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DETERMINATION OF CADMIUM AND TITANIUM IN HUMAN SERUM BY PROTON NUCLEAR ACTIVATION

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ABSTRACT.

An investigation of the quantitative content of Cd and Ti in human serum by proton nuclear activation has been performed and the results are presented.

The activation has been induced by a proton beam of 13.5 MeV of the AVF cyclotron of the University of Milan, via (p,n) reactions on the nuclei of the target.

For the quantitative determination a known quantity of a reference element has been added to the samples and comparison has been made with a standard sample containing also known quantities of the studied elements.

1. - INTRODUCTION.

The proton nuclear activation (PNA) has shown good possibilities of application in the field of the quantitative analysis of trace elements in biological samples.

It has been already employed for the determination of the content of a certain number of elements in human serum (Cu, Fe, Se, Sr, Zn) and the results are described in ref. (1).

Because the study of the biochemical roles of trace elements in biological materials is directly related to their accurate determination, it is very important to pay attention to those elements for which less informations can be found in literature.

With this aim, an investigation of the content of Cadmium and Titanium in serum carried out by this methodology, is presented in this paper. The PNA technique has been extensively described in previous works[1, 2, 3] and here is briefly summarized. It consists in a bombardment of a sample by a proton beam of appropriate energy to induce (p, xn) reactions.

The measurement of the intensities of the γ rays coming from the radioactive nuclei obtained from the nuclei of interest allows the sample content analysis.

The choice of the particular (p, xn) reaction is determined by the characteristics of the decay and by the mean life of the residual radioactive nucleus.

For the quantitative analysis, the sample is doped with a precisely known quantity of a suitable reference element; the ratio between the intensities of the transition relative to the trace element and to the reference element is then measured. By comparison with a standard sample containing the same quantity of the reference element and also an accurately known quantity of the studied element, one can obtain directly the trace element content.

2. - EXPERIMENTAL.

The target has been prepared with 1 ml of serum, taken from a mixture of sera of many subjects and then doped with 0.2 ml of a standard aqueous solution of 1 g/l of $CrCl_2$, corresponding to 200 μg of Cr, used as reference element. The serum, dried at 35°C and powderized in an agate mortar, was compressed in form of a self supporting disc of 12 mm in diameter and $\cong$ 0.7 mm thick. The disc was sandwiched between two foils, that were completely removed after irradiation.

The standard sample was prepared in the same way with addition of 200 μg of Cd and 200 μg of Ti, withdrawn from standard solutions of these elements. To avoid any chemical contamination all the containers were in Polithene and before use they were washed in a diluted solution of H_2SO_4 and in twice distilled and deionized water.

For the determination of Cd and Ti a (p, n) reaction was utilized, thus the samples were irradiated by a 13.5 MeV proton beam of 300 nA of the AVF cyclotron of the University of Milan. The value of the proton energy was chosen in order to have an energy of $\cong$ 11 MeV in the middle of the sample. Typical values of the irradiation time were 5 h for the sample and 1 h for the standard sample.

The irradiation was made in air to reduce the possibility of evaporation of some element, and moreover the heat produced was dissipated cooling the mounting frame with a liquid freon circulation.

A Ge(Li) detector (ORTEC VIP 8111-16195) was used for the measurement of the γ spectra. The data were collected with a standard nuclear spectroscopy system.

The series of measurements carried out in order to control the possible contamination, the temperature effects, the response linearity and reproducibility of the method are described in previous papers[1, 2, 3] on the same subject.

In particular, for what is concerning the response linearity, the test relative to the de-

termination of Ti is presented as an example in Fig. 1, where the quantities of Ti measured in 4 samples of the same serum, doped with different known quantities of Ti, are reported as a function of the added quantities.

