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A TARGET DESIGN FOR IRRADIATION OF NaI AT HIGH BEAM CURRENT

by J. W. Blue
Lewis Research Center
Cleveland, Ohio

and

V. J. Sodd
Nuclear Medicine Laboratory
HEW Bureau of Radiological Health
Cincinnati General Hospital
Cincinnati, Ohio

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ABSTRACT

A solution to the targetry problems encountered when the iodine nucleus is a target for cyclotron irradiation is given as a new target design. A target based on this design has been used in 30 microampere irradiations of 46 MeV alpha particles for one-half hour without significant damage. Such an irradiation produces 6 to 7 mCi of ^{129}Cs, an isotope useful in nuclear medicine. This target should also be considered for cyclotron production of the radioisotopes ^{127}Cs, ^{123}I and ^{127}Xe.

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J.W. Blue, Lewis Research Center, NASA

V.J. Sodd, Nuclear Medicine Lab. BRH, DHEW

The iodine nucleus has been the target of many cyclotron irradiations for the production of radioisotopes of interest in nuclear medicine. Table I lists some of the more important reactions.

TABLE I

$^{127}I\ (\alpha,\ 2n)\ Cs^{129}$

$^{127}I\ (\alpha,\ 4n)\ Cs^{127}$

$^{127}I\ (p,\ 5n)\ ^{123}Xe \xrightarrow{\beta^+} {}^{123}I$

$^{127}I\ (^{3}He,\ 3n)^{127}Cs$

$^{127}I\ (p,n)^{127}Xe$

The ^{127}Cs and ^{129}Cs have been found useful as scanning agents for myocardial imaging and cerebral blood flow, ^{127}Xe for lung perfusion and ventilation studies, and ^{123}I for thyroid studies and for tagging radiopharmaceuticals as a low radiation dose substitute for ^{131}I.

When ^{127}I is used as a cyclotron target, there is question as to what chemical form should be employed. Elemental iodine has been used as a target but it is extremely reactive, poisonous, and has a high vapor pressure. At the most recent meeting of the Society for Nuclear Medicine, DeNardo et al.[1] reported using elemental iodine (contained in tantalum) for ^{123}I production. Problems with target integrity were encountered and therefore the beam current had to be limited to a few microamperes.

Iodine as an alkali iodide has much greater chemical stability and is certainly more often chosen as the chemical form for cyclotron irradiations. Sodd et al.,[2] reported the yield and a scheme for chemical separation of ^{129}Cs from sodium iodide targets bombarded with 40 MeV alpha particles. However, target problems were encountered when routine production of 10 mCi quantities of ^{129}Cs was attempted. The problems with alkali iodides are listed in Table 2.

TABLE 2

1. Low thermal conductivity
2. Radiation induced decomposition
3. Radiation damage of the single crystal lattice
4. Hygroscopic

NaI powder targets were limited to low beam currents because the water bound to the sodium iodide was converted to vapor and caused pressurization of the target. Single crystal targets do not contain as much water but the radiation damage strains the lattice and cracks the crystal so that severe physical deterioration makes it difficult to hold the target material in the beam.

Other possible sodium iodide targets are 1) molten salt as planned for ^{123}I production at BLIP[3] and, 2) sodium iodide fused to water-cooled copper or silver plates in the manner Hrubý[4] used on RbCl. The first scheme was rejected because molten sodium iodide presents a containment problem and a reasonably thick walled container must be used, which would rule out low particle energy irradiations. The second scheme was also rejected, because of the complicated processing required to make the fused target and because of the greater hygroscopic nature of NaI compared to RbCl, would make handling of the target more of a problem.

A new target developed for the irradiation of sodium iodide has four novel design features which make it possible to irradiate single crystal sodium iodide with 30 μ amperes of 46 MeV alpha particles. Also the windows of this target are thin enough to allow it to be used with compact cyclotrons for the last two reactions in Table I.

The design features of the sodium iodide target are given in Table 3.

TABLE 3

1. Aluminum cooling fins extending into the target chamber
2. Thin slices of single crystal
3. A porous carbon foil window
4. A cryogenic pump to remove vapors from the target

Feature 1) provides a means of removing the heat energy deposited in the NaI during bombardment. Feature 2) has advantages over a powder in that it provides a target material that has lower moisture content, better thermal conductivity and one that can make good thermal contact with the cooling fins. Feature 3) provides a means of confining the target material and yet allowing the vapors produced during bombardment to escape. Feature 4) provides a means of removing the vapors from the target assembly.

