



شبكة المعلومات الجامعية
التوثيق الإلكتروني والميكروفيلم

بسم الله الرحمن الرحيم



MONA MAGHRABY



شبكة المعلومات الجامعية
التوثيق الإلكتروني والميكروفيلم



شبكة المعلومات الجامعية التوثيق الإلكتروني والميكروفيلم



MONA MAGHRABY



شبكة المعلومات الجامعية
التوثيق الإلكتروني والميكروفيلم

جامعة عين شمس التوثيق الإلكتروني والميكروفيلم

قسم

نقسم بالله العظيم أن المادة التي تم توثيقها وتسجيلها
علي هذه الأقراص المدمجة قد أعدت دون أية تغييرات



يجب أن

تحفظ هذه الأقراص المدمجة بعيدا عن الغبار



MONA MAGHRABY

Ain shams University
Faculty of Science
Chemistry Department



“Loading of some Radionuclides on Nano-sorbents for Nuclear Applications”

A Thesis

Submitted to Chemistry Department, Faculty of Science,
Ain shams University

By

Alaa Farid Mohamed El-Daoushy

(B. Sc., Chemistry 2008)

(M. Sc., Inorganic Chemistry 2016)

Assistant Lecturer at Radioactive Isotopes and Generator Dept.
Atomic Energy Authority

In Partial Fulfillment of the Requirements for the Degree of
PHD of SCIENCE
(Inorganic and Analytical Chemistry)

Under Supervision of

Prof. Dr. Wagiha Hamed Mahmoud

Prof. of Analytical Chemistry – Chemistry
Department – Faculty of Science – Ain Shams
University

Prof. Dr. Khalid Mohamed Saleh El-Azony

Prof. of Radiochemistry – Hot Labs Center –
Atomic Energy Authority

Prof. Dr. Sami Abu-Bakr El-Bayoumy

Prof. of Radiochemistry – Hot Labs Center –
Atomic Energy Authority

Dr. Tamer Mostafa Mohamed Hafez

Assist. Prof. of Radiopharmaceutical Chemistry – Hot
Labs Center – Atomic Energy Authority

2020

“Loading of some Radionuclides on Nano-sorbents for Nuclear Applications”

By

Alaa Farid Mohamed El-Daoushy

**Assistant Lecturer at Radioactive Isotopes and Generator Dept.
Atomic Energy Authority**

Supervisors

Approval

1- Prof. Dr. Wagiha Hamed Mahmoud

Prof. of Analytical Chemistry, Chemistry Department,
Faculty of Science, Ain Shams University

