

## Test of internal-conversion theory with precise $\gamma$ - and x-ray spectroscopy of $^{93m}\text{Nb}$ : source preparation

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One of the cases of interest in our series of precision ICC measurements is the 30.8-keV,  $M4$  transition in  $^{93m}\text{Nb}$  ( $T_{1/2}=16.12$  y), through which we can extend the range of our measurements down to  $Z = 41$ . There have been previous measurements of this transition, with the most precise result – published more than 40 years ago – giving  $\alpha_K = 25,800(1,500)$  [1]. This result can be compared with the theoretical values<sup>1</sup>  $\alpha_K$  (FO) = 26,000 and  $\alpha_K$ (NH) = 23,900, where “FO” designates a calculation that takes into account the atomic vacancy by the so called “frozen orbital” approximation, and “NH” is the result of a “no hole” calculation, with the atomic vacancy ignored. Since the 6% precision of the experimental result is insufficient to distinguish clearly between the two theoretical results, we intend to re-measure this transition. See Ref. [2] for details of our measurement techniques.

We have purchased 40  $\mu\text{Ci}$  of  $^{93m}\text{Nb}$  in the form of niobium nitrate in solution (1M  $\text{HNO}_3$  + 0.3M HF) from Eckert & Ziegler. The supplier stated that the solution also contains about ten times as much active  $^{94}\text{Nb}$ , which fortunately has a much longer half-life ( $T_{1/2}=20,300$  y) and consequently much lower specific activity. Our preliminary measurements have identified both the 702.6-keV and 871.1-keV transitions in  $^{94}\text{Nb}$  decay (as well as their coincidence summing peak), together with the  $K$  x rays of Nb; a small peak was also visible at 31 keV, which is likely our transition of interest, although conclusive identification awaits a full impurity analysis.

To prepare the  $^{93m}\text{Nb}$  source, the so-called molecular plating technique will be used. In principle the idea is to dissolve the analyte in an organic solution and apply a bias voltage to this solution to collect the material on the surface of one of electrodes. The procedure development includes several stages, such as experiments with stable niobium (standard ICP-MS solution), creation of LabVIEW-controlled software to monitor the electrodeposition process, and voltage/current variation to optimize the conditions and the source quality. Isopropanol was chosen as a well-known medium for electrodeposition, because it has a higher electrical window than that of any aqueous solutions.

In the tests performed with stable niobium, we used the high-voltage power-supply unit SRS PS300, which provides up to 1250 V and 20 mA, to create the electrical field. The unit was designed to provide only a constant voltage, while the current depends on the chemical condition and the metal concentration. In order to have some flexibility within the deposition and to record the voltage/current values, the power supply was connected to a PC controlled via LabVIEW software. The program we created allows us to set the desired current, while the voltage will be automatically adjusted to compensate for the material loss during the process. A series of experiments was performed to check if the molecular plating technique is applicable for Nb electrodeposition if the  $^{93m}\text{Nb}$  solution contains trace amounts of hydrofluoric acid (HF). The presence of HF could lead to niobium forming a very stable oxyfluorocomplex  $\text{NbOF}_3$ . Nevertheless, EDS and XPS analyses of the deposited layer (performed at Material Characterization Facility, TAMU) indicated that niobium was electrodeposited on the aluminum

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<sup>1</sup> Calculated with the interpolator code BrIcc (<http://bricc.anu.edu.au>)

electrode mostly in the form of niobium oxide  $\text{Nb}_2\text{O}_3$ . Optimization of niobium electrodeposition parameters will be finalized within the next round of experiments.

The work is in progress and will proceed with deposition and measurement of the radioactive  $^{93\text{m}}\text{Nb}$  source.

[1] M. Jurcevic, A. Ljubicic, and D.Rendic, *Fizika* **8**, 81 (1976).

[2] J.C. Hardy *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2016-2017) p. I-

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