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STUDY OF THE TECHNICAL FEASIBILITY OF PRODUCING AT-211 IN CYCLOTRON TYPE PARTICLE ACCELERATORS

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Abstract: Many chemical elements are irradiated to generate radionuclides and be used as radiopharmaceuticals for both diagnosis and therapy. Astatinium 211, whose production with the CV-28 Cyclotron at the Institute of Nuclear Engineering (IEN) is the subject of study here, has great potential for use in medical therapy. Astatinium 211 can be used satisfactorily in therapy as it has a half-life of 7.2 hours and decays both by electronic capture and by the emission of alpha particles, which makes it particularly suitable for the treatment of oncological diseases, due to the very localized ionization action of this type of charged particle. Astatinium 211, when used in association with iodine 123, makes joint therapy and diagnosis actions viable (Theranostics). In the production of this radioisotope we need to pay attention to its parameters such as the current and irradiation energy of the Bismuth target.

Therefore, the entire production process requires studies and care that are essential to its completion. The success of marking specific molecules to be used as radiopharmaceuticals also strongly depends on the physicochemical properties of the irradiation product to be used in its production process, which may even make it unviable. Our country is not yet dealing with the production of this radioisotope, hence the importance of this study in enabling its production and being able to be tested for use in Nuclear Medicine in the treatment of oncological diseases. The present work aims to verify the feasibility of producing this radioactive isotope of astatinium through irradiation of a bismuth target using an alpha particle beam from the Cyclotron CV-28 accelerator. We concluded that through these parameters, we were able to produce the radioisotope with adequate yield and activity.

Keywords: Astatinium-211, Cyclotron, Particle accelerator, Radiopharmaceuticals, Radionuclides

INTRODUCTION

The use of radiopharmaceuticals targeted through monoclonal antibodies can protect normal cells and cause fewer toxic effects than traditional chemotherapy. These agents are more effective through several mechanisms, being able, for example, to block cellular receptors or growth factors essential to the cell, induce apoptosis, bind to cellular targets and recruit functions, such as the complement system.

Theranostics is a medical procedure that combines treatment and diagnosis. Its practice consists of the use of one or more radionuclides, which meet the essential properties for diagnosis, such as the emission of gamma rays, and for therapy, such as the emission of charged particles.

Many radionuclides have been used in cancer therapy to reduce the number of invasive cells. To do this, it is necessary to choose the one that best suits nuclear medicine treatment, such as one with an adequate half-life, minimal toxicity and viable production. One of these most disruptive alpha particle-emitting radionuclides is astatinium 211 (Sathekge, 2019).

Astatinium 211 can be produced with good yield in a cyclotron with an energy of around 30 MeV. Few facilities produce this isotope, perhaps because the radionuclide requires chemical treatment to be extracted from the target after its production (Zalutsky, 2011).

The radiation used in therapy must take into consideration, the dose rate, energy and type of radiation. Emitted by radioactive isotopes, alpha particles are considered high linear energy transfer radiation (LET) and are used in therapy to annihilate abnormal cells through the labeling of peptides and antibodies. The alpha particle has a range of 50-100 μm in tissue, which is why it is a good option for cancer treatment (Groppi, 2005).

The astatinium 211 to be produced in the Cyclotron may have therapeutic use because it decays through the emission of alpha particles with an average energy of around 6.7 MeV. From the point of view of radiological protection, the energy emitted is LET close to ideal (Groppi, 2005).

Astatinium 211 has characteristics considered desirable for possible application in cancer therapy due to its physical, chemical and radiobiological properties. Its chemical properties allow astatin to be incorporated into biologically active and stable organic compounds via the carbonastatin bond.

Therefore, they can be used as molecular markers or even incorporated into targeted radiopharmaceuticals (Zhang 2006).

GOAL

Verify the technical feasibility of producing the radioisotope 211-At from bismuth-209 with beams of alpha particles produced in a Cyclotron-type particle accelerator.

