Radiology: A Bridge in Biophysics

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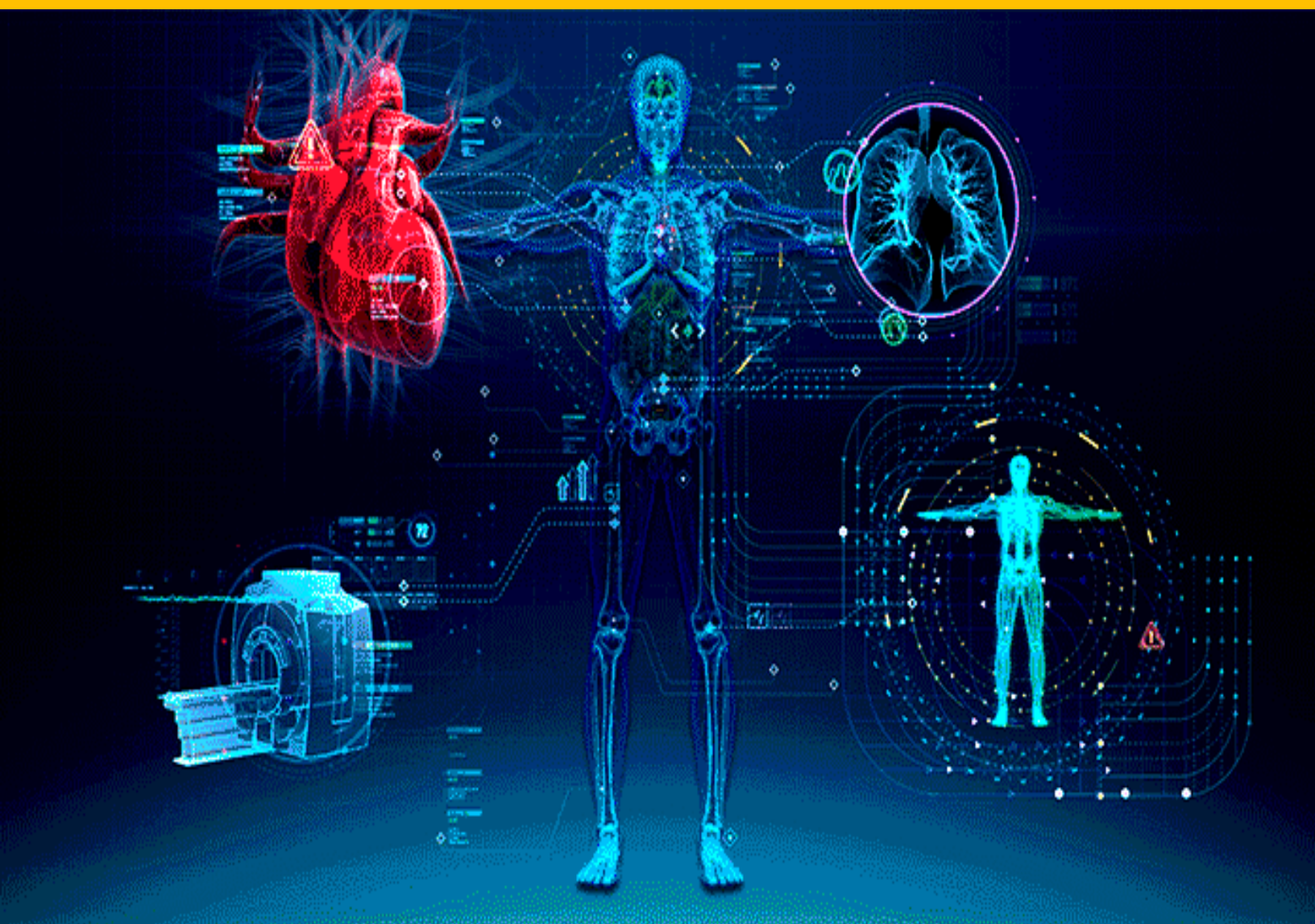
Pravina S. Ugile-Pawar
Madhav N Rode



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By:

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Sincere Dedicated
to my Daughter and Nephew
Adishree and Atharva

About The Authors

Dr. Prashant Somnath Kore received his M.Sc. and Ph.D. in Physics with specialization of Nuclear Physics from Dr. Department of Physics, Dr. Babasaheb Ambedkar Marathwada University, Aurangabad in 2017. He is currently working as Assistant Professor in Department of Physics in Mahatma Basweshwar College, Latur & teaching the Nuclear Physics, Statistical Mechanics, Electromagnetic Theory,Optics and Modern Physics subjects.Dr. Prashant has selected as Junior, Senior Research Fellow on Major Research Project funded by BRNS, BARC, Trombay, Mumbai. Dr. Prashant having 6years in Research and two years in teaching experience, his research interest are in Radiation Detection and instrumentation, Radiology, Nuclear and Particle Physics and having over 30 journals/conference papers/Technical Programs.

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Dr. Pravina S. Ugile-Pawar has complete her Ph.D in Nuclear Physics and she is now an Associate Professor in the Department of Physics, Dr. Babasaheb Ambedkar Marathwada University, Aurangabad (MS), India. Her research interests are gamma ray interaction studies, dosimetry, medical physics and nuclear medicine. She has completed two major research project. She has over 93 nos SCI / Scopus papers to her credit. Eight students have completed Ph.D and seven Ph.D students are currently working under her guidance.

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Dr. Madhav Namdev Rode is Associate Professor at Vaidyanath College of Arts, Science and Commerce, Parli-Vaijnath, Dist. Beed, with close to 20 years of experience in academics and research. He received M.Sc. and Ph.D. in Physics from Dr. Babasaheb Ambedkar Maratwada University, Aurangabad, Maharashtra State. He has also working as a Member, Board of Studies and Research guide in Physics, Dr. Babasaheb Ambedkar Maratwada University, Aurangabad, and his research is focused on Non-Linear optical crystals, Self frequency doubling crystals, NLO properties of Nano material's and optical biosensors, radiation effects and defects in materials, nuclear technology and radiation protection, low-z materials, polymer materials. Four research students working under his guidance and two students already awarded Ph.D. degree under his supervision. Two minor research projects sanctioned by UGC- New Delhi successfully completed. He has published more than 75 research papers in various National and International Journals of high repute and conferences.

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Preface

Nuclear and Particle physics, medical physics and Astrophysics are arguably the three major research frontiers of physics at the present time. Radiology is a branch of science concerned with an application of physics (Nuclear) to health (medical) physics which allows the precise study of radiation biology and phenomena Bridging the gap between nuclear and medical physics. Biomedical physics is a rapidly growing specialty concerned with the application of x-rays, gamma rays and ionizing radiation to diagnosis and treatment of human health disease. In contrast to other physics specialties, such as nuclear physics, solid-state physics, radiological physics and high-energy physics, studies of modern medical physics which attract a much broader base of professionals including graduate students, research students in medical physics, medical residents and technology students in radiation biology, radiation oncology and diagnostic imaging, biomedical engineering, radiation dosimetry, and educational programs. These professionals have several background of the knowledge of physics, chemistry biology and mathematics, but they all have a common incline to renovate their knowledge of the physics that underlies the use of ionizing radiation in medical field such as diagnosis and treatment of several disease. Health physics, radiological engineering are synonymous terms for that area of public health and environmental health engineering that deals with the safe use of ionizing and non ionizing radiation in order to inhibit harmful effects of the radiation to individuals, to population groups, and to the biosphere.

In this book, our primary focus of the aspect is the absorption and attenuation effect of gamma active isotopes with biomolecules and its applications. These phenomenons covers the knowledge of photon interactions with biological material and to develop understanding of various instruments used for measuring, monitoring and recording experimental phenomena.

The study of photon interactions with matter is crucial and the experimental data on the transmission and absorption of gamma rays in biological shielding and dosimetric materials assumed great significance by virtue of their diverse applications in the field of nuclear technology, space research and medical biology. The content is evenly balanced between the physical foundations of radiation measurements and their applications to nuclear and medical technology including methods and tools. An undergraduate knowledge of physics is assumed, and relevant basic material is summarized at the beginning of each chapter. This text is aimed at students and researchers in both medical and physical sciences. Radiology links the two disciplines; one as the point of radiation application and the other as the biomaterial. The emphasis is on the introductory theoretical basics, leading up to a practical framework for applications of nuclear technology. The increasing actively use of gamma-active isotopes in various fields viz. reactors physics, nuclear power plants, nuclear engineering and space technology also in medical fields motivated nuclear engineers, physicist, radiologists and

radiation physicists to focus on the radiation interaction with different kinds of compounds, materials for several purposes i.e. shielding, X-ray imaging and radiotherapy.

The aim of this book is to inculcate, motivate and inspire readers to take up the study and observations of theoretical and experimental content and enjoy its beauty and glory. The purpose of this book is to present some of these fascinating phenomena, in their full glory to the readers through ample number of illustrations, sketches and photographs. This book is mainly addressed to those who are starting to study the nuclear physics, radiation terminology, biomaterials and want to pursue an advance course in radiology. Each chapter is preceded by a brief introductory essential knowledge of the subject. The author has been very careful in selecting the topics, laying their sequence and the style of presentation so that student may not be afraid of learning new concepts. Realizing the mental state of undergraduate students, every attempt has been made to present the material in most elementary and digestible form. This comprehensive textbook is the outcome of wide teaching and research experience of the authors. It is designed for UG, PG and researchers of physical sciences students. The book discusses some of the important topics that have had a tremendous impact in the growth of science and technology. Each chapter ends with a summary of important results derived in the chapter.

We will be grateful for useful suggestions

Prashant Somnath Kore
Pravina S. Ugile-Pawar
Madhav Namdev Rode

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The journey of writing this book is Knowledgeable, inspirational and enjoyable experience. when I found myself at the top enjoying the beautiful scenery. I realized that it was, in fact, teamwork that got me there. Though it will not be enough to express my gratitude in words to all those people who helped me, I would still like to give my many, many thanks to all these people. So, firstly I express my sincere Gratitude to my mentor **Dr. Pravina P. Pawar**, Associate professor, Department of Physics, Dr. Babasaheb Ambedkar Marathwada University, Aurangabad. for her enthusiasm, and Kind nature. She gave me a valuable support, keynote guidelines.

The present investigation has been benefited from many valuable feedbacks, creative guidance, in dispensable supports and deep encouragement from my mentor;

Prof. Govind K. Bichile, Prof K. M. Jadhav, former HOD, dept. of physics, Dr. Babasaheb Ambedkar Marathwada University, Aurangabad and **Dr. D. V. Meshram,** Asst. Prof, HOD, dept. of physics, Vaidyanath College, Parli Vaijanath.

I express my deepest gratitude and indebted to (one man army) mentor **Dr. Madhav N. Rode,** Assosciate Prof. Dept of Physics, Vaidyanath College, Parli Vaijanath without whose generous help this book would neither have been started nor completed. So distinctive thanks for stimulating me and for kind support. I would like to express deep sense support of Respective organization and financial support through the Major Research Project from **BRNS, BARC**, Trombay, Mumbai, given to me. I would like to express my conspicuous thanks to **Dr. S. M. Dongarge,** Associate Prof., M.B. College, Latur, whose liberal support and help**.** Special thanks to close friends who providing me great source of strength, support and happiness; Rahul Dhage, Rahul Bandgar,

My special love, inspiration, encouragement, huge positive source of energy obtained to my parents **Sao. Usha Somnath Kore, Shri. Somnath Mukund Kore,** My conspicuous thanks to my innocent wife **Mrs. Anuradha P. Kore** for his continuous inspiration, forbearance and ethical recourse to me. I owe my every achievement to my family.

I have tried to eliminate the printing errors as far as possible, but it is likely there may be some missed out ones. I would greatly appreciate the kindness and interest of any readers who would point out such omissions, which can then be corrected in the subsequent print runs and editions.

Finally, I express my sincere thanks to the publisher **Dr. Akhter Alam and Empyreal Publication House** for their unfailing cooperation and for the meticulous processing of the manuscript in smoothing the process of publishing.

Prashant Somnath Kore

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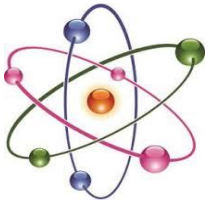
CHAPTER 1



Bio-Medical Physics, Decay, Gamma Radiations and Effects

1] Introduction

Bio-Medical physics is a branch of science concerned with an application of physics to bio-medicine. The area of medical physics, biological and biomedical engineering are broad, multidisciplinary and very much necessary to human health and society. Medical physics, biophysics is a rapidly growing specialty of physics, concerned with the application but not exclusively, in the application of x-rays, gamma rays and ionizing radiation to diagnosis and treatment of human health disease.

In contrast to other physics specialties, such as nuclear physics, solid-state physics, radiological physics and high-energy physics, studies of modern medical physics which attract a much broader base of professionals including graduate students, research students in medical physics., medical residents and technology students in radiation biology, radiation oncology and diagnostic imaging, biomedical engineering, radiation dosimetry, and educational programs. These professionals have several background of the knowledge of physics, chemistry biology and mathematics, but they all have a common incline to renovate their knowledge of the physics that underlies the use of ionizing radiation in medical field such as diagnosis and treatment of several disease.

Health physics, radiological health, or radiological engineering are synonymous terms for that area of public health and environmental health engineering that deals with the safe use of ionizing and non ionizing radiation in order to inhibit harmful effects of the radiation to individuals, to population groups, and to the biosphere. The health physicist is accountable for safety aspects in the design of processes, equipments, and facilities utilizing radiation sources and for the safe disposal of radioactive waste so that radiation exposure to personnel will be minimized and will at all times be within acceptable limits. He or she must keep personnel and the environment under constant observation in order to detection that these designs are virtually effective. If control measures are found to be ineffective or if they break down, the health physicist must be able to evaluate the degree of hazard and make recommendations regarding remedial action. Public policy radiation safety is based on political, economic, moral, and ethical considerations as well as on scientific and engineering principles. The scientific and engineering aspects of health physics are concerned mainly with, the physical measurements of varies types of radiation and radioactive materials, the emplacement of quantitative relationships between radiation exposure and biological damage, the agitation of radioactivity through the environment, and the design of radiologically safe equipment, processes, and environments. Clearly, health physics is a professional field that cuts across the basic physical, life, chemical, environmental and earth sciences as well as such applied areas as toxicology, industrial hygiene, medicine, public health, and engineering. The professional health physicist, therefore, in order to perform effectively, must have an appreciation of the complicated interrelationships between humans and the physical, chemical, biological, and social components of the environment[1].

1.1 Sub-specialties in the field of medical and health physics

There are many sub-specialties in the field of medical and health physics such as, Biological effects/radiation biology, Nuclear Medicine, Ionizing radiation instrumentation and measurement, Internal and external dosimetry, Radioactive waste management, Radioactive fouling, decontamination and decommissioning, Radio engineering, radiation monitoring and radon evaluation, Operational radiation protection, health physics, Accelerator physics, Radiological emergency response (e.g., Nuclear Emergency Support Team), Industrial and medical uses of radioactive material, Public information and communication involving radioactive materials, Radiation standards, Radiation risk analysis, Nuclear power, Radioactive materials and homeland security, Radiation protection, Nanotechnology. Among these sub-specialties some are mainly related to this work including Biological effects/radiation biology, Nuclear Medicine, Radiation technology, Ionizing radiation instrumentation and measurement, Internal dosimetry and external dosimetry, Radiological engineering (shielding, buildup factor, KERMA, etc.), Operational radiation protection/health physics, Industrial and medical uses of radioactive sources/material.

1.1.1 Radiation biology

The biological effects of ionizing radiation were discovered soon after the output of acute radiation sources in the form of X-ray machines and radioactive elements about a century ago. Radio-biology is defined as the study of the effects of ionizing radiation on biological systems. Understanding the effects is an important to the safe and effective use of radiation for diagnostic and therapeutic purposes. The human **sub aerial** is

configured in an increasingly complex manner from atoms to molecules, cells, tissues, organs, vein and systems. Interaction of x-ray and gamma ray with human tissue occurs at the atomic level through excitation and, more commonly, ionization (Fig.1.1)[2]. When an atom is ionized, its chemical binding properties are changed. If the atom is part of a large molecule, ionization may result in breakage of the molecule or a change in location of the atom within the molecule[3]. These transformation may impair function and result in cell death. However, cells and tissues can repair, and recover. Early effects of radiation are injuries that occur within minutes and days while late effects are those injuries that occur within days, years and decades after exposure.

Radiation acts on biologic systems directly and indirectly through the processes of ionization and free radical production. An indirect effect occurs as a result of the radiolysis of water and the production of free radicals while direct effect take place when the ionizing radiation interacts directly with a particularly radiosensitive molecule like deoxyribonucleic acid, DNA[4].

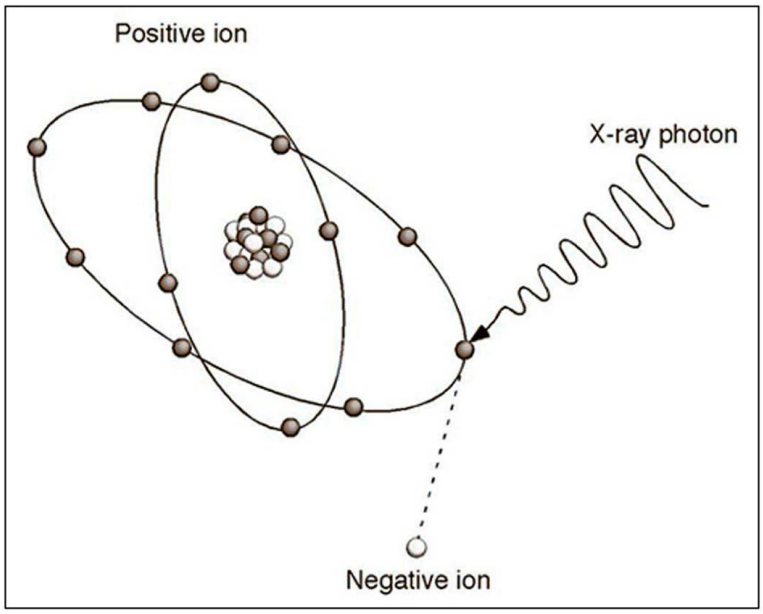


Figure-1.1: Ionization Interaction of x-radiation with human tissue occurs at the atomic level through excitation.

Also the radiation was found to stop the cell portion and could therefore to stop cancer growth therapeutically. On the contrary, the radiation applied locally was found to cause injury, which were difficult to heal, and to stimulating the cancer. Many of serious accidents occurred as a result of the use of radiation before an sufficient knowledge and proper understanding of its biological effects led to formulization of rules for protection of peoples.

The large radiation effect of whole body doses is biological sickness and early death, while large organ doses lead to local cell destruction and, possibly, organ death. On the other hand the effects at lower doses are cell changes (decreased surviving fraction, decreased rate of division, etc), which can be observed by microscope soon after irradiation. The prompting of the cancer may take years to execute and genetic changes may not be discovered until after several descent.

Many groups are actively busy in research (radiologists) on the biological effects of ionizing and non ionizing radiation for diagnosis and treatment of tumors; health physicists have the accountability of controlling the use of irradiation equipment and conservancy people from unwanted exposure to radiation; in co-partnership with oncologists (tumor researchers) and geneticists, radiobiologists observancy research to explain the effects of radiation on the cellular as well as molecular level, radio chemists are devoted in the interaction between radiation and the DNA molecule.

