Accurately determining the number of Auger electrons per nuclear decay for medical isotopes

M. Alotibi*,†, M. Vos*, T. Tornyi*, T. Kibédi*, B.Q. Lee*, A.E. Stuchbery*, M. Roberts‡ and I. Greguric‡

* Research School of Physics and Engineering, Australian National University, Canberra ACT 2601, Australia
† King Abdulaziz City for Science and Technology, Riyadh, Saudi Arabia
‡ Australian Nuclear Science and Technology Organisation, Lucas Heights, NSW, Australia

Synopsis We compare the intensity of conversion electrons and Auger electrons after decay of ^{125}I. This is a stringent test of our understanding of core-hole relaxation, as the first is part of the nuclear decay, and the second due to atomic relaxation.

Auger-emitting radionuclides have great potential in cancer treatment as low-energy Auger electrons (< 5 keV) deposit high radiation dose over a very short distance. Auger-based therapy is attractive as, in contrast to alpha and beta particles, the affected volume around the decaying radionuclides is much smaller than a cell. Moreover, low-energy electrons (3-20 eV) have been shown to be very effective in causing DNA cleavage. This development prompted renewed interest to test our understanding of the complete Auger cascade after core-hole creation [1, 2].

In this study, a third of a monolayer of ^{125}I was deposited on a gold ⟨111⟩ surface and the energy of the emerging electrons was measured. ^{125}I decays by electron capture to a nuclear excited state in ^{125}Te. A core hole, which is created in the electron capture, relaxes via emission of X-rays and Auger electrons. Subsequently, the nuclear excited state of ^{125}Te internally decays to the ground state and the excess energy can also eject an atomic electron (the conversion electron), which also leaves a core hole behind, and the newly created core hole will also relax by a cascade of Auger electrons and X-rays. In the case of ^{125}I the K-shell conversion electron and the L-shell Auger electrons have similar energies (see Fig. 1), and thus their intensities can be compared, linking the nuclear- and atomic-physics parts of the decay of ^{125}I.

The measured spectrum is compared with a simulated one using a Monte Carlo procedure based on the known intensity of the K conversion electron line, estimates of the decay rates for Auger and X-ray emission as well as an estimate of the contribution of 'shake-off' electrons [3]. In order to fit the spectrum, one has to assume a line shape, modeling e.g. the contribution of electrons first propagating into the gold, but entering the detectors after elastic and inelastic collisions. We will discuss if one can get a good description of the spectrum of ^{125}I *absorbed on Au*, based on the calculated one for a free ^{125}I atom and reasonable assumptions for the line shape.

The measurements of very low-energy Auger electrons (<1 keV), which are particularly relevant to medical physics, are even more difficult to quantify, and preliminary results in this energy range will be discussed as well.

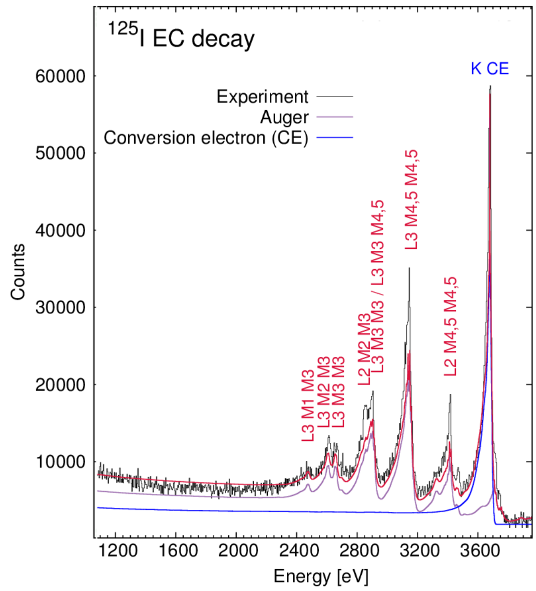

Figure 1. An example of a fit to the Auger spectrum from the EC decay of ^{125}I showing the Auger electrons emitted from the L-shell, as well as the K-shell conversion electrons (labelled as 'K CE'). Calculated spectra, obtained using the BrIccEmis program[3], are also shown.

[1] F.R. Knapp and A. Dash. *Radiopharmaceuticals for Therapy*, in *Auger Electron-Based Radionuclide Therapy*, Springer, 2016.

[2] A. Pronschinske, P. Pedevilla, C. J. Murphy, E.A. Lewis, F.R. Lucci, G. Brown, G. Pappas, A. Michaelides, and E.C.H. Sykes. Enhancement of low-energy electron emission in 2D radioactive films. *Nature Materials*, 14:904, 2015.

[3] B. Q. Lee, H. Nikjoo, J. Ekman, P. Jönsson, A. E. Stuchbery, and T Kibédi. A stochastic cascade model for Auger-electron emitting radionuclides. *International Journal of Radiation Biology*, 92:641, 2016.