MATERIALS AND METHODS

The α particle beam was obtained with helium-4 gas with an energy of 28 MeV, current of 1μA and duration of 16 minutes.

The irradiated material was bismuthNat (bismuth 209) with the following specifications: mass of 1.77 g, circular physical shape of 13 mm in diameter and 1.5 mm in thickness.

The material to be irradiated was fixed to a target holder made of aluminum pieces.

The irradiation chamber and its auxiliary components were made of aluminum in order to guarantee good electrical conductivity, thermal conductivity and low activation rates of the target support materials. The use of aluminum is intended to minimize the activation of the target holder and consequently radiological exposure when handling the material after irradiation.

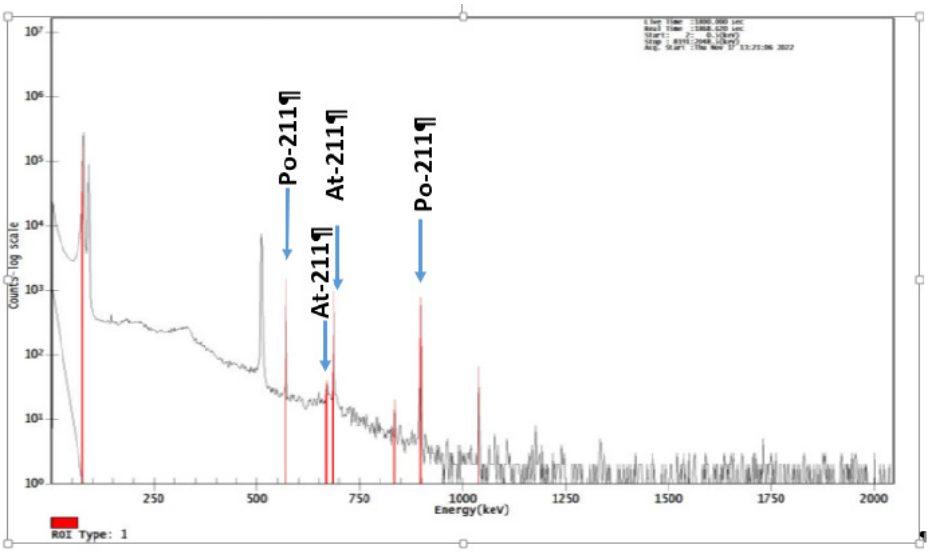

Figure 1: Gamma Ray Spectrum

The characterization of the material produced was carried out by gamma ray spectrometry, using a hyperpure germanium (HPGe) detector.

RESULTS

The irradiated material was removed from the target carrier one hour after the end of the alpha particle beam and transported in a lead shield to the HPGe detector.

From the observation of the spectra obtained throughout the decay, characteristic energies of gamma rays of polonium-211 (897.8 and 569.6 keV) and astatinium-211 (687.2 and 669.7 keV) were observed.

Monitoring activities in the sample over eight counts allowed us to corroborate the identification of the radionuclide of interest, astatinium-211, with an energy of 687.2 keV.

In addition to this characteristic energy of astatinium-211, an energy of 897.8 keV was also observed, which is typical of polonium-211, resulting from the decay of astatinium-211.

According to the particle beam parameters used in carrying out this work, a maximum activity to be produced with the aforementioned particle accelerator can be estimated at 388.96 389 ± 16 MBq (10.4 ± 0.4 mCi).

CONCLUSIONS

From the results obtained, the generation of the radionuclide of interest (At-211) was verified when performing bismuth gamma ray spectrometry ^{Nat}—irradiated and the visualization of its characteristic gamma energy of 687.2 keV.

Furthermore, a decay constant was found to be consistent with the radionuclide data available in the literature.

The feasibility of producing astatinium-211 through a cyclotron-type particle accelerator from bismuthNat with alpha particles, envisages the possibility of new studies covering separation and labeling techniques for new molecules.

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