

The KLM Shell Labels

William B. Jensen

Department of Chemistry, University of Cincinnati
Cincinnati, OH 45221-0172

Question

Why do the labels for the electron orbits in the Bohr model begin with the letter K?

Bartow Culp
Department of Chemistry
Purdue University
West Lafayette, IN 90032

Answer

The K, L, M-shell labels were not proposed by Bohr as part of his original 1913 quantum model of the atom but were rather the result of experimental studies of the phenomenon of X-ray fluorescence made by the British physicist, Charles Glover Barkla (figure 1), in the period 1906-1911 (1). Barkla characterized the secondary radiations produced when samples of the elements were exposed to an X-ray beam in terms of both their homogeneity and penetrating ability (measured in terms of the number of sheets of aluminum metal required to absorb them). He found that these secondary X-rays fell into two classes, which he labeled K and L, based on the observation that the K radiation was more penetrating than the L radiation. He also observed that the production of K versus L radiation correlated with the atomic weights of the elements, with the elements Ca through Rh producing only K radiation, W through Bi producing only L radiation, and Ag through Ce producing a mixture of both. In 1913 these latter observations were refined by the British physicist, Henry Moseley (1887-1915), in his classic study of the relationship between the frequency of the secondary X-rays and the atomic numbers of the elements (2).

Rationalization of the Barkla-Moseley X-ray fluorescence results in terms of the Bohr model is usually credited to a 1914 paper by the German physicist, Walther Kossel (1888-1956), who argued that the K radiation was due to an excited electron falling back into a vacancy in the first shell of an atom, and the L radiation to an excited electron falling back into a vacancy in the second shell (3, 4). As a consequence, the labels K and L became attached to the first and second shells



Figure 1. Charles Glover Barkla (1877-1944).

of the Bohr atom, especially in the literature dealing with spectroscopy. Already in his 1911 paper, Barkla had speculated on the possible existence of even softer secondary X-rays beginning round Au and Pt and corresponding to possible M and N series, and these labels were soon attached to the third and fourth shells of the Bohr atom as well. Interestingly, Bohr himself seldom made use of these spectroscopic shell labels in his own writings, preferring instead to use numerical quantum numbers (5).

So why did Barkla label his secondary X-ray series K and L? The answer appears in a footnote to his 1911 paper (1):

[These radiations were] previously denoted by the letters B and A ... The letters K and L are, however, preferable, as it is highly probable that series of radiations both more absorbable and more penetrating exist.

In other words, though Barkla assigned arbitrary letters to his X-ray series, he started in the middle of the alphabet, rather than at the beginning, in order to allow for future expansion of his results in either direction.

Given that M rather than K corresponds to the center of the alphabet, it has been suggested to the author that Barkla began instead at K and L because these two letters are found in his last name. Though a charming idea, I have found no documentary evidence to support this supposition.

Literature Cited

1. C. G. Barkla, "The Spectra of the Fluorescent Röntgen Radiations," *Phil. Mag.*, **1911**, 22, 396-412. See especially the footnote, p. 406.
2. H. Moseley, "The High Frequency Spectra of the Elements," *Phil. Mag.*, **1913**, 26, 1025-1034 and *Ibid.*, **1914**, 27, 703-713.
3. W. Kossel, "Bemerkung zur Absorption homogener Röntgenstrahlen," *Verhand. deutschen physik. Gesell.*, **1914**, 16, 898-909.
4. J. L. Heilbron, "The Kossel-Sommerfeld Theory and the Ring Atom," *Isis*, **1967**, 58, 451-485.
5. L. Rosenfeld, Ed., *Niels Bohr: Collected Works*, 9 Vols., North-Holland Publishing: Amsterdam, 1972-1996.

Do you have a question about the historical origins of a symbol, name, concept or experimental procedure used in your teaching? Address them to Dr. William B. Jensen, Oesper Collections in the History of Chemistry, Department of Chemistry, University of Cincinnati, Cincinnati, OH 45221-0172 or e-mail them to jensenwb@ucmail.uc.edu

2010 Update

I recently received an e-mail from a reader claiming that Bohr assigned K to the first shell because it is the 11th letter of the alphabet - 11 being shorthand for one shell, one subshell. Likewise L, as the 12th letter of the alphabet, was shorthand for one shell, two subshells, etc. Though this is certainly a clever mnemonic device for students, it has, to the best of my knowledge no basis in the historical record and is essentially a numerical coincidence, which, like the story associating the letters with Barkla's surname, is yet another example of an historical myth. Likewise, I have also encountered the suggestion that K and L were shorthand for the German words, *kurz* (short) and *lange* (long) and were a reference to the respective wavelengths of the two kinds of secondary X-ray radiation.

