

Yield calculation of positron Emitters for high specific activity



By

Asim Nisar Sheikh

I.D: 13002139007

Supervisor

Dr. Muhammad Imran Jamil

Department of Physics

School of Science

**University of Management and Technology C-II, Johar
Town Lahore – 54770, Pakistan**

**IN THE NAME OF ALLAH, THE MERCIFUL
THE BENEFICIENT**



**SHURU ALLAH KAI NAAM SE JO BARA
MEHARBAAN AUR REHAM WALA HAI**

Yield calculation of positron emitters for high specific activity

Submitted to University of Management and Technology Lahore in
partial fulfilment of the requirements for the award of degree of

MASTER OF PHILOSOPHY IN PHYSICS

By

AsimNisar Sheikh

I.D

1	3	0	0	2	1	3	9	0	0	7
---	---	---	---	---	---	---	---	---	---	---

SESSION: 2013-2015

Department of Physics

School of Science

University of Management and Technology

C-II, Johar Town Lahore – 54770, Pakistan

IQRA BEISME RABIKALAZI KHALAQ
AL-QURAN(SURA ALAQ)



“Read! In the name of your lord, who has created all that exists.”

Parhoapnerab k naam se jis ne paidakia.

DECLARATION

I Mr **ASIM NISAR SHEIKH** Roll No. **13002139007** student of **M.Phil.(Physics)** in the field of **Nuclear Medicine** session 2013-2015 hereby declare that the matter printed in the thesis titled **Yield Calculation of Positron Emitters for High Specific Activity** is my own work and has not been taken from others, printed, published and submitted as research work, thesis or publication in any form in university, research institution etc. in Pakistan or abroad.

Dated

Signature of Deponent

CERTIFICATE

It is certified that the work contained in this project dissertation titled **Yield Calculation of Positron Emitters for High Specific Activity** has been carried out and completed by Mr **ASIM NISAR SHEIKH** Roll No. **13002139007** during his MS/M.Phil. (Physics) studies under my supervision.

Supervisor
Dr. M.ImranJamil

External Examiner

Co-Supervisor
Dr. MazharHussain
Assistant Professor
Govt. College University, Lahore.

Dr. EhsanEllahiKhawaja
Chairperson
Department of physics
UMT, Lahore.

Dr. Muhammad AzharIqbal
Dean
School of Science,
UMT, Lahore.

Dedication

Dedicated to ALLAH ALMIGHTY(the creator of all mankind) and
MUHAMMAD(P.B.U.H)(the Leader of all mankind)

&

All human beings

ACKNOWLEDGEMENTS

All praise to ALLAH, who bestowed upon me HIS blessings, which enabled me to accomplish this work objectively and successfully. Also my deepest gratitude to all who offered me helping hand in accomplishing this task. However some names deserve explicit acknowledgements.

With the deep sense of respect, I am very thankful to my supervisor: **Dr.M.Imran Jamil** and Co-supervisor: **Dr.Mazhar Hussain** who has always been very kind to me guided me and encouraged me. I found him ready to take pain for my work at any time and who helped me a lot in this concern.

Thanks to all.....

ASIM NISAR SHEIKH

ABSRRACT

The development of longer lived positron emitter radionuclides,(termed as non-standard positron emitters) are required to study the metabolic processes, labelling of organic compounds leading to analogue tracers (e.g. with halogens) and quantification of targeted therapy. The decay characteristics of those non-standard positron emitters (half-lives, prompt emission of associated gamma rays, positron energy and positron decay fraction) determine the qualitative and quantitative accuracy (i.e. blurring, spatial resolution, sensitivity, radiation dose, etc.) of the image, which ultimately defines their possible utilization in PET.

The radioisotopes can be used in clinical trials after standard bench marking. Yield calculation is an integral part of this business. In this work, we will select some positron emitters which may be potentially important in nuclear medicine. The reaction cross section data will lead to calculate the yields. The specific activity will be estimated keeping in view the impurity level in each isotope. The recommended reaction routes will be suggested for the production of selected isotopes for medical applications.

