The ^{97}Ru half-life: high-precision measurement shows no temperature dependence

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This experiment was undertaken to investigate whether the half life of the electron-capture decay of ^{97}Ru located in a metallic environment shows any temperature dependence, as has been claimed for the electron-capture decay of ^{7}Be in a recent publication [1]. The results of our measurement on ^{97}Ru have now been published [2].

Previous publications claiming to observe temperature dependence of β^-, β^+ and electron-capture-decay half-lives [1, 3, 4] have used the so-called "Debye effect" to explain the phenomenon. The authors claim that the conduction electrons, present in a metal, comprise a sort of plasma, which they refer to as a Debye plasma. They argue 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. The change in phase space would be enhanced, they argue, if the source is cooled to very low temperatures. Although the half-life changes, which were reported at low temperature (~12K), were less than their proposed theory indicated, they were in the same direction.

We set out by repeating one of the reported experiments: the measurement of the half-life of ^{198}Au in gold at room temperature and at 19K [5]. Spillane *et al*. [3] had claimed a 3.6(10)% effect, but we found no effect and set an upper limit of 0.04%, two orders of magnitude lower than their claims. Having shown no effect to exist for the β^--decay of ^{198}Au, we next turned to a case of electron-capture: the decay of ^{97}Ru.

The details of this experiment were described in last year's Progress Report [6] and in our published paper [2]. From our analysis of the decay of the 216-keV delayed γ ray in ^{97}Tc, the daughter of ^{97}Ru, we obtained a half-life (statistical uncertainty only) of 2.8382(13) d for the cold-temperature measurement, and of 2.8370(13) d for the room-temperature measurement. The difference between these two results is 0.0012(18) d, which gives an upper limit of 0.0030 d, or 0.1%, on any temperature-dependent difference in the ^{97}Ru half-life at the 68% confidence level.

Since their delayed γ rays were present in the spectra as well, we have also obtained data at both temperatures for two other isotopes, ^{103}Ru and ^{105}Rh, which both decay by β^- emission. We were able to show that neither of these isotopes undergoes a change in half-life, as would be predicted by the "Debye theory":

- For ^{103}Ru, our measurements yield a half-life of 39.210 ± 0.016 d at room temperature and 39.219 ± 0.025 d at 19K. These results are also the same within 0.1%.
- For ^{105}Rh, our measurements obtain a half-life of 35.357 ± 0.036 h at room temperature, and a half-life of 35.319 ± 0.023 h at 19K. These results are the same within 0.2%

Obviously we cannot comment on the validity of the ^{7}Be measurement, which claimed to have observed a temperature effect [1], but we can certainly refute any suggestion that the half-lives of electron-capture decays in general exhibit significant temperature dependence when the source is placed in a metal host. Wang *et al.* [1] used their model to calculate that the half-life of ^{7}Be in a metal should

change by 1.1% between T = 293 and 12K, a result that agrees reasonably well with their measured values. Using the same model, we calculate that the half-life change for the ^{97}Ru decay should be 11.2% between T = 293 and 12K and 8.4% between T = 293 and 19K, the temperature we obtained. Our measured upper limit on any half-life change over this temperature range is nearly two orders of magnitude less than this model prediction. We have previously demonstrated that the "Debye model" has no validity for β^- decay [2] and have confirmed that conclusion in this work; we can now state with equal confidence that it also does not apply to electron-capture decay.

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

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

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

[6] J.R. Goodwin, V.V. Golovko, V.E. Iacob, and J.C. Hardy, *Progress in Research*, Cyclotron Institute, Texas A&M University (2008-2009), p. I-37.