

Measurement of the half-life of ^{198}Au in an insulator

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This experiment was undertaken to investigate whether the half life of the β^- decay of ^{198}Au changes depending on whether the nucleus is located in a metallic or insulating environment. The “Debye plasma model,” which was originally invoked to explain observed cross-section anomalies in the $d(d,p)t$ reaction, was later applied to radioactive decays by Limata *et al.* [1]. According to this model, the conduction electrons, present in a metal, comprise a sort of plasma, which is referred to as a Debye plasma. It is argued that this plasma changes the phase space available for the decay and thus increases (for β^- or electron-capture decay) or decreases (for β^+ -decay) the nuclide’s half life. If this model were correct, this change in phase space would occur only in metals, not in an insulator, and would be enhanced if the metal were to be cooled to very low temperatures.

In their subsequent study of the β^- decay of ^{198}Au , Spillane *et al.* [2] claimed to observe both these effects, albeit to a lesser extent than the theory predicted. The theory predicts that at room temperature the ^{198}Au half-life in a metal would be 8% longer than in an insulator, while at 12K it would be 32% longer. The corresponding numbers reported by Spillane *et al.* were 0.4(7)% and 4.0(7)%. We repeated their measurement in a metal at two different temperatures and have already reported [3] that any temperature dependence is less than 0.04%, two orders of magnitude below the value claimed by Spillane *et al.* However, we have not yet addressed the possibility that there might be a difference between sources located in metal and insulators. We do so in the study reported here.

We focused again on ^{198}Au , which we chose because of its suitability for a precise measurement (monoisotopic, single β -delayed γ peak, *etc.*). This time though we chose to irradiate gold in the form of Au_2O_3 (gold(III) oxide), which is an insulator. With a single measurement at room temperature we could then compare our result with the value we previously obtained at room temperature for ^{198}Au in a conductor (gold metal) [3].

We used a gold(III) oxide sample obtained from the Alfa Aesar Corporation. This was in the form of a powder, with a purity of 99.99% (metals basis). The sample (0.170 g on an Al disc) was activated in a flux of $\sim 10^{10}$ neutrons/cm²·s for 10 s irradiation time, at the Texas A&M Triga reactor. The irradiated Au_2O_3 sample was then placed upon the cold head of a CryoTorr 7 cryopump, precisely as had been done previously for our ^{198}Au measurement [3], and for our ^{97}Ru [4] experiment. A 70% HPGe detector was placed directly facing the sample, and just outside the plate covering the cryopump. A cavity had been bored in the cover-plate such that only 3.5 mm of stainless steel remained between the sample and the face of the detector. The detector and cryopump were placed such that the distance between them remained constant throughout the measurement.

Six-hour γ -ray spectra, from the 411-keV delayed γ -ray in ^{198}Hg , were acquired and saved consecutively, for a period of 27 days. All these spectra were collected for an identical, pre-set live time. Throughout the experiment, we synchronized the time, prior to each day’s collection, using the signal broadcast from radio station WWVB. We also kept the system’s dead time below about 3% for all the spectra. Since the TRUMPTM card used in our data collection corrects for dead time losses, our results

were basically independent of dead time losses. However, as before, we applied to all spectra a further experimentally-determined correction of $5.5 \pm 2.5 \times 10^{-4}$ per 1% increase in dead time to account for residual, rate-dependent effects.

We obtained a total of 107 spectra and extracted the peak area from each for the 412-keV β -delayed γ ray in ^{198}Hg , the daughter of ^{198}Au , using the same methods we used before [3, 4]. The resulting decay curve then yielded a half-life of 2.6948(9) d, a value that can be compared to the result we obtained for ^{198}Au in a metal at room temperature, 2.6949(9) d. The difference between the two measurements is 0.0001(12) d, which gives an upper limit of 0.0013 d or 0.05% at the 68% confidence level. We therefore conclude that the observed half-life is independent of the host material as well as being independent of its temperature.

[1] B. Limata *et al.*, *Eur. Phys. J. A* **28**, 251 (2006).

[2] T. Spillane *et al.*, *Eur. Phys. J. A* **31**, 203 (2007).

[3] J.R. Goodwin, V.V. Golovko, V.E. Jacob and J.C. Hardy, *Eur. Phys. J. A* **34**, 271 (2008).

[4] J.R. Goodwin, V.V. Golovko, V.E. Jacob and J.C. Hardy, *Phys. Rev. C* **80**, 045501 (2009); and *Progress in Research*, Cyclotron Institute, Texas A&M University (2009-2010), p. I-16.