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The radiochemistry cyclotron in University of Helsinki

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Abstract The 10 MeV proton cyclotron in the Laboratory of Radiochemistry, University of Helsinki is presented. Recent activities as well as the future research and teaching directions around the cyclotron are discussed.

Key words cyclotron • F-18 • radiochemistry • radiopharmacy • radiopharmaceutical chemistry

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Introduction

The Laboratory of Radiochemistry is one of the laboratories within the Department of Chemistry at the University of Helsinki, Finland. The laboratory was founded in 1962 in order to study the environmental effects of radioactive fallout from the nuclear weapon tests. Recently, the research in the laboratory has concentrated mostly on the nuclear waste disposal studies, waste treatment using ion exchangers, radiation chemistry and radiopharmaceutical chemistry. The Laboratory of Radiochemistry is the only academic institution teaching radiochemistry in Finland.

For supplying short-lived radioisotopes for research purposes to the laboratory, a 10 MeV proton/5 MeV deuteron cyclotron was purchased from Ion Beam Applications (IBA, Louvain-la-Neuve, Belgium) in 1998. This IBA 10/5 cyclotron is specially designed for production of light positron-emitting radionuclides for nuclear medicine purposes. The cyclotron accelerates negative ions which enable an efficient extraction of the beam and thus relatively high beam intensities, for protons up to 80 μA and for deuterons up to 40 μA. The cyclotron has eight target positions inside the magnet yoke and the beam can be extracted to two opposite target positions at the same time. One of the target positions has been converted to an outlet for an external beam line to enable option for beam tuning for specific applications. At the moment, the external beam line is two meters long with a quadrupole magnet pair for beam focussing. The cyclotron can be operated either in a manually controlled mode, where the magnet and ion source currents can be tuned separately, or in a totally automated mode. The main parameters of the cyclotron are presented in Table 1.

Recent activities

Our IBA 10/5 cyclotron has been used for several purposes during its five-year operation. Up to now, the emphasis of the work has been on the production of the short-lived, positron-emitting radioisotope ^{18}F, used in research and

Table 1. The working parameters of our IBA 10/5 cyclotron.

2 PIG ion sources	H^-, D^-
Maximum extracted beam current	80 μA (H^-), 40 μA (D^-)
Extraction radius	30 cm
Dee voltage	32 kV
Accelerating frequency	42 MHz
Working vacuum	$(1.1–1.3) \times 10^{-5}$ mbar
Stand-by vacuum	$<1.0 \times 10^{-6}$ mbar

clinical applications of radiopharmaceuticals. Several methods have been developed for labelling new pharmaceutical compounds with ^{18}F. The labelled compounds are evaluated by *in-vitro* autoradiography [1].

In the year 2000, our laboratory started a commercial production of 2-[^{18}F]fluoro-2-deoxy-D-glucose (FDG) for Finnish hospitals. FDG is a glucose analogue that can be used e.g. for detection of tumours with Positron Emission Tomography (PET). To facilitate the needed licensing procedures, the sales and the responsibility for pharmaceutical quality of FDG were transferred to a Finnish medical company, MAP Medical Technologies (MAP). In the year 2001, it became evident that the amount of FDG needed by the Finnish hospitals would increase. To release our personnel from commercial production work to their own research work, a decision was made to transfer also the production of FDG to MAP. Since the beginning of the year 2002 our laboratory has sold ^{18}F in the form of fluoride to MAP that nowadays is fully responsible for the radiopharmaceutical production. A cyclotron operator group consisting of undergraduate students of the Laboratory of Radiochemistry perform the ^{18}F production runs.

The external beam line enables directing the proton/deuteron beam to a variety of target types. One application has been the use of a gas target at the end of the beam line for production of short-lived Cs radionuclides via ^{nat}Xe(p,n)^{A}Cs reactions. The produced radionuclides, mainly with A = 129–132, have been utilised as tracers when studying sorption of caesium onto rock minerals. This study is a part of the project aiming at safe disposal of radioactive waste in crystalline rocks.

A preliminary study for utilising the cyclotron in radiation chemistry research was made when a batch of cholesterol was irradiated with 10 MeV protons. The aim of this project is twofold: on one hand, new cholesterol compounds, produced when high-energy radiation strikes the sample, are looked for. The second aim is to extend earlier studies on effects of cholesterol on the metabolism of cells during irradiation. These earlier studies were made with gamma irradiation. Finally, we have also provided beam time on the external beam line for astrophysicists for simple test irradiations of space electronic components.

A summary of the running hours of our cyclotron during the first five years of operation is shown in Fig. 1.

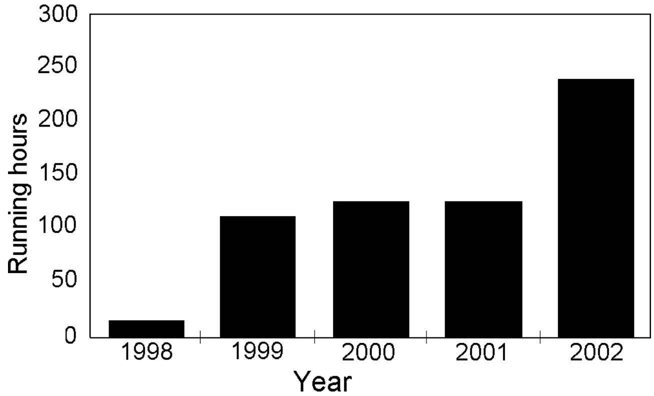

Fig. 1. The running hours of the cyclotron in the Department of Radiochemistry, University of Helsinki, during its first five years of operation.

Future directions

The main emphasis in the future will be to develop the use of the cyclotron for research and teaching applications. For this, several changes in our cyclotron infrastructure have to be made. The primary task is the renovation and extension of the external beam line. Our cyclotron vault can accommodate larger constructions than at present. Thus, the beam line could be split into 2–3 outputs using a switching magnet. Ion optical components such as an *x–y* magnet and a beam sweeping unit are needed for enhancing the options in beam tuning, in order to make full use of the high beam current. An extra concrete wall between the cyclotron and the beam line system is required for radiation safety, to allow work at the beam line area when the radiation levels at the cyclotron are high.

One main scientific activity around the cyclotron will be target development for the production of radiolabelled precursors, to be produced in amounts in excess of 400 GBq, for e.g. radiopharmaceutical chemistry. Gas, liquid and solid targets suitable for high intensity proton/deuteron irradiations, as well as their automatic handling systems will be developed. A first step towards this direction is at the moment on the way, as we have recently set-up and made the first test with irradiating solid nickel targets for copper radioisotope production. The targets used are electroplated with an electrodeposition cell on metallic backings.

References

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