CYCLOTRON PRODUCTION OF AC-225 FOR GENERATING BI-213 FOR TARGETED ALPHA THERAPY

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Abstract

By making use of our isotope production yield curves we have estimated the production of Ac-225, the mother nuclide of Bi-213, through (p,2n) and (d,3n) reactions on Ra-226 and also estimated the undesired activities being produced simultaneously through the (p,n), (d,n) and (d,2n) reactions on Ra-226. It is shown that from a thick Ra-226 target, Ac-225 yields of 1.1×10^{10}, 1.85×10^{10} and 2.04×10^{10} Bq can be obtained at proton bombarding energies of 20, 30 and 34 MeV respectively at an incident beam intensity of 100 μA and irradiation time of only one day. Similarly the yields of Ac-225 through the (d,3n) reaction on a thick target of Ra-226 have also been estimated to be 4.2×10^{9}, 1.1×10^{10} and 1.4×10^{10} Bq respectively at deuteron energies of 20, 30 and 34 MeV and beam intensity of 100 μA and irradiation time of one day. The results are presented in graphical form.

INTRODUCTION

Due to its physical characteristics the generator system Ac-225 / Bi-213 appears to be a very suitable and convenient method for producing an alpha-emitter for targeted alpha therapy. Ac-225, with an half life of 10 days, does not cause any disposal problem, while Bi-213 (half life of 45.6 min) and a 1.96 MeV beta to decay into Po-213, which instantly decays by emitting a 8.35 MeV alpha, is ideally suited for targeted alpha therapy. Furthermore, Bi-213 has only a relatively small fraction of hard gamma-emitting daughter nuclides in its decay scheme, has an easy chemistry as it can be readily separated from the mother nuclide and conjugated with carriers. It can conveniently be made available to hospitals in a radio nuclide generator with its parent nuclide Ac-225, which shows no radon presence in its decay scheme.

However, the production of Ac-225 is not so trivial and that is why only a limited quantity of this interesting isotope has so far been available for clinical applications. Till recently it was produced by the decay of the mother nuclide, Th-229 whose availability itself is very limited. Th-229 is the daughter of U-233 with a half life of 159200 years and is mainly produced in nuclear weapons programme. It is due to this extremely long life of U-233 that the concentration of Th-229 in U-233 is extremely small. Furthermore, U-233 is a fissionable material and extremely difficult to handle in large quantities. Therefore, the separation of Th-229 from U-233 is difficult and very costly process.

Recently an alternative method of production of Ac-225 has been suggested which involves irradiation of a Ra-226 target with protons from a cyclotron [1]. These authors have theoretically estimated to obtain an yield of 3.7×10^{10} Bq of Ac-225 after irradiating one gram of Ra-226 with 15-20 MeV protons at 100 μA for 10 days, through the (p,2n) reaction. The irradiation time of 10 days seems to be neither feasible nor practical even in the modern generation of cyclotrons. By making use of our isotopic yields data [2] we have estimated the production yields of Ac-225 through proton and deuteron induced reactions on Ra-226 but for feasible and practical irradiation time of one, rather than 10 days.

METHOD

Chaudhri et al [2] have estimated the production yields of all the isotopes which can be produced by the interaction of protons, deuterons and alphas of up to 36 MeV with elements and isotopes having atomic numbers from 20 to up to 90. They have presented the data in graphical form from which the production yields from an infinitely thick, moderately thick or even a thin target can be directly obtained under any given irradiation conditions.

For the production of Ac-225, through the (p,2n) and (d,3n) reactions on Ra-226 the appropriate yield curves have been selected from reference [2], and shown in figures 1 and 2. Production yield curves through (p,n), (p,3n), (d,n) and (d,2n) reactions on Ra-226, which might produce undesired and unwanted activities, are also presented. These would help estimate the amount of unwanted activities which would be produced simultaneously while producing Ac-225, and also indicate bombarding conditions in order to minimise their production. provided.

RESULTS AND DISCUSSION

The yield curves for the production of Ac-225, through the (p,2n) and (d,3n) reactions on a thick Ra-226 target are shown in figures 1 and 2 respectively. The production yields at saturation (irradiation time of around 40-50 days) as well as for an irradiation time of I day (one tenth the half life of Ac-225) are presented. From these curves the yields of producing Ac-225, under any known bombarding conditions and for any given irradiation time can be estimated. Due to the graphical nature of the results, the yields for any known target thickness can also be estimated for any irradiation conditions.

It can be seen from fig. 1 that from a thick Ra-226-target production yields of 1.1 x 10^{10}, 1.85 x 10^{10} and 2.04 x 10^{10} Bq can be obtained at proton beam intensity of 100 μA, irradiation time of only one day, at proton energies of 20, 30 and 34 MeV respectively.

The production yield curves through (p,n), (p,3n), (d,n) and (d,2n) reactions on Ra-226 are also given in figures 1 and 2. From these curves one can estimate the unwanted radio isotopes which are also being produced simultaneously. Furthermore, one can choose the optimal irradiation conditions in order to minimise the production of these unwanted activities.

