Contribution ID: **263** Type: **Verbal**

High specific activity ^{177g}Lu for metabolic radiotherapy: deuteron cyclotron vs. nuclear reactor

Tuesday, 20 April 2010 03:00 (30 minutes)

This work is focused on production of Lu-177g for uses in metabolic radiotherapy of tumors, due to the appropriate average beta- energy and gamma rays suitable for detection by gamma-camera and SPET: t1/2 = 6.734 d, b- 100 %, Ebeta-max = 489.3 keV, <E> = 163 keV, main Eg = 113 and 208 keV. It is one of the most promising beta-emitters for small cancers. The production methods are either direct neutron capture Lu-176(n,g)Lu-177(m+g) on (60-70 %) enriched Lu-176 target (sigma-th = 2 + 2100 10E-28 m^2, plus a contribution of epithermal neutrons from resonance peaks), with a lower specific activity AS than the theoretical carrier-free one: AS(CF) = 4.05 GBq.microg^-1, or neutron capture on highly enriched Yb-176, followed by beta- decay Yb-176(n,g)Yb-177 -> Lu-177g (sigma-th = 3.1 10E-28 m^2). Due to the long half-life Lu-177m is relevant, for rad-waste and dose to the patient and medical personnel. The second method produces a high AS NCA Lu-177g, whilst the first one a lower AS CA mixture of both, diluted in stable Lu isotopic carrier. Thus, in the latter case the Lu-177g is contaminated by the long-lived radionuclidic impurity Lu-177m. Several commercial samples of reactor produced Lu-177 were submitted to accurate measurement of both decay patterns and radionuclidic purity vs. time by using HPGe and LSCS. The measurement of the isomeric ratio of Lu (direct neutron activation) and the absence of other Lu RNs (indirect neutron or deuteron activation) allows identifying the production method adopted. In case of direct Lu-176(n,g) route, it was evidenced that - at administration time - the typical amount of the long-lived Lu-177m was of the order of 0.01 %. The experimental t1/2 for Lu-177g (6.724 ± 0.006 d) is in very good agreement with the reference value taken from the literature of 6.734 d.

An alternative method is based on deuteron activation of Yb-176, by (d,p) reactions followed by decay of the short-lived Yb-177 and direct (d,n) reactions as well. Deuteron activations have been carried out at JRC-Ispra Cyclotron (K=38) of EC, with deuteron beams up to 19 MeV.

To conclude Lu-177g can be produced in no-carrier-added form, by either neutron activation on enriched Yb-176 or by deuteron irradiation on very highly enriched Lu-176, both followed by decay of Yb-177. In both cases a AS value could be very close to the CF one, after selective radiochemical separation of Lu from Yb target. It is remarkable that Yb-177 decays solely to the ground level of Lu, leading to a very high radionuclidic purity Lu-177g, not contaminated by the long-lived metastable radioisotopic impurity Lu-177m. A much higher value of radionuclidic purity is achievable (theoretically 100 %) in case of direct Yb-176(d,n)Lu-177 route, whose effective threshold is at 13 MeV.

Several activation of thin Yb targets by deuterons led to the conclusion that a maximum thin-target yield for Lu-177g of 246 MBq.C^-1.MeV^-1 is achievable (sigma-max = 250 10E-25 m^2) at 12.5 MeV, on 100 % Yb-176 target. Our data will be compared with the data taken from the literature for the two neutron routes.

Finally ET-AAS and NAA were used to determine chemical purity and AS of the products.

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Session Classification: Production and Application of Radionuclides 1

Track Classification: Production and Application of Radionuclides