1.1.2 Nuclear Medicine

The diversity of technologies and procedures that includes nuclear medicine are now a routine and important part of diagnosing cancers, cardio disease, and certain neurological disorders, as well as treating some cancers. Nuclear medicine, which uses radioactive chemical elements called radio nuclides to treat diseases has grown tremendously as a result of research investments from many years. It now plays an vital role in medical specialties from cardiology to psychiatry. Millions of nuclear medicine procedures are carried out each year in the United States alone. Nuclear medicines keep a variety of imaging devices and therapeutics that use radio nuclides. Nuclear imaging devices, such as PET and SPECT scans, work by tracking radioactive chemicals that are ingested, respired, or injected into the body, where they deposit in the organ or tissue of interest and demonstration biochemical changes, such type of imaging devices visiable physicians to diagnose diseases including cancer, cardio diseases, and neurological disorders in their primary stages. These techniques permit the doctors to obtain medical information that would otherwise require more expensive and invasive procedures like surgery or biopsy. Nuclear imaging devices are also important for conducting research on the biology of human diseases and for developing and testing new treatment approaches. Highly targeted radio nuclides can also be used to deliver lethal doses of radiation to tumor cells. This approach has enabled physicians to treat thyroid cancer and lymphoma, and could become an important tool in the armory to fight other diseases. Although nuclear medicine has already made huge contributions to biomedical research and disease management, its obligation is only beginning to be realized in such areas as drug development, defensive health care, and personalized medicine. However, aging facilities and equipment, a shortage of educated nuclear medicine scientists, and loss of incorporated research support are risky for the advancement of the field. At the exhort of the Department of Energy and the National Institutes of Health, the National Research Council assembled a committee to criticism the current state of the science in nuclear medicine, identify future opportunities in nuclear medicine research, and recommend ways to reduce impediments to advancing the field.

Figure-1.2: It shows the clinical uses with advanced instrument.

1.1.3 Radiation Technology

Radiation technology is one of the expanding research area and well established over all the world. It is contributing to the industrial development, research and development etc., some well established applications like sterilization, and polymers and semiconductors modification are in common use. This is especially true for health care products in industrial sector area like the USA and Canada, where it is estimated that more than half of these products is currently sterilized using ionizing radiation. With continuous increase in the use

of radiation for industrial research and development sector and medical needs, the manufacturers and suppliers are responding by more improving and modifying the existing types of irradiators as well as designing new types. Such a proliferation of designs is a boon for the potential facility operator, but it also places a responsibility on him to meticulously compare various available irradiators and make the best selection for his needs. Correct selection affects not only the comfort of operation but also yields higher capacity, and thus improved economy [5].

1.2 Biomolecules

There are various molecules gives the contribution in biochemical reactions of living body. These molecules are termed as biomolecules. These molecules interact with each other under optimum conditions and form different products. Hence, biomolecules are complex chemical substances which form the basis of life. Biomolecules is defined as "A molecules which are involved in the maintenance, ability to reproduce and metabolic processes of all living organisms called biomolecules."

Biomolecules are an organic compounds which are building blocks of human body, i.e., they build up the living system and responsible for their growth and other things. It is present in living organisms, including proteins, carbohydrates, lipids, and nucleic acids, as well as small molecules such as primary metabolites, secondary metabolites, and natural products. A more general name for this class of material is biological materials. Biology and its subparts of biochemistry and molecular biology study biomolecules and their reactions. Almost biomolecules are organic compounds, and contains carbon, hydrogen, oxygen, and nitrogen and make up 96% of the human body's mass. The sequence relation of biomolecules to living organism is as follows[6];

Biomolecules → Organelles → Cells → Tissues → Organs → Living organism

There are four major classes of biomolecules:

- Carbohydrates
- Lipids
- Proteins
- Nucleic acids

1) Carbohydrates

The carbohydrates are the good source of an energy. These are long chains of sugars. Carbohydrates are vital for the growth of body tissues. Those in the form of sugar and starch represent a major part of the total caloric intake for humans and for animal life as well as for many microorganisms. The carbohydrates are the most abundant class of biological molecules found in all living organisms. It composed of sugars are the major form of energy and play a vital role in the structure of all living cells.

Examples: Glucose, Fructose, Sucrose, Maltose, Cellulose, Starch...etc.

2) Lipids

The lipids are natural long hydrocarbon chains and holds the large amount of an energy and having energy storage molecules. Lipids are normally esters of fatty acids and are building blocks of biological membranes. Most of the lipids have a polar head and non polar tail. Lipids are present in biological membranes are of three classes based on the type of hydrophilic head present:

1. The glycolipids are lipids whose head contains oligosaccharides having 1-15 saccharide residues.
2. The phospholipids contain a positively charged head which are linked to the negatively charged phosphate groups.
3. The sterols whose head contain a steroid ring. Example: Steroid.

Example of lipids: Oils, Fats, Phospholipids, Glycolipids, etc.

3) Proteins

The proteins are heteropolymers of a sting of amino acids and are large biological molecules, or macromolecules consisting of one or more than one long chains of amino acid relics. Amino acids are attached together by the peptide bond which is formed between the carboxyl group and an amino group of successive amino acids. The proteins are formed from 20 different amino acids, depending on the number of amino acids and the sequence of amino acids. Proteins execution of many functions in living organisms such as catalyzing metabolic reactions, replicating DNA, and transporting molecules from one place to another. Proteins are important parts of organisms, essential in cell signaling, immune responses, and the cell cycle and participate in virtually every process within cells. Proteins also have structural or mechanical functions, such asactin and myosin in muscle and the proteins in the cytoskeleton, which form a system of scaffolding that maintains cell shape.

4) Nucleic Acids

The nucleic acids are organic compounds having heterocyclic rings. The nucleic acids (DNA and RNA) are the molecular fund for genetic information and are jointly designated to as the 'molecules of heredity'. The structure of every protein, and ultimately of every cell constituent, is a product of information programmed into the nucleotide series of a cell's nucleic acids.

The nucleic acids are made up of polymer of nucleotides. Nucleotide consists of the nitrogenous base, a pentose sugar and a phosphate group. The nitrogenous bases are an adenine, guanine, thyamine, cytosine and an uracil.

Summary

- ✓ The carbohydrates provide source of fuel and energy to the body, it aids in proper functioning of brain, heart and nervous system, digestive and an immune system. The deficiency of carbohydrates in the diet causes fatigue, poor mental function.
- ✓ Each protein in the body has some specific functions, some are provide structural support which help in body movement, and also defense against germs and infections. It can be antibodies, hormonal, an enzymes and contractile proteins.
- ✓ The primary purpose of the lipids is energy storage into the body. The structural membranes are composed of lipids which form a barrier and controls flow of material in and out of the cell. Lipid hormones, like sterols, help in mediating communication between the cells.
- ✓ The nucleic acids are the DNA and RNA, they carry genetic information in the cell. They also help in synthesis of proteins, through the process of translation and transcription.

1.2.1 Functions of Biomolecules

Although there is vast multeity of living organisms. The chemical compositon and metabolic reactions of the organisms appear to be identical. The composition of living tissues and non-living matter also appear to be similar in qualitative analysis. Closer analysis demonstration that the relative plenty of carbon, hydrogen and oxygen is higher in living system.

All forms of life are composed of biomolecules only. The bio molecules are an organic molecules especially macromolecules like carbohydrates, proteins in living organisms. All living forms bacteria, algae, plant and animals are made of a similar macromolecules that are the responsible for the life. All the carbon compounds we get from living tissues can be called biomolecules.

1.3 Saturated Fatty Acids

In this work we are used some saturated fatty acids. These acids have no double bonds. Thus, saturated fatty acids are saturated with hydrogen (since double bonds reduce the number of hydrogen's on each carbon). Because it have single bonds, each carbon atom within the chain has 2 hydrogen atoms.

1.4 What Are Lipids?

Lipids are naturally occurring hydrophobic molecules. They are heterogeneous group of compounds with respect to fatty acids. The lipids are a large and a group of naturally occurring an organic compound which are soluble in non polar organic solvents like an ether, chloroform, an acetone, benzene, and generally

insoluble in water. There is great structural variety between the lipids. Lipids are one of the very essential group of compounds that are involved in the life of an organism and divided in to sub groups which depending on their functional characteristics. They are Fatty acids, Fats and oils (saturated or unsaturated), soaps and detergents, an eicosonoids, waxes, terpenes, phospholipids, steroids, lipid soluble vitamins and bio synthetic pathways. All the lipids have a large number of carbon hydrogen bonds which will make them highly energy rich.

1.4.1 Structure of Lipids

All lipids has a different structure but they all have a large number of C-H bonds. The length of the chain is normally linear is less than the chain length of the proteins. In the other words the molecular mass of lipids is in between an amino acids and the proteins. Fatty acids are straight chains with carbon chains having 12-20 carbon atoms. They have a terminal carboxylic group and may be saturated or unsaturated.

1.4.2 Function of Lipids

Lipids perform several biological functions

- lipids are a insoluble molecular organic compound included of hydrogen and carbon. As far as their aim in the human body goes, lipids are of crucial essential for both energy storage and cell membrane evolution.
- Lipids are storage compounds, triglycerides work as reserve energy of the body.
- Lipids are essential component of cell membranes structure in eukaryotic cells.
- Lipids regularize membrane permeability.
- They work as origin for fat soluble vitamins A, D, E, K.
- They play a role an electrical insulator to the nerve fibers, where the myelin sheath contains lipids.
- Lipids are components of some enzyme systems mode.
- Some lipids like prostaglandins and steroid hormones play a role as cellular metabolic regulators.
- lipids are small molecules and are insoluble in water, they act as signaling molecules.
- Layers of fat in the subcutaneous layer supply insulation and protection from cold. Body temperature maintenance is done by brown fat.
- Polyunsaturated phospholipids are essential ingredient of phospholipids, they gives fluidity and flexibility to the cell membranes.
- Lipoproteins that are complexes of lipids and proteins which occur in blood as plasma lipoprotein, they are enable transport of lipids in aqueous environment, and their transport throughout the body.
- Cholesterol balenced fluidity of membranes by interacting with lipid complexes.
- Cholesterol is the pioneer of bile acids, Vitamin D and steroids.
- Essential fatty acids like linoleic and linolenic acids are pioneer of many different types of ecosanoids including prostaglandins, thromboxanes. These play a essential role in pain, fever, inflammation and blood clotting.
- Fats in the body, which helps to cushion to an organs from shock and work as energy storage. In the recent studies show that the lipids helps in sending important signals to the other metabolic activities sensing the deficiencies. The metabolic activities like calcium mobilization, growth, reproduction, and controls like blood pressure, etc. are monitored by the lipid signaling.

1.4.3 Types of Lipids

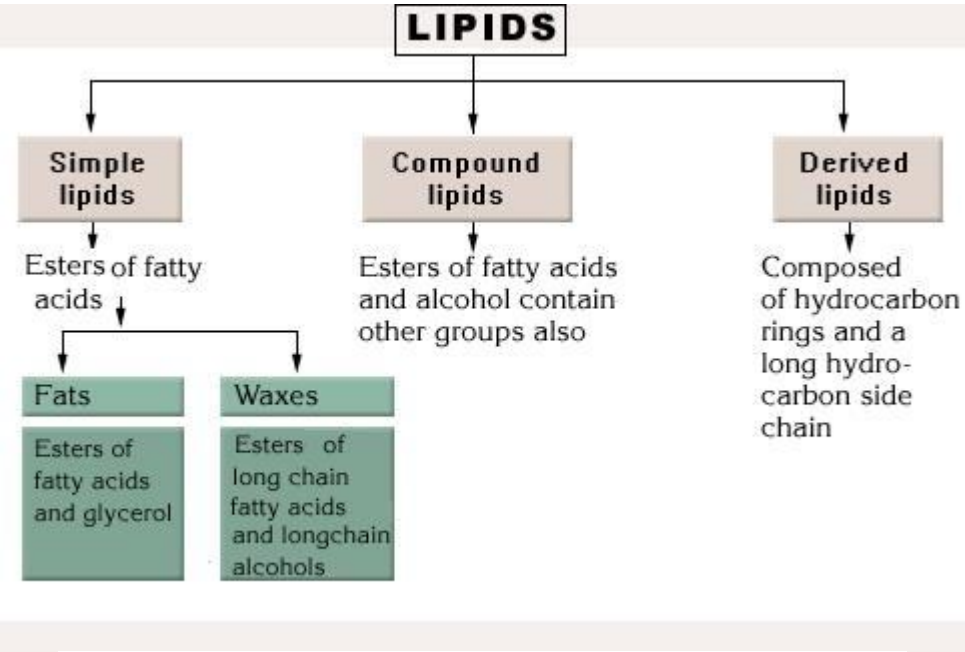


Figure-1.3: Classification of lipids based on their chemical composition.

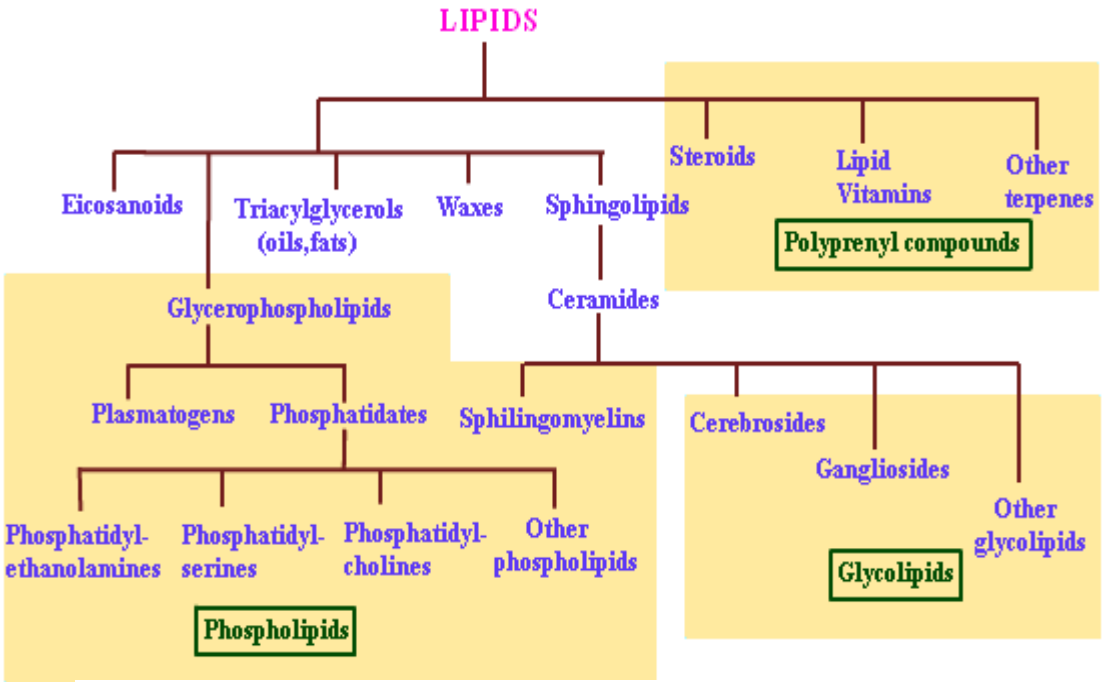


Figure-1.4: Lipids are a diverse group of naturally occurring organic compounds.

1.4.3.1 Sphingolipids

- These lipids are quite different form first two lipids and more complex compare to them.
- They composed of a sphingoid base backbone which is synthesized from serine; an amino acid and a fatty acids long chain.
- This further converted into glycosphingolipids, ceramides, phosphosphingolipids and other compounds.
- Some common examples of sphingolipids are ceramides; sphingomvelins (a phosphosphingolipids) are found in mammals.

1.4.3.2 Polyketides

- ❖ These lipids are synthesized by the polymerization method of acetyl and propionyl subunit in the presence of enzymes which share mechanistic feature with the fatty acid synthesis.
- ❖ Generally these molecules are rotational in nature whose backbones are then further improved by hydroxylation, methylation, glycosylation, and oxidation.
- ❖ Polyketides are used for as antimicrobial, anticancer agents and antiparacitic.
- ❖ Instance of polyketides are avermectins, tetracyclines, erythromycins and antitumor epothilones.

1.5 Characteristics of lipids

- Lipids are relatively insoluble in water.
- They are soluble in non-polar solvents, such as ether, chloroform, and methanol.
- Lipids have high energy content and are metabolized to release calories.
- Lipids also work as electrical insulators, they insulate nerve axons.
- Fats contains saturated fatty acids, they are solid at room temperature. Example, animal fats.
- Plants fats are unsaturated and are liquid at room temperatures.
- Pure fats are colorless, they have extremely bland taste.
- The fats are freely soluble in organic solvents like ether, acetone and benzene.
- The melting point of fats depends on the length of the chain of the constituent fatty acid of the lipid molecule produces geometric isomerism.
- Fats have insulating capacity; they are poor conductors of heat.

1.6 Nuclear Radiation

In the examination of radioactive materials there are three types of radiation were identified and namely, alpha, beta and gamma radiation. It was subsequently explore that alpha radiation consisted of fast-moving Helium atoms stripped of their electrons, and that beta radiation consisted of energetic electrons. The gamma rays were found to be packets of electromagnetic radiation also recommended as photons and having unit is an electron volt (eV), which is equal to the kinetic energy earned by an electron accelerated through an electric potential of 1 volt. The α and β radiation consist of energetic charged particles, their interaction with matter is primarily Columbic in nature. This leads to atomic excitation or ionization; that is, the interactions are with an electrons of the medium. The α and β particles hurriedly lose energy as they shift it to electrons in their passage through the medium. Their ranges of penetration are rather finite and in most materials are a function of the material properties and the energy of the particle. Radiation is energy that travels in waves or flow of particles. It comprise visible light, ultraviolet light, radio waves and other forms, including particles. Every type of radiation has different properties. Non-ionizing radiation can shake or move molecules. Ionizing radiation can break molecular bonds, causing unpredictable chemical reactions. Ionizing radiation comprise not only energy waves but also particles as well. Human beings cannot see, feel, taste, smell or hear ionizing radiation. Unavoidable exposure to ionizing radiation comes from cosmic rays and some natural material.

There are several types of radiation around us. When people hear the word radiation, they usually think of atomic energy, nuclear power and radioactivity, but radiation has different forms. Sound and visible light are intimate forms of radiation; other types include ultraviolet radiation, infrared radiation, and radio and television signals. Figure 1.5 shows an overview of The electromagnetic spectrum.

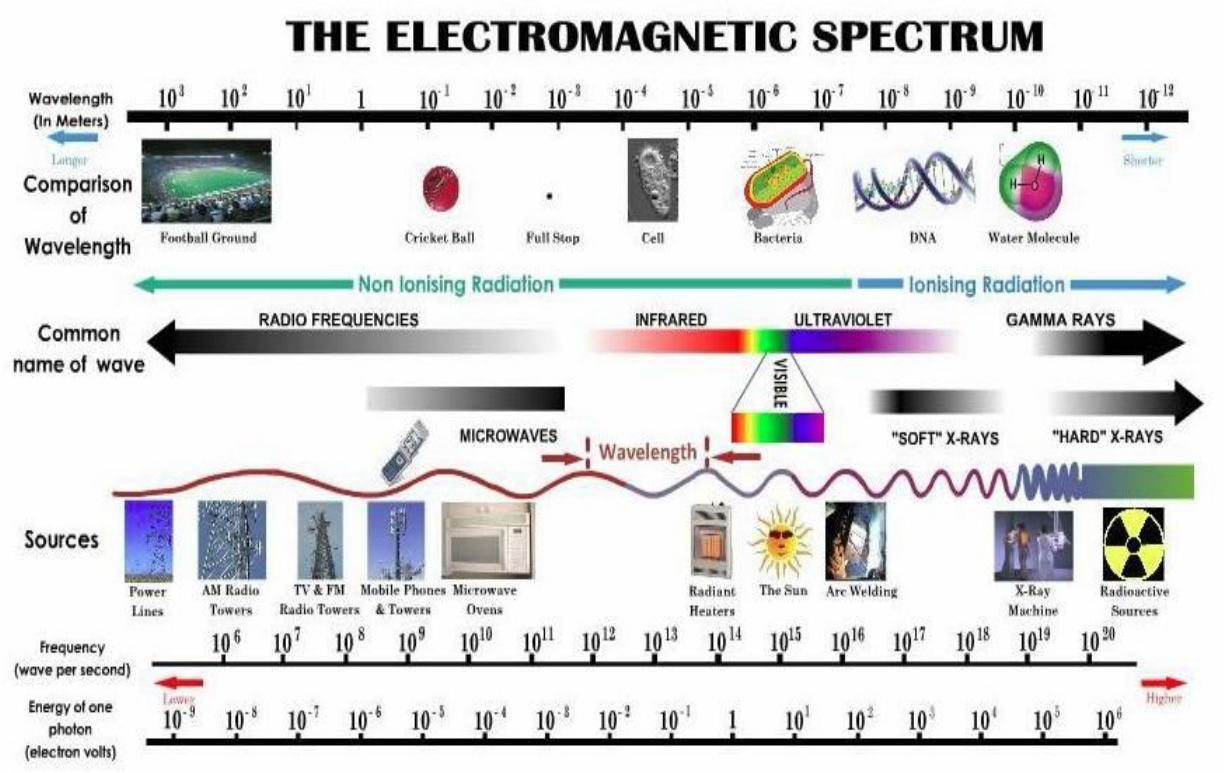


Figure-1.5: The electromagnetic spectrum.

