A Proposed Standard on Medical Isotope Production in Fission Reactors

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Abstract

Authors Robert E. Schenter, Garry Brown and Charles S. Holden argue that a Standard for "Medical Isotope Production" is needed. Medical isotopes are becoming major components of application for the diagnosis and treatment of all the major diseases including all forms of cancer, heart disease, arthritis, Alzheimer's, among others. Current nuclear data to perform calculations is incomplete, dated or imprecise or otherwise flawed for many isotopes that could have significant applications in medicine. Improved data files will assist computational analyses to design means and methods for improved isotope production techniques in the fission reactor systems. Initial focus of the Standard is expected to be on neutron cross section and branching data for both fast and thermal reactor systems. Evaluated and reviewed tables giving thermal capture cross sections and resonance integrals for the major target and product medical isotopes would be the expected "first start" for the "Standard Working Group".

KEYWORDS: Medical isotope production, neutron cross section data, fission reactor systems, Tungsten-188, Nuclear Medical Isotope Standard,

1. Introduction/Summary

Production of medical isotopes in fission reactor systems represents a very important current and future element in medical science. Medical isotopes are becoming major components improving methods of diagnosing and treating major diseases, cancers, heart disease, arthritis, Alzheimer's, among others [1]. In the United States, for example, over 12 million nuclear medicine procedures are performed annually.

Consequently, it is crucial to have an adequate and uninterrupted supply of many different types of radiopharmaceuticals which incorporate several different types of radioisotopes [2]. Table 1, for example, lists the first 18 medical isotopes giving their half lives and application from an alphabetically ordered table of 111 isotopes [3].

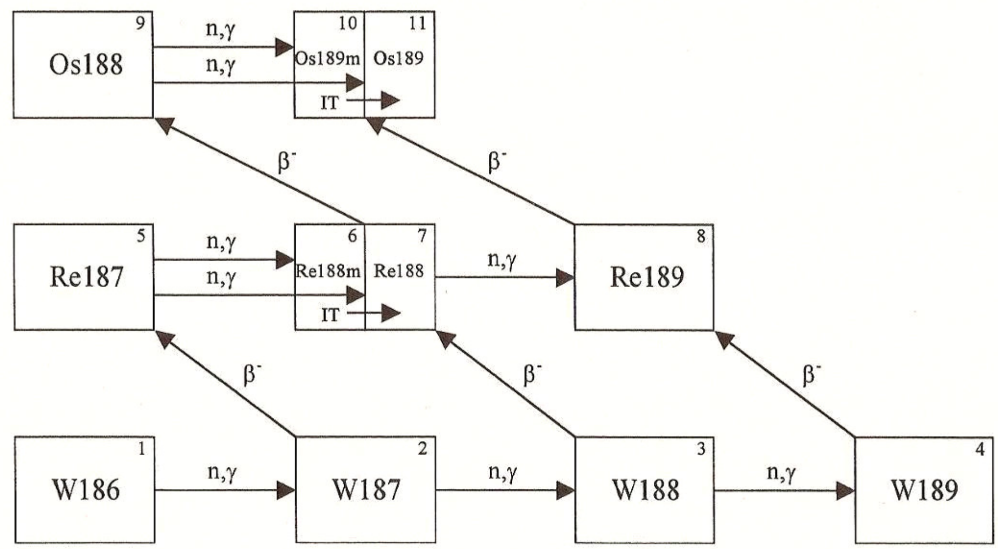
Table 1: Medical isotopes half lives and applications.

Medical Isotope Applications		
Isotope	**Half-life**	**Applications**
Ac-225	10.0d	Monoclonal antibody attachment used for cancer treatment (RIT), also parent of Bi-213
Ac-227	21.8y	Parent of Ra-223 (Monoclonal antibody attachment used for cancer treatment (RIT).
Am-241	432y	Osteoporosis detection, heart imaging.
As-72	26.0h	Planar imaging, SPECT or PET.
As-74	17.8d	Positron-emitting isotope with biomedical applications.
At-211	7.21h	Monoclonal antibody attachment (alpha emitter) used for cancer treatment (RIT), used with F-18 for in vivo studies.
Au-198	2.69d	Cancer treatment using mini-gun ,treating ovarian, prostate, and brain cancer.
B-11	Stable	Melanoma and brain tumor treatment.
Be-7	53.2d	Used in berylliosis studies.
Bi-212	1.10h	Monoclonal antibody attachment (alpha emitter) used for cancer treatment (RIT), cellular dosimetry studies.
Bi-213	45.6m	Monoclonal antibody attachment (alpha emitter) used for cancer treatment (RIT).
Br-75	98m	Planar imaging, SPECT or PET.
Br-77	57h	Label radiosentizers for Te quantization of hypoxia in tumors, and monoclonal antibody labeling.
C-11	20.3m	Radiotracer in PET scans to study normal/abnormal brain functions.
C-14	5730y	Radiolabeling for detection of tumors (breast, et al.).
Cd-109	462d	Cancer detection (b), pediatric imaging (b).
Ce-139	138d	Calibrates high-purity germanium gamma detectors <medical application?>.
Ce-141	32.5d	Gastrointestinal tract diagnosis, measuring regional myocardial blood flow.