Figure 1 shows a phantom cut-away view of the target. The target is designed to operate in the vacuum system of the cyclotron. It is designed for a beam 3 to 5mm in the vertical direction and 3 to 4 cm in the horizontal dimension. Such a condition in which the vertical focus dominates can be found in any accelerator beam system. An aluminum back plate has 3 horizontal fins 0.04 cm thick, spaced 0.17 cm apart and running the horizontal length of the beam. A single crystal of sodium iodide is cleaved in a dry box and the pieces are wedged into the five compartments formed when the fins of the aluminum back plate are inserted into a horizontal slot in a water-cooled copper block. The entrance side of the slot is covered with a 0.007 cm thick porous carbon foil[5] to contain the NaI pieces which might crack during irradiation. The carbon foil is attached to the copper block with silicone rubber cement. An aluminum frame onto which a .0025 cm aluminum foil window has been cemented is placed over the carbon foil. Through-bolts hold all three pieces together and gas tight seals of the backplate and the window frame to the center copper block are achieved by placing rectangular cut gaskets on each side of the copper block.

The cryopump system is shown in Fig. 2. The target is mounted by insertion into the beam duct and the cryotank is placed in a dewar of liquid nitrogen. This reduces the pressure in the target to 20 cm Hg. The carbon foil support has sufficient stiffness to support the thin aluminum window against this inward pressure difference. Subsequently the beam duct is evacuated and the thin window then bulges outward, due to the 20 cm Hg pressure, making a cavity between the carbon foil and the aluminum window for the vapors released from the target to diffuse to the cryotank.

This target assembly has been run at the Argonne National Lab. cyclotron for one-half hour irradiations with 30 μ amperes of 46 MeV alpha particles. The irradiation strongly colors the NaI crystals and causes some of them to break. There is no indication of a chemical reaction between the bombarded material and the aluminum fins or the carbon foil. The carbon foil shows no radiation damage. The irradiated material is removed from the target cavity by dissolution in water and the chemical procedure given in reference 3 is used to put the ^{129}Cs into an injectible form. The yield from this target has been between 6 and 7 mCi which is less than the 10.5 mCi predicted in reference 3. This discrepency is mostly accounted for by the beam which is intercepted by the aluminum fins. The target has only been run for one-half hour irradiations, but is expected to be satisfactory for longer periods.

REFERENCES

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5. Poco Graphite, Inc., Decateur, Texas. Foil designated type DFP 1.