1.6.1 Types of Radiation

Many people are already familiar with different kinds of electromagnetic radiation/light. Scientists categorize this type of radiation based on its wavelength and frequency. Some kinds of electromagnetic radiation are: Ionizing radiation comes from radioactive materials and x-ray machines and non-ionizing radiation (generally electromagnetic radiation) comes from other sources. Ionizing radiation carries more than 10eV, which is sufficient to ionize atoms or molecules, and break chemical bonds. This is essential for its harmfulness to living organisms. Non ionizing radiation does not cause microscopic damage, but some types can cause chemical changes or make things hotter.

Radio waves: Radio waves are kind of electromagnetic radiation with the maximum wavelength. And are usefull to send and receive communications.

Microwaves: Microwave is a special type of radio wave that is used by a microwave oven to warm up food. Microwaves are also used for communications, as weapons, and to move electrical power from one place to another.

Radar waves: This is also a kind of radio wave that is used to detect air planes in the sky and ships in the ocean. Radar is also used to see changes in weather.

Infrared waves: Most of the objects at room temperature let off infrared radiation. If humans cannot see it, special types of cameras can catch this kind of radiation. Usually, the hotter something is, the more infrared radiation it lets off, which means that these special cameras can see hot things, also behind walls.

Visible light: This is the most familiar radiation that we can see all around us as what most people call “light.”

Ultraviolet light: This is a kind of radiation with high energy than visible light that gives people a sunburn. Ultraviolet light is also useful for kill the bacteria and to make some kinds of invisible ink visible.

X-rays and Gamma rays: These are extremely strong rays that are usually used in medicine to photograph the interior of the body and treat cancer. However, in too large amounts, they are very harmful to regular life.

1.6.2 Radioisotopes

Isotopes that are not unstable and continuously emit radiations are called radioisotopes. It is an isotope of an element that undergoes spontaneous decay and emits radiation as it decays. During the decay process, it becomes less radioactive over time, finally goes to stable state.

Once an atom reaches a stable assortment, it no longer gives off radiation. For this reason, radioactive sources are spontaneously emit energy in the form of ionizing radiation as a result of the decay of an unstable atom become weaker with time. As more and more of the source's unstable atoms become stable, very less radiation is produced and the activity of the material decreases over time to zero. The time it takes for a radioisotope to decay to half of its initial activity is called the radiological half life, which is denoted by symbol t½. Every radioisotope has a unique half-life, and it can range from a fraction of a second to billions of years. For example, iodine^{131} has an eight-day half life, where as plutonium^{239} has a half-life of $24x10^3$ years. A radioisotope with a short half life is more radioactive than a radioisotope with a long half life, and then it will give off high radiation throughout the given time period. There are three major types of radioactive decay:

• **Alpha decay:** When an atom ejects a particle from the nucleus, which consists of two neutrons and two protons thereafter alpha decay occurs. After that the atomic number decreases by 2 and the mass decreases by 4. Examples of alpha emitters include radon, radium, uranium and thorium.

• **Beta decay:** In beta decay, a neutron is turned into a proton and an electron is emitted from the nucleus. The atomic number increases by one, but the mass number only decreases slightly. Examples of pure beta emitters are strontium^{90}, carbon^{14}, tritium and sulphur^{35}.

• **Gamma decay:** Gamma decay takes place; when the residual energy in the nucleus following alpha or beta decay or after neutron capture in a nuclear reactor. The residual energy is liberated as a photon of gamma radiation. Gamma decay usually does not affect the mass or atomic number of a radioisotope. Examples of gamma emitters comprise iodine^{131},cesium^{137}, cobalt^{60}, radium^{226} and technetium^{99m}. The number of nuclear disintegrations in a radioactive material per unit time is called the activity. The common mode of nuclear decay shown in figure 1.6. The activity is used as a measuring the amount of a radionuclide, and it's measured in Becquerel's (Bq). 1 Bq = 1 disintegration per second. If the original source of the radioactivity is known, it can be predicted how much long it will take to decay to a given activity. The decay is exponential and the isotope must go through many half life's to become non radioactive. Figure 1.7 describe the radioactive decay curve of carbon^{14}, which has a half-life of about $5,7x10^2$ years. Even after a radioisotope with a high activity has decay for several half life's, the level of remaining radioactivity is not necessarily safe. Measurements of a radioactive material's activity are always necessary to estimate potential radiation doses.

Decay Type	Radiation Emitted	Generic Equation	Model
Alpha decay	$^{4}_{2}\alpha$	$^{A}_{Z}X \longrightarrow {}^{A-4}_{Z-2}X' + {}^{4}_{2}\alpha$	Parent, Daughter, Alpha Particle
Beta decay	$^{0}_{-1}\beta$	$^{A}_{Z}X \longrightarrow {}^{A}_{Z+1}X' + {}^{0}_{-1}\beta$	Parent, Daughter, Beta Particle
Positron emission	$^{0}_{+1}\beta$	$^{A}_{Z}X \longrightarrow {}^{A}_{Z-1}X' + {}^{0}_{+1}\beta$	Parent, Daughter, Positron
Electron capture	X rays	$^{A}_{Z}X + {}^{0}_{-1}e \longrightarrow {}^{A}_{Z-1}X' + X\text{ ray}$	Parent, Electron, Daughter, X ray
Gamma emission	$^{0}_{0}\gamma$	$^{A}_{Z}X^{*} \xrightarrow{\text{Relaxation}} {}^{A}_{Z}X' + {}^{0}_{0}\gamma$	Parent (excited nuclear state), Daughter, Gamma ray
Spontaneous fission	Neutrons	$^{A+B+C}_{Z+Y}X \longrightarrow {}^{A}_{Z}X' + {}^{B}_{Y}X' + C\,{}^{1}_{0}n$	Parent (unstable), ENERGY, Neutrons, Daughters

Figure-1.6: Common Modes of Nuclear Decay

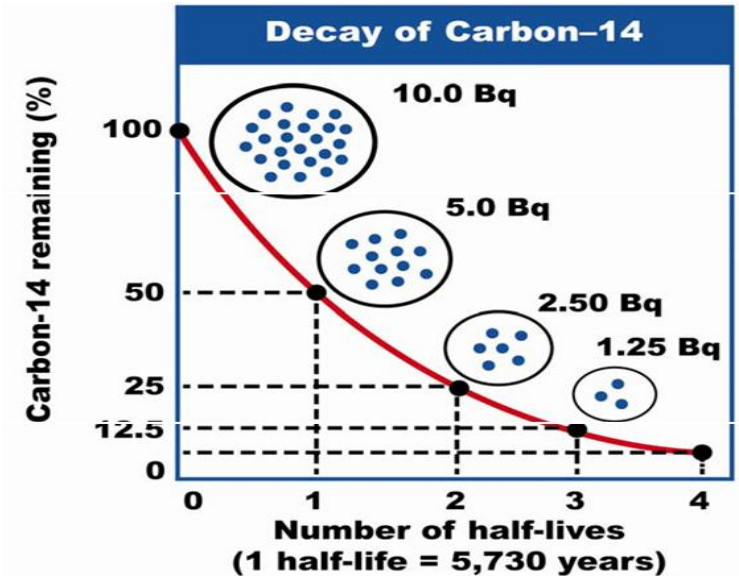


Figure-1.7: Adapted from University of Waikato.

1.6.3 Types and Sources of Radiation

Radiation is an energy in the form of waves of particles. There are two forms of radiation, ionizing and non ionizing. This will be discussed in sections 1.6.4 and 1.6.5, respectively.

1.6.4 Non-ionizing radiation

Non ionizing radiation has less energy than ionizing radiation; it does not possess sufficient energy to produce ions. Examples are visible light, infrared, radio waves, microwaves, and sunlight. Global positioning systems, FM and AM radio, baby monitors, cordless phones, cellular telephones, television stations etc. are use non-ionizing radiation. Other forms include the earth's magnetic field, as well as magnetic field exposure from proximity to transmission lines, household wiring and an electric appliance. These are defined as very low frequency waves and are not considered to pose a health risk**.**

1.6.5 Ionizing radiation

Ionizing radiation is an eligible for knocking electrons out of their orbits around atoms, upsetting the electron/proton maintain and giving the atom a positive charge. Electrically charged molecules and atoms are known as ions. Ionizing radiation includes the radiation that comes from both natural and artificial radioactive materials. There are many types of ionizing radiation:

1.6.6 Alpha radiation (α)

Alpha radiation consists of alpha particles that are made up of two protons and neutrons each and that carry a double positive charge. Due to their relatively large mass and charge, they have an extremely limited ability to penetrate matter. Alpha radiation can be stopped by a piece of paper or the dead outer layer of the skin (see fig.1.4a,b). Consequently, alpha radiation from nuclear substances outside the body is absent a radiation hazard. However, when alpha radiation emitting nuclear substances are taken into the body (for example, by breathing them in or ingesting them), the energy of the alpha radiation is totally absorbed into bodily tissues**.** For this reason, alpha radiation is only an internal hazard. An example of a nuclear substance that undergoes alpha decay is radon-222, which decays to polonium^{218}.

1.6.7 Beta radiation (β)

Beta radiation consists of charged particles that are ejected from an atom's nucleus and that are physically identical to electrons. Beta particles generally have a negative charge, are very small and can penetrate more deeply than alpha particles. However, most beta radiation can be stopped by small amounts of shielding, such as sheets of plastic, glass or metal. When the source of radiation is outside the body, beta radiation with sufficient energy can penetrate the body's dead outer layer of skin and deposit its energy within active skin cells. However, beta radiation is very limited in its ability to penetrate to deeper tissues and organs in the body. Beta-radiation-emitting nuclear substances can also be hazardous if taken into the body. An example of a nuclear substance that undergoes beta emission is tritium (hydrogen-3), which decays to helium-3.

1.6.8 Gamma (γ) and X-ray

Gamma radiation is electromagnetic radiation. There are two types of photon radiation of interest for the purpose of this document: gamma (γ) and X-ray. Gamma radiation consists of photons that originate from within the nucleus, and X-ray radiation consists of photons that originate from outside the nucleus, and are typically lower in energy than gamma radiation.

Photon radiation can penetrate very deeply and sometimes can only be reduced in intensity by materials that are quite dense, such as lead or steel. In general, photon radiation can travel much greater distances than alpha or beta radiation, and it can penetrate bodily tissues and organs when the radiation source is outside the body. Photon radiation can also be hazardous if photon-emitting nuclear substances are taken into the body. An instance of a nuclear substance that undergoes photon emission is cobalt^{60}, which decays to nickel^{60}.

1.6.9 Neutron radiation (n)

Apart from cosmic radiation, spontaneous fission is the only the natural source of neutrons (n). The common source of neutrons is the nuclear reactor, in which the splitting of an uranium or plutonium nucleus is accompanied by an emission of neutrons. The neutrons emitted from one fission event can poke the nucleus of an adjacent atom and cause other fission event, inducing a chain reaction. The production of the nuclear power is based upon this principle. All other sources of neutrons depends on reactions where a nucleus is bombarded with a certain kind of radiation (like photon radiation or radiation), and where as the resulting effect on the nucleus is the emission of a neutron. Neutrons are have ability to penetrate the tissues and an organs of the human body when the radiation source is external body. Neutrons can also be hazardous if neutron-emitting nuclear substances are credited within the body. Neutron radiation is best shielded or an absorbed by materials that contain hydrogen atoms, like paraffin wax and plastics. This is because of neutrons and hydrogen atoms have similar atomic weights and readily undergo collisions between each other. (Figure 1.4a,b) summarizes the types of radiation discussed in this document, from higher energy ionizing to lower-energy non-ionizing radiation. Each radiation source differs in its ability to penetrate the various materials, like paper, skin, lead and water.

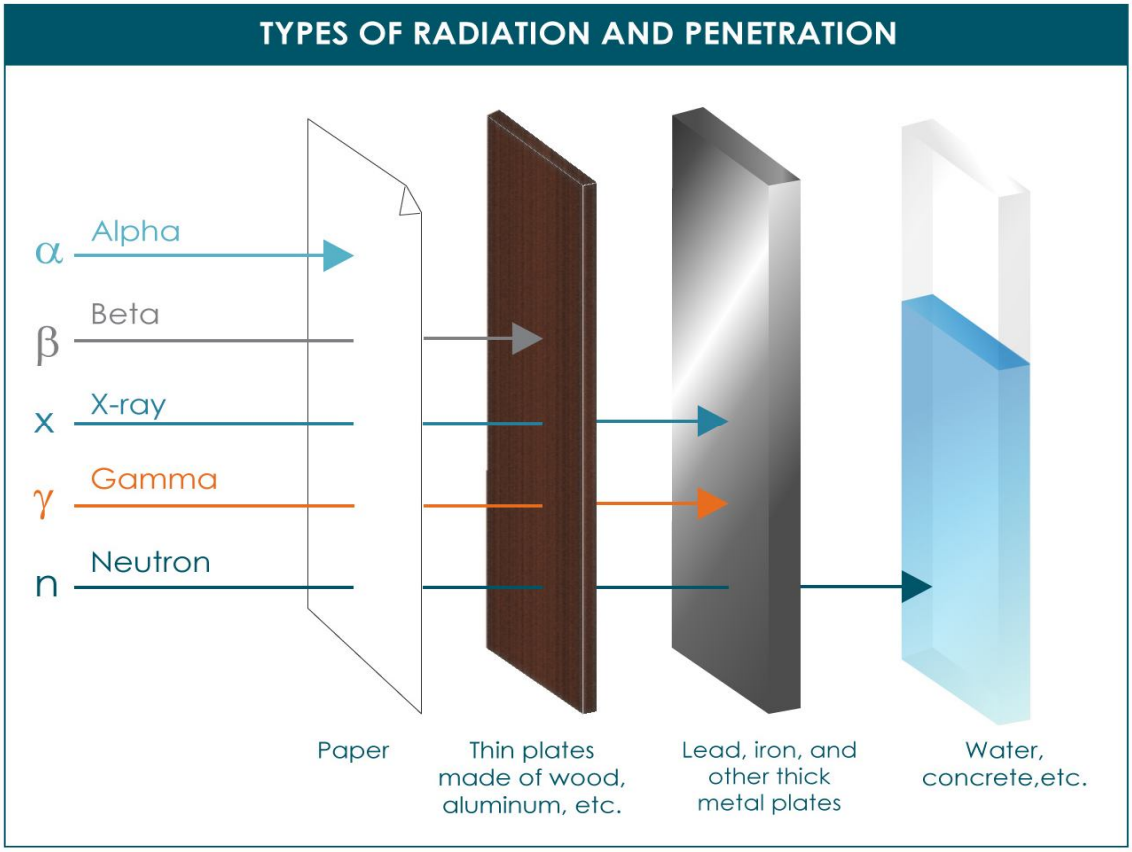


Figure-1.8a: Penetration of different types of ionizing radiation.

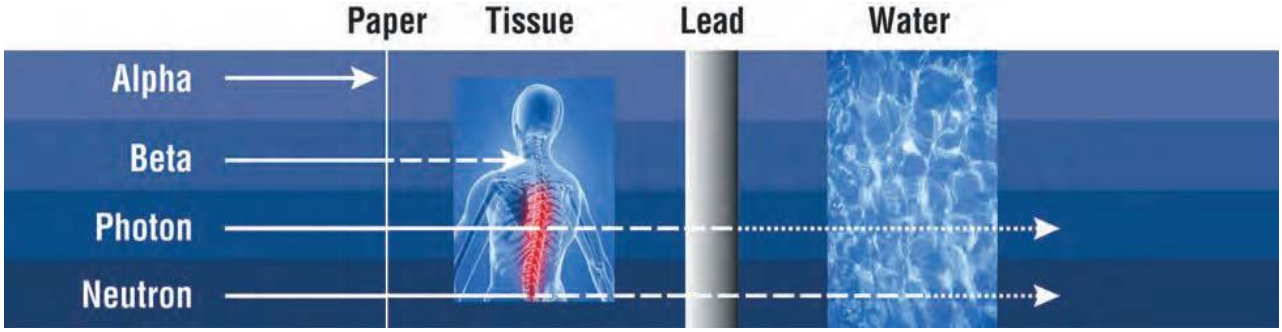


Figure-1.8b: Penetration abilities of different types of ionizing radiation.

1.7 Natural sources of ionizing radiation

Radiation has ever been present and is all around us in many forms. Our life has evolved in a world with significant levels of ionizing radiation, and our bodies have adapted to it. Various radioisotopes are naturally occurring, and originated while the formation of the solar system and through an interaction of cosmic rays with molecules in the atmosphere. Tritium is an example of a radioisotope which formed by cosmic rays' interaction with atmospheric molecules. Some radioisotopes (like uranium and thorium) that were formed when our solar system was created have half life's is a billions of years, and are still present in our environment. Background radiation is the ionizing radiation permanently present in the natural environment. Various radioactive isotopes also occur naturally which present within the human body.

1.7.1 Artificial sources of ionizing radiation

People are also exposed to artificial radiation from medical treatments and activities involving radioactive material. Radioisotopes are produced as a byproduct of the operation of nuclear reactors, and by radioisotope generators such as cyclotrons. Many artificial radioisotopes are used in the fields of radiology, nuclear medicine, biochemistry, the fabrication industries and agriculture. The following are the most common sources.:

1.7.2 Medical sources

Radiation has many uses in medicine, nuclear medicine, therapy etc. The best well known application is in X-ray machines, which use radiation to find fractured bones or to diagnose diseases. X-ray machines are regulated by Health Canada and provincial authorities. Another example is to diagnose and treat diseases like cancer. A gamma camera (see Figure 7) is one piece of medical equipment commonly used in diagnosis .The CNSC regulates these applications of nuclear medicine, as well as related equipment. It also licenses reactors and particle accelerators that produce isotopes destined for medical and industrial applications.