Radioisotopes are primarily produced in fission reactor systems. Also, some are produced by gamma irradiation and many are produced in accelerators. Most of the isotopes produced in fission reactors are capture products and some are fission products [4]. Accurate data for the medically significant isotopes must be made freely available.

In order to effectively determine, plan, and produce the isotopes used for expanding radiopharmaceutical applications nuclear data must first be developed and refined. Particularly, isotope production calculations and burnout calculations depend on accurate sets of nuclear data, which data for some isotopes are yet to be developed with sufficient precision. In addition, assurances relating to product quantity and quality require production and burnout calculations of both the target isotope and the associated "impurity" isotopes contained in the product. Figure1 shows the production paths illustrating this for the important medical isotope "generator" Tungsten-188 (W-188).

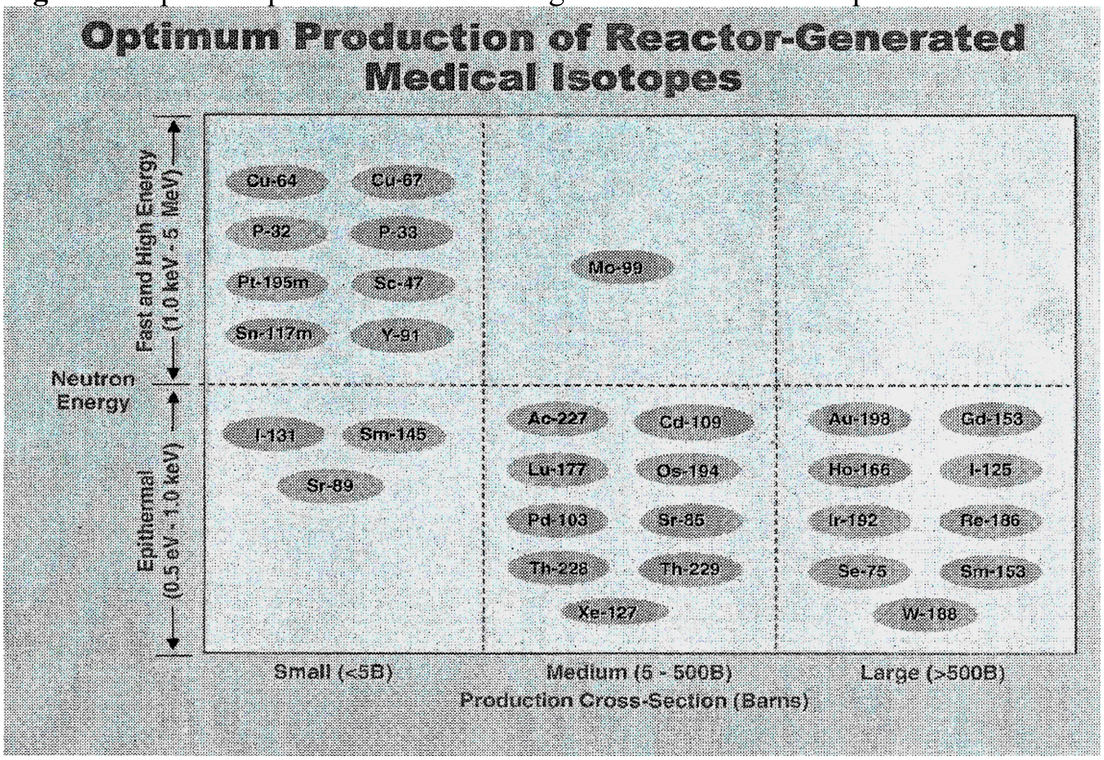
Figure 1: Production path for Tungsten-186 (W-186).



Tungsten-188 decay produces Rhenium-188 (Re-188) which has numerous medical applications. The Re-188 obtained from a W-188/Re-188 generator system is used in the treatment and diagnosis of cancer, heart disease and arthritis. Now over 20 countries including USA, Germany, Japan, Taiwan, China, South Korea and Italy, have medical research centers using Re-188 in numerous clinical trials addressing three major diseases: cancer, heart disease and arthritis.

