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Short Research Article

Chemical recovery and purification of ^{203}Tl stable isotope enriched by using an electromagnetic isotope separator†

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Introduction

Thallium has two stable isotopes (^{203}Tl and ^{205}Tl); ^{203}Tl is used to produce ^{201}Tl in a cyclotron for medical applications.[1,2] ^{203}Tl has been separated from ^{205}Tl by means of a 180° electromagnetic isotope separator (EMIS), but impurities remain in the ^{203}Tl following the bombardment process which result in the preparation of ^{201}Tl with undesirable active elements; so chemical refinement of ^{203}Tl is unavoidable. Depending upon the nature of elements, different purification methods such as precipitation, distillation, solvent extraction and ion exchange have been used. As there is insignificant absorption of thallium(III) ion onto cation exchange resins, in this study ion exchange methods were used for the purification of ^{203}Tl isotope.

Cation exchange resins combined with different concentrations of hydrochloric acid,[3] nitric acid[4] and mixture of hydrochloric acid and acetone[3] have been used for the separation of large amount of thallium from impurities. A mixture of hydrochloric acid and acetone is reported as the most suitable solvent for selective passage of thallium and absorption of impurities onto the resin. The low dielectric constant of organic solvents such as acetone causes the electrostatic attraction to increase and as a result the stability of the $TlCl_4^-$ ion is elevated. Apparently, organic solvent causes the hydration layer around the cation to weaken and provides an external force for exchange of water molecules with chloride ions in the coordination field; consequently, the stability of the thallium chloride complex increases. According to this procedure, traces of lead and minor amounts of cadmium were removed from large amounts of thallium by a mixture of 0.1 M hydrochloric acid and 40% acetone on a AG50W-X4 cation exchange resin.[4]

In the present study, we report the separation of milligram quantities of impurities such as Ni, Cu, Cr, Co, Mn and Fe ions from large amounts of ^{203}Tl isotopes by using a mixture of 0.1 M hydrochloric acid and 80% acetone. Formation of thallium(III) oxide was confirmed by powder X-ray diffraction (XRD) and the level of impurities in it was measured by inductively coupled plasma-atomic emission spectroscopy (ICP-AES).

Results and discussion

In this work, 3 g of ^{203}Tl collected in a copper pocket was extracted with 50% nitric acid. Copper was the main impurity, which was removed by an electrodeposition method. Other impurities such as Fe, Ni, Co, Mn and Cr were removed by using a mixture of 0.1 M hydrochloric acid containing free chlorine and 80% acetone on a Dowex50W-X8 cation exchange resin. Eluted ^{203}Tl solution was treated with concentrated ammonium hydroxide. The precipitate was allowed to settle overnight, filtered and calcined at 130°C for 3 h to convert it into brown thallium(III) oxide. Formation of highly pure thallium(III) oxide as a final product was confirmed by XRD, and the chemical purity of 99.9% ^{203}Tl isotope was determined by ICP-AES.

The method described herein is an efficient and accurate technique for the separation of transition

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Table 1 The analysis results of enriched ^{203}Tl isotope by ICP before and after purification

Element	Before purification (mg)	After purification (mg)
Tl	3000	2997
Fe	18.75	0.015
Ni	9.1	0.064
Co	2.74	0.005
Mn	0.725	0.001
Cr	4.5	0.043
Cu	6.25	0.014

metal ion impurities from gram amounts of thallium. In the present work study, about 42 mg of transition metal impurities in the form of Ni(II), Cu(II), Cr(II), Co(II), MN(II) and Fe(II) were separated from 3 g of ^{203}Tl using 10 g of cation exchange resin in a 20 cm chromatography column eluted with 0.1 M hydrochloric acid containing 80% acetone. Some free chlorine was added to the solution in order to prevent the thallium chloride from conversion to insoluble thallium(I) chloride.[5] When 0.1 M hydrochloric acid containing 80% acetone with some free chlorine was used to remove retained thallium, the flow rate became too slow to be useful for practical purposes. The reason for this is not known at this time; however, it seems higher concentration of acetone facilitates release of thallium species. The Ni(II), Cu(II), Cr(II), Co(II), MN(II) and Fe(III) ions partially separated on the column. Separation of Ni(II) and Fe(II) was complete, which allowed us to qualitatively assess them using dimethylglyoxime and potassium hexacyanoferrate, respectively. A Dowex50W-X8 cation exchange resin showed higher efficiency in separation of thallium from other elements in comparison to AGX50W-X4 resin which has a low degree of cross-linkage.[6] The higher efficiency of DOWEX50W-X8 probably arises from the higher cross-linkage degree of resin, by decreasing the exchange velocity of the ions. Furthermore, the low concentration of hydrochloric acid (0.1 M in acetone) prevents acetone polymerization and formation of non-volatile organic compounds; so the adsorption of transition elements on the resin increases.

Formation of highly pure thallium(III) oxide as a final product was confirmed by XRD. A chemical purity of 99.9% ^{203}Tl isotope was determined by ICP-AES. Table 1 presents the analytical results of ^{203}Tl isotope as determined by ICP.

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