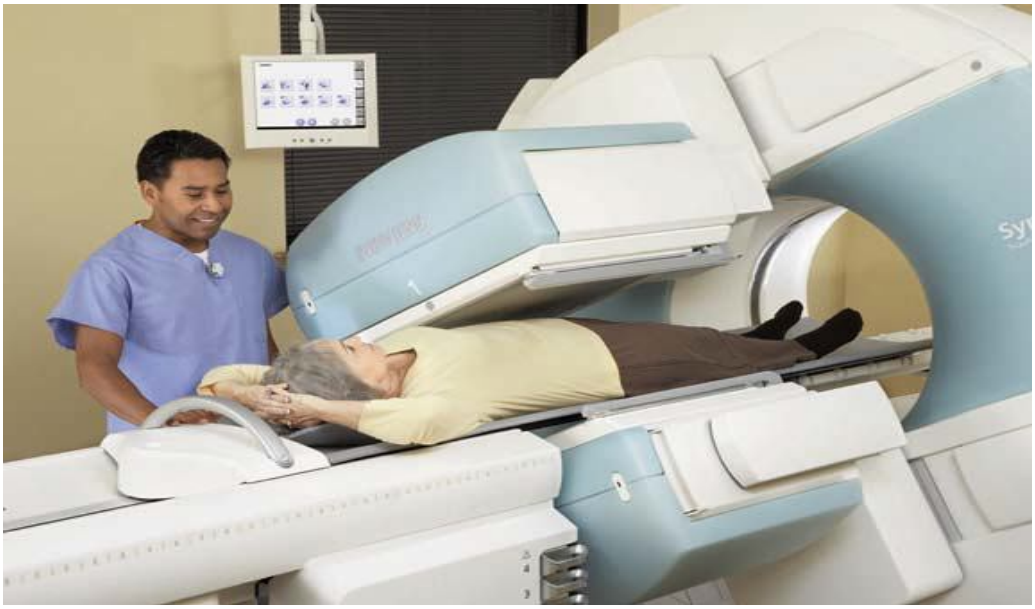


Figure-1.9: A gamma camera used in nuclear medicine, for diagnosing illnesses.

1.7.3 Industrial sources

Radiation has many industrial uses, which range from nuclear gauges used in the building of roads to density gauges that scale the flow of material through pipes in industries. Radioactive materials are also used as smoke detectors and some glow in the dark area exit signs, as well as to estimate reserves in the oil fields. The another applications are sterilization, which is performed using large, heavily shielded irradiators. Industrial activities are licensed by the CNSC.

1.7.4 Health Effects of Radiation Exposure

The radiation exposure carries a health risk which helps the CNSC and other regulatory bodies establish dose limits and regulations that keep exposure at an acceptable or tolerable risk level, where it is unlikely to cause harm. One significant advantage of radiation is that more is known about its associated health risks than about another chemical or otherwise toxic agent.

1.7.5 How radiation affects cells

Radiation affects our human body primarily through breakage of deoxyribonucleic acid (DNA) molecules. DNA is a long chain of amino acids whose pattern make the blueprint on how a cell lives and functions and radiation is ablity to break that chain.

1.7.6 Radiation Doses

For the aim of radiation protection, dose parameters are expressed in three ways: absorbed, equivalent, and effective. Figure 1.6 represents an overview of the relationship between them.

1.7.6(a) Absorbed dose

When ionizing radiation transfer into the human body or an object, it deposit an energy and it absorbed from exposure to radiation is called as an absorbed dose. It is measured in an unit called gray (Gy). A dose one gray is equivalent to an unit of energy (joule) deposited in a kilogram of a substance.

1.7.6(b) Equivalent dose

When radiation is absorbed in living matter, then a biological effect can observed. However, equivalent absorbed doses will not compulsory to produce equal biological effects and it's depends on the type of radiation. For example, 1 Gy of alpha radiation is more harmful than 1 Gy of beta radiation. For obtaining the equivalent and absorbed dose is multiplied by a specified radiation weighting factor (wR) is used to equate different kinds of radiation with different biological effectiveness. The equivalent dose is expressed in a measure is called sievert (Sv). This means that 1 Sv of alpha radiation will have the same biological effect 1 Sv of beta radiation. In other words, the equivalent dose gives a single unit that accounts for the degree of harm that different types of radiation would cause to the same tissue.

1.7.6(c) Effective dose

Different types of tissues and organs have the different radiation sensitivities. For example, bone marrow is much more radiosensitive than the muscle or nerve tissue. To obtain an indication of how much exposure can affect overall health or human body, the equivalent dose is multiplied by a tissue weighting factor (wT) which is related to the risk for a particular tissue or organ. This multiplication gives the effective dose absorbed by the body.

1.7.7 Summary

The radiation has always been present and is all around us. Life has developed in the world containing significant levels of ionizing radiation. We are also exposed to artificial radiation from sources such as medical treatments and activities involving radioactive material. Health effects of radiation are well understood. Since the early 20th century, radiation’s effects have been studied into depth, in both the laboratory and among human populations. Because of the well known health risks of radiation, it must be carefully used and rigorously controlled. A balance must be struck between radiation’s societal advantage and the risks that radiation pretense to people, health and the environment.

1.8 Importance of Gamma ray

In the universe there are kinds of energy and different ways it manifests itself. One common form is radiation. Radiation is the wave energy produced by electromagnetic forces. There are different kinds and their strength can be divided into three categories. There are alpha rays, beta rays, and finally gamma rays.

However, there are limitations for level. Alpha rays are the weakest and can be blocked by human skin and gamma rays are the strongest and only dense elements like lead can block them.

Gamma rays, also known as gamma radiation, and denoted by γ. Gamma rays are the strongest from of radiation. This is what makes the nuclear radiation so dangerous. This high energy radiation can damage human tissue and can cause mutations. In circumstances where gamma radiation is abundant most life forms would be killed within a short period of time. Gamma rays differ from alpha and beta waves in their composition. Alpha and beta rays are composed of isolate subatomic particles. This is the part of the reason why these rays are more easily deflected by less dense matter. Gamma rays are on a whole different level. They are pure energy and radiation so only the most dense kind of matter can be deflect it. Gamma rays can be found practically anywhere in the universe. The best example is the celestial bodies like the sun, pulsars. Each of these are the massive sources energy burning off hydrogen in massive nuclear reactions. This produces massive amounts of radiation in the form of rays. Outside of the earth's protective atmosphere the radiation manifests itself in cosmic rays. The cosmic rays carry tremendous amounts of energy but what makes them pack such a punch are the gamma rays that they are made up of. The most interesting characteristic of the gamma rays is that they don't have a uniform energy level. In some cases the energy levels are vary so much you can have gamma rays that meet the every criterion for the term but in the end have less energy than an x ray from a X ray machine. Energy of the gamma ray largely depends on the source and production of the radiation. At the end of gamma rays are one the many interesting energy occurrence in our universe and scientist are constantly looking into learn more about them and achieve the better understanding of their properties.

Gamma rays are ionizing radiation which biologically hazardous. They are classically produced by the decay from high energy states of the atomic nuclei (gamma decay), but are also created by other processes. Paul Villard, a French chemist and physicist, discovered gamma radiation in 1900, while studying the radiation emitted from radium and after than named "gamma rays" by Ernest Rutherford in 1903. Natural sources of the gamma rays on Earth include gamma decay from naturally occurring radioisotopes, and the secondary radiation from an atmospheric interactions with the cosmic ray particles. Rare terrestrial natural sources produce the gamma rays that are not of a nuclear origin, such as lightning strikes and the terrestrial gamma-ray flashes. Additionally, the gamma rays are also produced by a number of astronomical processes in which very high energy electrons are produced, that in turn cause the secondary gamma rays via bremsstrahlung, inverse compton scattering and synchrotron radiation. However, a large fraction of such an astronomical gamma rays are screened by earth's atmosphere and can be detected by spacecraft.

The gamma rays typically have frequencies above 10 exahertz (or >1019 Hz), and therefore have an energies above 100 keV and wavelengths less than 10 picometers. However, this is not a fast definition, but rather only a rule of thumb description for natural processes. The gamma rays from radioactive decay are defined as gamma rays no matter about their energy, so that there is no lower limit to gamma energy derived from radioactive decay. Gamma decay normally produces energies of a few hundred keV, and almost less than 10 MeV. In astronomy, the gamma rays are defined by their energy, and no production process need to specified. The energies of gamma rays from astronomical sources range over 10 TeV, at a level far too large to result from radioactive decay. The notable example is extremely strong bursts of high energy radiation generally referred to as long duration gamma ray bursts, which produce gamma rays by a mechanism not compatible with radioactive decay. These bursts of the gamma rays, thought to be due to the collapse of the stars called hyper novae, are the extremely powerful events so far discovered in the cosmos.

1.8.1 Gamma Ray Source Discovery

First gamma ray source to be discovered historically was the radioactive decay process called gamma decay. In this type, an excited nucleus emits the gamma ray almost instantly upon formation. Paul villard knew that his described radiation was more powerful than previously described types of radiations from radium, which included beta rays, first noted as "radioactivity" by Henri Becquerel in 1896, and alpha rays, discovered as less penetrating form of radiation by Rutherford, in 1899. However, Villard did not consider naming them as a different fundamental type[7]. Villard's radiation was recognized as being a type basically different from previously named, by Ernest Rutherford, who in 1903 named Villard's rays "gamma rays" by analogy with the beta and alpha rays that Rutherford had differentiated in 1899[8]. The "rays" emitted by the radioactive

elements were named in order of their power to penetrate different materials, using the first three letters of the greek alphabet: alpha rays as the very less penetrating, followed by beta rays and gamma rays. Rutherford also noted that gamma rays were not deflected or fluctuated by a magnetic field, any other property making them unlike alpha and beta rays. T gamma rays were first thought to be particles with mass, like alpha and beta rays. In 1914, the gamma rays were observed to be reflected from crystal surfaces, proving they were electromagnetic radiation. Rutherford and his colleague measured the wavelengths of gamma rays from radium and found similar to X-rays but with short wavelengths and high frequency. This was eventually recognized as giving them also some more energy per photon, then the gamma decay was then understood to generally emit a single gamma photon.

1.8.2 Importance of gamma rays in biological systems

The gamma radiation is somehow similar to x-rays in that both pass through the living materials easily. Also referred to as "photons" which travels the speed of light. Gamma rays have Enough energy to ionize matter and therefore can damage living cells. The damage produced in the cell or tissue is proportional to number of ionizing paths produced in the absorbing material. Isotopes of elements that are the emitters are radio nuclides essential in fission products from nuclear testing, nuclear power plant disasters or the waste. The harmful effect of gamma rays depends on (1) their number (2) their energy and (3) their distance from the source of radiation. Radiation intensity decreases exponentially with the increasing distance. Radiation damage on vascular plant species was demonstrated by [9] who subjected a mature pine oak forest at Brookhaven National Laboratory to gamma radiation from a cesium^{137} source.

Gamma rays are external emitters that penetrate biological materials easily and produce their insidious effects without being taken internally. Alpha particles and beta particles are internal emitters and their damage to organisms is greatest when taken internally. [10] The summarizes the concept best, the alpha, beta, and gamma series is one of the increasing penetration but the decreasing concentration of ionization and local damage. Alpha and beta radiations, unlike gamma radiation, are corpuscular in nature. While alpha particles travels but a few centimeters, and can be stopped by a layer of the dead skin, they are dangerous because they produce a large amount of the local ionization which can cause mutations disrupting cell processes. The beta particles are having high speed while much smaller than the alpha particles, they have ability to travel to a couple of centimeters in living tissue, giving up their energy over a large path. Beta particles, like alpha particles can damage tissue, and can cause mutations that affect the functioning of cells.

1.8.3 The history of gamma radiation as applied to biological systems

Most familiar with the discovery of x-radiation by Roentgen in 1895 and an isolation of radium by the Curies in 1898 [11]. The researchers soon learned that both x-rays and radioactive substances such as radium produced similar effects on the biological materials. The cell division was delayed on the x-ray and radium treated cells[12]. Both[12,13] described “striking chromosomal disruptions” after cells were dosed with the x-rays or exposed to radium, the gamma emitter. The gamma irradiated cells were also broken by radiation treatment[13,14]. For additional historical work on radiation and plant cytogenetic the reader is directed to a review article compiled a paper on the use of radiation in the production of useful mutations which based on papers presented in three symposia[1,15]. A more recent review article on an ionizing radiation damage to plants was prepared [16]. There are many studies applying gamma radiation to biological systems. Varies investigations involving botanicals follow, the yellow sweet Spanish onions exposed to 4000 or 8000 rad prevented sprouting in 97% of their experimental group suggesting that irradiation might be a viable method of prolonging storage life for onions [17]. This study, during intriguing, has not been easily accepted by a public concerned with the problems of radiation. The second article examined the effects of gamma radiation on the storage life of fresh strawberries[18]. The effect of the gamma radiation on the utilization of wheat straw by rumen microorganisms[19]. They concluded that, “high levels of gamma radiation were needed to release the nutrients trapped in wheat straw needed by microbes. However, the levels of gamma irradiation necessary for the nutrient release were well above what was the practical for commercial purposes.” The use of gamma irradiation on male sterilization on the control of screw-worm flies in the southern United States while [20-23] discussed this practice as a general way of controlling the certain insect pests. The response of the pocket mouse to an ionizing radiation[24]. The data on an irradiation of natural vegetation in southeastern United States while [25,26] published a similar study on the effects of the short-term gamma radiation on an old field. The examination of the radiation damage to a forest surrounding an

unshielded fast reactor [27,28] and followed this study with a report in 1969 on the radio sensitivity of the forest tree species to intense fast neutron radiation. The effect of an irradiation and ecology of a tropical rain forest in Puerto Rico[10].

1.8.4 Food irradiation

An ionizing radiation can be used to kill bacteria, germs on certain foods, which may make them safer to eat and help them longer. Many people may be concerned that an irradiated food may itself contain radiation. It's essential to understand that the radiation does not stay inside the food. According to the United States Department of Agriculture (USDA), irradiating food nither cause radioactive nor change nutritional value of the food any more than cooking or freezing it might.

1.8.5 Airport security scanners

In recent years, some airports have begun to use the whole body scanners as a way to detect the objects hidden by clothing. These scanners are different from the metal detectors many people are familiar with. Body scanner currently in use is based on millimeter wave technology. Neither millimeter wave scanners nor metal detectors expose to people to x-rays or gamma rays. Another type of body scanner based on the backscatter technology used very weak x-rays aimed at the surface of the body to catch the whole body image and these scanners are no longer in use.

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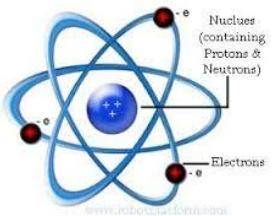
CHAPTER 2



Radiological Parameters and Photon Interactions

2] Attenuation

Reduction in intensity of a light wave propagating through a medium by absorption of a part of its photons is often called attenuation. The study of attenuation of the gamma radiations through different materials is of broad interest in industrial, medical, research and agricultural fields. X-rays and gamma rays are highly energetic radiations. The gamma radiations are penetrate the any state of the materials. The extent of penetration depends upon the several parameters including energy of incident radiation and the nature of intervening material. The study of absorption of the gamma radiations in shielding materials is very important subject in the field of radiation physics. The study of gamma photon attenuation coefficients is an important factor for characterizing the penetration and attenuation properties of the gamma rays in materials.[1].

The primary and basic quantity relating gamma radiation and its transmission through matter is the attenuation coefficient. Which characterizes how easily a material or medium can be penetrated by a beam of light , particle, sound, or other energy [2]. A large attenuation coefficient means that the 1) beam is quickly "attenuated" as it passes through the medium, 2) greater degrees of opacity. While a small value attenuation coefficient means that the medium is comparativelytransperent to the beam. The attenuation coefficient is having units of the reciprocal length (cm^{-1}). it is dependent upon the type of material and the energy of the radiation. Attenuation coefficient (μ) plays an essential role in calculations of treatment planning systems, also the determination of dose distributions in external beam therapy, dosimetry, phantom materials, protection, and industry. So, its exact measurement or calculation is very essential [3]. In 1928, Klein and Nishina [4] published their findings on the mechanics of the gamma ray scattering from free electrons. Their work, based on Dlrac's quantum theory, has served as the theoretical foundation for all gamma ray attenuation coefficient measurements. Tarrant [5] utilized the results of Klein and Nishina to calculate the scattering corrections to be applied to attenuation measurements. The first reported work to measure the absorption coefficients utilizing a scintillation detector and accurate energy discrimination was done by Colgate [6]. In 1964, [7] attenuation coefficients of grains and forages and before his work many experiments have been performed to determine the attenuation coefficients for mixtures of materials as well as for the rare earths and other heavy elements. This work has been characterized by the use of the narrow beam good geometry of the type employed by Davisson and Evans and by the utilization of improved scintillation detectors and counting circuits. As well as the excellent agreement between recent experiments and theory has given rise to several entirely theoretical investigations. Typical of this type of activity is the work of Grodstein [8]. The attenuation of gamma radiation (shielding) can be described by the following equation[9,10].

$$I = I_0 e^{-\mu t} \qquad (2.1)$$

I = intensity after shielding

Io = incident intensity

μ = attenuation coefficient (cm2/g)

t = thickness of absorber (g/cm2)

In practical terms, I is the intensity of gamma radiation after interaction with the shielding material. I is dependent on Io, the initial intensity of the gamma radiation (before shielding), μ, the mass absorption coefficient for the shielding material, and d, the “thickness (g/cm2)” of the shielding material

2.1 Effect of Atomic Number

$$\Delta I = I_0 - I_x \qquad (2.1a)$$

Exploring the magnitude of ΔI by placing different absorbers in turn in the radiation beam. What we would find is that the magnitude of ΔI is highly dependent on the atomic number of the absorbing material. For example we would find that ΔI would be quite low in the case of an absorber made from carbon (Z=6) and very large in the case of lead (Z=82).

We can gain an appreciation of why this is so from the following figure:

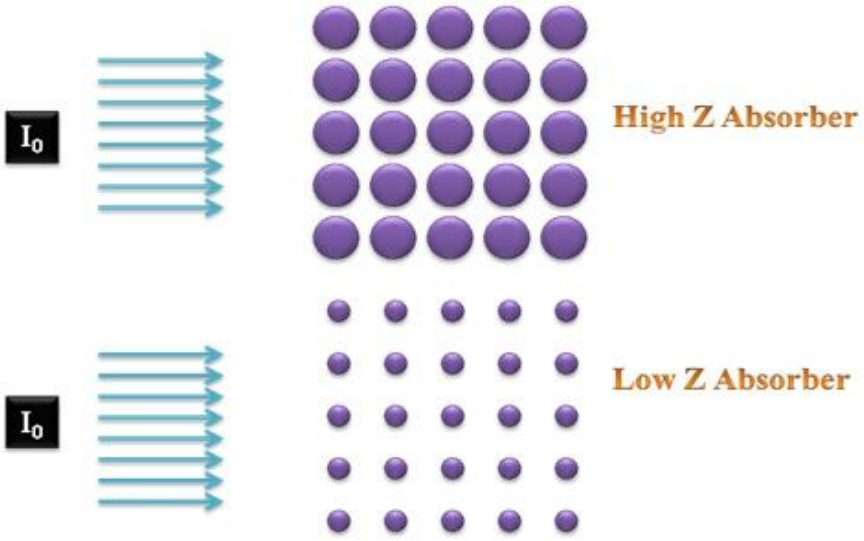


Figure-2.1: High and Low atomic number absorber

The figure illustrates a high atomic number absorber by the large circles which represent individual atoms and a low atomic number material by smaller circles.

The incident radiation beam is represented by the arrows entering each absorber from the left. Notice that the atoms of the high atomic number absorber present larger targets for the radiation to strike.

Hence, the chances for interactions via the Photoelectric and Compton Effects is relatively high. The attenuation should therefore be relatively large.

In the case of the low atomic number absorber however the individual atoms are smaller and hence the chances of interactions are reduced. In other words the radiation has a greater probability of being transmitted through the absorber and the attenuation is consequently lower than in the high atomic number case.

Therefore if we were to double the atomic number of our absorber we would increase the attenuation. So for this reason that high atomic number materials (Pb) are used for radiation protection.

2.1.1 Effect of Density

A second approach to exploring the magnitude of ΔI is to see what happens when we change the density of the absorber. We can see from the following figure that a low density absorber will give rise to less attenuation than a high density absorber since the chances of an interaction between the radiation and the atoms of the absorber are relatively lower.