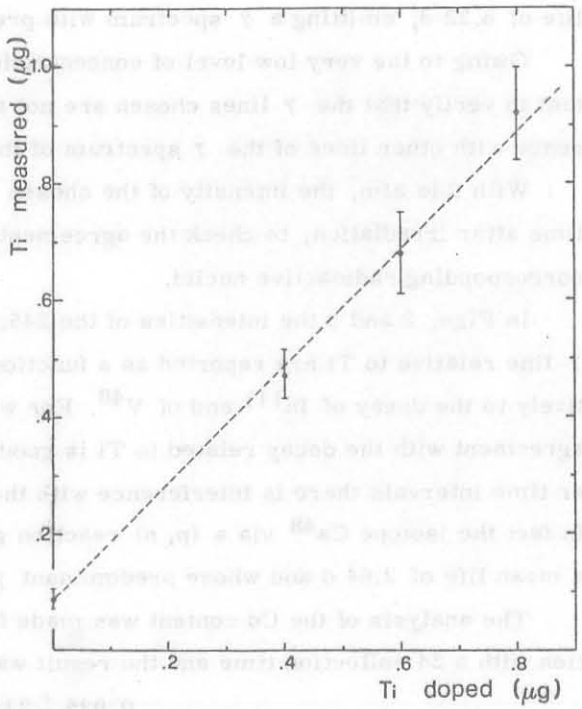

FIG. 1 - The quantity of Ti measured in a series of samples, prepared with the same serum and doped with different known quantities of Ti, as a function of doping.

3. - RESULTS AND DISCUSSION.

For the quantitative determination of Cd and Ti in serum, the same kind of nuclear reaction can be utilized, so that is possible to make the contemporary analysis of these elements on the same sample.

Both elements have in fact an isotope of relevant abundance that produces via a (p, n) reaction a radioactive isotope of sufficiently long mean life. Moreover the characteristic γ lines of the respective isotope do not present interference.

In Table I, the isotopes of interest with their relative abundance, the radioactive nuclei obtainable via a (p, n) reaction, their mean life and the γ lines utilized are indicated.

TABLE I

Isotope (abundance)	Radioactive nucleus	Mean life	lines (keV)
Cd^{111} (12.75%)	In^{111}	4.08 d	245.35
Ti^{48} (73.94%)	V^{48}	23.04 d	983.5 1311.9

As reference element Cr was chosen, because the mean life and the characteristic γ lines of the corresponding radioactive isotope are suitable for the studied elements. Via a (p, n) reaction on Cr^{52} (82.7% abundance) one obtains Mn^{52}, which decays with a mean

life of 8.22 d, emitting a γ spectrum with predominant lines at 744.1 keV and 935.5 keV.

Owing to the very low level of concentration of the studied elements, it is very important to verify that the γ lines chosen are not affected by spurious effects, such as interference with other lines of the γ spectrum of the sample.

With this aim, the intensity of the chosen γ lines were measured at different waiting time after irradiation, to check the agreement between their decay and the mean life of the corresponding radioactive nuclei.

In Figs. 2 and 3 the intensities of the 245.35 keV γ line relative to Cd and the 983.5 keV γ line relative to Ti are reported as a function of time: the dashed lines correspond respectively to the decay of In^{111} and of V^{48}. For what is concerning the 983.5 keV γ line, the agreement with the decay related to Ti is good only after a waiting of 200 h, because for lower time intervals there is interference with the γ line due to the presence of the intrinsic Ca. In fact the isotope Ca^{48} via a (p, n) reaction gives the radioactive Sc^{48}, which decays with a mean life of 2.64 d and whose predominant γ lines are at 983.5, 1037.6 and 1312.1 keV.

The analysis of the Cd content was made from a γ spectrum collected 71 h after irradiation with a 24 collection time and the result was:

$0.025 \pm 21\%$ μg/ml.

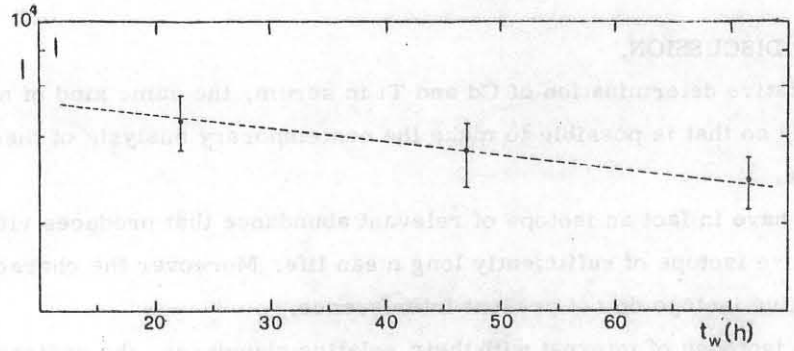

FIG. 2 - Intensity of the 245.35 keV line of the In^{111} radioactive isotope as a function of time.