CONTENTS

CHAPTER 1:	Page No.
INTRODUCTION.....	1
1.1 History of radioisotopes.....	1
1.1.1. Isotopes.....	1
1.1.2. Stable and Unstable Isotopes.....	1
1.2 Radioisotopes.....	2
1.2.1 Manufacturing of Radioisotopes.....	2
1.2.2 Radioisotopes in Nuclear Medicine.....	3
1.2.3Uses of Radioisotopes.....	3
1.3 Production of radioisotopes using cyclotron.....	3
1.3.1 Cyclotrons and their use in medicine.....	3
1.3.2 Applications of Cyclotron and data needs	4
1.4 Positron emitters.....	4
1.4.1 Positron emitters for PET.....	4
1.4.2 Organic positron emitters.....	5
1.4.3 Novel positron emitters.....	6
1.4.4 Positron Emitters for Slow Metabolic Processes.....	8
1.5 Radioisotopes in diagnostic studies.....	9
1.5.1 Diagnostic techniques in nuclear medicine.....	10
1.6 An Overview of PET and SPECT.....	11
1.6.1 A Comparison between PET & SPECT.....	12
1.6.2 Advantages of PET over SPECT.....	12
1.7 Radioisotopes and therapeutic Applications.....	12

1.7.1 Radioisotope methods in diagnosis and Cancer Therapy.....	13
1.7.2 Internal Radionuclide Therapy of Liver Tumours (Nuclear Oncology).....	13
1.7.3 Analogue approach of positron emitters.....	14
1.8- Yield calculation.....	15
CHAPTER 2:	
NUCLEAR PHYSICS & NUCLEAR MEDICINE.....	16
2.1. Excitation mechanism of nucleus.....	16
2.1.1. Basic forces of nature & building blocks of matter.....	17
2.1.2. Coulomb Excitation.....	18
2.1.3. Q-value and threshold for nuclear reactions.....	19
2.2. Nuclear decay.....	20
2.2.1. Alpha decay.....	20
2.2.2. Beta decay.....	20
2.2.3. Gamma decay.....	21
2.2.4. The Electron Capture.....	22
2.2.5. Isomeric transitions (IT).....	22
2.2.6. Internal conversion.....	22
2.3. Fundamental Nuclear Reactions.....	23
2.3.1. Scattering.....	23
2.3.2. Nuclear Fission Reaction.....	25
2.3.3. Nuclear Fusion Reaction.....	25
2.3.4. Radioactive Capture.....	25
2.3.5. Particle emission reactions.....	26
2.4. Excitation Model.....	26

2.5. Level Density Calculation.....	26
-------------------------------------	----

CHAPTER 3:

AIMS AND SCOPE OF THE WORK.....	27
--	-----------

CHAPTER 4:

STANDARDIZATION OF DATA.....	30
-------------------------------------	-----------

4.1. Nuclear Data.....	30
------------------------	----

4.1.1. Standardisation of Production Data.....	30
--	----

4.1.2. Application of Nuclear Data in medically related radioisotope programmes...31	
--	--

4.1.3. Significance of Nuclear Data Files.....	31
--	----

4.2. Nuclear Data Types.....	32
------------------------------	----

4.2.1. Nuclear Structure Data.....	32
------------------------------------	----

4.2.2. Radioactive Data.....	33
------------------------------	----

4.2.3. Nuclear Decay Data.....	33
--------------------------------	----

4.2.4. Nuclear Reaction Data.....	34
-----------------------------------	----

4.2.5 Other Nuclear Data Types.....	37
-------------------------------------	----

4.3. Accessibility of Data.....	37
---------------------------------	----

4.3.1. Data Libraries at IAEA.....	38
------------------------------------	----

4.3.2 Data Access and Services.....	39
-------------------------------------	----

4.4 Evaluation of data.....	42
-----------------------------	----

4.5. Compilation of Data.....	42
-------------------------------	----

4.6 Selection of Data.....	43
----------------------------	----

4.7 Developed Data for Applications.....	43
--	----

4.7.1 Data for Production.....	44
--------------------------------	----

4.7.2 Standards for Selection of a Radionuclide.....	46
--	----

4.8 Role of Nuclear Model Calculation.....	47
4.8.1. TALYS.....	48
4.8.2. ALICE-IPPE.....	48
CHAPTER 5:	
RESULTS AND DISCUSSIONS.....	49
5.1 Selection of experimental data for yield calculation.....	49
5.2- Evaluation of (p, α) reaction for the production of ^{11}C	50
5.2.1- Unsaturated Thick Target Yield for ^{11}C reaction.....	50
5.2.2- Saturated Thick Target Yield for ^{11}C	51
5.2.3- Analysis and discussion of results.....	53
5.3- Evaluation of (p, α) reaction for the production of ^{13}N	54
5.3.1- Unsaturated Thick Target Yield for ^{13}N	54
5.3.2- Saturated Thick Target Yield for ^{13}N	55
5.3.3- Analysis and Discussion of Results.....	57
5.4- Evaluation of (d, n) reaction for the production of ^{15}O	58
5.4.1- Saturated Thick Target Yield for ^{15}O	58
5.4.2- Evaluation of (p, n) reaction for the production of ^{15}O	59
5.4.3- Saturated Thick Target Yield for ^{15}O	59
5.4.4- Analysis and discussion of Results.....	61
5.5- Evaluation of (p, n) reaction for the production of ^{18}F	62
5.5.1- Unsaturated Thick Target Yield for ^{18}F	62
5.5.2- Saturated Thick Target Yield for ^{18}F	64
5.6- Evaluation of (d, α) reaction for the production of ^{18}F	66
5.6.1- Unsaturated Thick Target Yield for ^{18}F	66

