The half-life of ^{97}Ru: a test for temperature dependence in electron-capture decay

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This experiment was undertaken to investigate whether the half life of the electron capture decay of ^{97}Ru in a metallic environment shows any temperature dependence, as has been claimed recently for the electron capture decay of ^{7}Be [1].

Previous publications claiming to observe a temperature dependence of β-decay half-lives [1 - 3] in a metallic environment have used the so-called "Debye effect" to explain the phenomenon. This Debye-effect theory claims that the conduction electrons, present in a metal, comprise a sort of plasma, referred to as a Debye plasma, which alters the phase space available for beta decay. It is argued that the "Debye plasma" would decrease the phase space for β^--decay or electron capture, thus slowing the decay rate and increasing the half-life; and would increase it for β^+-decay, which would have the opposite effect on the half-life. The theory also indicates that this change in phase space should be enhanced if the sample is cooled to very low temperatures (e.g., ~20 K).

We have already demonstrated that this effect does not, in fact, exist in the case of β^--decay by measuring the half-life of ^{198}Au in gold at room temperature and at 20 K [4]. We are now examining the electron-capture decay of ^{97}Ru in ruthenium. We have already completed the 20-K portion of the measurement.

We used a ruthenium disc obtained from Goodfellow Corporation. This was a single crystal, 8 mm in diameter, 1 mm thick, with a purity of 99.999%. The crystal was activated in a flux of ~10^{13} neutrons/cm^2·s for 10 s irradiation time, at the Texas A&M Triga reactor. For the decay measurement we used the same set-up as we did previously for ^{198}Au [4]. The activated ruthenium sample containing ^{97}Ru (and other activities produced from stable ruthenium isotopes) was placed upon the cold head of a CryoTorr 7 cryopump. A 70% HPGe detector was placed directly opposite the sample, and just outside the plate covering the cryopump. A cavity is bored in the cover-plate such that only 3.5 mm of stainless steel remains 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.

Consecutive six-hour γ-ray spectra were acquired and saved for a period of 29 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 but the first few days' spectra. Since the TRUMP^{TM} card used in our data collection corrects for dead time losses, our results were nearly independent of dead time losses, but we also made a small additional correction determined empirically [4].

We measured the half-life of ^{97}Ru via the 216 keV γ-ray in ^{97}Tc, which follows its β-decay. We used the least-squares peak-fitting program GF3 (in the RADware series [5]), to obtain the peak area in each of the ~115 recorded spectra. Use of this program allowed us to make very accurate determinations of spectral backgrounds and areas. Each peak was analyzed and then corrected for residual, rate-dependent effects, as mentioned above. The decay curves resulting from this analysis were then plotted as a function of time and analyzed, by a maximum-likelihood fit (single exponential), using a code based

on ROOT [6]. We had tested this code previously to a precision of 0.01%, with Monte-Carlo generated data.

From our analysis we have already obtained a preliminary half-life value of 2.8382 ± 0.0026 d at 20 K. We hope to have the room-temperature results available by June 2008. We expect that the final quoted uncertainties at both temperatures will be less than half the uncertainty now on our preliminary result. This precision (*i.e.* ~0.07%) will be about the same as we quoted for our completed ^{198}Au result [4].

[1] B. Wang *et al*., Eur. Phys. J. A **28**, 375 (2006).

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

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

[4] J. R. Goodwin *et al*., Eur. Phys. J. A **34**, 271 (2007); *Progress in Research*, Cyclotron Institute, Texas A&M University (2007-2008), p. I-35.

[5] D. Radford, **http://radware.phy.ornl.gov/main.html** (private communication).

[6] R. Brun, and F. Rademakers, Nucl. Instrum. Methods Phys. Res. **A389**, 81 (1997).