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ESRF

Experiment Report Form

The double page inside this form is to be filled in by all users or groups of users who have had access to beam time for measurements at the ESRF.

Once completed, the report should be submitted electronically to the User Office using the **Electronic Report Submission Application:**

http://193.49.43.2:8080/smis/servlet/UserUtils?start

Reports supporting requests for additional beam time

Reports can now be submitted independently of new proposals – it is necessary simply to indicate the number of the report(s) supporting a new proposal on the proposal form.

The Review Committees reserve the right to reject new proposals from groups who have not reported on the use of beam time allocated previously.

Reports on experiments relating to long term projects

Proposers awarded beam time for a long term project are required to submit an interim report at the end of each year, irrespective of the number of shifts of beam time they have used.

Published papers

All users must give proper credit to ESRF staff members and proper mention to ESRF facilities which were essential for the results described in any ensuing publication. Further, they are obliged to send to the Joint ESRF/ ILL library the complete reference and the abstract of all papers appearing in print, and resulting from the use of the ESRF.

Should you wish to make more general comments on the experiment, please note them on the User Evaluation Form, and send both the Report and the Evaluation Form to the User Office.

Deadlines for submission of Experimental Reports

- 1st March for experiments carried out up until June of the previous year;
- 1st September for experiments carried out up until January of the same year.

Instructions for preparing your Report

- fill in a separate form for each project or series of measurements.
- type your report, in English.
- include the reference number of the proposal to which the report refers.
- make sure that the text, tables and figures fit into the space available.
- if your work is published or is in press, you may prefer to paste in the abstract, and add full reference details. If the abstract is in a language other than English, please include an English translation.

ESRF	**Experiment title:** **For future sequestering agents to face actinide contamination in humans**	**Experiment number**: CH3934
Beamline: BM20	**Date of experiment**: from: 22/02/2014 to: 25/02/2014	**Date of report**: 23/02/2015
Shifts: 9	**Local contact(s)**: C. Hennig	*Received at ESRF:*

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Context of the experiment

In case of an accidental nuclear event, contamination of humans by actinide elements may occur. Such elements have the particularity to exhibit both a radiological and chemical toxicity that may induce severe damages at several levels depending on the biokinetics of the element. In order to eliminate the actinide elements before they are stored in target organs (depending on the element: liver, kidneys, bone), sequestering agents must be quickly injected. However to date, there is still no ideal sequestering agent, despite the recent interests in contamination concerns. This project aims to better understand the interaction of actinide elements with two types of molecules that are currently inspiring future sequestering agents : DTPA (diethylenetriaminepentaacetic acid) and the LIHOPO (hydroxypyridonate) family. Note that DTPA is currently the only available treatment in case of accidental contamination. The SRI company is for instance developing a new formulation of this chemical (Ca-DTPA) for the treatment of internal contamination with plutonium, americium, and curium caused by exposure to a radiological dispersal device or improvised nuclear device.[1]

Experimental results

In this experiment we have investigated the structure of Th(IV), Pu(IV) and $\{U(VI)O_2^{2+}\}$ complexes with DTPA and 3,4,3LI-(1,2-HOPO) in aqueous solution.

1/ the hydroxypyridonate family

Figure 1ab shows as an example the EXAFS spectrum of the $\{U(VI)O_2^{2+}\}$-LI-HOPO complex together with a schematic structure of the complex (fitting data provided in the legend). In this complex, the uranyl coordination plane is fulfilled by 4 of the LI-HOPO hydroxamine and carbonyl chelating functions. IR spectroscopy has confirmed this assignment. We have also verified that the complex at pH = 2 (at this pH any uranium hydrolysis is avoided) and at pH closer to physiological conditions (5 - 6) are identical. Furthermore, the stoichiometry of the complex (1:2) has been determined using size exclusion chromatography coupled to UV-Vis. The complex formula is therefore assumed to be $[(UO_2)_2$LI-HOPO$(NO_3)_2]^{2+}$. The Th(IV) and Np(IV) adducts have also been prepared and are now compared to the very different $\{U(VI)O_2^{2+}\}$ adduct.

In parallel, competitions between LI-HOPO and Fetuine (Fet, a protein with high uranyl affinity involved in bone turnover) has been investigated by size exclusion chromatography. The occurrence of a ternary complex $\{U(VI)O_2^{2+}\}$-LI-HOPO-Fet has been identified. Characterization of the modification of the uranyl

[1] http://www.sri.com (Oral Formulation of DTPA to Counter Radiation Exposure)

coordination sphere with EXAFS in presence of Fet is in progress but difficulties come from the necessity to subtract the pure $\{U(VI)O_2^{2+}\}$-LI-HOPO signal. This is currently being carried out.

