CYCLOTRON PRODUCED IODINE ISOTOPES FOR THERAPEUTICAL MEDICINAL USE

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Abstract

In this paper we explore the possibility of producing iodine isotopes, with a low-medium energy electron, to be used for medical therapy. The analysis of the spectrum of the emitted radiation suggests that the cyclotron produced 1261 may be used to substitute the nuclear reactor produced 1311. One of die advantages of 1261 is that the caracteristic gamma emission makes it easier to monitor with SPECT techniques. The presence of 13 + emission makes possible also tile monitoring with Positron Emission Tomography (PET).

Keys Words: Cyclotron, radioisotopes: ^{131}I, ^{126}I, ^{124}I, ^{123}I, hyperthyroidism, thyroid autonomous nodules, thyroid cancer.

Resumen
Iodo radiactivo para uso terapéutico, producido en el ciclotrón.

Se estudia la posibilidad de producir radioisótopos del Yodo para uso terapéutico en un ciclotrón de baja a media energía. El análisis espectrométrico de la radiación emitida, sugiere que el 1261, producido en el ciclotrón, puede reemplazar, habitualmente usado parafines terapéuticos y producido en el reactor. Una de las ventajas del 1261 con respecto al 131I es que su emisión Gamma puede se Computed Tomography, SPECT). Además, gracias a la emisión de positrones (13+), se puede hacer lo mismo utilizando la tomografía por emisión de positrones (Positron Emission Tomography, PET).

Palabras claves: Ciclotrón, radioisótopos: ^{131}I, ^{126}I, ^{124}I, ^{123}I, hipertiroidismo, nódulos autónomos tiroideos, cáncer tiroideo.

INTRODUCTION

In this communication we explore tile possibility and convenience of producing with a cyclotron iodine radioisotopes to be used for therapy in nuclear medicine.

Iodine radioisotopes of their compounds have been used as scanning agents and as therapeutically tools for liver, pancreas, kidneys, and thyroid diseases. Moreover, regarding certain thyroid diseases such ashyperthyroidisin (Graves-Basedow) and toxic autonomous nodules, the radio iodine is one of the elective therapeutic agents, and in thyroid cancer is the ideal ablative agent for remmant thyroid tissues and/or the only therapeutic alternative for thyroidal metastasis disease.

Until today, the most widely used therapeutic radionuclide in nuclear medicine has been the ^{131}I, which is produced by a nuclear reactor. The half life of ^{131}1 of 8.07 days with β and γ emissions makes it suitable for therapeutically use because patients must receive a relatively high radiation dose.

On the other hand, the cyclotron produced ^{123}I has become the most used radioiodine for diagnostic purposes given its web known advantages related to low exposure *in vivo:* short half life (13.3 hours), absence of β - emissions which are usually to be avoided for patients exposure, a γ emission at 0.159 MeV easily detected by common scintigraphy devices (y-Camera), radiation dose to the patients only 4%-5% of that corresponding to the same diagnostic dose with ^{131}I.

Cyclotron produced iodine isotopes suitable for therapeutically use must have are least a lifetime and emission properties similar to those of ^{131}I. The candidates for this purpose may be ^{124}I and ^{126}I.

Nuclear reactor radioiodines produced for therapeutically uses are generally commercially available at costs inferior to those of equivalent, cyclotron-produced radioiodines.

Nevertheless, there are situations for which it may turn out to be convenient to acquire the latter. For example, hospitals located in areas not too far from a cyclotron laboratory, besides radioisotopes such as ^{131}I, will use cyclotron produced, short-lived radionuclides

(Salvadori *et al.,* 1982) which cannot be generated by a nuclear reactor. These could be ^{123}I, and for applications of die Positron Emission Tomography (PET) (Wolf, 1981), the isotopes ^{11}C, ^{13}N, ^{15}O, and ^{18}F. lf these hospitals are offered a package at accessible price, which includes tile previous radionuclides plus ^{126}I, may find convenient to use ^{123}I for diagnostic purposes, and 1261 for therapeutically uses instead of ^{131}I specially in thyroid cancer patients.

Furthermore, it should be considered that ^{126}I presents emission characteristics which make it appropriate for therapeutically applications, but which are somewhat different from those of ^{131}I. We believe that further studies and research in this area may show that ^{126}I could be more advantageous than ^{131}I for a range of clinical applications where a more aggressive therapeutically agent is required.

CYCLOTRON PRODUCTION OF IODINE ISOTOPES

We consider target choices for machines which accelerate mainly protons up to low-medium energies with a maximum range of 40 MeV. The simplest target choice is a natural tellurium target which composition is the following:

Te^{120} 0.09**%;** Te^{122} 2.46%; Te^{123} 0.87%;
Te^{124} 4.61%; Te^{125} 6.99%; Te^{126} 18.71%;
Te^{128} 31.79%; Te^{130} 34.49%.

For convenience of the reader we report in, the known (Acerbit *et al.,* 1974) excitation function for the production of iodine radioisotopes in a natural tellurium target for 10 to 35 MeV protons. The results are expressed in terms of *μCi/ μAh MeV* as a function of the proton energy in MeV.

