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A new compact high power e-beam accelerator for radioisotopes production: a first evaluation

Samy Bertrand, Jean-Michel Geets, Cristiana Gameiro, Benoit Nactergal, Jeremy Brison
IBA SA,Louvain-la-Neuve, Belgium Contact: Samy.Bertrand@iba-group.com

Background and objectives

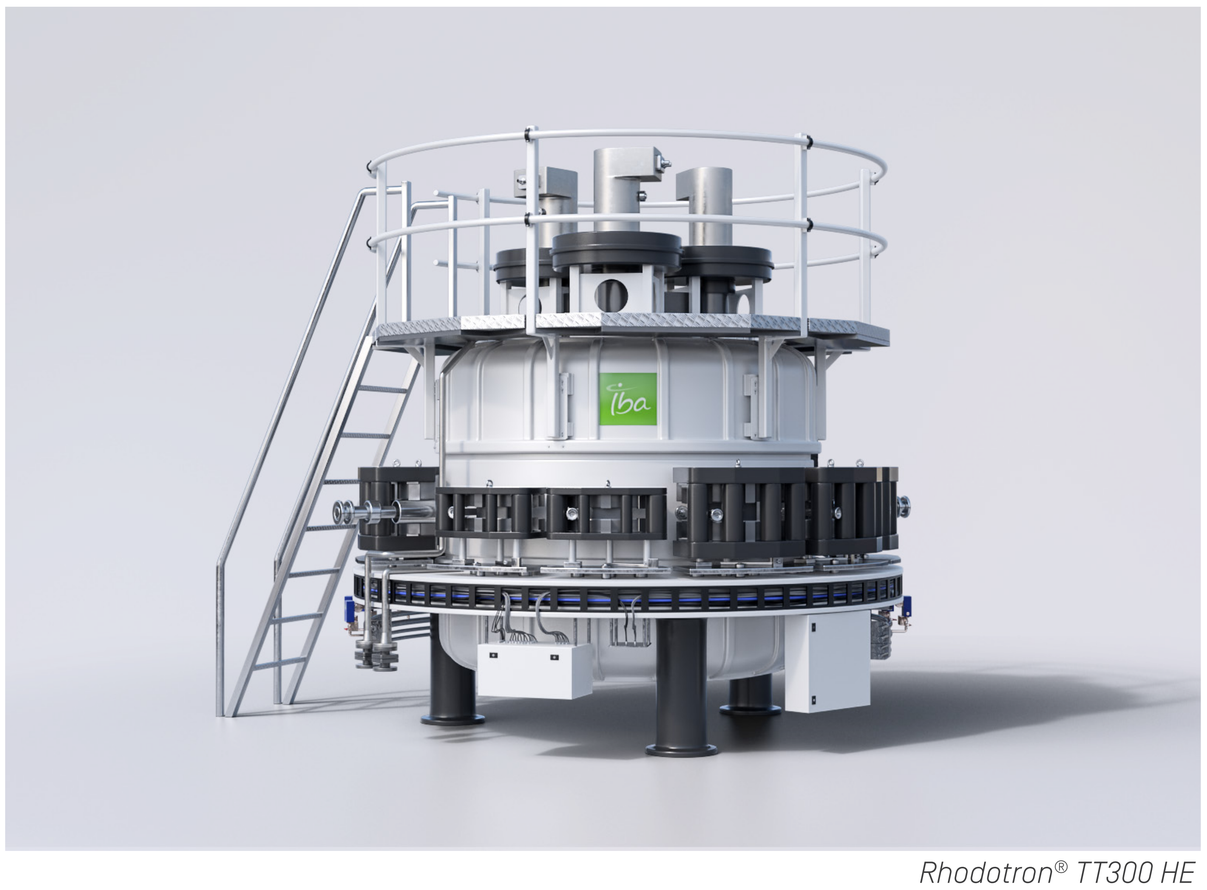
^{225}Ac

Recent developments in the theranostics field have put actinium-225 [^{225}Ac] under the spotlight. Its historical supply from ^{229}Th generators is inherently limited (yearly supply of 1-2 Ci). As the demand forecast is growing, this has led to the development of alternative production routes. Among them, the photoreaction route from Radium has shown promising results. This production route is relatively safe when compared to proton irradiation and results in good purity of final product [1]. However, the low intrinsic reaction yield is a showstopper, especially when combined with the low power of most available electron accelerators.

This paper presents a new concept of a high-power industrial electron accelerator capable of producing several curies of ^{225}Ac from photoreaction on ^{226}Ra. This technology can also be used for production of molybdenum-99 and two other therapeutic isotopes [^{67}Cu and ^{47}Sc]

Methods

The Rhodotron® is a well-known electron accelerator for industrial applications between 1 MeV and 10 MeV electron energy with more than 50 units sold worldwide. It is a compact and reliable accelerator, in operation 24/7 in various countries for sterilization purpose.



Rhodotron® TT300 HE

The new high energy version, the Rhodotron® TT300 HE, is a 125kW beam accelerator with the following specifications:

- Maximum energy of 40 MeV
- High current: up to 25mA peak or 3.125mA average
- ‘continuous’ beam ability with 12.5% duty cycle

This compact accelerator may be ideal for radiotherapeutic isotopes production. Based on theoretical models and practical experiments [2], a production of 0.0211 µCi of ^{225}Ra / (h . mg of ^{226}Ra . µA) was demonstrated with electron energy of 18MeV. After 18 days of decay, 44% of ^{225}Ac can be extracted, leading to a production yield of ^{225}Ac of 0.0093 µCi / (h . mg of ^{226}Ra . µA).

Considering the specifications of the Rhodotron® TT300 HE, the following parameters can be used to estimate the production yield that could be obtained:

- Higher electron energy from 18 MeV to 40 MeV will provide larger cross-section
- Mean current from 26µA to 3.125mA will increase the integrated amount of photons hitting ^{226}Ra target
- Target material ^{226}Ra quantity: higher quantity of radium can be encapsulated. After irradiation, the radium could be recycled and reconditioned.
- Irradiation geometry: optimization could be made in order to have the larger surface of target material in front of the beam

Results and discussions

The potential production yield estimated is 147.85µCi of ^{225}Ra/(h . mg of ^{226}Ra) or 65µCi of ^{225}Ac/(h . mg of ^{226}Ra). Considering an irradiation of 150h of 1g of ^{226}Ra, one could weekly produce up to 9.7Ci of ^{225}Ac. In this approach, the target capsule containing large quantities of Radium is totally decoupled from the accelerator and beam line vacuum can be designed to avoid radon release.

The following technical challenges are under evaluation: high power converter electron-gamma, target container for large quantities of ^{226}Ra, radon containment system, target cooling and shielding.

Conclusion

Extrapolation from photoreaction route for ^{225}Ac production shows that the Rhodotron® TT300 HE could provide sufficient levels of production to respond to the increasing demand of ^{225}Ac. The challenges to integrate such accelerator in a radioisotope production line have been highlighted. Appropriate design of the facility could allow to produce other therapeutic isotopes such as ^{67}Cu and ^{47}Sc using the same photonuclear routes.

References

[1] Development of ^{225}Ac Radiopharmaceuticals: TRIUMF Perspectives and Experiences, Robertson A. et al., Current Radiopharmaceuticals, 2018

[2] Production of ^{225}Ac for cancer therapy by photon induced transmutation of ^{226}Ra, Melville G., University of Western Sydney, 2007