A TRIBUTE TO MANNE SIEGBAHN

Henk Kubbinga – University of Groningen (The Netherlands) – DOI: https://doi.org/10.1051/epn/2017507

Spectroscopy came to dominate the 19th century, with a crucial role for Swedish physicists. It was Anders Ångström who introduced the tenmillionth part of a millimeter as the wavelength unit (1868), a unit that was adopted by Rowland for his tables of the solar spectral lines (1887-1893). Janne Rydberg, then, followed in Ångström's footsteps in searching for relations between the emission spectra of the elements and their place in the Periodic Table. Röntgen's new rays became a next challenge, demanding a form of spectroscopy of their own. Manne Siegbahn, an assistant of Rydberg, then, devised appropriate instruments of ever increasing precision.

▲ FIG. 1: Manne Siegbahn by Bror Kronstrand (1936; oil on canvas, 50×60 cm; courtesy Gustavianum-Uppsala University Museum). The original version was by Sam Uhrdain, 1928. Siegbahn's desk features a self-devised X-ray tube in porcelain, for his high precision spectroscope.

Karl Manne Georg Siegbahn (1886-1978) was born in Örebro, a city in Sweden's Lake District. After graduation in 1906 he enrolled at the University of Lund, where he was charmed by the teachings of the mathematical physicist Janne Rydberg (1854-1919). From Rydberg he adopted a bent for the numerical relations between the elements' spectral lines and their place in the Periodic Table. In the year that Rydberg promulgated what came to be known as the $2x^2$ rule, with x (= 1 or 2) as the ordinal index of the element at the Periodic Table, Siegbahn came in. On 26 April 1911, then, he passed the doctorate on a dissertation entitled *Magnetische Feldmessungen*, which revealed his primarily experimental propensity. In hindsight an unusually short track indeed, since he made also time for two trips abroad (1908, Göttingen; 1909, Munich). Physics' Europe was in the making: in 1911 and 1914 new trips followed, to Berlin, Heidelberg and Paris.

From Barkla to Moseley; atomic number *versus* atomic mass

In Munich, Siegbahn had made the acquaintance of Arnold Sommerfeld and Max von Laue, who familiarized him with the particularities of Röntgen's rays. This domain lived a boost the moment, in June 1912, that Laue, Friedrich and Knipping published their epoch-making crystal-diffraction patterns. No wonder that Siegbahn came under the spell of the new rays. The Braggs subsequently introduced reflection instead of diffraction, a technique that reduced the required time significantly. For a while transverse waves, ether pulses and particles lived side by side in the physicists' minds. Laue's rather complex mathematics was exchanged, by Bragg Jr., for a straightforward expression for the difference in path length, lattice constant, and angle of incidence:

