## Obituary

# Arne Westgren
# 1889–1975

Arne Westgren, a pioneer in the application of X-ray diffraction methods in physical metallurgy and also well known for his X-ray crystallographic work in other fields of inorganic chemistry, died in Stockholm on 7 March 1975 at the age of 85.

Westgren started his academic career in Uppsala as a pupil of The Svedberg and in 1915 obtained his doctoral degree with a thesis on Brownian motion. After having spent a year studying colloid chemistry in Zsigmondy's laboratory in Göttingen he began employment as a physical metallurgist with the ball-bearing company SKF in Gothenburg. Westgren used to relate how, on the railway journey from Uppsala to Gothenburg, he read a textbook on metallography and also found time to study the book *X-rays and Crystal Structure* by W. H. and W. L. Bragg that had just appeared. The knowledge thus acquired proved to be very important for the direction of his future work.

In 1919 Westgren established contact with Manne Siegbahn (at that time in Lund) to inquire whether the structure of the iron modifications might be determined by means of powder diffraction methods. Westgren was invited to Lund in order to attempt this and the first experiments were carried out in collaboration with Axel E. Lindh. The work was continued in the autumn of 1920 with a high-temperature camera, the first ever to be used. It was then found that the $\alpha$–$\beta$ transition was not accompanied by any structural change, whereas $\gamma$-iron showed the same cubic face-centred structure as austenitic steels at room temperature. This work was instrumental in giving Westgren an appointment at the Institute for Metal Research in Stockholm in 1921. He there began to collaborate with Gösta Phragmén, who at that time had made his first attempts at X-ray crystallography under the guidance of Gregori Aminoff. Westgren's great imaginative power and skill in numerical calculations, as well as the speed and ease with which he worked, were complemented very nicely by Phragmén's critical attitude, thorough knowledge of thermodynamics and great experience in workshop problems and instrument construction. The success with which they solved fundamental structural problems was to a large extent the product of their great experience in physical metallurgy, their sound methods of sample preparation, and in particular the excellent powder cameras constructed by Phragmén. These cameras were of the Seemann–Bohlin type, but following an analysis of the focusing

conditions, Phragmén had succeeded in obtaining a resolution which for many years could not be attained by any other camera. This put the Stockholm laboratory in a very favourable position at a time when most equilibrium diagrams had to be revised by means of phase analysis with powder photographs and when a great many structures were determined by powder methods.

The studies of the iron modifications were now continued and the structure of $\delta$-iron was found. The unit-cell dimensions of cementite were determined. In the system copper–aluminium a phase with the $\gamma$-brass structure was found for the first time although its structure was then not solved. The structural analogies between the systems copper–zinc, silver–zinc and gold–zinc were found in 1925, At about the same time Westgren and Phragmén investigated the modifications of manganese, and studied the carbide systems of chromium, molybdenum and tungsten. They also succeeded in characterizing the so-called high-speed steel carbide.

In April 1926 Westgren and Phragmén found the structural analogies between the three systems copper–zinc, copper–aluminium and copper–tin. At a discussion meeting at the Institute of Metals in London one month earlier, Hume–Rothery had called attention to the similarities between the $\beta$ phases of these systems as observed metallographically. He suggested that this was due to the fact that the ratio of the number of valence electrons to the number of atoms in all three phases is 3:2 (Hume–Rothery rule). Through the studies of Westgren and Phragmén on these and several other binary systems this rule was put on a more solid foundation.

In the autumn of 1926 A. J. Bradley came from Manchester to Stockholm to participate in the X-ray work on alloys. He was particularly interested in the structure of $\alpha$-manganese and succeeded in determining its structure, which is unusually complex for an element. Using diffraction data obtained in Stockholm for $\gamma$-brass and for analogous phases in several other systems, he was also able to determine the structure of the $\gamma$ phases in the copper–zinc and copper–aluminium systems.

In 1927 Westgren was appointed Professor of General and Inorganic Chemistry at the University of Stockholm. The close collaboration with Phragmén at the Institute for Metal Research was maintained, however, and the use of the X-ray diffraction equipment was shared by the two institutes. The equipment was also modernized, and new apparatus obtained. The work on metallic systems continued and resulted amongst other things in more complete structure determinations of phases found earlier, as well as the solving of a great number of new structures. Pupils in increasing numbers began to come to Westgren's laboratory, and, to a large extent through their contributions, the field of action was widened to include non-metallic systems.

In 1943 Westgren was appointed Secretary of the Royal Swedish Academy of Sciences, thus leaving his chair at the Stockholm University, and in 1944 Phragmén died. From that time Westgren was able to turn to X-ray crystallography only in leisure moments. He retired from this last appointment in 1959. Westgren also served as Secretary to the Nobel Committees for Physics and Chemistry from 1926 to 1943 and was Chairman of the Committee for Chemistry from 1944 to 1965. He was Vice President of the International Union of Crystallography during the period 1948–51.

Arne Westgren opened up new ground in crystallography and metal science and we are greatly indebted to him for this achievement. His old pupils and other friends will always remember the outstanding scholar and teacher and the loyal friend. We feel the loss of his noble personage.

GUNNAR HÄGG