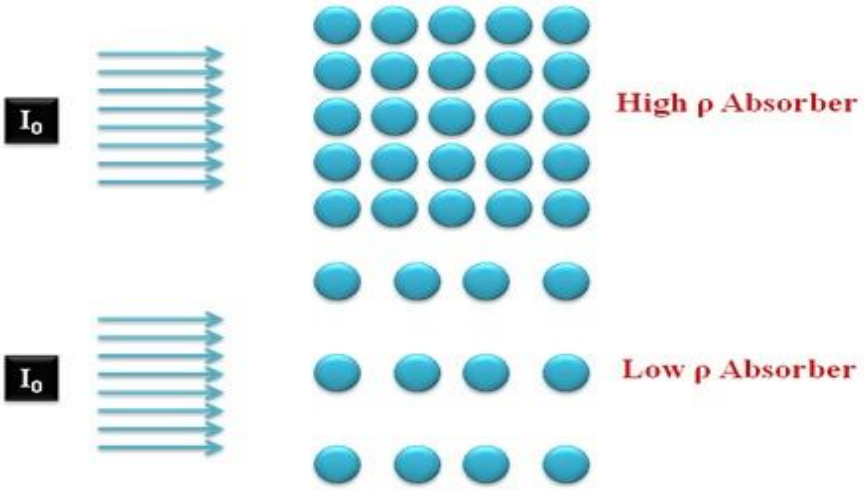


Figure-2.2: High and Low density absorber

So in our analogy of the spaceship entering a meteor cloud think of meteor clouds of different density and the chances of the spaceship colliding with a meteor.

2.1.2 Effect of Thickness

A factor effect of thickness, which we could vary is the thickness of the absorber. As you should be able to predict at this stage the thicker the absorber the greater the attenuation.

2.2 Linear Attenuation Coefficient

The definition for Linear Attenuation Coefficient (μ) is the percent reduction per unit thickness of absorber. Also we can say intensity of an energy beam is reduced as it passes through a specific material. Linear attenuation coefficient (μ) cm^{-1} is determined by using a well collimated narrow beam of photon passing through a homogeneous absorber of thickness 't', the ratio of intensity of emerging beam from the source along the incident direction, to the intensity given by eq.^{n} (1.1) (Beer Lambert law) [11]. The meaning of this statement is that for each unit thickness (such as a millimeter) of absorbing material placed in the path of the beam there is a set percentage of reduction in intensity of the radiation.

$$\textbf{Linear Attenuation Coefficient } (\mu) = \frac{\textbf{\% Reduction in Intensity}}{\textbf{Thickness of absorber}}$$

Linear Attenuation Coefficient (μ) is expressed by following equation;

$$\mu = \frac{1}{t}\ln\left(\frac{Io}{I}\right) \qquad (2.2.1a)$$

The coefficient μ depends on photon energy and on the material being traversed.

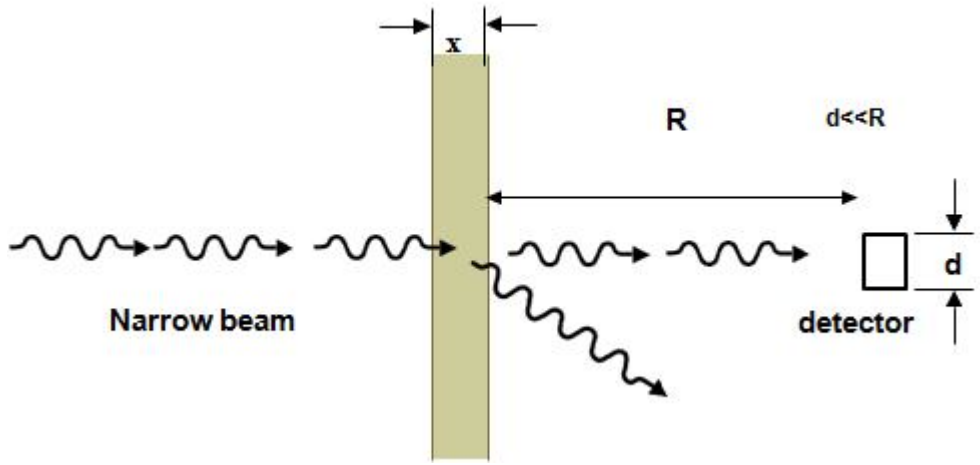


Figure-2.3: Good scattering geometry for measuring linear attenuation coefficient [12].

The linear attenuation coefficient can be measured by the experimental arrangement shown in Fig.3. A narrow beam of mono energetic photons is directed toward an absorbing slab of thickness x. A small detector of size d is placed at a distance R>>d behind the slab directly in the beam line. The probability of all interaction processes between photons and atom is expressed with the linear attenuation coefficients μ (cm-1),Under these conditions, referred to as "narrow-beam" or "good" scattering geometry, only photons that traverse the slab without interacting will be detected The interaction probability μ is actually the sum of the three possible photon interaction mechanisms[12]:

$$\mu = \tau + \sigma + \kappa \qquad (2.2.1b)$$

τ - is the photoelectric effect interaction probability.

σ - is the Compton scattering interaction probability.

κ - is the pair production interaction probability.

The linear attenuation coefficients in aqueous solutions of three carbohydrates, glucose (C6H12O6), maltose monohydrate (C12H22O11H2O), and sucrose (C12H22O11), were determined at different energies by the gamma-ray transmission method in a good geometry setup.

A parameter Linear attenuation coefficient is used in acoustic for characterizing particle size distribution [13]. It is also used for modeling solar and infrared radioactive transfer in the atmosphere.

2.2.1 Mass attenuation coefficient (μ/ρ)

Linear attenuation coefficients are convenient quantity for technical application, but they are not usually tabulated because of their dependence on the absorber density, ρ i.e. on the physical state of the material. Since the density of a given material can vary widely, a coefficient more accurately characterizing a given material is the density-independent mass attenuation coefficient. Therefore, for the purpose of tabulation it is common practice to use the mass attenuation coefficient. The ratio of the linear attenuation coefficient to the density is called the mass attenuation coefficient (μ/ρ. If μ is in cm^{-1} and ρ is in g/cm^3, then μ/ρ will be in the customary units of cm^2/g. Mass attenuation coefficient values are normalized with respect to material density, and therefore do not change with changes in density.

$$\mu(cm^{-1})/\rho(gcm^{-3}) = \mu/\rho(cm^2g^{-1}) \qquad (2.2.2a)$$

The mass attenuation coefficient is defined as a measure of probability per unit mass per unit area (or per unit area mass, see equation (1.7)) for interactions that occurs between the incident photons and matter.

A narrow beam of mono-energetic photons with an incident intensity Io, penetrating a layer of material with mass thickness t and density ρ, emerges with intensity I given by the following relation,

$$I/I_0 = \exp[(-\mu/\rho)a] \qquad (2.2.2b)$$

$$\mu/\rho = a^{-1} \ln(I/I_0) \qquad (2.2.2c)$$

From which the mass attenuation coefficient can be obtained from measured values of incident photon intensity I_0, transmitted photon intensity I and thickness of the absorber t. The thickness of the absorber is defined as the mass per unit area, and it is obtained by multiplying thickness t and density of the absorber, i.e. a = ρt.

The μ/ρ values for gamma ray and X-ray photons are required for variety of applications in the diverse fields such as radiation biology and biophysics, radiography, fluorescence studies (X-ray and gamma ray), geophysical prospecting, nuclear diagnostics (computerized tomography), radiation protection and dosimetry, nuclear medicine etc.

Alternatively, the attenuation law, equation (2.1), can be written in terms of the mass attenuation coefficient, μ/ρ, which is a fundamental quantity:

$$I = I_0 \exp\{-(\mu/\rho)\rho t\} \qquad (2.2.2d)$$

The product ρt is called the mass thickness or area mass. The thickness of absorbers used in radiation measurements is often expressed in mass thickness rather than physical thickness, because it is a more fundamental quantity in this context. For a slab of material the mass thickness is measured as the mass of the slab divided by the area. The value of (μ/ρ) can be obtained from various experimental techniques[14]. The values of mass attenuation coefficients are available for a wide range of elements and composite materials from the National Institute for Standards and Technology NIST-XCOM database. The linear attenuation and mass attenuation coefficients by dilute solutions for varying concentrations at various gamma energies have been studied [15-17]. Linear and mass attenuation coefficients of 0.511 MeV and 0.662 keV gamma radiations from alcohol ethanol by dilute solution of Phenol similarly for para-nitroaniline studied for different concentrations [18] and [19]. Similarly, 662 and 1170 keV gamma radiations, concentrations of solutions were studied.

So mass attenuation is the fundamental tool to derive many other photon interaction parameters such as molecular cross-section, atomic cross-section, electronic cross-section, equivalent and effective atomic numbers, electron density, KERMA, buildup factor etc.

2.2.2 Attenuation cross-sections

The concept of an interaction cross-section is very useful in nuclear physics, radiation physics and many fields of sciences. Each atom has associated with it an area ρ, called the cross-section, which is imagined to be oriented at right angles to the incident photon beam. It is a measure of the probability of interaction of photons with matter. The area of the cross-section is so chosen that if an incident photon strikes the area ρ and interaction will take place; and if an incident photon misses the area ρ then no interaction takes place. The common unit for this parameter is the barn (b),

where $1b = 10^{-28}\ m^2 = 10^{-24}\ cm^2$.

One can derive an expression for the total target area presented by all interaction centers within a thin layer of area *A*' and thickness d*x*. The layer is assumed to be so thin that the cross-sectional area presented by any one atom does not overlap or cover with that of any other atom as shown in figure 2.4

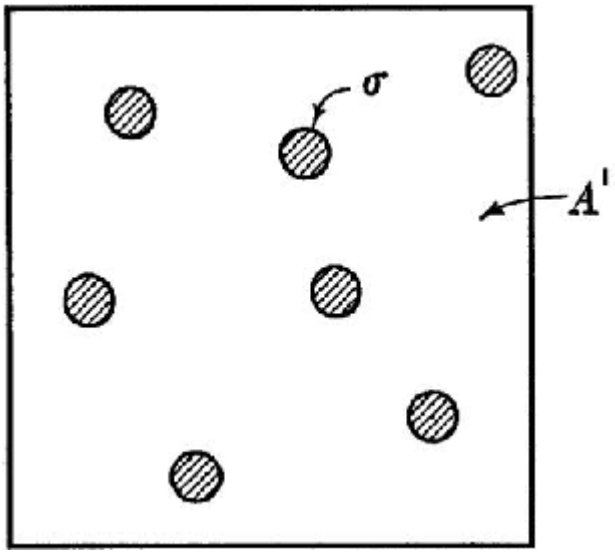


Fig-2.4: Target areas presented by the interaction centers (atoms).

The cross-sections parameter is the sum of contributions from various interaction processes.

Only six interaction processes have any real significance in radiation physics: photoelectric absorption, Compton scattering, Rayleigh scattering, pair production, triplet production and photonuclear process. The total photon interaction cross-section, □□, can be written as the sum of the cross-sections of the partial interaction processes:

$$\sigma = \sigma_{pe} + \sigma_{incoh} + \sigma_{coh} + \sigma_{pair} + \sigma_{trip} + \sigma_{ph,n} \qquad (2.2.2e)$$

where σ_{pe} (or τ), σ_{incoh} and σ_{coh} are the photoelectric cross-section, incoherent (Compton) and coherent (Rayleigh) cross-sections, respectively. σ_{pair} (or κ_n) and σ_{trip} (or κ_e) are the cross-sections for electron-positron pair production in the field of the nucleus and in the field of the atomic electrons ("triplet" production), respectively. $\sigma_{ph,n}$ is the photonuclear cross-section. The photonuclear cross section, $\sigma_{ph.n}$, is a measurable effect [20]. However, this process in which the photon is absorbed by the atomic nucleus and one or more nucleons (neutrons and/or protons) are ejected, is not readily amenable to systematic calculation and tabulation. This is due to a number of factors including its irregular dependence, both in shape and in magnitude, on both *A* and *Z*, and its sensitivity to isotopic abundances in a given sample of an element [21-23].

2.2.3 Molar extinction coefficient(ε)

Molar extinction coefficient is a measurement of how strongly a chemical species absorbs light at a given wavelength. Extinction coefficient refers to several different measures of the absorption light in a medium: In chemistry, biochemistry, molecular biology or microbiology. It is an intrinsic property of the species; the

actual absorbance of a material, of a sample also depends on the path length and the concentration of the species. Molar extinction coefficient equation is as follow,

$$A = \varepsilon c \ell \qquad (2.2.4a)$$

where ε is the molar attenuation coefficient of that material; c is the molar concentration of those species, ℓ is the path length.The molar extinction coefficient expressed in SI units is m^2/mol. but in practice, they are usually taken as M^{-1} cm^{-1} or L mol^{-1} cm^{-1}. The use of the terms "molar extinction coefficient" and "molar absorptivity" for molar attenuation coefficient is discouraged.[24,25].Use of this term has been discouraged since the 1960s, when international agreement with non-chemical societies reserved the word "extinction" for diffusion of radiation, i.e. the sum of the effects of absorption, scattering, and luminescence[26].

The molar absorptivity based on the wavelength examined. however, depends on the concentration or path length utilized. It is a basic value which depends on the compound. It is measure of how efficiently a molecule have ability to absorb photons of a particular wavelength. Molar absorptivities vary in value from very small up to around $10x10^4$M-1cm-1 or more. A very large value essentially means that every photon that hits a molecule is absorbed.

2.2.3.1 Importance of Molar extinction coefficient

- Molar extinction coefficient is a measurement of the how strongly a chemical species absorb the light at a given wavelength.
- It is an intrinsic property of chemical breed i.e. it depends on chemical composition and the chemical structure of the material as well as independent on concentration. So it use to detach between different molecules.
- Measuring the absorbance is a very rapid method for chemical concentration, although the specific chemical species in the solution must be known.
- Another method of measuring concentration, like titration can take more time and require supplementary chemicals.
- Molar extinction coefficient allows us for the estimation of molar concentration of solution from its measured absorbance.
- It is particularly useful in spectroscopy for measuring the concentration of chemical solution.
- Molar extinction coefficient is used to findout the absorption cross section (σ), relation is given as $\sigma(\lambda) = \mathcal{E}(\lambda)$. Which gives the information of surface coverage on desensitized solar cell.
- It used as a fingure print for molecule.
- Molar extinction coefficient used to define the range of wavelength where light has its maximum depth of penetration in tissue.

2.2.4 Mass energy absorption coefficient,(μ_{en}/ρ)

The quantity of energy that is actually deposited in the medium is essential in evaluating biological effects, explaining the respond of a radiation detector and another applications. For this aim, one can define a linear energy absorption coefficient (μ_{en}) and includes only the energy absorbed in the medium from photoelectrons, Compton electrons, and the electron positron pair. But, the energy carried away by scattered Compton photons, annihilation radiation, and bremsstrahlung radiation is not included.

A more detailed version of the energy deposition parameter is the mass energy absorption coefficient (μ_{en}/ρ), and can be described more clearly through the use of an intermediate parameter called as mass energy transfer coefficient. The mass energy transfer coefficient (μ_{tr}/ρ) is the mass attenuation coefficient multiplied by the fraction of energy of the interacting photons which is transferred to the charged particles as a kinetic energy. Hence μ_{tr}/ρ is a measure of an average fractional amount of incident photon energy transferred to charged particles as kinetic energy due to all kinds of interactions of photons with matter.

The mass energy-absorption coefficient (μ_{en}/ρ), takes into an account the fraction of the kinetic energy that is afterward lost in radiative energy loss processes as the charged particles (electrons or positrons) slow to rest

into absorbing medium. The net kinetic energy of the charged particles is in turn, a more or less acceptable approximation to the amount of the photon energy made available for the production of chemical, biological and other effects associated with the exposure to an ionizing radiation. Therefore, μ_{en}/ρ has an essential role in estimating the absorbed dose in medical and health physics. The μ/ρ and μ_{en}/ρ are basic quantities used in calculations of the penetration and the energy deposition by photons (gamma ray, X-ray and bremsstrahlung) in biological, shielding and other materials [27].

2.2.5 Mixtures and compounds

As the materials are composed of various elements, it is assumed that the contribution of elements of the compound to the total photon interaction is yielding the well known mixture rule [28] that represents the total mass attenuation coefficient of any compound as the sum of appropriately weighted proportion of the individual atoms, For a chemical compound or a mixture (assumed to be homogeneous), the mass attenuation coefficient, μ/ρ, can be calculated from the mass attenuation coefficients of its constituent elements, $(\mu/\rho)_i$, according to the simple mixture law (Bragg additivity law):

$$\frac{\mu}{\rho} = \sum_i w_i \left(\frac{\mu}{\rho} \right)_i \qquad (2.2.6a)$$

where w_i is the fraction by weight of the i^{th} constituent element present in a compound or mixture. For any chemical compound, w_i is given by:

$$w_i = \frac{n_i A_i}{\sum n_i A_i} \qquad (2.2.6b)$$

where n_i and A_i are the number of formula units and the atomic weight of the i^{th} constituent element. Equation (2.2.6a) is called the *mixture rule* [29]. It is based on the idea that radiation interacts with atoms individually and the atoms do not influence each other's interaction probability.

The limitation of the mixture rule is that it treats the complex medium under consideration as a mixture of various atomic constituents. Thus it does not account for any variation in the atomic wave functions, which occur due to changes in the molecular, chemical or crystalline environment of the atom. This in fact may seriously affect the accuracy of the results obtained by the application of the mixture rule. This is true only when the incident photon energy is in the vicinity of the edge energies of the constituent elements of the compound [29, 30].

2.2.6 Total electronic cross-section

The total electronic cross-section (σ_{ele}) for the individual elements was calculated by using the following relation [31],

$$(\sigma_{t,el}) = \frac{1}{N_A} \sum_i \frac{f_i A_i}{Z_i} (\mu_m)_i = \frac{\sigma_{t,a}}{Z_{eff}} \qquad (2.2.7a)$$

where f_i denotes the fractional abundance of i^{th} element with respect to number of atoms such that f1 + f2 + f3 +…..+ fi = 1, Zi is the atomic number of i^{th} element.

2.2.7 Effective atomic number and electron density

The study of ionizing radiations, and their interaction with different materials has gained great importance and finds wide application in areas such as medicine, agriculture, industry, radiation sterilization, medical radiation dosimetry, radiation shielding, science and technology, space research programs, radiometric gauging and process control, security screening etc [32-35]. The parameter effective atomic number is the ratio of total photon interaction (total atomic cross section) to the total electronic cross section has a physical meaning and allows many characteristics of a material to be visualized with a number. In order to make use of fact that scattering and attenuation of photon are related to the density and atomic number of the absorber, knowledge of μ/ρ is necessary. The effective atomic number (Z_{eff}) of the compound which is determined by

using following relation [36],

$$Ze_{ff} = \frac{\sigma_{t,a}}{\sigma_{t,el}} \qquad (2.2.8a)$$

The atomic number, *Z*, is a universal parameter in radiation physics, and in nuclear and atomic physics which occurs in almost any formula. For a complex medium the effective atomic number is a convenient parameter, in some cases, for representing X-ray and gamma ray interactions, for example: in designs of radiation shielding or in calculations of absorbed dose in radiology, radiotherapy. However, as stated by Hine [37], for gamma photon interactions a single number cannot represent the "effective" atomic number of a multi element material, composed of several elements, uniquely across the entire energy region. Instead, one defines the so-called effective atomic number, Z_{eff}.

