ID de Contribution: **3** Type: **Non spécifié**

Production of innovative radionuclides for medical applications

lundi 17 novembre 2014 14:30 (30 minutes)

Nuclear medicine is a medical specialty using radioactive isotopes for therapy or diagnosis of diseases such as cancers. Currently, only few radio-isotopes are routinely used. Among them1, Iodine-131 is used for the treatment of diseases related to thyroid, Yttrium-90 for liver cancer therapy, Technetium-99m and Fluorine-18 allow to detect and to localize cancer cells for diagnosis.
Most of the time, radionuclides are vectorized to target the cells of interest. It is then important to match the radionuclide properties with those of the vector molecule (peptide, antibody…). For that purpose, radionuclides with different half-live must be available. Since few years, there is an interest in personalized medicine: The goal is to combine diagnosis and therapy in order to adjust the administered dose to each patient in order to get the best benefit. To do that, pairs of radioactive isotopes, one for diagnosis and the other one for therapy, can be used such as Copper-64/Copper-67 or Yttrium-86/Yttrium-90, the administered dose can be adjusted to get the best benefit for the patient.
In addition and depending on the disease, it can be of interest to have access to radionuclides with different emitted radiations (β-, α, Auger electrons emitters). Therefore, a panel of new radioactive isotopes has to be available. Physicists have to define optimum production methods for these innovating radioisotopes.
During my PhD thesis, I explore the production of new radioactive isotopes for medical applications and identify the constraints related to their production. I focus my work on radio-isotopes that can be produced using the ARRONAX2 cyclotron. Four elements have been identified: Thorium-226 (α emitter) has a great potential for leukemia therapies3; Rhenium-186 (β- emitter) has shown successful results on bone metastases palliation4; Terbium-155 could be used in therapy using Auger electrons and Scandium-44 (gamma/β+ emitter) is the heart of the "three-gamma imaging" concept5 developed at the SUBATECH laboratory (Nantes).
I first made cross section measurements associated to the production of these radioisotopes using deuterons6 as projectiles and the stacked-foils technique. In addition to direct production7, I looked at the fission fragments obtained during the irradiation of a thorium target. Among these products, several isotopes of medical interest are present: Molybdenum-99, Iodine-131 and Cadmium-115g. Their production yield has been determined up to 34 MeV with deuterons and up to 70 MeV with protons. These data allow us to compare both production routes. The irradiation of natural thorium by light charged particles could be an alternative to nuclear reactors for the production of medical isotopes, minimizing the long lived radioactive waste generation. Experiments on the production of Terbium-155 are in progress using a deuteron beam impinging a natural gadolinium target. In addition to the medical yield applications, these experimental values will help nuclear theoretical physicists to validate and/or improve their analytical models.

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Classification de Session: Applications médicales

Classification de thématique: Applications médicales