CONCLUSIONS

It is suggested that practical quantities of Ac-225 can be produced by the reaction of protons and deuterons on Ra-226, for irradiation time of only one day, and not 10 days as mentioned in ref. [1] which is obviously impractical. The energies considered here are usually available from medical cyclotrons operating in many hospitals and medical institutions around the world. Furthermore, it is also shown that proton induced reactions on Ra-226 produce much higher yields than the reactions with deuterons. These are also more economical because to obtain the same energy of deuterons, as those of protons, one would generally need a cyclotron of twice the size and hence of much higher costs.

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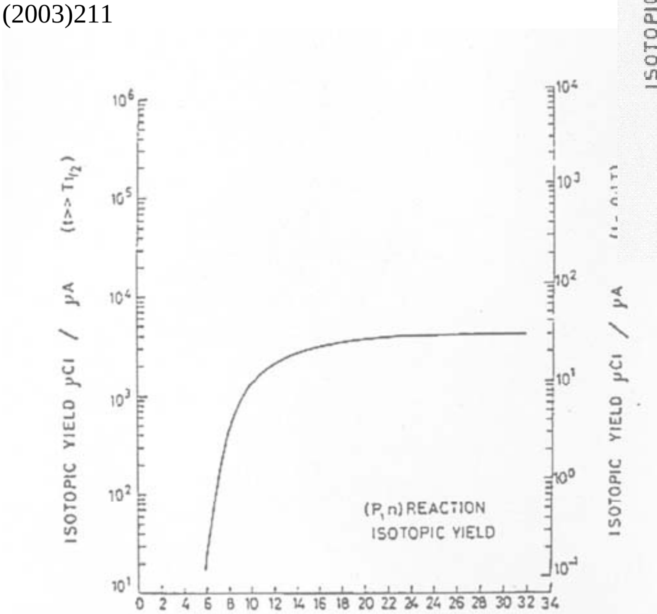

Fig. 1 (a)

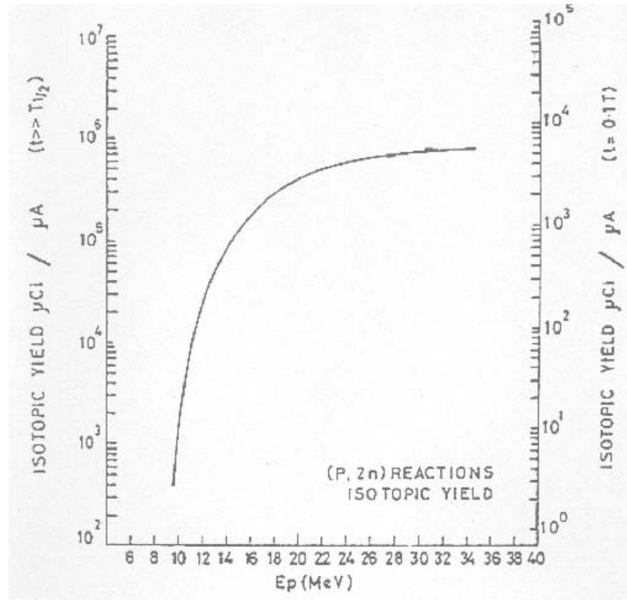

Fig. 1 (b)

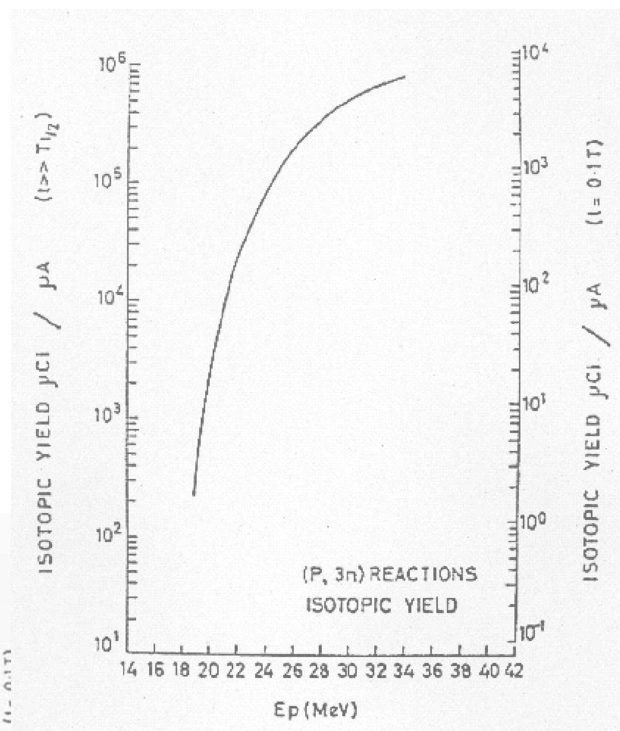

Fig. 1 (c)