The value of this parameter can provide an initial estimation of the chemical composition of the material. A large Z_{eff} generally corresponds to inorganic compounds and metals, while a small Z_{eff} (≤ 10) is an indicator of organic substances. For many applications, for example in radioisotope monitoring, cross-section studies of absorption, scattering and attenuation of electromagnetic radiation, testing of multi-component, heterogeneous and composite materials etc., this parameter is of principal significance. The scattering and absorption of gamma rays are related to the density and atomic numbers of an element. For a material composed of several elements, it is related to the effective atomic number and the effective electron density. The effective atomic number also finds its utilization in the computation of some other useful parameters, namely the effective dose and buildup factor.

2.3 Interaction of Radiation With Matter

A knowledge of gamma-ray interactions is important to the nondestructive assayist in order to understand gamma-ray detection and attenuation. The gamma ray intensity measured outside the sample is always attenuated because of gamma-ray interactions with the sample. Gamma rays and X-rays are high energy electromagnetic waves. According to quantum theory, the apparently continuous electromagnetic waves are quantized and consist of discrete packets of energy called quanta or photons. Thus, a beam of gamma rays (or X-rays) of wavelength λ consists of a stream of particle-like photons, each having an energy E as below,

$$E = h\nu = \frac{hc}{\lambda} \qquad (2.3a)$$

where *h* is Planck's constant. In practical units, one has *hc* =12.398 keV. Å .

In general a gamma photon can interact with matter by interacting with atomic electrons, nucleons, nuclear electric field. Consequently the photon can be totally absorbed, coherently scattered or incoherently scattered in which case gamma energy loss is involved. All four type of gamma interactions can result in either absorption, coherent or incoherent scattering, thus giving rise to 12 different processes. The process photoelectric absorption, Compton scattering, and pair production will lead to absorption or scattering of the gammas from a collimated beam and thus the beam intensity will be reduced when traversing material. Other processes are minor effects and are of interest in other cases. For photon energies below 1 MeV, the three major interaction processes are photoelectric absorption (< 0.5 MeV), Rayleigh scattering and Compton scattering (0.5-5 MeV). Above 1 MeV (> 1.02 MeV, usually> 5 MeV) nuclear-field "pair" production and atomic-field "triplet" production starts to appear, and they become the dominant mode of interaction as the energy increases > 10 MeV). In order to investigate this attenuation a setup consisting of a collimated gamma beam and a scintillation counter will be used. We determined the attenuation coefficients and respective cross-sections depending on the gamma energy and attenuator material.

2.3.1 Attenuation coefficients and interaction cross-sections

Attenuation and related quantities which plays an important role for characterizing the absorption, penetration, dose rate and scattering of gamma or X-rays. linear attenuation coefficient(μ), this quantity may be defined as the probability per unit path length that a photon will interact with the medium. Consider a slab of material of thickness, *t*, located in between a narrowly collimated source of monochromatic photons and a

narrowly collimated detector, as indicated in figure 1.3. In a layer d*x* within the slab there will occur a reduction of the intensity, *I*, of the photon beam due to attenuation of the beam. The attenuation occurs due to the absorption (photoelectric absorption and pair production) and scattering (coherent and incoherent) of photons. The resulting fractional reduction of the intensity, probability of interaction, can be written as,

$$\frac{dI}{I} = -\mu\, dx \qquad (2.3.1a)$$

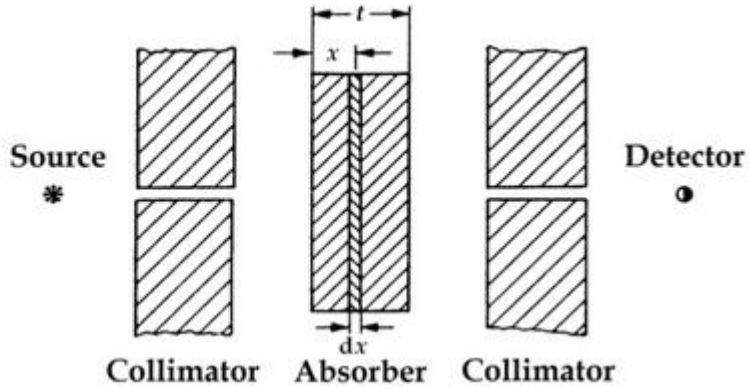


Figure-2.5: Set up for determination of narrow-beam attenuation coefficients. Integrating this equation.

$$I = I_0 \exp\left[-\int_0^t \mu(x)\, dx \right] \qquad (2.3.1b)$$

where I_0 is the incident intensity of photons. For a homogeneous medium this reduces to the following exponential law:

$$I = I_0 e^{-\mu t} \qquad (2.3.1c)$$

It is apparent that μ has dimensions of an inverse length (cm^{-1}). Equation (1.4) is sometimes called the Beer's-Lambert law. The ratio I/I_0 represent the fraction of photons transmitted.

The photon interaction can also be characterized by their mean free path (λ), which is defined as the average distance traveled by a photon in the medium before an interaction takes place. For a photon traversing in a medium which has linear attenuation coefficientμ, the probability of interaction in any short distance dx is μdx. Then the probability that a photon can travel a distance x without any interaction is given by exp (−μ x), equation (1.4). Thus, the mean free path, λ, can be calculated as:

$$\lambda = \frac{\int_0^\infty x e^{-\mu x}\, dx}{\int_0^\infty e^{-\mu x}\, dx} = \frac{1}{\mu} \qquad (2.3.1d)$$

Therefore, the mean free path is simply the reciprocal of the linear attenuation coefficient.

Gamma rays have many modes of interaction with matter. The interactions of these photons with matter are independent of the mode of origin of the photons and depend only upon their energies. On passing through matter, photon beam undergoes attenuation, i.e. its intensity decreases gradually by absorption and scattering. Absorption refers to the case in which an incident photon gives up all of its energy. Scattering refers to those photons that have undergone a change in direction after interaction with atoms of matter. Other photons which neither absorbed nor scattered only pass through the matter which called as transmission.

2.4 Interaction mechanisms

The total mass attenuation coefficient for gamma rays or X-rays traveling through a medium has main contributions from photoelectric absorption, Compton scattering, Rayleigh scattering, pair production and triplet production processes. In the present work, photonuclear and some other such small effects are neglected. When a gamma ray interacts with matter, there are interactions that occur in the material other than those due to the Compton scattering. All of these interactions occur in the detector just like they occur in the material that the effect is being studied. There are 3 primary ways that photons interact with matter namely: photoelectric absorption, Compton scattering, and pair production. All of these effects occur in the detector, just as they do in the material that is being studied and they make up different portions of the measured energy spectra. Photoelectric absorption predominates for low-energy gamma rays (up to several hundred keV), Pair production predominates for high-energy gamma rays (above 5-10 MeV), and Compton scattering is the most probable process over the range of energies between these extremes.

2.4.1 Photoelectric absorption: (γ, e^-)

Photoelectric absorption is a process in which the incident gamma ray photon interacts with a tightly bound core electrons (orbital electron) of an atom of the material. If the energy of the incident photon is equal to the binding energy of electron, then the photon is completely absorbed. This results in the removal of that electron from the atom. The freed electron is known as a photoelectron and an ion results when the photoelectron leaves the atom.

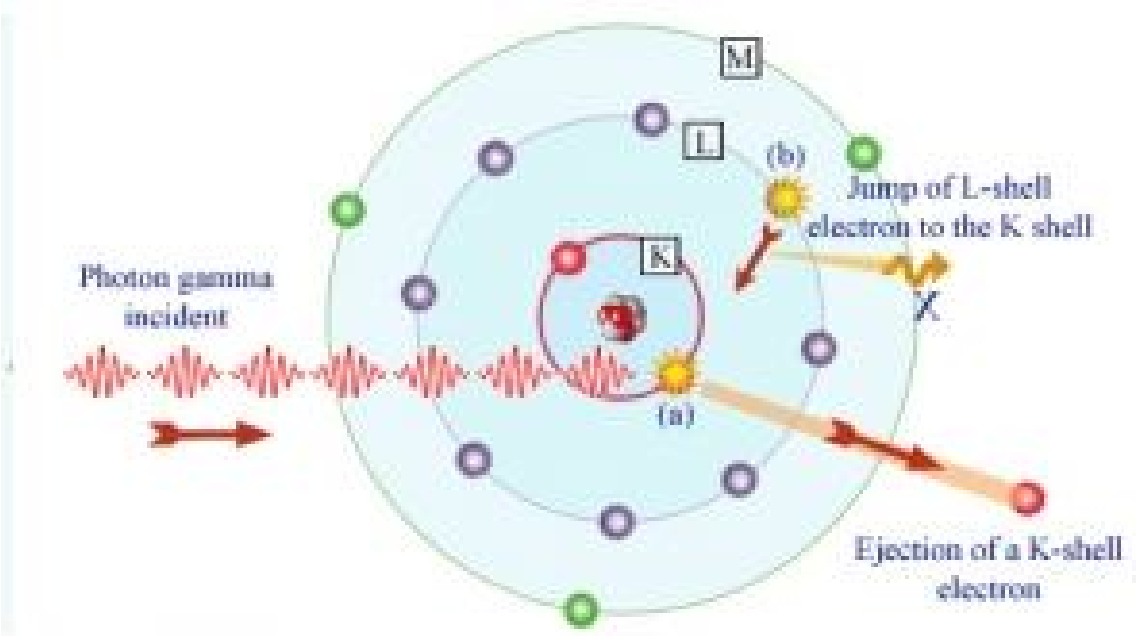


Figure-1.5: illustrates the photoelectric absorption process.

If the incident photon energy is greater than the binding energy of the electron, then part of the energy of photon is used to overcome binding energy of the electron and most of the remainder is transferred to the freed photoelectron as kinetic energy. During this process the recoil of the entire residual atom conserves the momentum. In order to conserve energy and momentum, the electron must be bound to the atom. Hence this interaction is with the atom as a whole and cannot take place with free electrons. Two subsequent points should also be noted. Firstly, the ejected photoelectron will produce secondary ionization events with its surrounding atoms in a similar manner to beta particles. The electron rapidly loses its energy and moves only a relatively short distance from its original location. Secondly, the vacancy or hole created in one of the electron orbits of the atom is quickly filled by an outer orbital electron or a free electron from the medium. This transition is accompanied by an emission of characteristic X-ray, often called a fluorescent photon. The energy of the emitted photon is equal to the difference in energy levels of the transferred electron. Some of these photons are reabsorbed by electrons of less tightly bound shells, which results in the emission of an Auger electron.

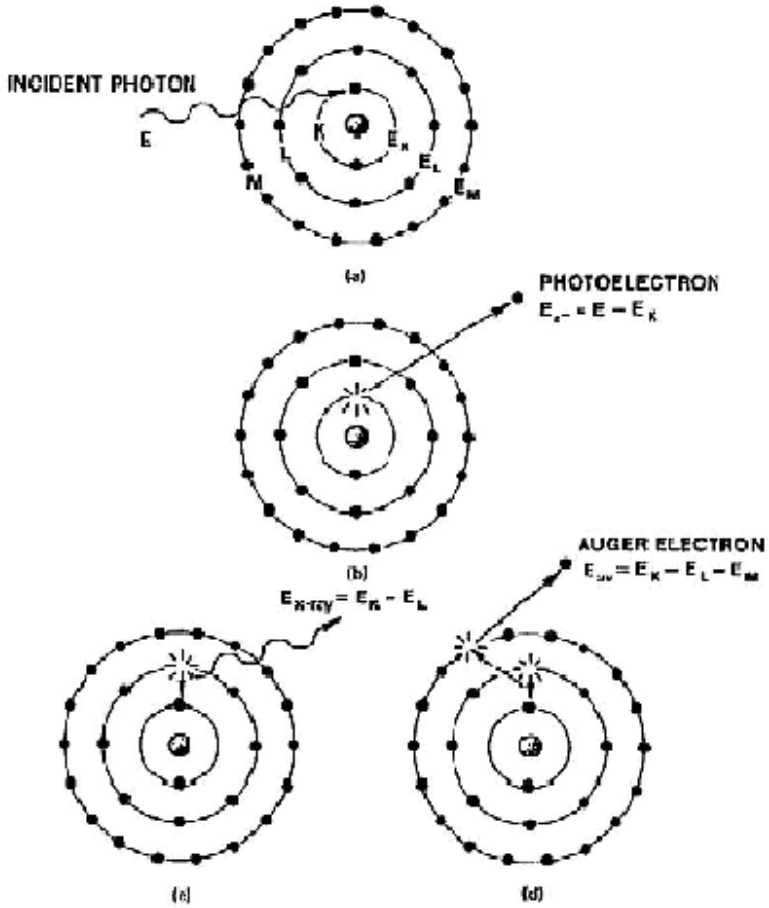


Figure-2.6: X-ray fluorescence and Auger effect following a photoelectric absorption.

It follows from the principle of conservation of energy that, the resulting photoelectron has kinetic energy E_{e^-} is given by,

$$E_{e^-} = E - E_B \qquad (2.4.1a)$$

where E is the energy of the incident photon and E_B is the binding energy of the electron. The process is possible only for $E \geq E_B$, because one has to have $E_{e^-} \geq 0$. Thus the incident photon energy must exceed binding energy or ionization energy of the electron shell considered, otherwise cannot occur photoelectric interaction.

Figure 2.5 shows the basic processes involved in a photoelectric absorption [38]. Figure 2.5a shows an atom with various energy levels having binding energies

E_K, E_L, E_M etc., and a photon of energy E is incident on it. The notation K, L, M etc., refers to electron shells with principal quantum numbers n = 1, 2, 3, 4... etc.

Figure 2.5b shows the ejected photoelectron leaving the K-shell of the atom with kinetic energy $E - E_K$. The illustrated process is possible only when $E \geq E_K$. Figure 2.5c shows an electron jumping from the L shell into the vacancy in K shell. This electron transfer will result in the production of a fluorescent X-ray photon, called a Kα photon, with energy

$$E_{K\alpha} = E_K - E_L \qquad (2.4.1b)$$

There is another de-excitation process, called the Auger effect that can occur. It may happen that the ionization of an inner shell electron produces a photon which in turn gets absorbed by an outer shell electron of the same atom. Thus, as shown in figure 125d, the Kα photon is immediately absorbed by an M electron, which is ejected as a so called Auger electron. In the illustrated case, the energy of the Auger electron is,

$$E_{ae} = E_K - E_L - E_M \qquad (2.4.1c)$$

This process is enhanced for absorber materials of high atomic number, Z. A plot of the photoelectric absorption cross-section versus energy for medium and high-Z elements shows discontinuities at several characteristic energies. The discontinuities in the curve or absorption edges appear at photon energies that correspond to the binding energies of electrons in the various shells of the absorber atom. Therefore the edge lying highest in energy corresponds to the binding energy E_K of the K-shell electron.

The photo effect cross-section greatly depends on the atomic number Z (nuclear charge) of the absorber. The cross-section decreases with increase in energy. So the photoelectric absorption will give major contribution to the total attenuation of gamma rays for lower energy photons and high Z materials. In the current study, photoelectric absorption contribution to the total photon attenuation cross-sections is significant only below 150 keV, but it has much less importance at high energies.

An explanation for the increase in photoelectric interactions with atomic number is that, as atomic number increases the binding energies become closer to the photon energy. The probability is greater for more tightly bound electrons. Therefore K shell electrons are most affected, about 70-80% of the photoelectric absorption takes place in the K shell, provided the gamma ray energy exceeds the K-electron binding energy.

Most of the early calculations of the atomic photo effect were for K-shell only, typified by the high-energy work of Pratt [39] showing the asymptotic behavior going to arbitrary high energies, and by Pratt *et al.* [40] in the range 200 keV to 2 MeV. Hultberg *et al.* [41,42] used the Swedish BESK computer to compute K-shell cross-section including photoelectron angular distributions, for 21 elements $Z = 1$ to 100 for photon energies extending as low as 1 keV ($Z = 1$) to as high as 10 MeV ($Z = 92$). Pratt *et al.* [43] reviewed the development on theory of photo effect for incident photon energies above 10 keV.

Rakavy and Ron [44,45] produced a significant advance with their atomic photo effect cross-section calculations for not only the K shell, but also for all the significantly contributing higher sub-shells ($L_{I–III}$, $M_{I–V}$, $N_{I–VII}$ and $O_{I–III}$) over the energy range 1 keV to 2 MeV for Z = 13, 26, 50, 74 and 92. Other important multi-shell photo effect calculations in this time period, which also provide historical reviews of earlier work, are those by Alling and Johnson [46], Matese and Johnson [47], and by Schmickley and Pratt [48]. Interpolations from these works, along with the K-shell high-energy asymptotic behavior provided by Pratt[49], were helpful in constructing the tables of Hubbell [50], along with a large body of experimentally determined total photo effect cross-section data obtained by subtracting "known" theoretical scattering cross-sections from measured total cross-sections (attenuation coefficients).

However, Scofield [51] introduced the major advance with his systematic calculations of atomic photo effect cross-sections for all sub shells and for all elements Z = 1 to 101 over the photon energy range from 1 keV to 1.5 MeV. These non-relativistic calculations were based on solution of the Dirac equation for the orbital electrons moving in a static Hartree-Slater central potential. For Z = 2 to 54, Scofield [51] provided renormalization factors to convert his cross-section results to values expected from a relativistic Dirac-Hartree-Fock (DHF) computation.

This renormalization was performed for two subsequent compilations of μ/ρ and μ_{en}/ρ by Hubbell [51, 53] and by Hubbell et al. [54]. However, detailed comparisons [55,56] with the extensive NBS/NIST μ/ρ measurement database tend to favor the un-renormalized σ_{pe} over the renormalized values [57]. Hence, in subsequent compilations by Berger and Hubbell [58], and Hubbell and Seltzer [59], the unrenormalized σ_{pe} values [60] have been used.

Scofield [61] later extended these calculations down to 0.1 keV, and these unrenormalized values are also included in the compilation by Saloman and Hubbell [62] and Saloman et al. [63], both numerically and graphically, with the NBS/NIST μ/ρ measurement data base as well as with an experiment-based compilation by Henke et al. [64]. Values of σ_{pe} are also given in the extensive theoretical results of Chantler [65] computed within a self-consistent Dirac–Hartree–Fock framework, mentioned earlier.

2.4.1.1Mechanisms of Energy Loss: Photoelectric Effect

- In the photoelectric absorption procedure, a photon pass off an interaction with an absorber atom in which the photon totally disappears.
- In its place, an energetic photoelectron is an ejected from one of the bound shells of the atom.
- For the gamma rays of equivalent energy, the most believable origin of the photoelectron is the most strongly bound or K shell of an atom.
- The photoelectric process is the predominant phase of photon interaction at
  - comparetively low photon energies
  - high atomic number Z

2.4.2 Compton scattering or Incoherent scattering: (γ ; γ', e^-)

Compton scattering was discovered in 1922 by Arthur H. Compton**[66]** while conducting research on the scattering of X-rays by light elements. Subsequently he reported his experimental and theoretical results. The theoretical explanation is known as Compton scattering deviated from classical theory and required the use of special relativity and quantum mechanics, both of which were hardly understood at the time. The Compton effect is based on treating light as consisting of particles of a given energy related to the frequency of the light wave. In this context, the particle of light is given the name "photon". An energetic photon with energy of 0.1 MeV or larger is also often referred to as a gamma ray. Photons whose energy is in the range of 0.1 to 100 keV are usually referred to as X-rays (1 keV = 10^{-3} of 1 MeV). Compton scattering involves the scattering of photons. where both energy and momentum are transferred to the charged particle during the photon moves off with a reduced energy and the change of momentum. Generally, the charged particle is an electron considered to be at the rest and the photon is normally considered to be an energetic photon like an X-ray or gamma ray photon. The theory of Compton scattering make uses of relativistic mechanics for two reasons. First, it involves the scattering of the photons that are mass less, and secondly, an energy transferred to the electron is comparable to its rest energy. As the result an energy and momentum of the photons and an electrons must be expressed using their relativistic numbers. The laws of conservation of an energy and conservation of momentum are then used with relativistic values to develop the theory of Compton scattering.