2- Prof. Dr. Sami Abu-Bakr El-Bayoumy

Prof. of Radiochemistry, Hot Labs Center, Atomic
Energy Authority

3- Prof. Dr. Khalid Mohamed Saleh El-Azony

Prof. of Radiochemistry, Hot Labs Center, Atomic
Energy Authority

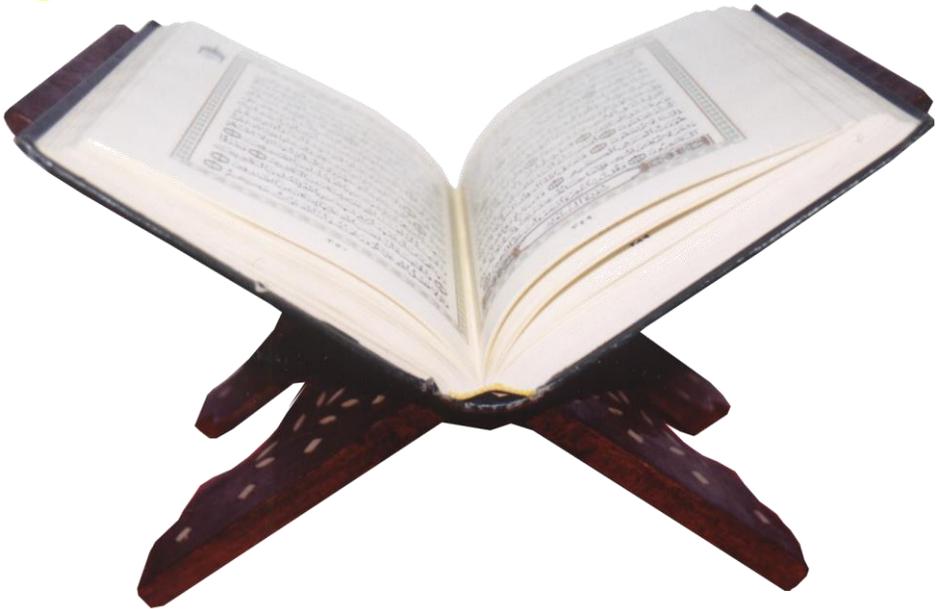
4- Dr. Tamer Mostafa Mohamed Hafez

Assist. Prof. of Radiopharmaceutical Chemistry, Hot
Labs Center, Atomic Energy Authority



بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ
وَمَلِكِكُمْ لَكُمْ وَعَلَمِ
وَكُنْ أَنْ فَضَّلَ اللَّهُ عَلَيْكَ عَظِيمًا

سورة النساء / آية 113



Dedication

**This thesis is dedicated to my father, my mother, my husband,
my daughter, my brother and my sisters**

Acknowledgments

My first and most important acknowledgement goes to **Allah** for enlightening my way and strengthening my will to produce this work, asking **Allah** to increase **His** Grace and Generosity.

If one were to consider the significant milestones in their own lives, it would become necessary to also consider those who have made these milestones possible. Who does not thank people does not thank God. So here, I will do my best to acknowledge the people who have made this thesis a reality.

I would like to express my deep gratitude and appreciation to **Prof. Dr. Sami Abu-Bakr El-Bayoumy**, Professor of Inorganic Radiochemistry, Chemistry, Hot Labs. Center, Atomic Energy Authority, for his direct supervision, keen interest, valuable guidance and continuous help throughout the completion of the thesis.

I would like to express my great thanks to **Prof. Dr. Wagiha Hamed Mahmoud**, Prof. of Analytical Chemistry, Chemistry Department, Faculty of Science, Ain Shams University, for her valuable scientific supervision, kind and careful revision of this work. She has always been and will represent to me supervisor, whom I respect and I am honored to be now one of her students.

I would like to express my sincere appreciation to **Prof. Dr. Khalid Mohamed Saleh El-Azony**, Prof. of Inorganic Radiochemistry, Hot Labs. Center, Atomic Energy Authority, for planning of the experimental work, giving me all the scientific and moral support, cooperation, encouragement and kind help in the practical part of this thesis.

I would like to offer my deepest gratitude and appreciation to **Assist. Prof. Tamer Mostafa Mohamed Hafez**, Assist. Prof. of

Radiopharmaceutical Chemistry, Hot Labs Cener, Atomic Energy Authority, for suggesting the point of the research, for his valuable supervision, instructions, advises and indispensable help during the course of this work.

I cannot find words to thank **Dr. Mohammed Ismaeal Mohammed Mohammed**, Lecturer of Inorganic Radiochemistry, Hot Labs. Center, Atomic Energy Authority, for his continuous advice and kind support during the course of the thesis.

I cannot find suitable words to thank my beloved family, **my father** and **my mother** I thank them for the values that they have instilled in me. From them, I have learned what it means to set goals and to work hard to achieve them. I would like to thank them for their kind encouragement and confidence.

I would like to express my love before thanks to my husband **Mohamed Fawzy Nawar** who was beside me along the way and share me the most difficult moments in my progress, and I hope that we will remain together throughout my life and will always be witness for his success and I will be beside him.

I cannot find words to thank my beloved **daughter; Malika, my brother; Ahmed** and **my sisters; Nada & Esraa**. I would like to thank them for their encouragement and support.

My final thanks devoted to all members of radioactive isotope and generators department, Atomic Energy Authority and chemistry department, Benha University for their nice cooperated interaction.

