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Optimisation of ion source efficiency for AMS analysis of the rarest known naturally-occurring radioisotope ^{244}Pu

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The recent discovery of naturally-occurring ^{244}Pu [1,2] has been made possible by achieving high overall detection efficiency for plutonium by AMS [3]. Overall efficiency is determined by a combination of ionisation efficiency, charge state yield and beam transmission through the AMS system. Of these, ionisation efficiency remains as the principal limitation, with few instances where efficiency greater than 1% has been reported. Using the Vega AMS system at ANSTO, we have achieved reproducible ionisation efficiency, for formation of PuO anions, of 3-4%. However, the achievement of high overall efficiency has come at the cost of operational efficiency, as it can take of the order of 10 hours to fully consume each sample.

We have performed a series of tests to understand what determines ionisation efficiency, focussed on plutonium AMS, and to seek improvements where possible.

In the standard method used at ANSTO, plutonium samples are dispersed in iron oxide and mixed with niobium powder as 'binder'. An initial observation made by us was that the overall efficiency (number of atoms detected / number of atoms in the sample, with sample run to exhaustion) is linearly proportional to the total mass of the iron oxide + niobium mixture.

We have performed a series of tests by varying the following sample parameters: (i) recess depth of material in cathode; (ii) use of layered samples; (iii) varied binder / iron oxide mix; (iv) different cathode materials; (v) different binder; (vi) varied sample surface area. We have also checked the molecular composition of the Pu anions: PuO_x^- of extracted beams for x = 0 to 3.

The results will be reported and compared to a sputtering model that has been developed to account for the observed variation in count rates versus time as the sample is consumed. In the course of these tests, a maximum ionisation efficiency of 6% has been observed for PuO anions.

[1] A. Wallner et al. Science, 372 (2021) 742.
[2] D. Koll, PhD Thesis, ANU and TUD, 2023.
[3] M.A.C. Hotchkis et al. Nucl. Inst. and Meth. B 438 (2019) 70.

Student Submission

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