



## Production of Pb-203 from target manufacturing to chemical separation Tl/Pb

Thomas Sounalet, Cyrille Alliot, Nadia Audouin, Nicolas Bozovic, Fabien Brelet, Remy Dureau, Lucas Granger, Arnaud Guertin, Ferid Haddad, Keerthana Kamalakannan, et al.

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## 1. Introduction

**Why <sup>203</sup>Pb?** <sup>203</sup>Pb emits a strong 279 keV gamma line and has a half-life of 51.9h. <sup>203</sup>Pb is suited for SPECT imaging.

**What else?** <sup>203</sup>Pb forms a theranostic pair with <sup>212</sup>Pb which is used for targeted alpha-therapy.

**Which impurities are to be avoided for <sup>203</sup>Pb production?** <sup>201</sup>Pb ( $t_{1/2} = 9.33$ h) is to be avoided and it must be limited during production. The only way to minimize this production is to respect the cooling time of a minimum of several hours for its value to be considered low enough: below 0.07%.

## 2. Objectives

The objectives of this research are:

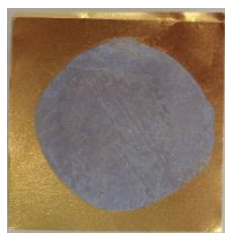
- ✓ To manufacture <sup>205</sup>Tl deposit by electrodeposition technique. This deposit is used for the study of cross section measurements of <sup>203m1+m2+g</sup>Pb and of <sup>201m+g</sup>Pb through deuteron induced reaction and the future production on an industrial scale;
- ✓ To estimate the yield production of <sup>203m1+m2+g</sup>Pb and <sup>201m+g</sup>Pb by bombarding enriched <sup>205</sup>Tl target with deuteron particles at GIP ARRONAX, France. To estimate this production yield, the stack-foils technique is used in the energy range from 21 MeV to 34 MeV;
- ✓ To study the chemical separation of Tl and Pb with Pb resin from Triskem to obtain a high purity of <sup>203</sup>Pb and to recover <sup>205</sup>Tl to be reused.

## 3. How to produce <sup>203</sup>Pb?

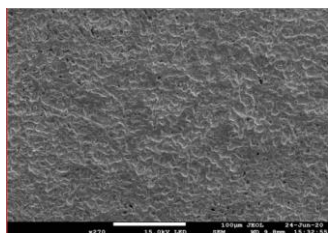
<sup>203</sup>Pb is produced in an accelerator at GIP ARRONAX in France, with deuteron particles on <sup>205</sup>Tl target. Measurements of cross sections of <sup>205</sup>Tl(d,4n)<sup>203m1+m2+g</sup>Pb and <sup>205</sup>Tl(d,4n)<sup>201m+g</sup>Pb nuclear reactions are performed by using the stacked-foils in the energy range 21-34 MeV. The <sup>205</sup>Tl deposits are manufactured by electrodeposition. To obtain a smooth and dense Tl deposit free from filaments and dendrites, the reverse pulse potential is applied.

Reduction potential	Oxidation potential	Reduction time	Oxidation time
-1.10 V/NHE	-0.73 V/NHE	60 ms	40 ms