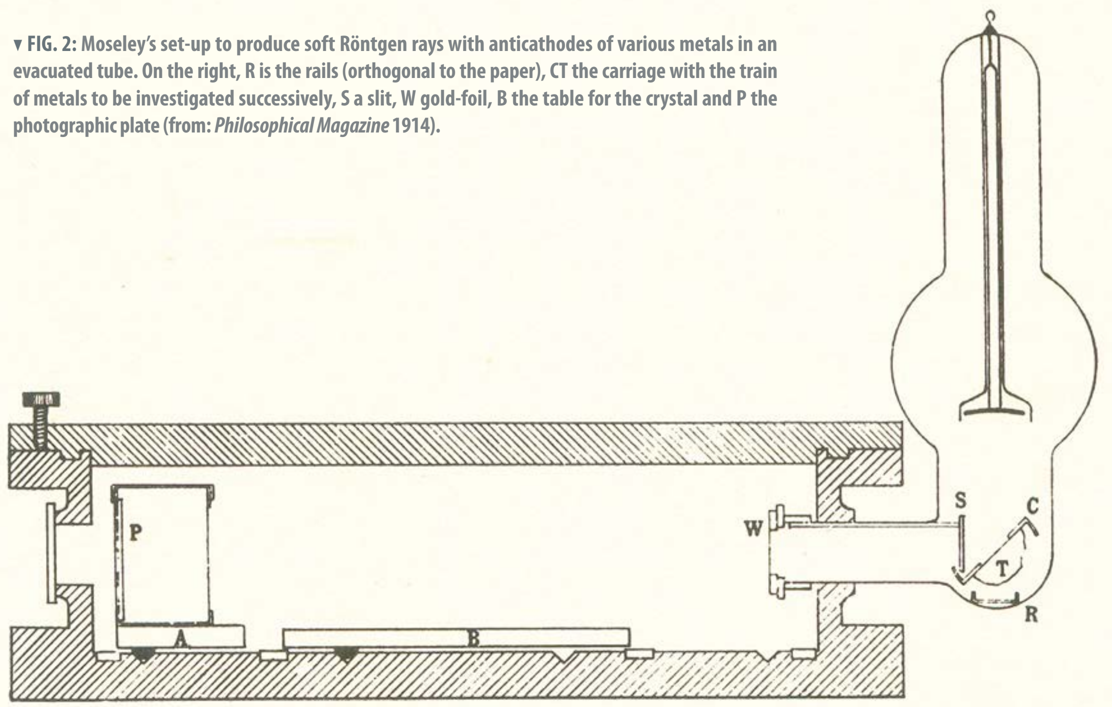
$$n\lambda = 2d \sin\varphi$$

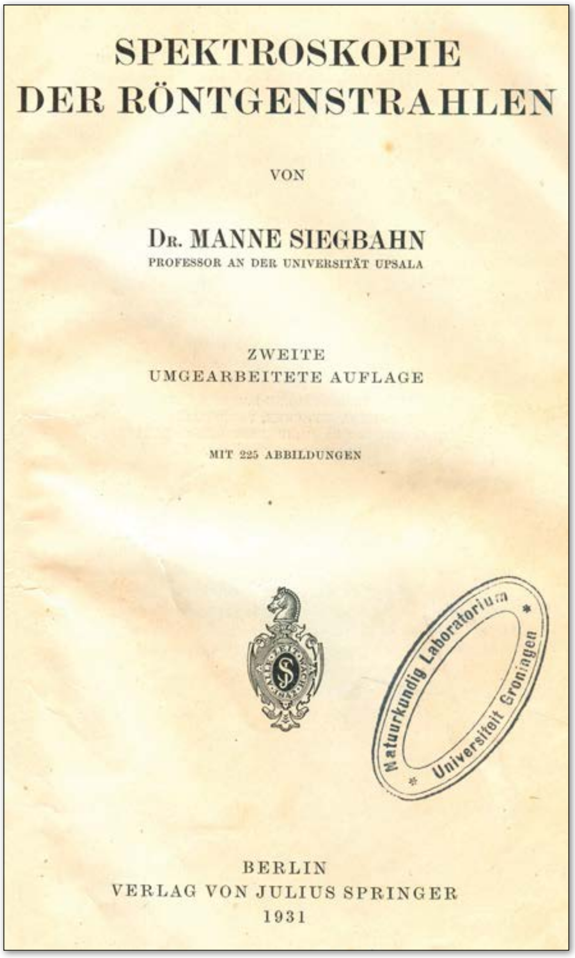
with $n = 1, 2, 3, ...$ No doubt, there was a highly energetic electromagnetic radiation at issue, the wavelength of which could now be calculated using the available data for the crystal at stake. In case of rocksalt (NaCl) the mean distance between the constituent atoms could be calculated from the density ($\rho = 2{,}17$ g·cm^{-3}), the molar mass (58,5 g), and the constant N called after Avogadro: $d = 2{,}814 \cdot 10^{-8}$ cm. With $\varphi = 11{,}55$ and $n = 1$ the Braggs found $\lambda = 1{,}78 \cdot 10^{-8}$ cm. In October 1912, Henry Moseley, working under Rutherford at Manchester, set out to check the results reported from Munich and Cambridge. For a platinum anticathode he found, in the spring of 1913, five wavelengths, in other words, an emission spectrum consisting of five lines. Simplicity itself, compared to the traditional emission spectra, and therefore full of promises. Where others focused on the rays themselves, Moseley weighted the consequences for the ideas on atomic structure and its relation with the Periodic System. There were reasons to believe that the ordering principle of the System was not atomic mass, but the positive charge of Rutherford's nucleus. Indeed, at least three cases showed that the order did not always follow atomic mass. Moseley, then, set out to study one of these, the couple Co ($Z = 27$) and Ni (28). The idea was to study the series Ca (20) through Zn (30), all metals ready to produce sufficiently soft X-rays when used as anticathode material. The pencil of rays was reflected by a crystal of potassium ferrocyanide and detected, initially by a normal counter, but later by a photographic plate. The results were unambiguous in that the atomic number prevailed, as could be read out from the shift of the two K-lines in question. There were also less energetic lines, it appeared; following Barkla's system (1907) they were known as L-lines. Barkla had weighted the eventuality of even higher energetic lines, to be called J, I, H, *etc.*, but these never showed up.

