*The Genesis and Beginnings of X-ray Crystallography at Caltech**

C. L. Burdick

That Caltech was one of the first two centers in America where X-ray crystallography was started and continued was due entirely to the imagination, vision, and conviction of Dr. Arthur A. Noyes. In 1916, which was very early in Caltech's beginnings, Dr. Noyes was nominally visiting professor of chemistry, but actually he, with Drs. Millikan and Hale, was planning and shaping the future of this whole great institution. This particular specialty was only one of the many in which he saw great promise and forthcoming utility.

Prior to 1915 Dr. Noyes was occupied wholly as director of the Research Laboratory of Physical Chemistry at MIT in Boston, and it was there in 1913–14 that I came to know Dr. Noyes and to be a graduate student under him at the laboratory in MIT's old 'Engineering C' building. This was near the end of the halcyon days of classical physical chemistry when on the staff could be noted among the younger men such names as G. N. Lewis, C. A. Kraus, and F. G. Keyes.

Dr. Noyes encouraged me to go abroad for doctorate work and postdoctoral study, and it turned out that I sailed from New York in July 1914 on the last regular German liner to get through to Hamburg. Because of war conditions my doctorate period was divided between Professors Fichter and Rupe in Basel and Professor Willstätter at the Kaiser Wilhelm Institute for Chemistry in Berlin-Dahlem. It might be noted that there were then two young, comparatively unknowns by the names of Hahn and Meitner in this same Institute. Following this, the writer had a brief period of postdoctoral work at the Kaiser Wilhelm Institute of Physical Chemistry under Professor Fritz Haber and then a later opportunity to work on 'Reststrahlen' with Rubens at the University of Berlin and to sit in on the lecture courses of Nernst,

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Planck, and Einstein. What untold recognition and appreciation these names call forth today.

Early in 1916 it was only with some circumlocution, occasioned by the separate British and German censorship of all mail from America, that advice came to me from Dr. Noyes to try to find a way to spend my last months abroad working in the X-ray laboratory of Professor William H. Bragg at University College in London. In his letter Dr. Noyes expressed his strong belief in the importance of X-ray atomic structure analysis for the future of theoretical chemistry, and his wish to get something of the kind started at MIT.

It was not so simple for an impecunious, young PhD of American neutrality without connections to get from Berlin to London during the critical period of the Zeppelin raids and unrestricted submarine warfare. But due to the volunteered help and influence of Professor Kamerlingh Onnes of the Cryogenic Laboratory in Leiden, it was accomplished.

The six months in the laboratory of Professor Bragg were of inestimable value, even though its leader was largely occupied with war work. With what time Dr. Bragg had to spend with us in guidance, Dr. E. A. Owen and the writer were able to work out a tentatively satisfactory X-ray structure for carborundum, which was later published.

An interesting presentation could be made of the primitiveness of the equipment then available, the old-fashioned induction coil with Leyden-jar condensers and a mercury interruptor, the gas-filled X-ray tubes of unpredictable and uncertain output and 'hardness', and gold-leaf electroscopes with the strangest static aberrations when it came to measuring ionization intensities.

On returning to MIT, which was in process of moving from Boston to Cambridge, my assignment from Dr. Noyes was to build a Bragg X-ray spectrometer with any improvements which the state of the art would permit. This meant, first, having at hand a really good X-ray transformer with rotary-disc rectifier and secondly, and of most importance, an only just then developed, new Coolidge X-ray tube fitted with a palladium target. Dr. James A. Beatty, then a student, was principal collaborator in building, putting this machine into initial operation, and testing.

In the latter part of 1916 when Dr. Noyes left for his annual tour of duty as visiting professor at Caltech he asked me to go with him and build another spectrometer embodying the refinements which our tests had shown could be made. The Caltech team on this was James H. Ellis, Fred Hensen (instrument maker), and myself. The things

which made the original Caltech spectrometer probably the best of its day were its high-power input and relative constancy of measured electrical energy to the tube. This gave possibilities for narrower spectrometer slits, precise angle measurements, sharp reflection peaks, and better measurement of relative reflection intensities of the spectral orders than had probably ever been made before.

The measurements carried out in these months permitted the determination of the crystal structure of chalcopyrite and resulted in two papers by Ellis and Burdick. These were submitted to the *Journal of the American Chemical Society* and the *Proceedings of the National Academy of Sciences* early in 1917, and appeared as publication Number 3 of the Gates Laboratory of Chemistry.

Then the United States entered the war. Dr. Noyes' time was spent in large measure in Washington, Burdick was called from the US Ordnance Reserve into the nitrogen fixation program, and for a time the X-ray crystal work at Caltech lagged. After the war, with the arrival of Dr. Roscoe G. Dickinson, the wheels hummed again. High-voltage sparks flew and research results by many collaborators came out apace. Today the successorship of Dickinson is in the notable hands of Pauling. Dr. Noyes' vision of the early days of 1916 has paid off and will continue to do so in generous measure.

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