The characteristic of the Compton Effect (Fig.2.3) is that only part of its total amount of an energy is transferred from the entering photon to an electron. The free electron, which is called Compton electron (recoil electron), reaches a certain velocity that is dependent on the energy transferred to the electron. The rest of the energy continues as a photon of lower energy in another direction, and is therefore called a scattered photon. Because of the lower energy the scattered photon has a longer wavelength than the original.

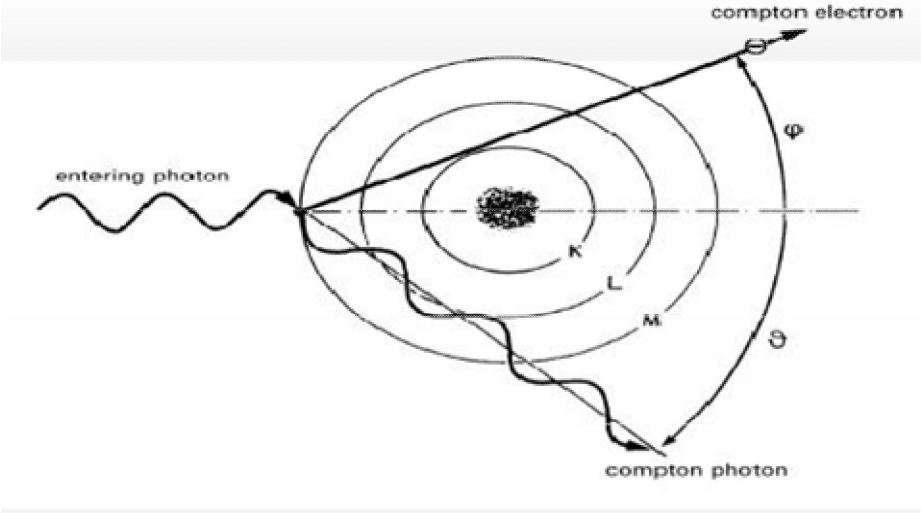


Figure-2.7a: Compton effect.

φ:departure angle Compton electron

Θ:departure angle Compton photon

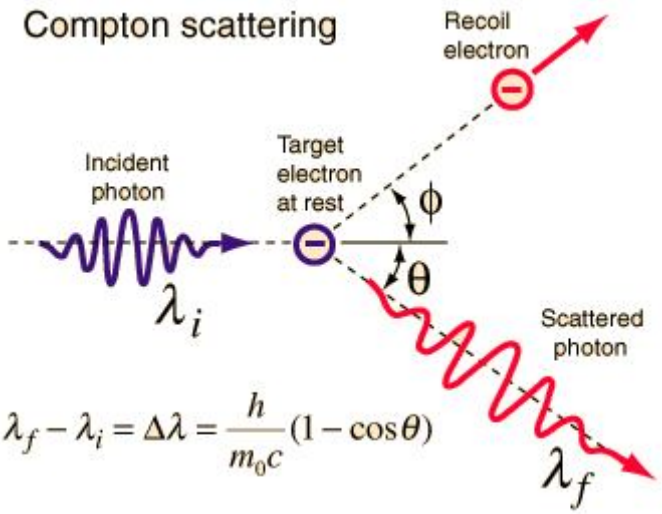


Figure-2.7b: Compton scattering. Schematic view of a photon hitting an electron and traveling onwards.

where λf and λi are respectively the outgoing and incoming energy of the photon.

[Picture from: http://hyperphysics.phy-astr.gsu.edu/hbase/quantum/compton.html]

The Compton process occurs only when the photon energy passes the limiting value of the photoelectric process. Since the impulse and an energy are divided among the Compton electron and the scattered photon, law of the preservation of an impulse is complied with, and the process occurs with an electrons from the outer shells as well. For this reason, the atomic number (Z) of the material is less effective. The freed Compton electrons can, depending on the energy content, an ionize another atoms along their routes. The scattered photon continues its path and continues to enter into Compton processes up till the energy is reduced to such an extent that a photoelectric process occurs. Only then the photon has disappeared. Because an electron binding energy is very small relatively the gamma ray energy, the kinetic energy of an electron is nearly equivalent to an energy lost by the gamma ray.

$$E_e = E_\gamma - E' \qquad (2.4.2a)$$

where E_e – energy of scattered electrons

E_γ- energy of incident of gamma ray

E'- energy of scattered of gamma ray

The Compton process is appreciable only when the photon energy passes the limiting value of the photoelectric absorption process. In Compton scattering, a gamma ray photon interacts with a free or weakly bound electron (outer, least tightly bound electrons), loses some of its energy and is deflected from its original direction of travel. In this process part of the incident photon energy is imparted to the recoil electron; hence it is called *inelastic scattering*. In this case there is no phase relationship between photons scattered by the different electrons of the same atom and hence it is also said to be *incoherent*. By the conservation of momentum and energy, the electron must recoil in a specific direction with a specific energy. The recoil electron rapidly loses its energy and moves only a relatively short distance in the medium. The scattered photon deflects off in a different direction with lower energy. The direction of the Compton photon, a "secondary photon" like the fluorescent photon in a photoelectric process, is not along the same trajectory as the initial incoming photon. This deflected or scattered photon may escape from the matter or undergo further Compton scattering or can be absorbed through the photoelectric effect within the material.

Data to verify the Compton Scattering theory is collected in this experiment using the gamma ray spectrometer that the consists of a scintillation detector, high voltage supply, an amplifier system, and a

multichannel analyzer to measure an energy distribution of the detected gamma rays. There are plenty ways to detect the gamma rays, and include: an ionization chambers, photographic film, proportional counters, Geiger-Mueller detectors, germanium detectors, solid state diodes, liquid and solid scintillation materials with the photomultiplier tubes, and so many methods using similar materials and approaches. To the study of Compton Effect a gamma ray spectroscopy method is needed to measure the gamma rays energy before and after an interaction. The scintillation detector is an adequate of doing this, and the one used in this experiment is composed of a sodium iodide (NaI) scintillation crystal and a photomultiplier tube. The detector system produces a voltage pulse that is the proportional to the energy deposited in the crystal by the absorbed gamma ray. Detected gamma ray may be from the radioactive source directly or by scattering. The size of the voltage pulse, and hence the energy deposited in the detector, is measured with a multichannel analyzer (MCA). The energy deposited in the scintillation crystal depends on the type of interaction between the gamma ray and the crystal even for a single gamma ray of a single energy. A MCA measures the distribution of the voltage pulse heights or spectrum of the voltage pulses for multiple gamma rays interacting in the crystal depending on the kind of interaction that takes place.

2.4.3 Coherent Scattering

In the Rayleigh scattering all atoms works as the target (Fig2.4). When the incident photon is scattered by an atom and changes its direction. The target atom recoils to conserve momentums before and after the scattering. The recoil energy of an atom is very less and can be fiddling because of the large atomic mass.

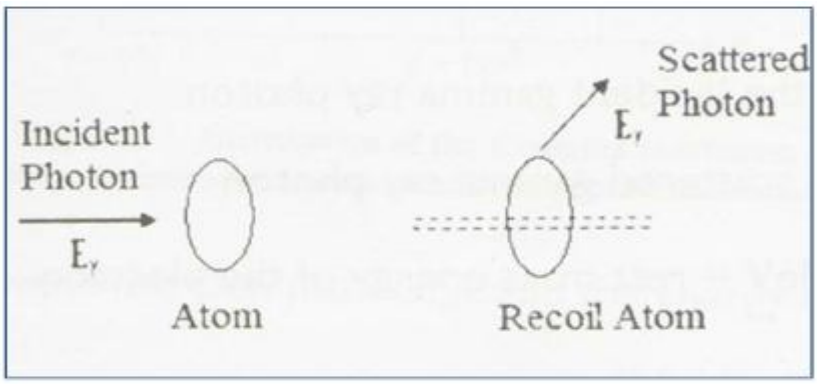


Figure-2.8: Coherent scattering

Therefore, photon changes its path only and retains the same energy after scattering. As a result no energy is transferred.

Coherent scattering frequently called Rayleigh scattering, involves the scattering of a photon with no transfer of energy (elastic scattering)[67]. The electron is oscillated by the electromagnetic wave from the photon. The electron, in turn, reradiates the energy at the same frequency as the incident wave. The scattered photon has the same wave length as the incident photon. The only effect is the scattering of the photon at a small angle. This scattering occurs in high atomic number materials and with low energy photons. This effect can only be detected in narrow beam geometry.

2.4.4 Pair production or elastic pair production: (γ ; e^-, e^+)

The third photon interaction process, called pair production, is very unique in that "pure energy" in the form of a photon is transformed into 2 particles. When a high energy -ray transfers its energy into the spontaneous creation of an electron-positron pair is called Pair production(Figure 2.3). This phenomenon only happens when h_ exceeds twice the creation energy of the electron($E_\gamma \geq 2M_ec^2$=1.022 MeV).

These interactions were first observed in Patrick Blackett's counter-controlled cloud chamber. If the photon is near an atomic nucleus, the energy of a photon can be converted into an electron-positron pair:

$$\gamma \rightarrow e- + e+ \qquad (2.4.4a)$$

When a high energy photon passes near a nucleus, the incoming photon suddenly disappears and in its place appears 2 particles an electron and a positron. This process is simply a transformation of energy into mass in accordance with Einstein's equation $E = MC^2$. It follows that the incident photon's energy must be at least

the mass equivalent of the electron and positron. The mass of an electron or positron is 0.00055 amu, converted to energy (1 amu = 931 Mev): 2(0.00055 amu)*931amu/MeV = 2*0.511 MeV= 1.02 MeV.

The minimum energy photon in theory for pair production then is 1.02 MeV. However, it is highly unlikely that a 1.02 Mev photon will pair produce. In general, this type of interaction is not observed for photons having energies less than about 2.5 Mev. The excess energy of the photon (above the 1.02 Mev required to create the electron positron pair) is shared by the two particles as kinetic energy.

The photon must be near a nucleus in order to satisfy conservation of momentum, as an electron-positron pair producing in free space cannot both satisfy conservation of energy and momentum[68]. Because of this, when pair production occurs, the atomic nucleus receives some recoil. The reverse of this process is electron positron annihilation.

The creation of an electron-positron pair (e^-, e^+) when a gamma photon interacts with the coulomb field of a nucleus is called pair production. In this process, the incident photon is completely absorbed and in its place an electron-positron pair appears.

$$\gamma \rightarrow e^- + e^+ \qquad (2.4.4b)$$

Pair production is an example of materialization of energy. This interaction has a threshold of 1.022 MeV (i.e. twice the electron rest mass energy: $2m_0c^2$), because that is the minimum energy required to create the electron and positron[69]. If the photon energy exceeds 1.022 MeV, the excess energy is shared between the electron and positron as kinetic energy. The total kinetic energy of the resultant particles is equal to the incident photon energy minus the rest mass energy of the two particles which have been created[69].

The electron and positron from pair production are rapidly slowed down in the absorber. After losing its kinetic energy, the positron will eventually encounter one of the atomic electrons (free electron), and these two particles will annihilate each other (positron interaction), converting their mass directly into energy which produces two gamma photons of energy equal to the electron rest energy, roughly 0.511 MeV. These two 0.511 MeV photons travel exactly in opposite directions (180°) away from each other. These lower energy gamma photons may interact further by Compton scattering or the photoelectric effect, or they may escape[69].

Pair production is impossible for gamma rays with energy less than 1.022 MeV. Above this threshold, the probability of the interaction increases rapidly with energy. At high energies, above several MeV, it becomes the dominant mode of interaction. The cross-section for pair production, σ_{pair}, varies approximately as the square of the nuclear charge Z, and is significant in high-Z materials[69].

$$\text{i.e } \sigma_{pair} \sim Z^2 \qquad (2.4.4c)$$

The σ_{pair} calculation [69] begins with the Bethe and Heitler [70] Born-approximation unscreened pair-production cross-section as an initial approximation, to which Coulomb screening corrections and radiative corrections are applied. The differential Bethe-Heitler unscreened σ_{pair} cross-section has been cast in forms, suitable for computation, by Bethe and Maximon [71], Davies et al. [72] and by Maximon [73].

The Coulomb correction for the Hubbell et al. [54] computations was pieced together from the low-energy results of Øverbø et al. [74, 75], the intermediate energy results of Øverbø [76] and the high-energy results of Sørenssen [77, 78] which is the high energy limit go to the Davies et al. [79] extreme relativistic Coulomb correction. Screening corrections were pieced together from the near-threshold results of Tseng and Pratt [80, 81] and the intermediate- and high-energy work of Øverbø [82]. The Øverbø work [82] used the Jost et al. [83] expression for nuclear-field pair production in the Born approximation for small nuclear recoil, but without the extreme high energy approximation. This expression required values of the atomic form factor F(q, Z), for which Øverbø [82] used the relativistic F(q, Z) values pieced together from Doyle and Turner [84], Cromer and Waber [85] and Øverbø [86, 87], later published as systematic tabulations by Hubbell and Øverbø [88]. The radiative corrections [89,90] of the order of 1/137 and associated with the emission and re-absorption of virtual photons and with the emission of both soft and hard real photons, were obtained from Mork and Olsen [91].

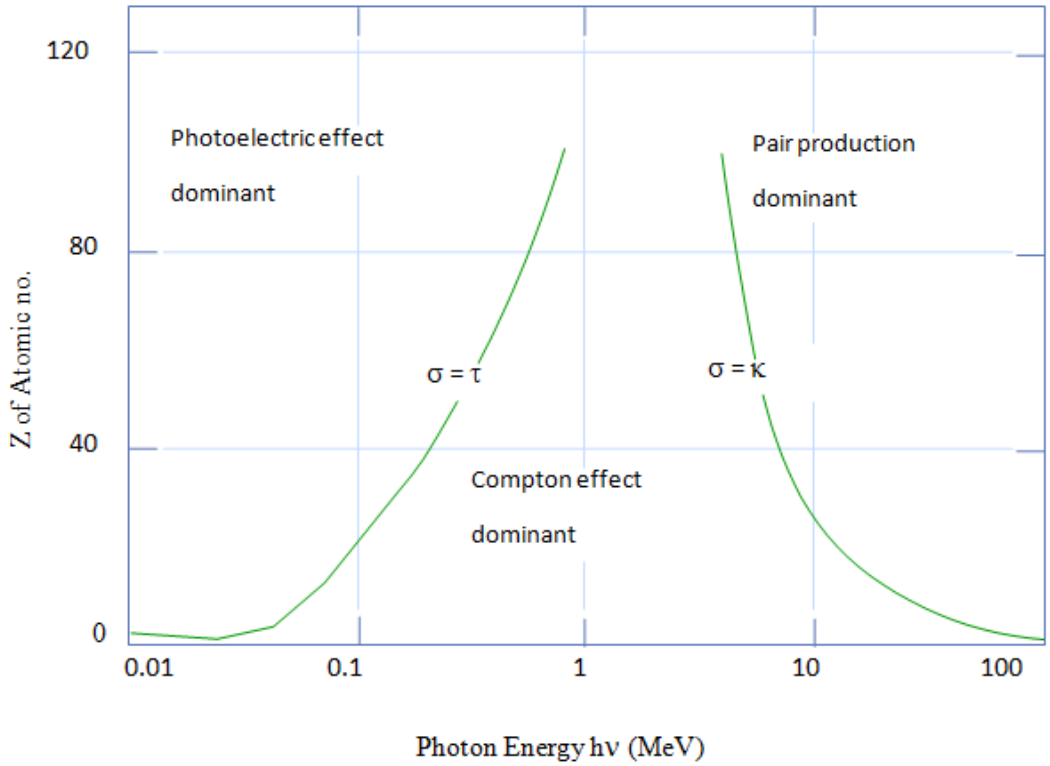


Figure-2.9: Relative importance of the three major types of gamma ray interactions. The curves show the values of Z verses E [92].

- Photoelectric effect: produces a scattered photon and an electron, varies as ~ Z^4/E^3
- Compton effect: produces an electron, varies as ~ Z
- Pair production: produces an electron and a positron, varies as ~Z^2

2.4.5 Thomson scattering

It is a process in which an incident photon gets elastically scattered by free electrons. This is treated as limiting case of Compton scattering. The cross section is independent of energy and is proportional to *Z*.

2.4.6 Nuclear resonance scattering

In *nuclear resonance scattering*, a nuclear level is excited by incident photons and de-excited by the re-emission of the excited energy. If the energy of the incident photon is very close to the excitation energy of a nuclear level, a large resonance scattering is expected. Due to the narrow width of nuclear levels at low energies, the chance of overlap of the incident photon energy with the excitation energy of a target nuclear level is very rare. The cross section of nuclear resonance scattering is proportional to Z^2/A^2 and depends on nuclear energy levels.

2.4.7 Mössbauer effect

The recoilless emission and absorption of resonance radiation by a nucleus emdedded in the crystal lattices is referred to as *Mössbauer effect*. Mössbauer showed that if the emitting system is embedded in a strongly bound lattice, not only the gamma emission takes place without recoil i.e., with full transition energy, but in many cases the emitted gamma ray line has the natural line width determined entirely by the lifetime of the nucleus in the excited state. Under these conditions the phonon occupation number remains unchanged and hence Mössbauer emission is called the *zero phonon emission*. It may be pointed out that even in well-bound solids, all gamma rays are not emitted with zero phonon process but only a fraction of them. This fraction depends upon the binding energy of the lattice and is factor is referred to as the Lamb-Mössbauer factor.

2.4.8 Nuclear Thomson scattering

The elastic scattering of the photons by the nucleus is termed as *Nuclear Thomson scattering*. The effect is independent of nuclear energy levels and energy also. Because of the large mass of the nucleus the effect is very small but appears to have been detected. It is comparable with Rayleigh scattering for angles $\geq 90°$.

2.4.9 Nuclear Compton scattering

The *nuclear Compton scattering* takes place when the energy of the incident gamma rays is greater than 100 MeV. In this scattering, a photon interacts with individual nucleons.

2.5 Delbrück scattering

Delbrück scattering or *Elastic nuclear potential scattering* is the result of the interaction between the incident photon and the strong coulomb potential of the nucleus. The actual mechanism involves the absorption of the incident photon by an electron in a negative energy state and the subsequent production of a positron-negatron pair. Annihilation of this positron-negatron pair produces a photon with energy just equal to that of the incident photon. Therefore, Delbrück scattering is referred as coherent scattering from negative-energy electrons.

The creation of a positron-negatron pair takes place in intermediate states and gives rise to complex amplitudes. The real part is related to virtual pair production and the imaginary part to real pair production. If the incident photon energy is above 1.022 MeV, a real pair may result. When the incident photon energy is very high (> 20 MeV), creation of real pair dominates. The cross section of Delbrück scattering has a Z^4 dependence.

2.5.1 Meson production

Meson production requires photon energies above about 150 MeV. The cross section for this process is very negligible compared with other processes.

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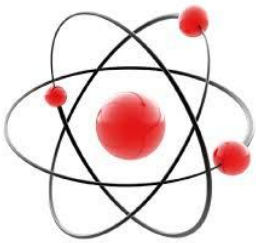
CHAPTER 3



Detectors Experimental Techniques And Specifications

3] Introduction

The development of detectors for counting and measuring the energy of particles and photons has played an vital role in the evolution of nuclear physics. Radiation of various kinds are widely utilized for non destructive inspection supervision and testing such as in medical diagnosis, material analysis industrial inspection, and other diverse fields. In such applications, radiation detectors play an essential role. There are several methods for detecting radiation. For example, typical detectors include proportional counters, semiconductor detectors that make use of gas and solid ionization respectively, radiation sensitive films, cloud chambers, and scintillation counters NaI(Tl). It have greatly contributed to radiation measurements in several fields. The need for accurate gamma ray response has prompted many studies, both experimental [1-6] and theoretical [7-16].