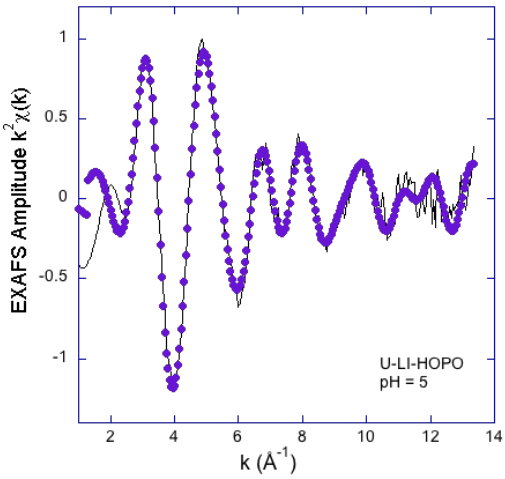

Fig. 1a : EXAFS spectrum (data, straight line and fit, dots) of the $\{U(VI)O_2^{2+}\}$-LI-HOPO complex at pH = 5

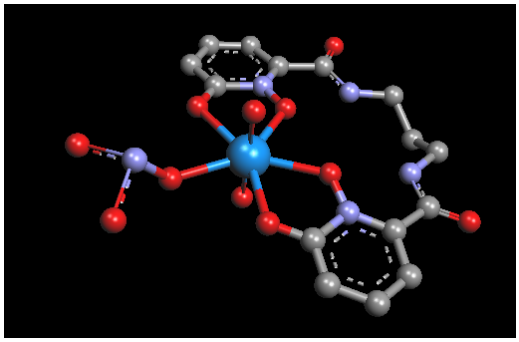

Fig. 1b : Corresponding schematic molecular model.
EXAFS data fitting :
2 O at 1.80(1) Å, $s^2 = 0.0062$ Å^2
2 O_C at 2.39(1) Å, $s^2 = 0.0004$ Å^2
2 O_N at 2.55(1) Å, $s^2 = 0.0063$ Å^2
$S_0^2 = 1.0$, e0 = 6.20 eV, Rfactor = 1.8%

2/ the DTPA family

The series of complexes An(IV)-DTPA (An = Th, Np, Pu) has been investigated in aqueous solution at acidic pH (pH = 3-4). Aminocarboxylate ligands (NTA, EDTA, DTPA) exhibit a double coordination mode : the oxygen of the carboxylate function in the first coordination sphere and the nitrogen of the tertiary amine function in the second coordination sphere. This has been observed on the NTA ligand.[2] Similar trend has been observed with DTPA although this double coordination mode must be taken with much care because of the similarity from the EXAFS point of view between the oxygen and nitrogen backscatters. The fitted distances are summarized in Figure 2a. In parallel, molecular dynamics simulations have been able to define the radial distribution functions for the $[PuDTPA]^{-1}$ complex for Pu-O, Pu-N and Pu-C. The trend observed by EXAFS is reproduced with an average Pu-O distance equal to 2.29 Å and Pu-N distance equal to 2.73 Å. An article is currently under preparation.

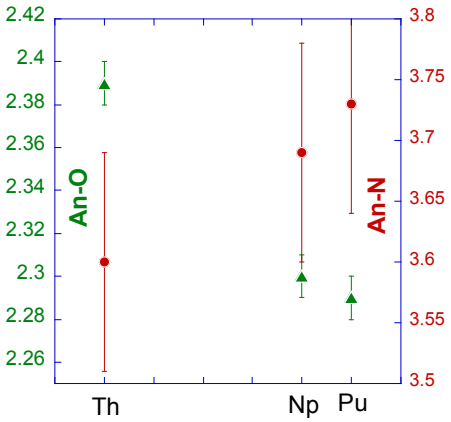

Fig. 2a : An-O and An-N distances in the An(IV)-DTPA complexes (1:1 complexes) for An = Th, Np, Pu.

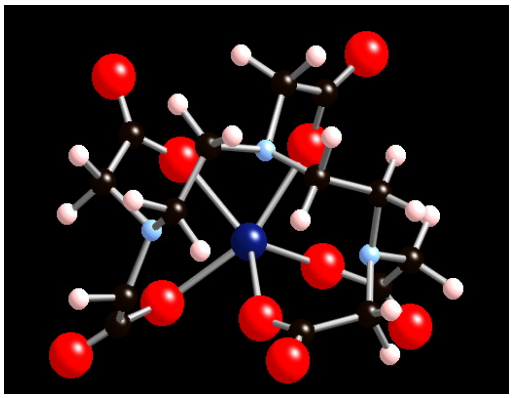

Fig. 2b : Structure of the $[PuDTPA]^{-1}$ complex after molecular dynamics simulation (GGA + U)[3]

As a continuation, the group is currently investigating supramolecular sequestering agents based on DTPA grafted on nanoparticles.

[2] L. Bonin, D. Guillaumont, A. Jeanson, C. Den Auwer, M. Grigoriev, J-C. Berthet, C. Hennig, A. Scheinost, Ph. Moisy, Inorg. Chem. (2009), **48**, 3943.
[3] N. Pineau, B. Siberchicot, M. Torrent, G. Robert, J. Aupiais, C. Den Auwer, Choc (CEA DAM) (2014), **46**, 19.