5.6.2- Analysis and discussion of results.....	68
5.7- Evaluation of (p, 2n) reaction for the production of ⁶⁸ Ge.....	69
5.7.1- Unsaturated Thick Target Yield for ⁶⁸ Ge.....	69
5.7.2- Analysis and discussion of results.....	71
5.8- Evaluation of (p, x) reaction for the production of ⁸² Sr.....	72
5.8.1- Unsaturated Thick Target Yield for ⁸² Sr.....	72
5.8.2- Analysis and discussion of results.....	74
5.9 Conclusions.....	75
5.9.1 Research Orientation.....	75
5.9.2 Future Guidelines and Outlooks.....	75
REFERENCES.....	76

LIST OF TABLES

1.1	Some commonly used positron (β^+) emitters.....	6
1.2	Novel Positron (β^+) Emitters for PET.....	7
1.3	Nuclear data of some longer-lived β^+ -emitters used to study slow metabolic processes.....	8
1.4	Radionuclides for applying analogue approach.....	14
2.1	Characteristics of various nuclear arrangements.....	17
2.2	The summary of the nature of α , β , γ radiations.....	21
3.1	Reaction channels of Positron (β^+) emitters for PET.....	28
4.1	World-wide Nuclear Data Centres.....	41
4.2	Various models at low energy nuclear dynamics.....	47
5.1	$^{14}\text{N} (p,\alpha)^{11}\text{C}$ Reaction for unsaturated thick target yield.....	50
5.2	$^{14}\text{N} (p,\alpha)^{11}\text{C}$ Reaction for saturated thick target yield.....	52
5.3	$^{16}\text{O} (p,\alpha)^{13}\text{N}$ Reaction for unsaturated thick target yield.....	54
5.4	$^{16}\text{O} (p,\alpha)^{13}\text{N}$ Reaction for saturated thick target yield.....	56
5.5	$^{14}\text{N} (d,n)^{15}\text{O}$ Reaction for saturated thick target yield.....	58
5.6	$^{15}\text{N} (p,n)^{15}\text{O}$ Reaction for saturated thick target yield.....	60
5.7	$^{18}\text{O} (p,n)^{18}\text{F}$ Reaction for unsaturated thick target yield.....	63
5.8	$^{18}\text{O} (p,n)^{18}\text{F}$ Reaction for saturated thick target yield.....	65
5.9	$^{20}\text{Ne} (d,\alpha)^{18}\text{F}$ Reaction for unsaturated thick target yield.....	67
5.10	$^{67}\text{Ga} (p,2n)^{68}\text{Ge}$ Reaction for unsaturated thick target yield.....	70
5.11	$^{\text{Nat}}\text{Rb} (p,x)^{82}\text{Sr}$ Reaction for unsaturated thick target yield.....	73

LIST OF FIGURES

1.1	PET with CT imaging using X-rays.....	10
2.1	Interaction between charge carriers and fundamental particles.....	17
2.2	Short range strong forces with great strength.....	18
2.3	Excitation of stable nuclei by bombarding a projectile.....	19
4.1	Location of Nuclear Data Centres on the Glob.....	40
4.2	Schematic illustration of an (n,2n) reaction on a nucleus.....	48

1.1. History of Radioisotopes

In 1896, when Henry Becquerel discovered the phenomenon of radioactivity, a new idea was born to use these radioisotopes in medicine. A Hungarian physical chemist, George De Hevesy at first gave idea of using radio tracers in biological and life sciences. And since then a great work has been started for the production of new radioactive tracers and their uses. The advancement in the technology of nuclear reactor and their great role in the production of radioisotopes gave motivation to the general applications of tracers and particular applications of nuclear medicine. In this scenario γ -emitting radionuclides ^{18}F , ^{51}Cr , $^{99\text{m}}\text{Tc}$, ^{131}I , etc. were introduced and serious efforts were also made to develop cyclotrons and accelerators for the production of positron emitters. Along with the production of radioisotopes via cyclotron, the development of nuclear data is an essential part for the purposeful use of radioisotopes.