Determination of Thallium in Brain Tissue by Stable Isotope Dilution and Field Desorption Mass Spectrometry *

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The utility of field desorption mass spectrometry for quantitative metal cation analysis in forensic sciences is demonstrated by the determination of a lethal thallium level in the brain tissue of an experimental animal. Stable isotope dilution and accumulation of the electrically recorded field desorption ion currents with a multi-channel analyzer allowed a direct estimation of thallium in homogenized tissue samples without further pretreatment. Experiments with standard solutions revealed the limit of detection for thallium to be about 10 pg of the metal cation.

Introduction

The heavy metal thallium has a pronounced toxic effect on mammals. Poisonings by thallium ions normally proceed very slowly; they are accompanied by loss of hair, severe polyneuritic symptoms, and tachycardia, and can culminate in paralysis of the central nervous system [1].

Atomic absorption is a common spectroscopic method for the determination of thallium and is capable of determining thallium concentrations down to a few ppm [2].

The direct determination of thallium from human urine showed a limit of detection of approximately 30 ppb, whereas direct estimation from plasma and brain tissue was not successful without pretreatment [3].

Field desorption (FD) mass spectrometry (MS), originally introduced for soft ionization of organic compounds of low volatility [4, 5], has proven to be an extremely sensitive technique for metal cation analysis, especially for alkali determinations [6 to 9]. In continuation of our efforts to exploit the capacity of FD MS as an additional independent method for metal cation analysis we applied this novel mass spectrometric technique to a number of elements from the second series in the periodic system, such as calcium, strontium, barium [10], and cadmium [11], and in this study also to thallium. In particular, we were interested in a possible application of FD MS in forensic or other medical sciences which requires a reliable, sensitive, and fast determination of thallium in biological fluids and tissues.

Experimental

A mouse was fed a portion of cheese containing 80 mg of thallium chloride. After the animal's death (5 hours after application) the brain was removed (0.20 g), homogenized with about 1 ml of doubly distilled water, and then further diluted to give 2.0 ml of a suspension. For the preparation of the solution of the internal standard isotopically enriched elemental thallium (Rohstoff-Einfuhr GmbH und Handelsgesellschaft Ost, Düsseldorf, W.-Germany) was dissolved in 0.1 m nitric acid to give a thallium concentration of 1 mmole/liter.

The mass spectrometric studies were performed on a double focussing mass spectrometer of type Varian MAT 731 equipped with a combined EI/FI/FD ion source and, alternatively, on a home-built single-focussing FD mass spectrometer. The emitters used were 10 μm diameter tungsten wires activated at high temperature with an average length of the microneedles of 30 μm. The samples were applied by the syringe technique and 2 μl of sample solution were used for one analysis on average. The FD ion currents were recorded electrically and accumulated by a multi-channel analyzer of type CAT-1024 Varian which was triggered from the cyclic magnetic scan of the mass spectrometer [12].

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* Quantitative Field Desorption Mass Spectrometry: Part 11; for Part 10 see ref. [7].

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Results and Discussion

Since thallium naturally occurs as a mixture of two stable isotopes and since isotopically enriched thallium is commercially available, stable isotope dilution appears to be the method of choice for a mass spectrometric quantitation. The utility of this technique of internal standardization for quantitative studies by field desorption mass spectrometry has been demonstrated for a number of organic compounds [13] as well as for organic [14] and inorganic cations [15]. Coupling of the mass spectrometer to a multi-channel analyzer is especially advantageous for these investigations because it allows integrating electrical recording of the FD ions in the mode of repetitive scanning. Thus the fluctuations of the FD ion currents can be compensated effectively and quantitative data of good precision are obtained. Fig. 1 shows the isotopic abundances of naturally occuring thallium, of the isotopically enriched thallium standard, and of a model mixture measured by this procedure.

For the quantitative determination of thallium in the homogenizate of mouse brain tissue an aliquot of this sample was diluted 1:1 with our thallium standard solution. The result of the thallium isotope analysis performed on this mixture is displayed in Fig. 2.

Evaluation of the data from Fig. 2 revealed a thallium concentration in the mouse brain of 4.0 ± 0.3 μmol/g fresh weight, which results in 0.8 ± 0.06 μmol thallium in the complete brain. Thus, only 0.3% of the total amount of thallium applied could be determined in the brain tissue.

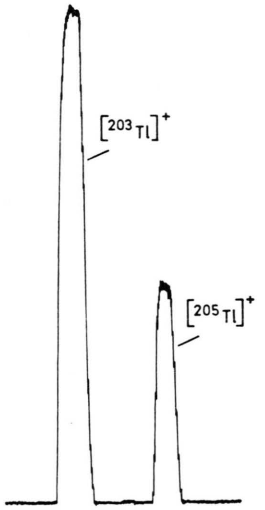

Fig. 2. Isotope dilution experiment for the determination of thallium in a mouse brain homogenizate. The sample was diluted 1:1 with the standard solution (Fig. 1 b). The isotopic abundances are: *m/e* 203 70.0%, *m/e* 205 30.0%. 80 Scans were accumulated.

The slow time scale of thallium poisonings and the relatively low amount of thallium found in this study indicate that the toxic metal is transported slowly into the brain tissue.