X-ray-spectroscopy as such

In 1914, on the eve of the Great War, Manne Siegbahn esteemed that the utility of X-ray spectra in the identification of elements was obvious, even though the resolution of the lines left much to be desired, not unlike the precision in the wavelength determinations. While quite a lot of his colleagues got fully involved in war activities, Siegbahn could subsequently focus on the perfection of the apparatus. Initially he used an instrument similar to that of Moseley, that is, one in which a series of anticathodes could be checked in a row (Fig.2). A first advance was the integration of the reflecting crystal and the registration unit in the discharge tube in view of reducing losses of soft rays by absorption in the air. With his PhD-students he showed, for zirconium and neodymium, that the 2 K-lines were in reality doublets, a fact that again stressed the importance of precision. Next the scope of his research was greatly widened to include also lighter elements. In 1916 new series—M and N—of longer wavelength showed up. Siegbahn became the undisputed leader in the field. Students from abroad, among whom Dirk Coster from Leiden, flocked to Lund. In 1919 Siegbahn organized a first post-War congress on the topic with Sommerfeld and Bohr as key-notes; both were delighted to see their ideas on atomic structure confirmed. No wonder that Siegbahn was among the invités for the next Solvay Conference on Physics, that of 1921, which was devoted to 'Atoms and electrons'. In 1922 he moved on to the Faculty of Science

▾ **FIG. 2: Moseley's set-up to produce soft Röntgen rays with anticathodes of various metals in an evacuated tube. On the right, R is the rails (orthogonal to the paper), CT the carriage with the train of metals to be investigated successively, S a slit, W gold-foil, B the table for the crystal and P the photographic plate (from: *Philosophical Magazine* 1914).**




SPEKTROSKOPIE
DER RÖNTGENSTRAHLEN

VON

DR. MANNE SIEGBAHN
PROFESSOR AN DER UNIVERSITÄT UPSALA

ZWEITE
UMGEARBEITETE AUFLAGE

MIT 225 ABBILDUNGEN

Natuurkundig Laboratorium Universiteit Groningen

BERLIN
VERLAG VON JULIUS SPRINGER
1931

◂ **FIG. 3:** Spektroskopie der Röntgenstrahlen

of Uppsala University to continue his endeavours to bridge the gap between the UV-part of the normal spectrum and the X-rays. Rocksalt was exchanged for calcite, the X-unit took the place of the Ångström, with 1 Å= 10^3 X.U. A monograph entitled *Spektroskopie der Röntgenstrahlen* (1923, 1931; Fig.3) summarized the results of a new survey of the relevant elements.