A "Nuclear Isotope Standard" should be made available. This would provide current, accurate and focused information/data permitting computational analysis and optimization of the means and methods to improve the availability of these materials. It is expected that the "First Priority" information would be neutron cross section and branching data for both fast and thermal reactor systems. Figure 2, for example, shows the different energy ranges and cross section types for calculations involved in the production of 30 important medical isotopes.

Figure 2: Optimum production of reactor-generated medical isotopes.



Tables of thermal cross sections, resonance integrals, and fission spectrum weighted cross sections are the obvious starting points for the needed information. The thermal and resonance integral values would apply primarily to (n, gamma) reactions and the fission spectrum values primarily to (n,p), (n,alpha), (n,d) and (n,t) sets of reactions.

Previous major evaluation files of neutron cross section data (ENDF/B,JENDL,JEFF, et al.) have not focused on medical isotope production. In addition, there will be a need for a number of cross sections for radioactive isotopes (eg. W-187, see Figure 1) in the production schemes for medical isotopes. Even the 16th edition of the "Chart of the Nuclides" is missing a number of "required" thermal cross sections and resonance integrals, especially for the radioactive isotopes.

Obtaining more accurate values from those given previously or even currently available is also an issue. The following two examples involving the capture cross sections of Ruthenium-105 (Ru-105) and Radium-226 (Ra-226) illustrate this point.

The first example involves Ru-105: This cross section was reported in 1960 based on the observation of double capture by Ruthenium-104 (Ru-104) [5]. The analysis used a value of the cross section for the production of Ru-105 from Ru-104 that is 50% higher than the presently accepted value.

The second example involves Ra-226: The naturally occurring radioisotope Ra-226 has been suggested for use in the production of Actinium-227, Thorium-228 and

Thorium-229 which eventually decay to three medically important alpha emitters (Radium-223, Bismuth-212 and Bithmuth-213, respectively). Three previous measurements of the capture of Ra-226 have been reported, all dating from the period 1942-1952. One of these measurements was based on the observation of gamma rays that are not currently listed among the emitted radiations of Ra-226. The results of the other two measurements differ substantially from one another.

The above discussion argues for the need of a "Medical Isotope Production Standard", where "Working Groups" comprised of experts in several different fields (Nuclear Physics, Reactor Physics, Nuclear Medicine, Radiology, Chemistry, and so forth) would determine the required nuclear data values relating to the most isotopes that are clinically important. The task will be to focus on obtaining the high accuracy needed in the data so that effective and useful medical isotope production calculations can be performed. Even existing information needs to be reviewed. Two excellent sources of thermal capture cross sections and resonance integrals have significant differences. This is shown in Table 2 for the cross sections needed for the production calculations of the major important medical isotopes.

Medical Isotopes must play a larger role in the diagnosis and treatment of disease in the future. Scientists from multiple disciplines should have access to the most accurate information so that promising isotopes can be made more widely available around the world. Without the detailed information, production techniques will languish and the potential of treatments made possible by the isotopes will not be realized because computational optimization will not be as accurate as is needed.

Table 2: Medical isotope production cross section information.

Medical Isotope Production Cross Section Comparisons Of Thermal And Resonance Integral Values From Two Sources				
Target Isotope	SIGT (a) (Barns)	SIGT (b) (Barns)	RESI (a) (Barns)	RESI (b) (Barns)
P31	0.172	0.17	0.14	0.08
SC45	27.2	27	12	12
Fe54	2.25	2.3	1.2	1.4
Co59	37.18	37	75.9	74
Se74	51.8	52	560	540
Sr88	0.058	0.058	0.065	0.06
Y89	1.28	1.28	1	1
Mo98	0.137	0.13	6.9	7.2
Pd102	3.4	3	10	---
Ag107	37.6	36	100	100
Cd108	0.72	1	11	15
Sn114	0.115	0.1	5.1	5
Te130	0.29	0.2	0.3	0.44
Xe124	165	168	3600	2600

Xe126	3.8	3.4	60	58
Ba130	8.7	9	170	225
Sm152	206	210	2970	3000
Eu151	9200	9200	3300	5800
Gd152	735	700	2020	700
Ho165	64.7	61.1	665	670
Yb168	2300	2300	21300	21000
Lu175	23.1	25	610	850
Lu176	2090	2300	1087	1200
W186	38.5	38	485	490
Re185	112	112	1717	1700
Ir191	954	920	3500	4100
Pt194	0.58	1.2	1.44	4
Au197	98.5	98.7	1550	1550

(a) Mughabghab (2003)
(b) 16th Edition of Chart of Nuclides (2002)

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