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A STUDY OF IRRADIATION CONDITIONS OF MERCURY TARGET WITH PROTONS TO OBTAIN THALLIUM-201.

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SUMMARY

The ^{201}TlCl solution is used in Nuclear Medicine for myocardial visualization. ^{201}Tl is a cyclotron-produced radioisotope, obtained indirectly from the decay of ^{201}Pb or directly by irradiating mercury with protons. In this work, ^{201}Tl was obtained by irradiating a natural mercury target with protons in the energy range of 24 to 19 MeV, using the IPEN's CV-28 cyclotron. Range calculations of protons in the targets and in the materials used to degrade the proton beam energy were made. At the end of the bombardment of a 329 μm thickness (6 MeV thickness) target of natural metallic mercury with 19 MeV protons provided a yield of 10 MBq ^{201}Tl/μA.h.

Key words: thallium-201, mercury, target, protons, cyclotron

INTRODUCTION

The radionuclide ^{201}Tl is used in the diagnosis of myocardial ischemia and myocardial infarct in Nuclear Medicine. The most comon way to produce ^{201}Tl is through the $^{203}\mathrm{Tl(p,3n)}\ ^{201}\mathrm{Pb} \rightarrow {}^{201}\mathrm{Tl}$ reaction. This reaction requires proton energy of about 28 MeV. Due to the maximum proton energy (24 MeV) of IPEN's CV-28 cyclotron, studies were made concerning the irradiation conditions of natural mercury oxide pellets and drops of natural metallic mercury with 24, 20 and 19 MeV proton beam, through the reaction $^{202}\mathrm{Hg(p,2n)}\ ^{201}\mathrm{Tl}$. A target holder made with aluminium was used and it had water cooling in the front and back of the target. The water and windows layers were adequated to degrade the proton beam energy from 24 MeV to 19 MeV.

EXPERIMENTAL

Targets of natural mercury oxide pellets with 815 mg/cm^2,509 mg/cm^2 and 445 mg/cm^2, and drops of natural metallic mercury with 445 mg/cm^2 were irradiated in the cyclotron model CV-28 of the Cyclotron Corporation - U.S.A. installated at IPEN. The targets of 815 mg/cm^2 and 509 mg/cm^2 were irradiated, for 1 hour with beam current of 1,7 μA (measured using a Faraday cup), with

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incident proton beam energy of 24 MeV and 20 MeV, respectively, using a steel target holder with back water cooling. For the thin target irradiation (HgO:445 mg/cm^2 and Hg^0:445 mg/cm^2) a target holder made of aluminium was fabricated and it was water cooled in the front and in the back of the target (Figure 1). This target holder allowed better target cooling and irradiations with beam currents of 2,6 μA during 1 hour with proton beam energy of 19 MeV. The incident beam energy on the target was reduced to 19 MeV due the water layer and the materials used as window. Before reaching the target the proton beam passed through one aluminium collimator (Ø 10 mm), an aluminium holder cover (200 μm thick), a channel for water (1,2 mm thick), an aluminium window (150 μm thick) and a tantalum window (10 μm thick). The range calculations of protons in the targets and in the materials used to degrade the proton beam energy were made using the data tables from Williamson, C.F. et al(5).

The yield of ^{200}Tl, ^{201}Tl and ^{202}Tl in the end of target bombardment was calculated measuring the activity of 1 ml of the dissolved target solution using a Ge (Li) detector coupled to a 4096 multichannel analyzer.

The chemical separation of thallium from mercury was made utilizing the extraction chromatography technique. Colums of glass were packed with Voltalef powder (polytrifluorochloroethylene)/cyclohexane. Thallium was eluted from the column with hot solution of 10% hydrazine dihydrochloride(3).

The ^{201}TlCl solution was prepared and subjected to different quality control processes required for its use in Medicine. The radionuclidic purity was performed by multichannel pulse-height analysis, using a Ge(Li) detector (Figure 2), and the concentration of mercury impurity (10 a 30 ng/ml) was checked via activation analysis using fast neutrons(4).

RESULTS AND DISCUSSION

Table 1 and Table 2, respectively, give the production yields of ^{200}Tl, ^{201}Tl and ^{202}Tl at the end of bombardment for the HgO thick target and the HgO, Hg thin targets.

