent of Chemical and Explosive Research in the Ministry of Supply during the Second World War.

On leaving Woolwich Arsenal he was appointed Assistant Lecturer in the University of Birmingham (January 1919) and later Assistant Lecturer at

University College, London (October 1919). From that time dated his close and happy association with Professor F. G. Donnan and a fruitful period of research which was to have a significant influence on developments in physical chemistry. Garner had a wide interest in, and deep knowledge of, many branches of physical chemistry and was only happy when following several developing lines. It was during his University College period that he began his studies on heterogeneous catalysis and heats of adsorption, the kinetics of reaction in gases and in solution and in particular the study of explosive reaction in gases, and the ionization and radiation from flames.

In 1927 Garner was appointed to the Leverhulme Chair of Physical and Inorganic Chemistry in the University of Bristol, and until his retirement at the age limit in 1955—except for the war period—he carried out a series of experimental studies of far-reaching practical and theoretical importance. He began a wide and systematic study of the kinetics of solid reactions.

Garner's work was interrupted by the Second World War and immediately on its outbreak he established an extra-mural research team in the University of Bristol to assist the Government Ordnance Factories in explosives and munitions research. This large team continued for the duration of the war and was of invaluable help to the production factories and in developing new explosives and other essential war materials. Although never losing contact with the work of this group, Garner moved to Fort Halstead in Kent in 1943 to become Superintendent of Chemical and Explosives Research for the Ministry of Supply. He later became Deputy Chief of Armament Research and then later Chief Superintendent Armament Research. His enthusiasm, wise guidance and inspiration were of paramount importance to the war effort. He served on very many high-level committees and was associated with many notable developments in new armaments and munitions. His services were recognized in 1946 by the award of the C.B.E. During the whole of the period that he was at Fort Halstead Garner would return to Bristol on the Friday evening, give his lectures on Saturday morning and attend to departmental matters before returning to London on the Sunday afternoon.

On the cessation of hostilities Garner returned to his University work in Bristol, although until his retirement he was actively engaged in the work of the Scientific Advisory Council of the Ministry of Supply and other Government committees. During the post-war period he built around him in Bristol one of the strongest research groups in the country, and continued with increasing vigour his studies of heterogeneous catalysis.

Garner was a man of charm and kindness who won the affection and admiration of all who came into contact with him. His unselfishness and sincerity made him the most likeable of men and he was always ready with encouragement, advice and assistance to his students and colleagues. He was a quiet, unobtrusive man, entirely devoid of personal ambition; devoted to his work whether in the laboratory or the councils of the University. But these qualities did not obscure the greatness of the man. He was an enthusiastic and

inspiring leader of research, conscientious in the discharge of his duties and an adherent of the best traditions of science. His interests were wide; he was a collector of paintings and china and had a critical appreciation of art. He was knowledgeable on many subjects—he had a good library of books on the history of chemistry; he was very interested in period furniture and he always enjoyed an hour or so in the sale-room. But above all, he was an enthusiastic gardener and it was a great thrill to him to raise a rare seedling or to produce some unusual fruit. These hobbies were a great comfort to him in his retirement and in recent years he extended his greenhouses and took up the growing of orchids. The care of his plants was a major concern to him during his illness.

He was a man of great tenacity and courage. This characterized his scientific work and everything else he tackled; no problem ever daunted him. When I visited him when he was in hospital he was busy studying catalogues of wheel-chairs since it was thought that he would be able to walk only with difficulty. But despite the doctors' fears Garner, with his indomitable courage, was soon on his feet again and for a short time before his final illness he visited the Staff House of the University for lunch—a pleasure he enjoyed during the five years of his retirement.

He had a wide circle of friends and those who had the pleasure of knowing him valued a friendship which will endure as a cherished memory of a lovable character.

Garner was a well-known figure at scientific gatherings and although not outstanding as a lecturer he was at his best in presenting his own experimental discoveries or introducing some new idea which he was then developing. Scientific societies and Government committees made great calls upon his time. He was President of the Faraday Society (1945-1947) and served as a member of the Council of the Royal Society and of the Faraday Society. He was a member of the Scientific Advisory Council of the Ministry of Supply for almost the whole of the period 1942-1960 and had been associated with that body since its inception. He was also Senior Scientific Adviser for Civil Defence in the South West Region.

He received many honours: he was elected to the Fellowship of the Royal Society in 1937; was a Fellow of University College, London, and was made a Commander of the British Empire in 1947. He was well known abroad and was an honorary member of the Polish Chemical Society, a correspondent councillor of the Patronato 'Alfonso el Sabio', Madrid, 1959. He was a member of the Joint Services Mission to the U.S.A. and Canada 1948.

