

## REVISITING PROTACTINIUM CHEMISTRY FOR A RANGE OF NEW MEASUREMENTS

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Protactinium is one of the less studied actinide elements, yet it is as abundant as radium in uranium ore, where the theoretical mass ratio of  $^{231}\text{Pa}:$  $^{226}\text{Ra}$  is  $0.961 \pm 0.018$  ( $k=2$ ). Protactinium has a complex chemistry (similar to that of niobium and tantalum), with several oxidation states being available to it, although the major challenge is to maintain it in solution, given the ease with which it hydrolyses and precipitates in aqueous solution. Protactinium may be stabilised in acid solution with sulphate, fluoride and chloride as well as in alkaline solution with sodium hydroxide (if sufficiently concentrated)<sup>[1]</sup>. In addition, it may be stabilised in nitric acid solution by the addition of oxalic acid as a complexant<sup>[2]</sup>.

In this presentation, we present our current work on protactinium which has three aims:

- To support standardisation of  $^{234}\text{Th}$ ,
- To improve the nuclear decay data for  $^{231}\text{Pa}$ ,  $^{234\text{m}}\text{Pa}$  and  $^{234\text{g}}\text{Pa}$ , and
- To produce calibrated  $^{233}\text{Pa}$  as a tracer.

These requirements will be discussed more fully in the presentation, but the outcomes will include the completion of improvements to the  $^{231}\text{Pa} \rightarrow ^{227}\text{Ac} \rightarrow ^{227}\text{Th} \rightarrow ^{223}\text{Ra} \rightarrow \dots \rightarrow ^{207}\text{Pb}$  decay series, some of which has been previously reported<sup>[3,4,5]</sup>.

The radiochemical techniques studied include:

- Solvent extraction (mainly with 2,4-dimethyl pentan-3-ol),
- Anion exchange chromatography, and
- Extraction chromatography

These techniques are being applied to procedures we are developing (or adapting) to effect the separation of  $^{234\text{g}}\text{Pa}$  from  $^{234}\text{Th}$ ,  $^{233}\text{Pa}$  from  $^{237}\text{Np}$  and  $^{231}\text{Pa}$  from  $^{227}\text{Ac}$ ,  $^{227}\text{Th}$  and  $^{223}\text{Ra}$  (*et seq.*) to address the needs briefly outlined above and will be discussed in the presentation.

- [1] Kirby, H.W., *'The Radiochemistry of Protactinium'*, US National Academy of Sciences, NAS-NS, (1959)
- [2] Woods, M.J., *et al*, *'Standardization and Decay Data of  $^{237}\text{Np}$ '*, Applied Radiation and Isotopes, **56(1-2)**, 415-420, (2002)
- [3] Collins, S.M., *et al*, *'Direct measurement of the half-life of  $^{223}\text{Ra}$ '*, Applied Radiation and Isotopes, **99**, 46-53, (2015)
- [4] Collins, S.M., *et al*, *'Precise measurements of the absolute  $\gamma$ -ray emission probabilities of  $^{223}\text{Ra}$  and decay progeny in equilibrium'*, Applied Radiation and Isotopes, **102**, 15-28, (2015)
- [5] Collins, S.M., *et al*, *'The half-life of  $^{227}\text{Th}$  by direct and indirect measurements'*, Applied Radiation and Isotopes, **104**, 203-211, (2015)