Table 1 - Production yields (EOB) of ^{200}Tl, ^{201}Tl and ^{202}Tl in the irradiations of natural mercury oxide pellets with protons.

Target Thickness (mg/cm^2)	Incident Proton Energy (MeV)	Final Proton Energy (MeV)	Yield (EOB) (MBq/μAh)		
			^{200}Tl	^{201}Tl	^{202}Tl
HgO (815)	24	14	20,2	14,5	0,36
HgO (509)	20	14	12,0	9,5	0,19

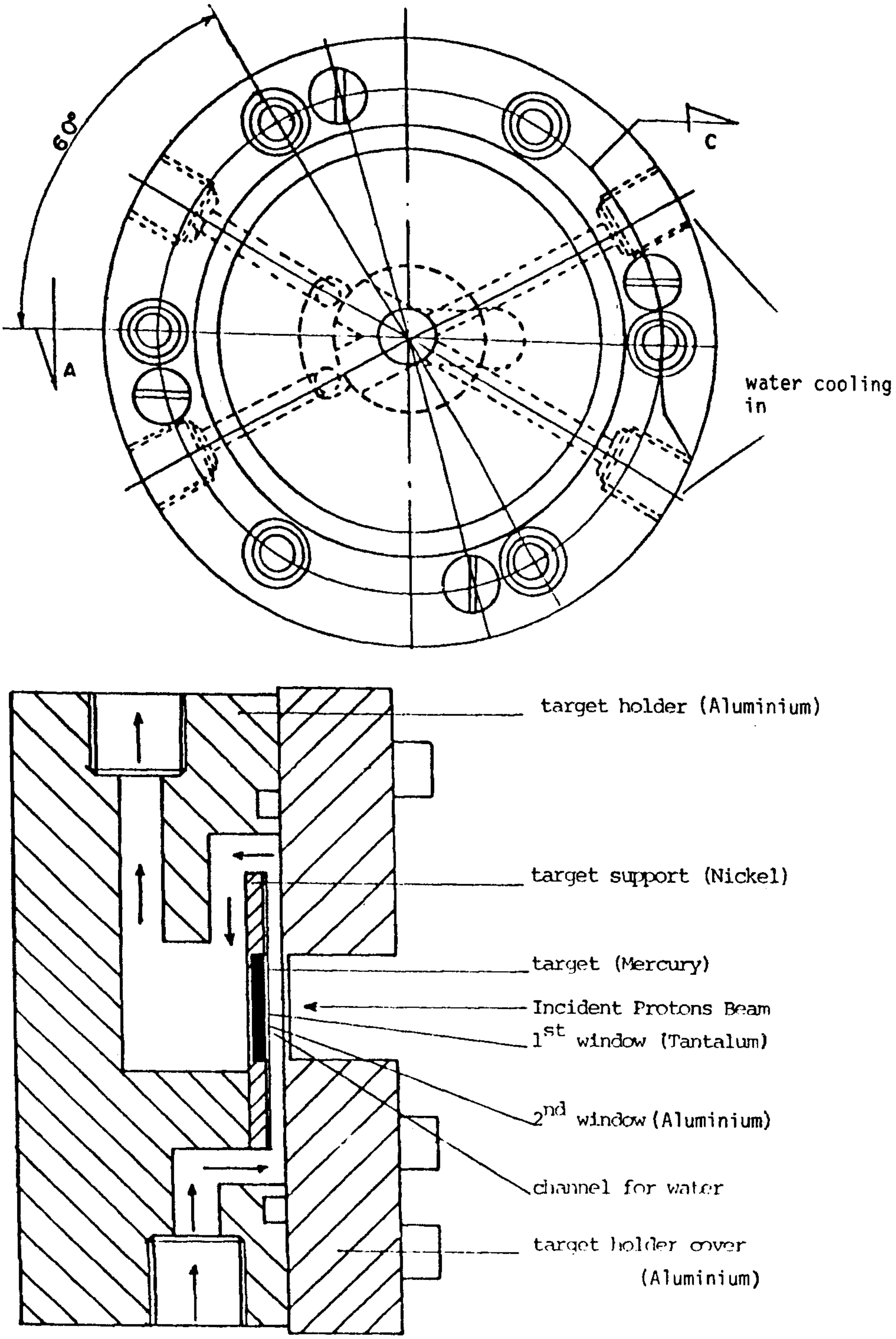

Figure 1 - Aluminium target holder with water cooling in the front and in the back of the target.

