

Production and separation of 'Tracer Packet' of most similar elements in the periodic table: A novel method

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Abstract – NRC7 Abstract

This paper describes the production of tracer packet of most similar elemental pairs containing no-carrier-added (nca) radionuclides of zirconium, hafnium, molybdenum and tungsten, produced by medium energy proton and ${}^7\text{Li}$ irradiation consecutively on Y_2O_3 and Lu_2O_3 mixed target. The subsequent separations of bulk Y and Lu from the nca products have been carried out using liquid-liquid extraction (LLX) technique. The mutual separation between the group IV elements Zr, Hf from that of the group VI elements Mo, W has also been done. This tracer packet will be helpful to compare the extraction patterns of element 104 (Rf) and element 106 (Sg) with their lighter homologues.

Keywords – Tracer Packet of similar elements, mixed target, multiple projectiles, liquid-liquid extraction, Rf, Sg

INTRODUCTION

Studies on the extraction behavior of Zr, Hf (group IV) and Mo, W (group VI) in different systems are important in order to establish the chemical properties of their higher homologues Rf and Sg respectively. Due to short half-life and the low production cross sections of the Rf and Sg fast and efficient separation technique must be designed. The presence of all these four elements together in a solution is an opportunity for radiochemists to study their chemical behavior in presence of others in a single experiment rather than setting up many different experiments one for each element.

Keeping this in mind we have used the concept of 'tracer packet' introduced by ourselves [1-2] and designed the new "tracer packet of most similar elemental pair" consisting of nca ${}^{89}\text{Zr}$ (3.268 d), ${}^{173}\text{Hf}$ (23.6 h), ${}^{93\text{m}}\text{Mo}$ (6.85 h) and ${}^{177}\text{W}$ (2.21 h) by irradiating $\text{Y}_2\text{O}_3 + \text{Lu}_2\text{O}_3$ mixed target with p and ${}^7\text{Li}$ beam consecutively. The nca radionuclides were separated from the targets using LLX technique.

EXPERIMENTAL

A homogeneous mixture of Y_2O_3 and Lu_2O_3 was pressed to make a pellet of thickness 16 mg/cm^2 . The mixed target was irradiated first with proton at two energies 13 and 24 MeV; followed by ${}^7\text{Li}$ projectile at 32 and 48 MeV at BARC-TIFR Pelletron, Mumbai, India, for 5 h at each projectile energy. The choice of the energy for p and ${}^7\text{Li}$ was governed by the theoretical calculation of excitation function using ALICE-91 and PACE 2 code, experimental determination of the yield of the product radionuclides and the terminal voltage (12 MV) of the pelletron. The basis of choice in the beam sequence is that the longer half-life radionuclides should be produced first. The product radionuclides were

identified by their corresponding photo peaks detected by an HPGe detector of 2.13 keV resolution at 1.33 MeV in conjunction with a PC-based MCA, PCA2 (OXFORD).

The mixed target was dissolved in conc. HCl and conc. HNO_3 mixture, spiked with nca ${}^{169,170-173}\text{Lu}$, evaporated to dryness, and taken in 2 mL 0.1 M HCl. In order to study the separation and extraction profile, 100 μL of the active stock solution was taken in 5 mL HCl solution of varying concentrations between 0.001 to 8 M HCl and vigorously shaken with an equal volume of 0.1 M trioctylamine (TOA) dissolved in cyclohexane, for 5 min. After separation of the liquid phases the activities present in both the phases were measured by γ -ray spectrometry.

RESULTS AND DISCUSSIONS

Nondestructive γ -spectrum of p and ${}^7\text{Li}$ activated mixed target confirms the presence of ${}^{90\text{m},91\text{m}}\text{Y}$, ${}^{89}\text{Zr}$, ${}^{173}\text{Hf}$, ${}^{93\text{m}}\text{Mo}$ and ${}^{177}\text{W}$ in the matrix produced through the (p, xn) and (${}^7\text{Li}$, xn), (${}^7\text{Li}$, xpyn) reactions.

At 0.1 M TOA and 0.001 M HCl concentration ~80% of Zr and Hf was extracted in the organic phase keeping Y, Lu as well as Mo and W in the aqueous phase. The high extractability of nca Zr and Hf in lower HCl concentration might be explained by the formation of $[\text{ZrCl}_6]^{2-}$ and $[\text{HfCl}_6]^{2-}$ type of complexes, which in turn is extracted by TOA. Also the formation of $\text{MX}_4(\text{TOA})_2$ type of complexes are possible [M = Zr, Hf]. Again at 0.1 M TOA and 8 M HCl concentration 100% of Mo and 80% of W was extracted in the organic phase keeping Y, Lu and Zr, Hf in the aqueous phase. This might be explained by the formation of $[\text{MoCl}_6]^{3-}$ and $[\text{WCl}_6]^{3-}$ type of complexes, which in turn is extracted by TOA [3]. The lower extractability of nca Mo and W in lower HCl concentration is due to the formation of aquo-cationic complexes such as $[\text{Mo}(\text{H}_2\text{O})_6]^{3+}$, $[\text{W}(\text{H}_2\text{O})_6]^{3+}$. It has been found that more than 95% of all the four nca radionuclides can be back extracted when using 1M HNO_3 twice.

The production of all these four elements together in a single mixed matrix in a single experiment may help us to investigate the insight chemistry of Rf and Sg. At the same time the selectivity of any reagent for an element can be effectively studied when the same is used in multielemental system.

REFERENCES

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