Alaa Farid El-Daoushy

2020

Table of contents

List of tables.....	I
List of figures.....	IV
Abbreviations.....	X
Aim of the work.....	XII
Abstract.....	XV

Chapter One: Introduction

1.1. General consideration.....	1
1.2. Radioisotopes.....	1
1.3. Production of radioisotopes.....	1
1.3.1. Cyclotron-produced radionuclides.....	2
1.3.1.1. Technical criteria for irradiation at cyclotrons using high beam currents.....	2
1.3.1.1.1. Irradiated material.....	4
1.3.1.1.2. Optimum conditions for production.....	4
1.3.1.1.3. Medical radionuclides.....	5
1.3.2. Reactor-produced radionuclides.....	7
1.3.2.1. Neutron capture reaction.....	7
1.3.2.2. Fission reaction.....	9
1.3.3. Radioisotopes generators.....	10
1.4. Separation of radioisotopes.....	11
1.4.1. Precipitation.....	11
1.4.2. Solvent extraction.....	11
1.4.3. Ion-exchange.....	13
1.4.4. Adsorption.....	14
1.5. Sealed radioactive sources (SRSs).....	15
1.6. Design and manufacture characteristics of SRSs.....	18

1.6.1. Geometry.....	19
1.6.2. Capsule material.....	19
1.6.2.1. Titanium.....	20
1.6.2.2. Aluminum and its Alloys.....	21
1.6.2.3. Stainless steel.....	21
1.6.2.4. Other materials.....	22
1.6.3. Sealing techniques.....	23
1.6.3.1. Material Deposition.....	23
1.6.3.2. Welding.....	24
1.6.3.3. Other sealing techniques.....	24
1.6.4. Physical and chemical characteristics of the radioactive material.....	25
1.6.5. Decay effects.....	26
1.6.6. Types of radiation.....	26
1.7. Applications of SRSs.....	26
1.7.1. Medical field.....	27
1.7.1.1. Brachytherapy.....	27
1.7.1.2. Characteristics for used Isotope.....	31
1.7.1.3. ¹²⁵ I Brachytherapy.....	31
1.7.1.4. ¹²⁵ I Brachytherapy source requirements.....	32
1.7.1.5. Preparation of ¹²⁵ I miniature source cores.....	33
1.7.2. Research field.....	35
1.7.2.1. Radiometric calibration.....	35
1.8. Nano technology.....	37
1.9. Classification of nanoparticles.....	40
1.9.1. Carbon based nanomaterials.....	41
1.9.2. Inorganic-based nanomaterials.....	41
1.9.2.1 Metallic nanoparticles.....	41

1.9.2.2. Metal based oxides.....	42
1.9.3. Organic-based nanomaterials.....	42
1.9.4. Composite-based nanomaterials.....	42
1.10. Synthesis of nanoparticles.....	43
1.10.1. Chemical synthesis of NPs.....	43
1.10.1.1. Sol–gel method.....	43
1.10.1.2. Hydrothermal synthesis.....	47
1.10.1.3. Chemical reduction.....	48
1.10.1.4. Coprecipitation.....	48
1.10.1.5. Solution combustion synthesis (SCS).....	49
1.10.1.6. Sol-gel combustion synthesis (SGC).....	49

Chapter Two: Experimental

2.1. Chemicals and Solvents.....	53
2.2. Equipment.....	53
2.2.1. Water thermostat shaker.....	53
2.2.2. pH-meter.....	53
2.2.3. Analytical balance.....	53
2.2.4. Hot plate stirrer.....	53
2.2.5. Centrifuge.....	55
2.2.6. Fourier transform infrared spectroscopy (FT-IR).....	55
2.2.7. X-ray diffraction (XRD).....	55
2.2.8. Thermal analysis (TGA & DTA).....	55
2.2.9. High resolution transmission electron microscope (HRTEM).....	55
2.2.10. Energy dispersive x-ray spectroscopy (EDX).....	55
2.2.11. Gamma-scintillation counter.....	55