The reactions Te (p,n), Te (p,2n), and Te (p,3n) contribute to the production of the iodine isotopes ^{123}I ^{124}I ^{126}I as a function of the energy. The threshold energy for the (p,n) reaction is of the order of few MeV (2.15 MeV for ^{123}I), so that even low energy medical cyclotrons may be used for the production of these iodine isotopes. On the other hand, higher yields may be obtained at higher energies achievable with medium energy machines.

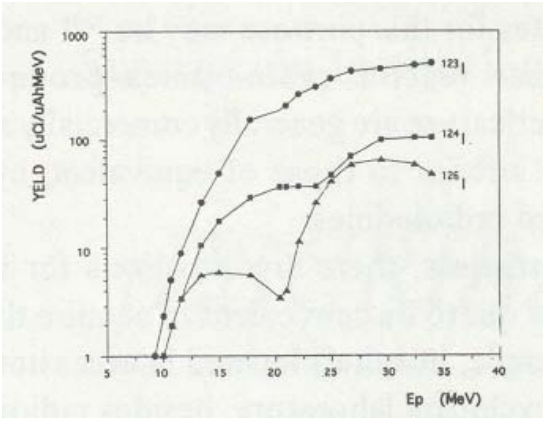

Fig. 1. Excitation function for the production of ^{123}I, ^{124}I, ^{126}I in natural tellurium target for 10 to 35 MeV protons.

Also the isotopes ^{121}I ^{128}I and ^{130}I of half life $T_{1/2}$ h, 25m, 12.3 h, are products of the target bombardment, but they decay fast and for this reason are not suitable for medical therapy and will not be considered.

Of the two cyclotron isotopes, ^{124}I has a lower production yields but it decays faster than ^{126}I. Considering that most of the disruptive energy comes from the contribution of the β- emission, in the long range the predominant radioactivity useful for therapy will be that of ^{126}I, but the radioactivity of ^{124}I may have a certain therapeutically impact and it is worth considering also this isotope.

After irradiation, the following sequences are to be routinely performed for the radio chemical separation: separation of iodine isotopes via distillation, labeling of iodine compounds with the radioisotopes, biological tests on the labeled product, recovery of tellurium for further irradiation. This last step is particularly convenient in the case of targets with a certain degree of enrichment (for example for the production of ^{123}I).

EMISSION PROPERTIES OF TRE CYCLOTRON PRODUCED ^{124}I AND ^{126}I AND OF NUCLEAR REACTOR PRODUCED ^{131}I.

In the following Table 1, are shown some of die physical features of these isotopes (Lederer et al., 1978). All features is necessary for the use of tile

isotope for therapy where the patient has to be exposed to a prolonged doses of radio activity which attacks malignant tissues. Both 1311 and 1261 are β emitters. This feature implies that the particle energy is dissipated en tissue producing the therapeutically effect required. The presence of β emissions for 1241 and 1261 suggests that some of the of the particle (the kinetic energy) will be delivered to the tissue and will add to the disruptive effect of the β particle.

The decay energy of β particles emitted by cyclotron produced iodine isotopes are greater than tile corresponding one of tile reactor produced isotopes, this fact suggests that ^{124}I and ^{126}I are more aggressive therapeutically agents than ^{131}I.

Table 1. PHYSICAL FEATURES OF IODINE ISOTOPES

isotope	lifetime	decay modes	decay energy (MeV)	particle energie (MeV)	particle itensities
				0.250	1.6
				0.330	6.9
^{131}I	8.07*d*	*β*-	0.97	0.487	0.5
				0.610	90.4
				0.790	8*
^{124}I	4.2*d*	*β*+,*EC*	3.17	1.530	46
				2.130	46
				0.380	6*
		β+,*EC*	2.15*β*+	0.860	29
^{126}I	13*d*	*β*-	1.12*β*-	1.250	12

The mass potential *energy* (mc^2) of the particle will transform into y particles of characteristic energy which will add to tile spectrum of the gamma emissions. The energy distribution of all the γ particles are shown in Table 2

Energy will be absorbed locally due to interaction of gamma rays will file nuclei and file electronic clouds of the atoms and molecules composing file tissue. Again, since file spectrum of the gamma rays emitted by the cyclotron isotopes is more energetic than that of file reactor isotopes, one is led to file conclusion that the former are more disruptive and, therefore, they probably will turn out to be more efficient therapeutical agents for cancer diseases.

Table 2. GAMMA ENERGY DISTRIBUTION

isotope	gamma energy (MeV)	gamma intensities
	0.284	5.9
^{131}I	0.364	79
	0.637	6.7
	0.602	100*
^{124}I	0.645	18
	0.722	21
	1.691	21
	0.388	100*
	0.492	6.3
^{126}I	0.666	1.3
	0.880	97.1
	0.753	12.2

One of the disadvantages (Clark, 1991) of all the mentioned radioisotopes used for therapy is that, whilst a small abundance of gamma radiation results in poor images and contributes to file whole-body radiation burden of file patient under treatment without significantly increasing the radiation damage to the target tissue. Furthermore, file high-energy gamma radiation also adds to file radiation dose to staff and relatives, necessitating admission and isolation of patients undergoing intense radio-iodine therapy.

One of the advantages of 1261 over 1311 is that the former possesses a characteristic gamma emission, due to the presence of 13+ emission and file consequent positron annihilation, which makes it easier to monitor with SPECT techniques and makes possible also file monitoring with Positron Emission Tomography (PET).

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