Electrochemical parameters to obtain a smooth and dense Tl deposit

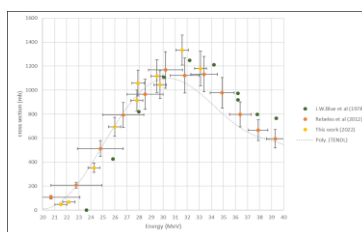


Photograph of a Tl deposit on gold backing

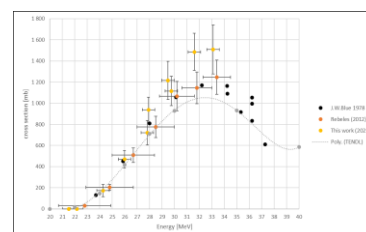


Microscopic image of surface morphology of a Tl deposit

The Tl deposit is suited for the irradiation



Cross-section of <sup>205</sup>Tl(d,4n)<sup>203m1+m2+g</sup>Pb nuclear reaction



Cross-section of <sup>205</sup>Tl(d,4n)<sup>201m+g</sup>Pb nuclear reaction

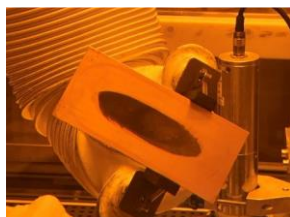
There is a high production of <sup>203</sup>Pb at 31.6 MeV. At GIP ARRONAX, deuteron energy can reach up to 32.5 MeV. <sup>203</sup>Pb production yield in the energy range from 32.5 MeV to 30 MeV is estimated to be 56 MBq/μA/h.

The production yield in the energy range from 32.5 MeV to 30 MeV is estimated to be 370 MBq/μA/h. To avoid the production of <sup>201</sup>Pb, the enrichment of <sup>205</sup>Tl is crucial and must be very high (above 99%) to minimize its production.

The calculation predicts that for 5h of irradiation with 50 μAe in the energy range of 32.5 MeV to 30 MeV, it is necessary to cool down for 61h after end of bombardment if the enrichment of <sup>205</sup>Tl is 99.75%. From these parameters of irradiation, 299 mCi can be produced at EOB leading to 133 mCi after 61h of EOB of <sup>203</sup>Pb.

## 4. How to separate Tl and Pb to obtain final product of <sup>203</sup>Pb with a high purity?

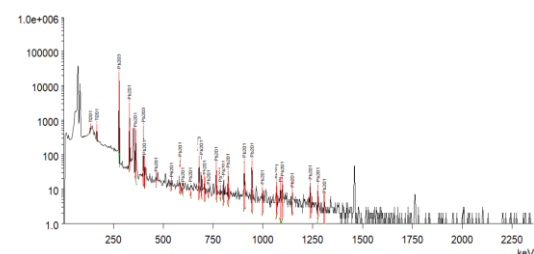
For routine production of <sup>203</sup>Pb large targets are mandatories. To mimic this and prepare chemistry procedure to separate Pb from Tl, a natural Tl deposit of 13.52 cm<sup>2</sup> and 40 μm of thickness has been manufactured by electrodeposition. The Tl deposit was irradiated at an energy of 32.5 MeV with an intensity of 30 μA for a duration of 1h. A Pb resin from Triskem was used to separate Tl and Pb. 1 mol/L of HNO<sub>3</sub> was used to dissolve the deposit and filled firstly in the column with the volume of 150 mL to recover Tl. In a second step, 1 mol/L of ammonium acetate with the volume of 15 mL was filled in the column to recover <sup>203</sup>Pb. To obtain a final product of <sup>203</sup>Pb with a small volume, the solution is dried through evaporation and the residue is dissolved in 2 mL of 0.25 mol/L of ammonium acetate at pH 7.



Photograph of a Tl deposit after irradiation in a hot cell

## 5. Results of final product of <sup>203</sup>Pb and of recycle natural thallium

The final product of <sup>203</sup>Pb has been analysed by γ-ray spectrometry and ICP-OES to determine the purity of <sup>203</sup>Pb. The yield rates are determined by using 2 radiotracers, <sup>203</sup>Pb and <sup>202</sup>Tl.



HPGe gamma spectrum of the final product of <sup>203</sup>Pb

No Tl impurity except for <sup>201</sup>Tl, which comes from the decay of <sup>201</sup>Pb in the final production of <sup>203</sup>Pb

The chemical yield of Pb and Tl are 85% and 82% respectively. The final amount of Tl is 27 μg and for stable Pb, the value is below the detection limit (<4.4 μg).

## 6. Conclusion and perspectives

The final product of <sup>203</sup>Pb and the yield rates are in accordance to expectations based on cross sections measurements. The next step is to use <sup>205</sup>Tl to produce very high purity of <sup>203</sup>Pb, with less than 0.07% of <sup>201</sup>Pb after several hours of cooling and less than 0.05 μg/mCi of chemical purity of Tl by increasing the volume of Tl elution.