Although the desorption of thallium occurs at relatively low emitter heating currents (20 – 25 mA) no interference from organic ions could be observed in the investigation of the brain tissue homogenizate. For a FD mass spectrometric investigation, however, the concentration of about 90 ng/μl thallium is high as compared to sample amounts usually required for an alkali determination. In order to determine

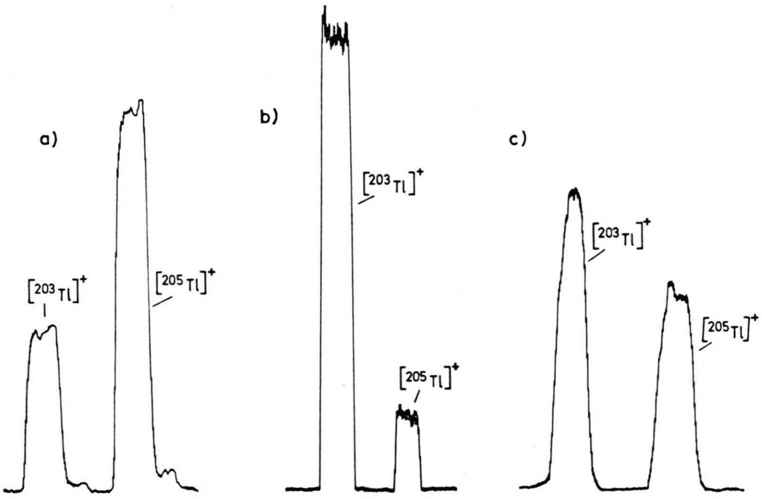

Fig. 1. Isotopic abundances of thallium recorded by FD MS and signal accumulation. For each measurement 120 cyclic magnetic scans were accumulated.
a) natural abundances of thallium, *m/e* 203 29.5%, *m/e* 205 70.5%.
b) stable isotope enriched internal standard, *m/e* 203 87.0%, *m/e* 205 13.0%.
c) model mixture of equimolar amounts of a) and b) *m/e* 203 58.5%, *m/e* 205 41.5%.

the sensitivity of FD MS for thallium, sample amounts between 10 ng and 10 pg thallium dissolved in distilled water were applied to the FD emitter and completely desorbed. During the whole desorption the FD ion currents in the mass region *m/e* 200 – *m/e* 208 were accumulated by the use of the multichannel analyzer. The results of this study are displayed in Fig. 3.

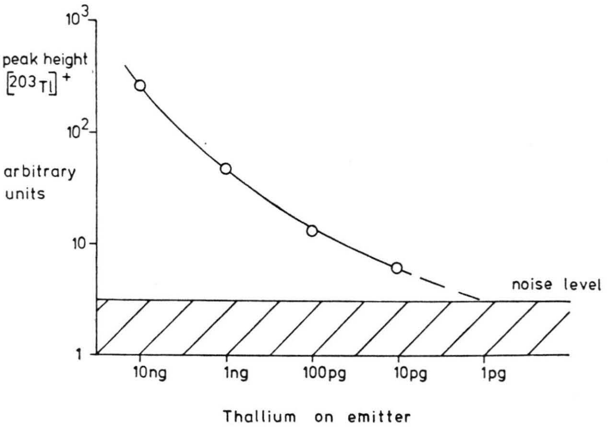

Fig. 3. Accumulated peak heights of the thallium isotope at *m/e* 203 (29.5% natural abundance) as a function of the total sample amount of thallium desorbed in one FD analysis.

The original plot obtained for the analysis of 10 pg of thallium is shown in Fig. 4.

Due to the relatively high atomic weight of thallium this corresponds to only about 50 fmol. These studies show that thallium can be analyzed by FD with essentially the same sensitivity as metals from the alkali series which is consistent with the marked similarity of thallium and potassium with respect to their ion radii and their chemical properties. However, in the analysis of untreated biological samples the actual sensitivity for alkali cations might be larger since these cations desorb at higher emitter heating currents (ca. 30 – 100 mA). Under these conditions the organic matrix is already pyrolyzed and destroyed to a large extent whereas at heating currents favourable for thallium (ca. 20 to 25 mA) interference from organic ion species might hamper an extremely sensitive detection.

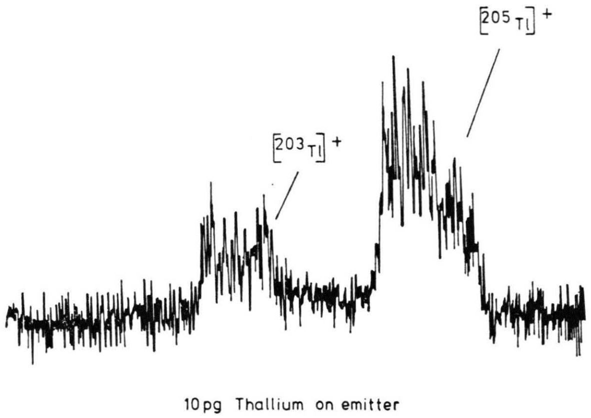

Fig. 4. Original recording for the analysis of 10 pg of thallium (≃ 50 fmol) by FD MS. 25 scans were accumulated.

Conclusion

Field desorption mass spectrometry appears to be a reliable, sensitive, and fast method for the determination of thallium in biological samples. In particular, the use of a stable isotope labelled internal standard and the possibility of analyzing untreated samples are important advantages of the method. Finally, the sensitivity of field desorption for thallium appears to be of the same order as for alkali metals, which enables its determination in trace and ultratrace quantities.

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