Table 2 - Production yields (EOB) of ^{200}Tl, ^{201}Tl and ^{202}Tl of thin natural mercury target (445 mg/cm^2) irradiated with protons of 19 MeV.

Target Thickness (mg/cm^2)	Incident Proton Energy (MeV)	Final Proton Energy (MeV)	Yield (EOB) (MBq/µAh)		
			^{200}Tl	^{201}Tl	^{202}Tl
HgO (445)	19	13	11,8	9,5	0,19
Hg (445)	19	13	11,9	9,5	0,19

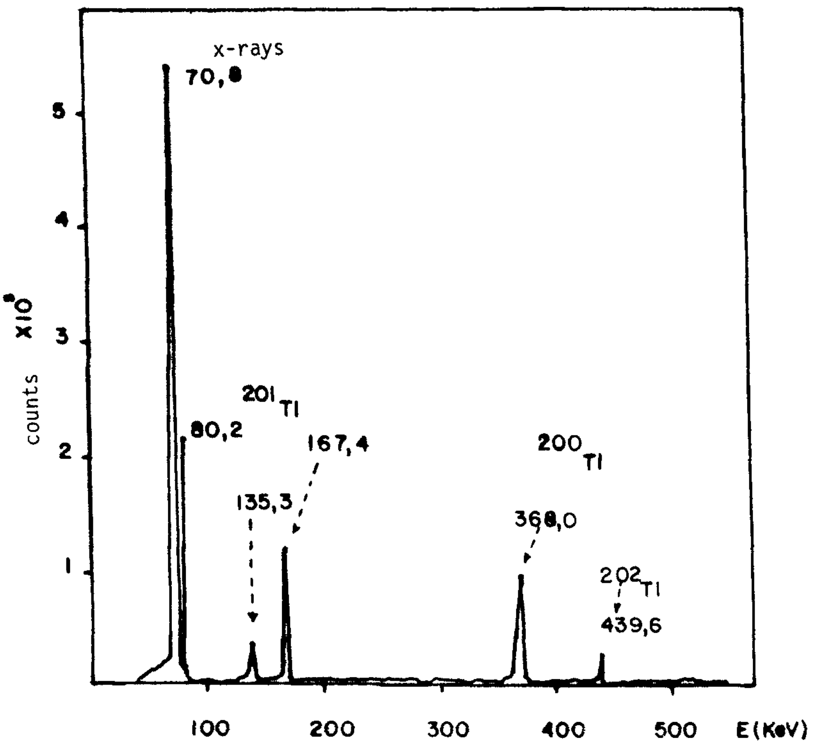

Figure 2 - Ge(Li) spectrum of ^{201}TlCl solution obtained 36 hours after target irradiation.

The results showed that ^{201}Tl had a high level of radionuclidic impurities,(^{200}Tl and ^{202}Tl) even 36 hours, after the target irradiation. This contamination comes from the fact that the target used for irradiation was of natural mercury which isotope composition (^{204}Hg:7%; ^{202}Hg: 30%; ^{201}Hg: 13%; ^{200}Hg: 23%; ^{199}Hg: 17% and ^{198}Hg: 10%) leads to this radionuclidic impurity(1).

At the end of the bombardment of a 445 mg/cm^2 thickness (6 MeV thickness) target of natural metallic mercury with 19 MeV protons provided a yield of around 10 MBq ^{201}Tl/μAh. If one employs a 98,6% enriched ^{202}Hg target under the irradiation conditions mentioned above, the ^{201}Tl yield will be around 33 MBq/μAh. This yield value is smaller than the one obtained by Birattari et al.(1): 51 MBq/μAh (after the decay time of 60 hours from the EOB for a 98,6% enriched ^{202}Hg, 6 MeV, target thickness) and by Dmitriev, P.P.(2): 46 MBq/μAh (at the end of the bombardment of a 95% enriched ^{202}Hg, 4 MeV, target thickness).

CONCLUSIONS

The EOB yield of ^{201}Tl obtained in this work shows the necessity of improvement in the target support so that this experimental yield will be higher. This ^{201} TlCl solution can not be used in humans unless enriched ^{202}Hg is used as target.

This work was useful for learning more about cyclotron irradiation tecniques in respect to target, target holder fabrication and cooling system.

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