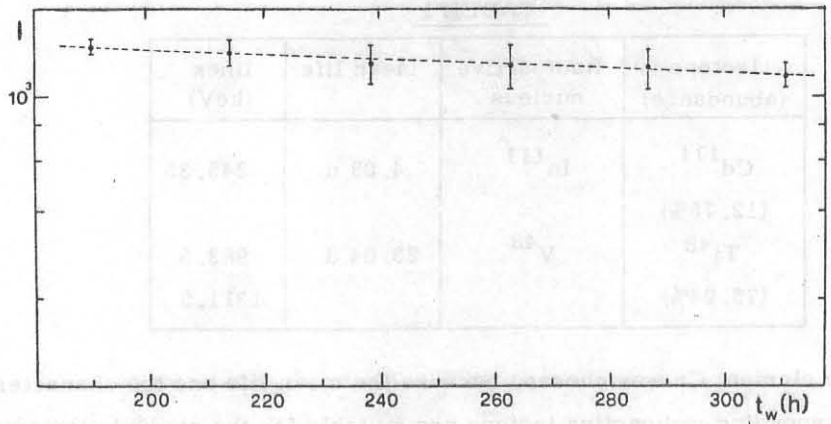

FIG. 3 - Intensity of the 983.5 keV line of the V^{48} radioactive isotope as a function of time.

The rather large value of the statistical error can be justified on the basis of the very low level of the concentration of Cd in serum and of the high level of the background in the energy range of the 245.35 keV.

On the other hand one has to observe that no satisfactory results for the determination of Cd in serum with other methodologies can be found in the literature.

An estimation of a possible value of 0.005 μg/ml for the concentration of this element in serum is given in ref. (4).

The determination of the Ti content as obtained from the γ spectrum collected 310 h after irradiation for a 24 h collection time, gave the following results:

0.09 $\pm$ 10% μg/ml from the 983.5 keV line;

0.09 $\pm$ 11% μg/ml from the 1311.9 keV line.

Also if the level of concentration is low, the statistical error ranges in satisfactory values; due to the long mean life of V^{48}, the considered γ lines have appreciable intensities also at a value of waiting time where the overall background becomes very low.

The obtained results are comparable with those of 0.01 - 0.08 μg/ml obtained from measurements performed by PIXE[5].

4. - CONCLUSIONS.

As it has been pointed out in the introduction, the possibility of precise absolute determinations of the trace elements content in biological samples is a very important requirement for the study of their influence in human methabolism.

It has also to be emphasized the need of certified reference materials for some biological samples, such as human serum for example.

These considerations show the necessity of developing the researchs toward those elements which cannot be easily determined by other methods.

In view of the scarceness of information concerning Cd and Ti, the results obtained for the quantitative determination of their content in human serum can be considered very satisfactory. These results confirm the possibilities of the PNA in the field of the trace elements analysis in biological samples and are promising for the future applications of PNA both for acquisitions of new data and for comparative studies.

REFERENCES.

(1) - M. C. Cantone, N. Molho and L. Pirola, Trace elements analysis in biological samples by proton nuclear activation, Clin. Phys. and Physiol. Meas., in publication.
(2) - M. C. Cantone, N. Molho and L. Pirola, Report INFN/TC-79/18 (1979).
(3) - M. C. Cantone, N. Molho and L. Pirola, Report INFN/TC-80/15 (1980).
(4) - Elemental Analysis of Biological Materials, IAEA, Vienna, STI/DOC/10/197, p. 349-350.
(5) - E. D. Vis, P. M. A. Van der Kam and H. Verheul, Nuclear Instr. and Meth. 142, 159 (1977).