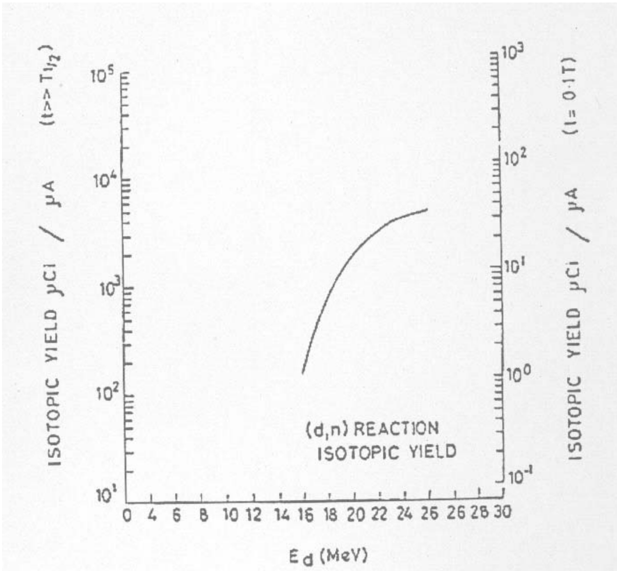

Fig. 2 (a)

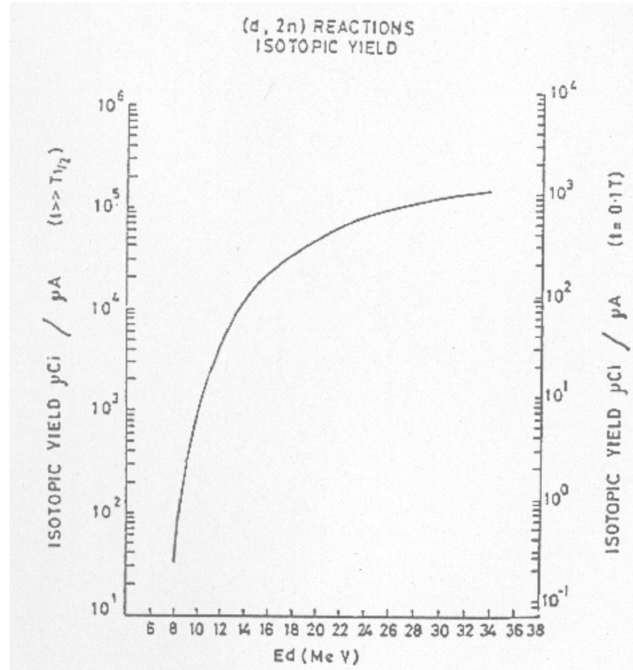

Fig. 2 (b)

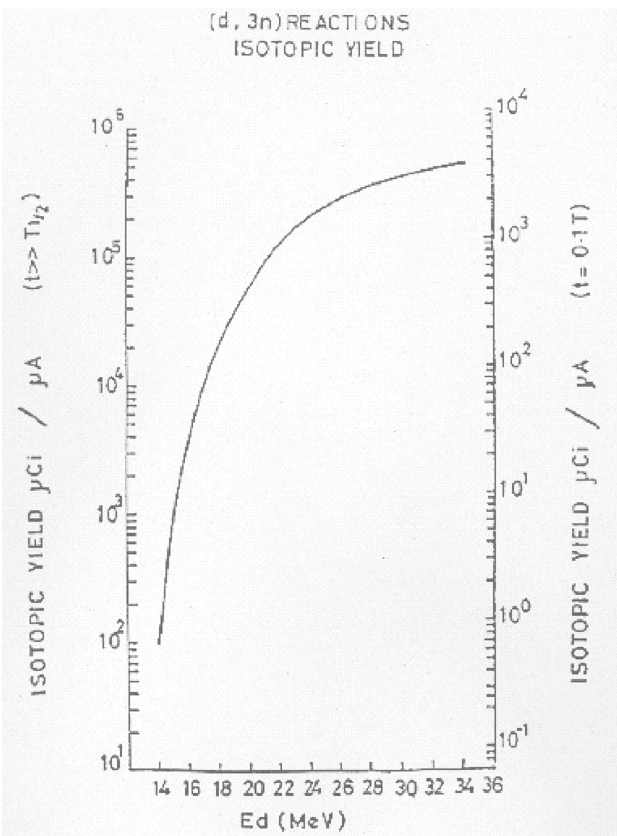

Fig. 2 (c)

Fig. 1. The yield curve **(b)** for the production of Ac-225 through the (p,2n) reaction on a thick Ra-226 target for irradiation times : much greater than the half life of Ac-225, and one-tenth of the half life of Ac-225 (1 day). The yield curves **(a) and (b)** give the yields of the isotopes which are being simultaneously produced from Ra-226 target through (p, n) and (p, 3n) reactions for the two different irradiation times.

Fig. 2. The yield curve **(c)** for the production of Ac-225 through the (d ,3n) reaction on a thick Ra-226 target for irradiation times : much greater than the half life of Ac-225, and one-tenth of the half life of Ac-225 (1 day). The yield curves **(a) and (b)** give the yields of the isotopes which are being simultaneously produced from Ra-226 target through (d, n) and (d, 2n) reactions for the two different irradiation times.