Combustion researches

When Garner joined the staff of Woolwich Arsenal during the First World War the theoretical and experimental facts underlying combustion and explosion in solids were not well established. The available experimental data were incomplete, especially in respect of the volume of gases and water

formed, and reliable values of the heats of detonation and effect of confinement on detonation were not available. In collaboration with Sir Robert Robertson, Garner began a systematic investigation of the determination of the heat and volume of gases produced when high explosives were detonated under standard conditions of confinement and compression in order to obtain a measure of the energy developed, the nature of the gases evolved and the chemical reactions which occurred in the period after explosion. The development of the necessary calorimetric procedures and the results for a number of military explosives stand among the most valuable and important contributions to this aspect of military science.

It was his war-time experience, together with his earlier interest in catalysis, that induced Garner on returning to the University to embark on a systematic study of explosion in gases, particularly the effects of small additions of other gases to the radiation emitted. He made the significant observation that the radiation of the 'dry' carbon monoxide flame decreased by the addition of small amounts of hydrogen or water and that an abrupt fall occurred at a critical percentage of hydrogen. Parallel with these studies he made detailed investigations of the spectra of explosion in gases, infra-red emission from flames and ionization phenomena in gaseous explosions. This series of investigations taken together form a significant contribution to explosion phenomena and the elucidation of the reaction occurring in flames.

Thermochemical measurements

From the time of his association with F. G. Donnan, Garner was keenly interested in colloidal and biological problems and especially the possibility of interpreting these phenomena in physico-chemical terms. As early as 1925 he was writing on the mechanism of muscle contraction and it was this interest which led him into the fields of the study of adsorptions and the properties of substances related to the fats. His publications on the melting points and heat of crystallization of fatty acids and their esters in which he discovered the alternating relationships constitute one of the most fundamental and systematic investigations in this field. The relationship between the melting point T_F of the lower chain paraffins and molecular weight established with van Bibber and King has recently been extremely valuable to polymer chemists working with the newer polyolefins.

Solid state and heterogeneous catalysis

Since the days of Gibbs, Roozeboom and Tammann the study of heterogeneous systems has had a long development. The modern view is not essentially different from that of Tammann, who was a pioneer in many fields, but is governed by ideas which possess greater precision than was possible fifty years ago. In these studies the newer knowledge gained regarding dislocations, lattice defects, and energy levels in the solid state find direct

application. It was not unnatural therefore that Garner, who did his post-doctoral research under Tammann, should become one of his disciples and adopt aspects of the kinetics of heterogeneous reaction as his principal field of research. He recognized the three-dimensional aspect of reactions in multi-phase systems. He expanded the two-dimensional picture developed by Langmuir and others of catalytic reactions occurring in absorbed films to one of penetration of the solid in some depth. The kinetics of chemical reactions accompanied by a change of phase are of much greater complexity than homogeneous reactions due to diffusion processes, interface reaction and the creation of new phases. Garner made a wide and systematic study of the latter two processes. His investigations fell naturally into two groups. (a) Endothermic solid reactions such as the dissociation of hydrates and carbonates in which dissociation and recombination processes occur simultaneously. These reactions provided information about the mechanism of interface reactions and nucleation processes. (b) Exothermic reactions of the kind $A_{\text{solid}} \rightarrow B_{\text{solid}} + C_{\text{gas}}$ and in particular the azides and fulminates. Garner showed that the surface reaction which occurred produced lattice vacancies which may be localized near surface discontinuities, may spread over the whole surface or diffuse into the interior. He showed that the nuclei of the new solid phase was probably created within aggregations of lattice vacancies. In carrying out these investigations he developed a number of fruitful experimental methods, including pressure-time measurements, loss of weight using a micro-balance, and microscopic examination of surfaces of decomposing crystals—especially useful in studying nucleation.

Parallel with these researches he continued his interests in catalysis and chemisorption on oxide surfaces. As early as 1924 he recognized the importance of measurements of heats of adsorption and developed and continued to perfect calorimeters for their measurement. The distinction between chemical and physical adsorption was clearly brought out in the paper by Garner & Kingman in 1931, the same year that Taylor & Williamson, and Benton & White proposed the existence of the two types of adsorption. In his extensive studies of the chemisorption of oxygen and carbon monoxide on metal and oxide surfaces Garner realized the full significance of the electronic structure of the solid in catalysis and kinetic processes at surfaces. Although essentially an experimentalist he had a profound knowledge of modern progress in solid state physics and was a pioneer in applying these new developments to heterogeneous reactions. His measurements of the heats of adsorption on zinc, manganese, chromium and copper oxides and the elucidation of the reversible and irreversible chemisorption of gases on these oxides and the interpretation of the experimental results in terms of lattice defect theories provides a model example of the application of many disciplines to the solution of the important problem of the understanding of catalytic reactions at surfaces.

After his retirement in 1955 Garner organized a symposium on chemisorption at Keele, Staffordshire, which was published by the Chemical Society,

and edited a large volume on *The chemistry of the solid state.* Most of the contributors to the latter volume were former students or colleagues at Bristol —others were close scientific friends—and this work, which presents the broad basis of progress in solid state chemistry, is very much a tribute to Garner's inspiration and guidance.

C. E. H. Bawn

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