CYCLOTRON TARGET FOR NaI BOMBARDMENT

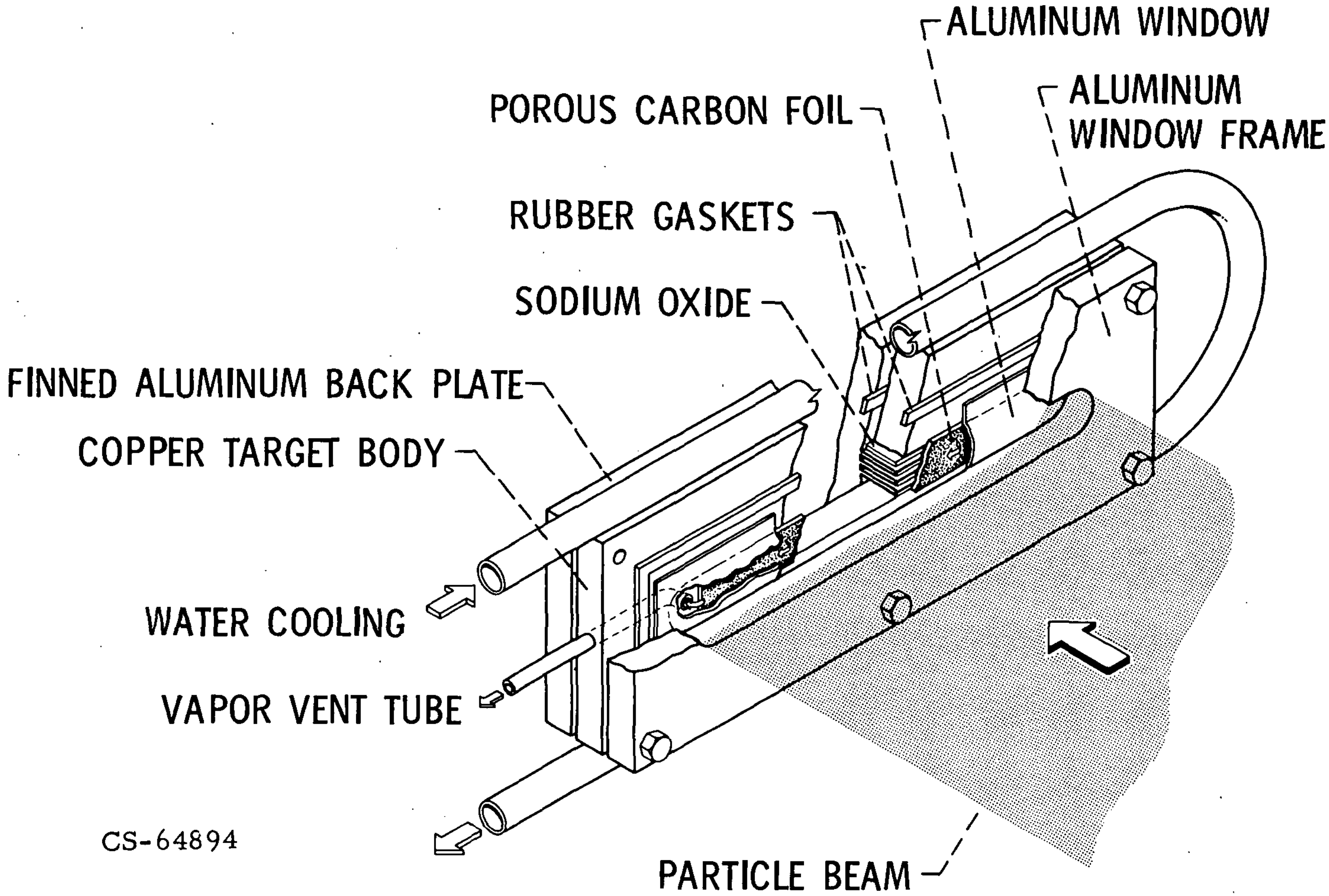

Figure 1

SCHEMATIC OF NaI TARGET SYSTEM

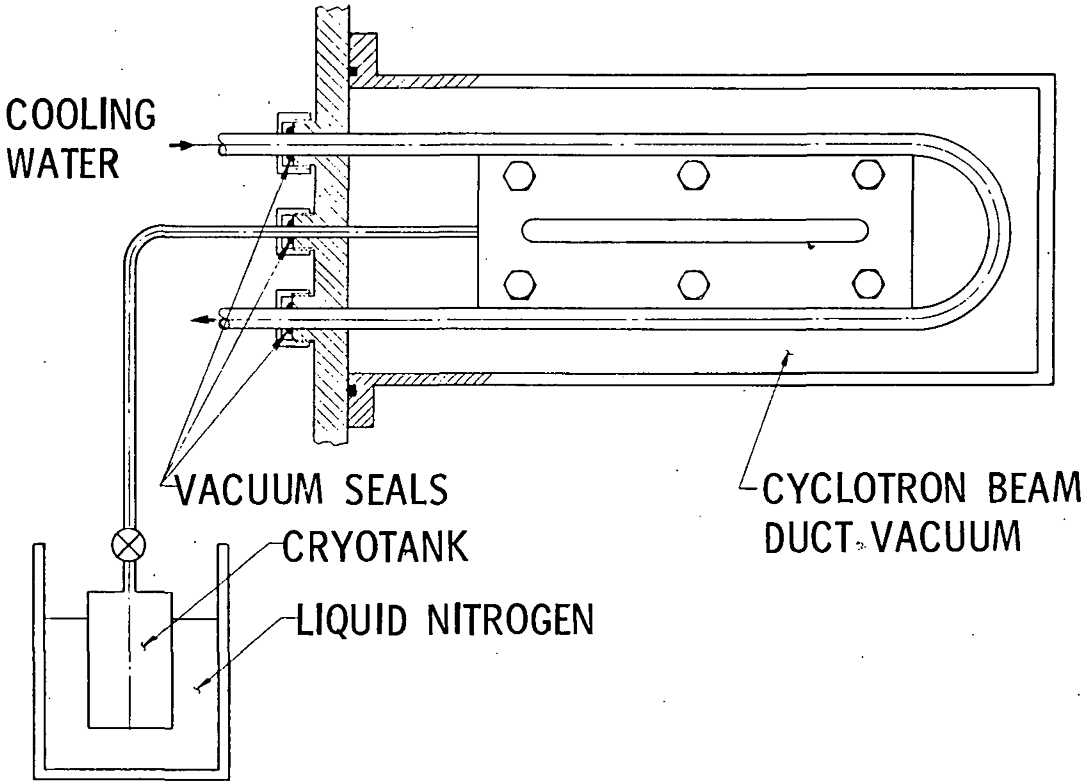

Figure 2