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This Week's Citation Classic®

Siegbahn K, Nordling C, Fahlman A, Hamrin K. Hedman J, Ndberg R, Johansson C, Bergmark T, Karlsson S-E, Lindgren I & Lindberg B. Atomic, molecular and solid-state structure studied by means of electron spectroscopy. *Nova Acta Regiae Soc. Sci. Ups.* 20.1-282, 1967; and, **Siegbahn K, Nordling C, Johansson G, Hedman J, Heden P-F, Hamrin K, Gelius U, Bergmark T, Werme L O, Manne R & Baer Y.** *ESCA applied to free molecules.* Amsterdam, The Netherlands: North-Holland, 1969. 200 p. [Institute of Physics. University of Uppsala, Sweden]

X-ray excited electron spectra are presented as a spectroscopic means of probing the electronic structure of atoms and molecules, both in the free state of a gas and in the bound state of a solid. The method is shown to have considerable potential for chemical analyses. Instruments developedforthese purposes are described. [The *SCI*® indicates that these publications have been cited in more than 515 and 1,605 publications, respectively.]

Making Electrons Talk

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Electrons, for many years, had been quite communicative in our laboratory as messengers from the atomic nucleus. Nevertheless, in the early 1950s, Kai Siegbahn decided to replace the radioactive source in his very best electron spectrometer with an X-ray tube and a thin converter foil, from which photoelectrons and Auger electrons were expelled by the X rays. The aim was to find a method of determining, with high precision, the binding energies of inner atomic electrons. As a graduate student, I became involved in the new project.

One of the requirements for success in these experiments was the effective elimination of external magnetic fields, including the Earth's magnetic field. One of the obstacles to success was therefore the frequent and unannounced changes that were made by the magnetic field of a synchrocyclotron, located at some distance from our lab. It was not until we identified these erratic, stray fields and compensated for them that we developed reproducible data and established the chemical shifts.[1,2]

A conspicuous demonstration of the chemical shift was obtained in a rather serendipitous way. We were exploring the powers of electron spectroscopy for elemental analysis and, for this purpose, wanted to record the sodium, sulfur, and oxygen spectra from Na_2SO_4. However, no such chemical was available in our "larder" at the physics department on that particular night. (University workers often work late hours!) Instead, we took some fixative salt, $Na_2S_2O_3$, from the photographic darkroom. And—of course—obtained *two* well-separated sulfur peaks. The potential of electron spectroscopy for more refined chemical analysis now became apparent.[3]

Two revelations turned out to have profound consequences. First, making thinner and thinner samples in an effort to wipe out the contribution from electrons which had been degraded by energy losses turned out to be both fruitless and unnecessary. Energy losses come in discrete quantities and the resolution of our instrument was sufficiently high to allow us to record the "no-loss" peak separate from the energy loss peaks. Second, the observation that gas phase samples could indeed be studied opened a vast field of applications in molecular science and triggered the work that led to the second *ESCA* book.

The first book was published in the proceedings of one of our local scientific societies in Uppsala. A few weeks after publication, the printer told us he would have to destroy the press plates unless we were willing to pay storage costs. Not realizing what great demand the book would enjoy in the years to come, I decided, as a deputy project leader, to let go of the plates. The manuscript for the second book was sent to a professional publishing house.

These two books demonstrated the great potential of a new spectroscopy and became the basic references in many laboratories, hence the large number of citations. Siegbahn received the Nobel Prize in 1981 for his contribution to the development of high-resolution electron spectroscopy.

1. **Nordling C. Sokolowski E & Siegbahn K.** Precision method for obtaining absolute values of atomic binding energies. *Phys.Rev.* 105:1676-7,1957.
2. **Sokolowski E, Nordling C & Siegbahn K.** Chemical shift effect in inner electronic levels of Cu due to oxidation. *Phys.Rev.* 110:776,. 1958.
3. **Hagstrtöm S. Nordling C & Siegbahn K.** Electron spectroscopy for chemical analysis. *Phys. Lett.* 9:235-6, 1969.

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