2.2.12. (HPGe) γ -ray spectrometer.....	55
2.3. Irradiation facility.....	56
2.4. Radioactive isotopes.....	56
2.5. Preparation of silver nanoparticles.....	57
2.5.1. Preparation of silver metal nanoporous foam (Ag_m NPF).	57
2.5.2. Preparation of silver oxide nanoparticles (Ag_2O NPs).....	57
2.6.Characterization of both silver metal and silver oxide nanoparticles.....	58
2.6.1. Chemical stability.....	58
2.6.2. Fourier transform infrared spectroscopy (FT-IR).....	58
2.6.3. X-Ray diffraction (XRD).....	59
2.6.4. Thermal analysis (TGA & DTA).....	59
2.6.5.High resolution transmission electron microscope (HRTEM).....	59
2.6.6. Energy dispersive x-ray spectroscopy (EDX).....	59
2.7. Sorption studies using batch technique.....	59
2.7.1. Effect of pH.....	60
2.7.2. Effect of contact time.....	61
2.7.3. Effect of the initial concentration of the studied element..	61
2.7.4. Effect of reaction temperature.....	61
2.8. Sorption Models.....	62
2.8.1. Sorption Kinetics.....	62
2.8.2. Diffusion mechanism.....	62
2.8.3. Sorption isotherms.....	63
2.8.4. Thermodynamic parameters.....	63
2.9. Maximun sorption capacity.....	63
2.10. Sealed Sources.....	64
2.10.1. Sealed source core preparation of ^{134}Cs	64

2.10.2. Sealed source core preparation of ^{60}Co	65
2.10.3. Holder material and packing of radioactive material.....	65
2.10.4. Quality control.....	67
2.10.4.1. Leaching test.....	67
2.10.4.2. Leak test (immersion test).....	67
2.10.4.3. Wipe test (surface contamination testing).....	67
2.10.4.4. Impact test.....	67
2.10.4.5. Dispatching of the sealed source.....	68

Chapter Three: Results and Discussion

Part I: Preparation & Characterization

3.1. Preparation of silver metal NPF.....	69
3.2. Preparation of silver oxide NPs.....	71
3.3. Characterization of both silver metal NPF and silver oxide NPs	73
3.3.1. Chemical stability.....	73
3.3.2. Fourier transform infrared spectroscopy (FT-IR).....	74
3.3.3. X-ray diffraction (XRD).....	77
3.3.4. Thermal analysis (TGA & DTA).....	78
3.3.5. High resolution transmission electron microscope (HRTEM).....	83
3.3.6. Energy dispersive x-ray spectroscopy (EDX).....	86

Part II: $^{34}\text{Cs(I)}$ and $^{60}\text{Co(II)}$ Sorption Study & Sealed Source Preparation

3.2.1. Sorption Mechanism.....	92
3.2.2. Sorption Study.....	95
3.2.2.1. Effect of solution pH.....	95
3.2.2.1.a. Silver metal NPF.....	95
3.2.2.1.b. Silver oxide NPs.....	99

3.2.2.2. Effect of contact time.....	106
3.2.2.3. Effect of the initial concentration of the studied element.....	109
3.2.2.4. Effect of temperature.....	113
3.2.3. Sorption Models.....	116
3.2.3.1. Sorption Kinetics.....	116
3.2.3.1.1. Pseudo-first-order model.....	117
3.2.3.1.2. Pseudo-second-order model.....	117
3.2.3.1.3. Elovich model.....	118
3.2.3.2. Diffusion models.....	122
3.2.3.2.1. Film diffusion model.....	122
3.2.3.2.2. Intra particle diffusion model.....	122
3.2.3.2.3. Pore diffusion model.....	123
3.2.3.3. Sorption isotherms.....	132
3.2.3.3.1. Langmuir isotherm model.....	132
3.2.3.3.2. Freundlich isotherm model.....	133
3.2.3.3.3. Temkin isotherm model.....	134
3.2.3.4. Thermodynamic parameters.....	138
3.2.4. Maximum sorption capacity.....	142
3.2.5. Comparative study of sorption capacity of different sorbent materials.....	145
3.2.6. Sealed radioactive source.....	145
3.2.6.1. Radioactivity measurements.....	145
3.2.6.2. Preparation of the sealed radioactive source.....	150
3.2.6.3. Quality Control.....	153

Part III: I-131

3.3.1. Effect of solution pH.....	155
-----------------------------------	-----