A retroactive Nobel-Prize

A rarety in the history of the Nobel Prize. For the Prize of 1924, 23 candidates had been nominated, none of whom was deemed a worthy candidate in the light of Nobel's last will, so the awarding was postponed. Siegbahn, then, was among the nominees for 1925—for the first time—and the Nobel Committee awarded him the still open Prize of 1924 "for his discoveries and research in the field of X-ray spectroscopy". Among the nominators was Max von Laue who, in his nomination letter dated 18 November 1924, had stressed that Siegbahn was the one who had measured the wavelengths in the Röntgen spectrum with such a precision that by now the term scheme of Bohr's atomic theory could be used with full confidence, allowing us even an insight in the hitherto entirely dark structure of the heavier atoms.

From Swedish icon to global eminence

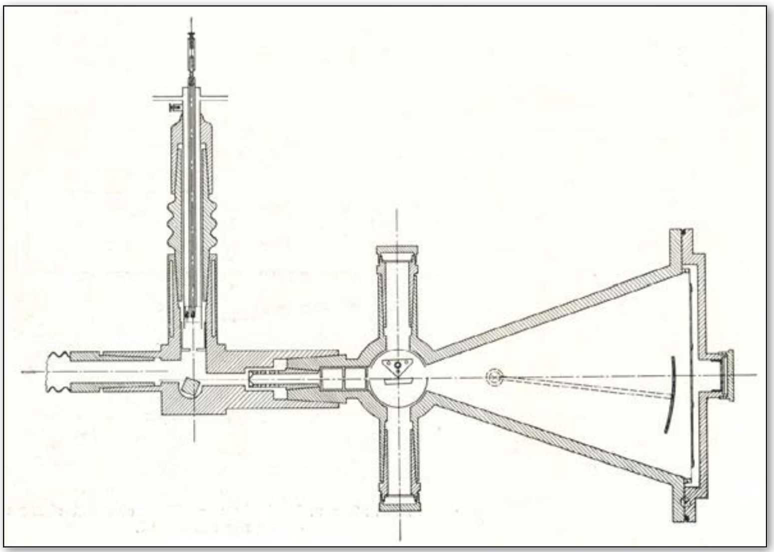
In the late 1920s the use of ruled gratings—first flat, later concave, like those of Rowland—enabled the exact determination of wavelengths and the introduction of an absolute scale; very soft X-rays, then, came to be identified with extreme UV light. Conversely, the lattice constant of calcite could now be calibrated anew, leading to a more precise value of Avogadro's constant. Early in the 1930s Siegbahn's attention was drawn by the remarkable discoveries in the field of nuclear physics, particularly the confirmation, by Chadwick, of the existence of 'neutrons' as postulated by Rutherford and their curious behaviour as reported by Fermi. Sweden should also play a role in all this, Siegbahn esteemed, and he argued for an entirely new laboratory, at nearby Stockholm, under the wings of the Swedish Academy of Sciences. With financial support of the Wallenberg Foundation and the Swedish Government he succeeded in creating, in 1937, a Nobel Institute of Physics close to the Royal Swedish Academy of Sciences. At the new institute powerful cyclotrons were built, funded by the Wallenberg and Rockefeller Foundations. From 1988 until 2011 it was known as the Manne Siegbahn Institute of Physics and functioned under the wings of the University of Stockholm. ■

Acknowledgment

I am indebted to Karl Grandin (Royal Swedish Academy of Sciences, Stockholm; Chair EPS-HoP-Group) for kind permission to see the nomination letter by M. von Laue and to Rolf Siemssen (University of Groningen) for consultation. I am also obliged to Johanna Axnér and Anna Hamberg of Uppsala University-Gustavianum for archival assistance.

About the author

Henk Kubbinga is a historian of science at the University of Groningen and member of the EPS-HoP-Group. Actually he is finishing the fifth and last volume of *The collected papers of Frits Zernike*.



▾ **FIG. 4:** Vacuüm flat-grating spectrometer for λ ≥ 10^4 X.U. as devised by Siegbahn *et al.* (1930; from *Spektroskopie der Röntgenstrahlen*, 1931, p.396). On the left the X-ray tube with the reflecting crystal, in the middle the grating with a shutter, on the right the photographic plate.