PRODUCTION OF RADIOISOTOPES FOR NUCLEAR-MEDICAL APPLICATIONS AT THE VINCY CYCLOTRON

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The construction of the VINCY cyclotron, the main part of the TESLA Accelerator Installation in Vinča, proceeds according to the plans. The extraction of the first beam is expected in early 1997. Together with the construction of the cyclotron, the concept of the production of radioisotopes and radiopharmaceuticals for nuclear medicine centers in Yugoslavia, and neighboring countries is in development.

1. Introduction

At present there are thirteen nuclear medicine centers in Yugoslavia, which are dealing with in vivo diagnostics and about thirty centers which perform in vitro diagnostics. They are equipped with twenty five computerized gamma cameras with other related equipment. Presently, all of the common radioisotopes used in nuclear medicine can be applied, except the positron emitters. Due to its favorable geographic location, the VINCY cyclotron is planned to be a regional center for the production of radioisotopes and radiopharmaceuticals for the Balkan region as well as for some other countries.

2. TESLA Accelerator Installation - VINCY Cyclotron

The main parameters of the VINCY cyclotron are shown in Table 1.

Table 1. The main parameters of the VINCY Cyclotron (under construction)

Diameter of the pole: 2000 mm	Bending constant: 145 MeV
Spiral angle of the sector: 0^0	Focusing constant: 75 MeV
Angular span of the sectors: 42^0	Number of resonators: 2
Number of sectors: 4	Eigenfrequency of the resonator: 17-31 MHz
Distance between the hills:: 51 mm	Angular span of the dee: 33^0
Distance between the valleys; 190 mm	Angular span of the anti-dee: 48^0
Minimal magnetic gap: 31 mm	Ion beam aperture of the dee; 22 mm
Number of main coils; 2	Amplitude of the dee voltage: 35-100 kV
Maximal magnetic induction at the center: 2.02T	Injection: spiral inflector
Number of trim coils: 10 per pole	Extraction of heavy ions: foil stripper, or electrostatic deflector
Number of harmonic coils: 8 per pole	Extraction of H^-, D^-, H_2^+ and H_3^+ ions : foil stripper

The VINCY Cyclotron will provide the following beams which can be used for the production of radioisotopes:

a) Deuteron beam:
Energy 60-73 MeV
Current 10-20 μA

b) Proton beam
Energy 22-36 MeV
Current 20-40 μA

c) Proton beam
Energy 7-13 MeV
Current 60 μA

3. Plan of the production of radioisotopes for nuclear medicine applications

The plan of radioisotope production is based on the present status of the nuclear medicine in the world as well

as on the needs of Yugoslav nuclear medicine, with special emphasis on the possibilities for export of the produced radioisotopes and radiopharmaceuticals.

The chosen radioisotopes must be suitable for the production of a wide range of radiopharmaceuticals, and their production must be possible with the beams available on the cyclotron. According to the first considerations, a preliminary choice of the radioisotopes has been made. The list of the selected radioisotopes is as follows.

3.1 Iodine-123

This very useful radioisotope can be successfully produced with the beams which will be supplied by the VINCY Cyclotron.

The most promising way for the production of ^{123}I is the irradiation of enriched Xe according to the following indirect nuclear reactions[1] :

^{124}Xe (p, 2n) ^{123}Cs
$^{123}Cs \rightarrow {}^{123}Xe$
^{124}Xe (p, pn) ^{123}Xe
$^{123}Xe \rightarrow {}^{123}I$.

The less favor reactions producing ^{123}I from natural ^{127}I could also be used :

^{127}I (p, 5n) ^{123}Xe
^{127}I (d, 6n) ^{123}Xe,

but with relatively high yield of unwanted ^{125}I.

The nuclear reaction which is under the consideration as the reaction of choice, is ^{124}Xe (p, pn) ^{123}Xe, which gives the best quality of the produced ^{123}I. The target, gaseous ^{124}Xe, is bombarded with a proton beam of energy about 30 MeV in a specially designed target station.

3.2 Fluorine - 18

This important positron emitter could be, according to the parameters of the VINCY Cyclotron, successfully produced by the reaction[2]:

^{18}O (p, n) ^{18}F

or alternatively with deuterons on neon target, by the reaction:

^{20}Ne (d, α) ^{18}F.

Bearing in mind the complexity of the target stations for irradiation of gaseous targets, the reaction which could be used on the VINCY Cyclotron is ^{18}O (p, n) ^{18}F using a liquid target[2] ($H_2{}^{18}O$).

Using a special collimator, this radioisotope can be also used with the equipment already present in the Yugoslav nuclear-medical centers.

3.3 Thallium-201

High activities of this radioisotope can be produced via indirect nuclear reactions[3]:

^{203}Tl (p, 3n) ^{201}Pb
^{205}Tl (p, 5n) ^{201}Pb.

It seems that, under the given conditions, the production of ^{201}Tl could be achieved by using the nuclear reaction ^{203}Tl (p, 3n) ^{201}Pb. The target is enriched, solid ^{203}Tl, bombarded by protons of energy of about 30 MeV.

These radioisotopes can be used for labeling a number of useful radiopharmaceuticals, especially ^{123}I - hippuric acid, ^{123}I - fatty acids, ^{123}I - MIBG, ^{123}I - IMP, ^{123}I - receptors, etc.[4] and ^{18}FDG.[5]

After the production of this three radioisotopes will be achieved, the possibilities for the production of some other radioisotopes and radiopharmaceuticals will also be considered. This refers particularly to the development of some potentially useful generator systems ($^{82}Sr/^{82}Rb$ and others).

4. Organization of the radioisotope production

The necessary conditions for the organization of the routine production of the radioisotopes and radiopharmaceuticals are also considered. Only the most important points are commented.

4.1 The shielded rooms for the target stations

According to the present status, it is suggested that a special building for the production of the radioisotopes should be constructed. It shall consists of at least three separate irradiation stations (for the solid, liquid and gaseous targets) with all the necessary equipment for the irradiation, remote handling, manipulations with the irradiated targets, etc.

Some place should be reserved for the storage and for manipulations with the irradiated targets, hot laboratories, etc.

4.2 Radiochemical separations, labeling and quality control

For these purposes the existing place, equipment and knowledge of the Laboratory for radioisotopes could be used (some special equipment is however, needed).

The collaborators in the field of the application of the radioisotopes and radiopharmaceuticals will be the Yugoslav nuclear-medical centers, particularly the Institute of Nuclear Medicine of the Clinical Center of

Serbia, Belgrade and the Institute of Nuclear medicine of the Military Medical Academy, Belgrade.

5. Conclusion

The VINCY Cyclotron will provide good conditions for the production of different radioisotopes and radiopharmaceuticals for nuclear medical applications. The first isotopes to be produced will be ^{123}I, ^{18}F and ^{201}Tl. Future development might include some other radioisotopes and radionuclidic generator parents as well as new radiopharmaceuticals.

6. References

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