In scintillation counter is the combination of a scintillator and photomultiplier tube which is most commonly used detectors for practical applications.[17] Scintillation counter has many advantages over other detection methods, for an example, a wide choice of scintillator materials, good time response, high detection efficiency, and area. In this experiment, you will be introduced to the scintillation counter which is particularly suitable for detecting γ-ray photons and will use it to observe an energy spectrum of γ-rays from several nuclei and study of absorption of γ-rays. The development of scintillation counting in the few years back has depended upon the replacement of a photomultiplier tube for the human eye in the detection of small flashes of light by florescent materials traversed by radiations.

The detection of an ionizing radiation by the scintillation light produced in certain materials is oldest techniques on record. The scintillation process remains one of the most useful techniques available for the detection and spectroscopy of a wide classification of radiations. The development of detectors for counting and measuring the energy of particles and photons has played vital role in the evolution of nuclear physics. Here, we introduced to one such detector the scintillation counter which is particularly suitable for detecting gamma ray photons.

Selection of detector are depends upon the type of radiation to be detected. We are interested in gamma ray detection and the detector should have the following characteristics,[18].

1) It should be higher efficiency of detection of gamma radiations.

2) Response to electron has linearly.

3) Good resolution power.

4) It has better mechanical and electrical stability.

5) The scintillation material should be an ideal.

The scintillation detectors are classified into three groups basis on the kind of material.[19]

1) Organic scintillation detector.

2) Inorganic scintillation detector.

3) Light collection and scintillation detector mounting.

Among these detectors, the inorganic scintillation detectors are comparatively found to be the best detectors. For gamma ray detection the scintillation detector gives a typical output from PMT. That collects the light with a long time constant measuring circuit. Scintillation detectors constitute the other major class of radiation detectors used in nuclear medicine, radiology, research area etc. They have significant advantages over gas-filled detectors. Because they are solid rather than gaseous, they have much greater efficiency for interactions with gamma rays compared to gas-filled detectors. The scintillation counters have the good efficiency for fast secondary electrons produced by gamma ray interaction in material.

Here, in this work we used it to observe the energy spectrum of gamma rays from several nuclei and study the absorption of gamma rays in elements, compounds, mixture etc.

Scintillation detectors have wide application in many processes that involve detection of the gamma rays. In nuclear medicine, they are found in thyroid probes, well counters, gamma cameras, and positron emission

tomography (PET) systems. Liquid scintillation detectors operate on somewhat similar principles, but are rarely used in nuclear medicine.

Radiation detectors, like doped NaI, are generally used in the field for the determination of gamma dose rates. In most of the cases, and even though these systems generally permit one to record the full gamma spectrum between 0 to near about 3 MeV, this dose rate is computed from the count rates recorded in a limited number of "windows"[20].

Twenty years back, research programs to develop very low activity NaI(Tl) detectors have been carried out by various groups [21]: relevant improvements have been reached and the work is still in progress. Finally we concludes that NaI(Tl) is the best detector for gamma ray detection.

The statistical properties of a scintillation detector set a limit to the accuracy achievable in energy and in time measurements in nuclear physics. Theoretical investigations of the problem are present with different approximations, from several works [22-24].

3.1 Basic Principles of Scintillation

Scintillation is a general term referring to the process of giving off light; it is used both literally and figuratively. More specifically in the sciences, a scintillator is any material that can release a photon in the UV or visible-light range, when an excited electron in the scintillator come back to its ground state. These scintillation photons are detected by a photomultiplier tube (PMT) and converted into an electronic signal. Some of the terms used to describe nuclear medicine studies, such as scintigraphy and scintiscans, derive from this aspect of the detection process. The importance of many of the factors that influence the shape of the response function for NaI(Tl) Scintillators, is detailed by Mueller and Maeder[25].

3.1.1 Introduction to Scintillators

The first device which used a scintillator was built in 1903vby Sir William Crookes and used a ZnS screen.[26,27]The scintillations produced by the screen were visible to the naked eye if viewed by a microscope in a darkened room; the device was known as a spinthariscope.

Scintillator is a material that exhibits scintillation the property of luminescence[28] when excited by an ionizing radiation. Luminescent materials, when struck by an incoming particle, absorb its energy and scintillate. When an ionizing radiation interacts with matter it will excite or ionize a large number of molecules. When these molecules come to the ground state, this will sometimes give rise to the emission of a photons in the visible or near to the visible energy range. This incidence has as scientific name ‘radio luminescence’, but it is more generally called scintillation. The observation of the scintillation process was one of the first techniques used for the detection of an ionizing radiation. Plenty of transparent materials will produce some small amount of the scintillation light when hit by a high energy particle or photon, but commonly this light signal is very weak. In a few materials, the conversion of the excitation energy into the light is more efficient, and such materials are called a scintillators. If the light emission sustain for a long time after the excitation, i.e. much longer than 1 ms, this phenomenon is called as phosphorescence rather than the scintillation and the corresponding material is called as phosphor.

Many different types of materials have the ability to scintillate. The organic materials, particularly conjugated ring compounds, produce the scintillation photons in the process of de-excitation of orbital electrons. The scintillators can also be made of glass or of noble gases like xenon, helium or both of which may be used for detection of the particulate radiation. However, all of these scintillators have a low average atomic number, so therefore are not very efficient for interactions with gamma rays.

An ideal scintillation materials should possess the following properties:

1. It should transform the kinetic energy of charged particles into detectable light with a high scintillation efficiency.
2. This transformation should be linear the light yield should be proportional to deposited energy over as wide range as believable.
3. The medium should be transparent to the wavelength of its an own emission for better light collection.

4. The decay time of induced luminescence should be short so that fast signal pulses can be produced.
5. The material should be of good optical property and subject to the manufacture in sizes large sufficient to be of an interest as a practical detector.
6. Its index of refraction should be close that of glass to permit accomplished coupling of the scintillation light to the photomultiplier tube or other light sensor.

No such material simultaneously match all these criteria, so the choice of a particular scintillator is always compromise among these and related factors. The most widely applied scintillators include an inorganic alkali halide crystals, of which sodium iodide is the favorite, and an organic based liquids and plastics.

The scintillators used in nuclear medicine applications are an inorganic crystalline scintillators, always with the small amounts of impurities that help them to scintillate more efficiently. The most general inorganic scintillator employed in nuclear medicine is a thallium activated sodium iodide or NaI(Tl) developed for useful in radiation detection by Robert Hofstadter in 1948. The scintillation crystals are made to exacting durability and require exceptional care in the fabrication process. The crystal must be optically transparent, without cracks or boundaries that could cause the scintillation photons to be reflected.

The scintillation crystals are quite delicate, and can fracture under conditions of mechanical stress or intense temperature change (>5°C or 9°F per hr). dernier care must be used when working near an exposed crystal. Additionally, sodium iodide is hygroscopic, meaning that it an absorb the moisture from the air. When its happens, the crystal turns yellow and absorbs scintillation photons rather than transmitting them. Another essential characteristic of a scintillator is about its decay time, which allude how long scintillation photons are released after the radiation interaction. A long decay time means that radiation events will need to be much more widely spaced if we desire to count them in the pulse mode. The decay time for the sodium iodide is relatively long at 230 nsec, which in turn contributes to the detector's total dead time. As with any material, sodium iodide shows decreased efficiency for an interaction as the gamma ray energy increases. A comprehensive review has been published[29] of an effects of radiation damage in a number of common inorganic scintillators. It was found that the creation of color centers dominates over the damage to the scintillation mechanism in all of the scintillators studied (NaI(TI), CsI(TI), CsI, BaF2, BGO, and PbW04).

3.1.2 NaI(T1)

In 1948, demonstrated that crystalline sodium iodide, in which a trace of thallium iodide had been added in the melt, produced an exceptionally large scintillation light output compared with an organic materials that had previously received initial attention [30]. NaI(T1) is hygroscopic and will contort due to the water absorption if exposed to an atmosphere for any length of time. Crystals must therefore be "canned" in an air tight container for general use. The most notable property of NaI(T1) is of its excellent light yield. In general with the other typical inorganic scintillators, NaI(T1) shows a small but measurable non proportionality of its scintillation response with deposited an electron energy. The most desirable characteristic of sodium iodide is an excellent produce scintillation light higher than most other scintillators. This is essential because the large number of scintillation photons leads to greater precision in measuring an energy of the absorbed gamma ray.

NaI(Tl) or sodium iodide doped with thallium: NaI(Tl) is the most widely used scintillator material. It is available in a single crystal form or the more rugged polycrystalline form (used in high vibration environments, e.g. wireline logging into the oil industry). Another applications include nuclear medicine, basic research, environmental monitoring, and aerial surveys. NaI(Tl) is lot off hygroscopic and needs to be housed in an air tight enclosure.

3.1.3 Applications of scintillators

The scintillators are used by the American government as a Homeland security radiation detectors. Scintillators can be used in neutron and high energy particle physics experiments, new energy resource exploration, nuclear cameras, X-ray security, computed tomography and gas exploration. Other applications of scintillators includes CT scanners and gamma cameras in medical diagnostics, and screens in older style CRT computer monitors and televisions sets. The use of a scintillator in conjunction with a photomultiplier tube finds wide use in hand held survey meters used for detecting and measuring radioactive fouling and

monitoring nuclear material also used in the petroleum industry as detectors for gamma ray logs.. The scintillators generate the light in fluorescent tubes, to convert the ultra violet of the discharge into the visible light.

3.2 Scintillation Detector

3.2.1 Basic principle of the scintillator

Scintillates are one of the oldest kind of radiation detector because measurements could be made with photographic film. Images could be collected or intensity measurements could be made. The measurements were also made with the human eye inspecting the brightness of frequency of flashes in the scintillator. Now a days, the light output is converted into the voltage pulses that are processed in the same way as pulses from the proportional counters, semiconductor detectors etc. The entire point of scintillation detectors is that we want to produce the large light output in the visible range[17].

3.2.2 Working

The modern electronic scintillation counter was invented in 1944 by Sir Samuel Curran. In this section we discussed about working of scintillation counter**;** Gamma ray spectrometry is an analytical method that allows an identification and quantification of gamma emitting isotopes in a variety of the matrices. The scintillation counter is widely used for quantitative and qualitative measurements of photon radiation. The scintillation counter consist of a luminescent material known as scintillation reflecting layer such as an aluminum foil enclosing the luminescent substances to facilitate the collection of light, photomultiplier tube, amplifier, light pipe, voltage discriminator and electric circuit to record the output pulses. One of the most efficient methods of counting of gamma ray and measurements of their energy by using scintillation gamma ray spectrometer. The spectrometer employs a scintillation detector which is usually a thallium activated sodium iodide NaI(Tl) crystal as scintillator. The scintillator is covered from all sides by layer of reflecting material like MgO or Al_2O_3 powder. A glass window is provided at one end so that light produced by the scintillator can pass on to the photo cathode. The NaI(Tl) crystals are generally in the form of right circular cylinder.

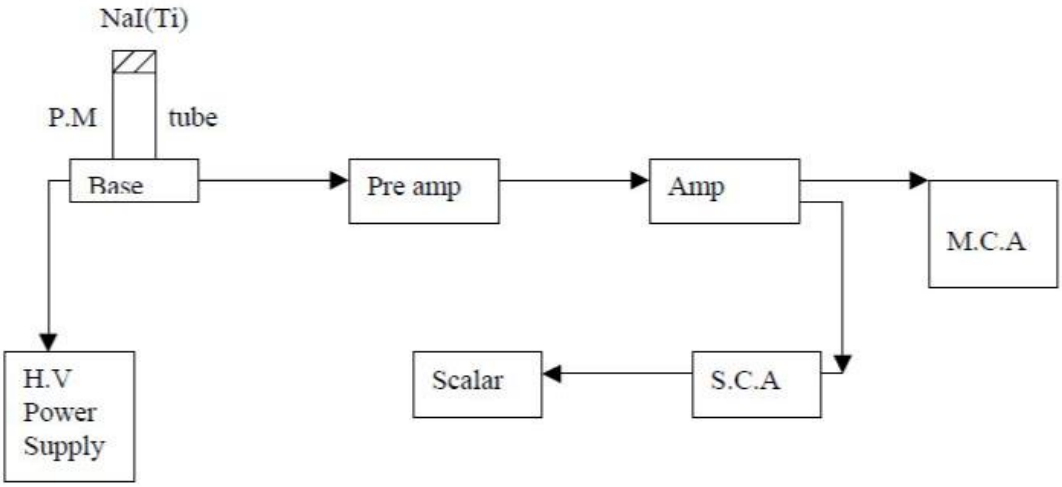


Figure-3.1a: Nuclear electronic system of a scintillation spectrometer

There are varies substances (organic and inorganic) which emits the light flashes or scintillation when charged particles ray or gamma ray go through them. These substances are called a scintillator. When a gamma ray enters the crystal and undergoes an interaction, it produces one or more secondary electrons with high kinetic energy. In one single measurement and with little sample preparation, gamma ray spectrometry allows you to detect several gamma emitting radio nuclei in the sample. The measurement gives a spectrum of lines, the amplitude of which is the proportional to the activity of the radionuclide and its position on the horizontal axis gives an idea on its energy. When a charged particle strikes on scintillator, then its atoms are excited and photons are emitted. These are directed at the photocathode of photomultiplier tube's, which emits electrons by photoelectric effect. These electrons are an electro statically accelerated and focused by an electrical potential so that they strike the first dynode of the tube. The variance introduced by the

photomultiplier tube can be a significant contribution. Uniformity of photoelectron collection from the photocathode is an important factor, as is the statistical fluctuation in the electron multiplication. There is considerable variation in the performance of different photomultipliers in this regard, even among different samples of the same design. For example, in a study of several hundred PM tubes sampled from a few standard types, [31] observed an average NaI scintillator energy resolution of 10-11 % for 57Co radiation (122 keY).

The best PM tube included in the sample, however, gave a corresponding value of 8.5%. The impact of a single electron on the dynode releases the number of secondary electrons which are in turn accelerated to strike the next dynode. Each subsequent dynode effect releases further electrons, and so there is a current amplifying effect at each dynode stage. Every stage is at a higher potential than the previous to provide the accelerating field. The resultant output signal at the anode is in the form of a measurable pulse for every photon detected at the photocathode, and is passed to the processing electronics. The pulse carries information about an energy of an original incident radiation on the scintillator. Thus both the intensity and energy of the radiation can be measured. The scintillator must be in complete darkness so that visible light photons do not mire the individual photon events caused by an incident ionizing radiation. To achieve this a thin opaque foil, such as an aluminized Mylar, is always used, though it must have a low sufficient mass to prevent undue the attenuation of an incident radiation being measured. Thus, a scintillation detector can be used not only for counting but also for an energy analysis. Because of its versatility, there has been considerable development of a scintillation detectors.

3.2.3 Principle of operation

A scintillation detector or counter is obtained when a scintillator is coupled to an electronic light sensor such as a photomultiplier tube (PMT), photodiode or silicon photomultiplier. PMTs absorb the light emitted by the scintillator and reemit it in the form of an electrons through the photoelectric effect. The subsequent multiplication of those electrons sometimes called a photoelectrons results in an electrical pulse which can be then an analyzed and yield meaningful information about the particle that an originally struck the scintillator. The vacuum photodiodes are similar but cannot amplify the signal while silicon photodiodes, on the other hand, detect the incoming photons by the excitation of the charge carriers directly into the silicon. Silicon photomultipliers consist of an array of photodiodes which are reverse biased with enough voltage to operate in avalanche mode, enabling each pixel of an array to be sensitive to single photons.

Application of scintillation counter

Scintillation counter is an analytical method that allows the identification and quantification of gamma emitting isotopes in a variety of matrices. In one single measurement and with little sample preparation, gamma ray spectrometry allows you to detect several gamma emitting radio nuclei in the sample. The measurement gives a spectrum of lines , the amplitude of which is proportional to the activity of the radionuclide and its position on the horizontal axis gives an idea on its energy.

Applications of gamma ray spectrometry include

• Monitoring in nuclear facilities,

• Health physics,

• Nuclear medicine,

• Research in materials,

• Bioscience,

• Environmental science, and

• Industrial uses of radioisotopes.

3.2.4 Photomultiplier Tube

Among the photosensitive devices in use today, the photomultiplier tube (or PMT) is a versatile device that provides extremely high sensitivity and an ultra-fast response. A typical photomultiplier tube consists of a photo emissive cathode (photocathode) followed by focusing electrodes, an electron multiplier and an electron collector (anode) in a vacuum tube, as shown in Figure 3.2a, 3.2b and actual PMT photographs is in

figure 7.9c. When gamma photons enters the photocathode, the photocathode emits photoelectrons into the vacuum. These photoelectrons are then directed by the focusing electrode voltages towards the electron multiplier where electrons are multiplied by the process of secondary emission. The multiplied electrons are collected by the anode as an output signal. Because of secondary-emission multiplication, photomultiplier tubes provide extremely high sensitivity and exceptionally low noise among the photosensitive devices currently used to detect radiant energy in the ultraviolet, visible, and near infrared regions. The photomultiplier tube also features fast time response, low noise and a choice of large photosensitive areas.

- A photomultiplier converts light into an electrical signal, then amplifies that signal to a useful level by emission of secondary electrons. Figure 1.1 shows the essential elements:
- A photocathode which converts light flux into electron flux;
- An electron optical input system which focuses and accelerates the electron flux;
- An electron multiplier consisting of a series of secondary-emission electrodes (dynodes); and, finally
- An anode which collects the electron flux from the multiplier and supplies the output signal.

3.2.4.1 Photocathode

The cathodes normally used in photomultipliers are made of a deposited photoemissive semiconductor. There are two main kinds:

1. Semi-transparent cathodes, the most widely used, are deposited on the inside of the input window; electrons are emitted from the side opposite to the incident light. The cathode can be large (from ten to a few hundred millimetres in diameter) and the window on which it is deposited can be flat or curved.
2. An opaque cathodes are deposited on a metal electrode inside the tube. Electrons are emitted from the illuminated side. The area is usually limited to a few square centimetres because of the size of the focusing electrodes.

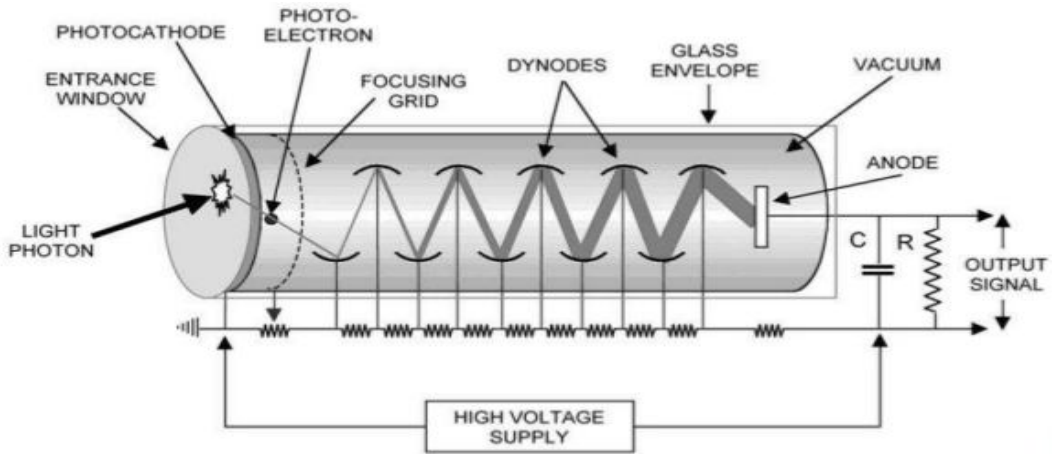


Figure-3.1b: The schematic view of Photomultiplier tube..

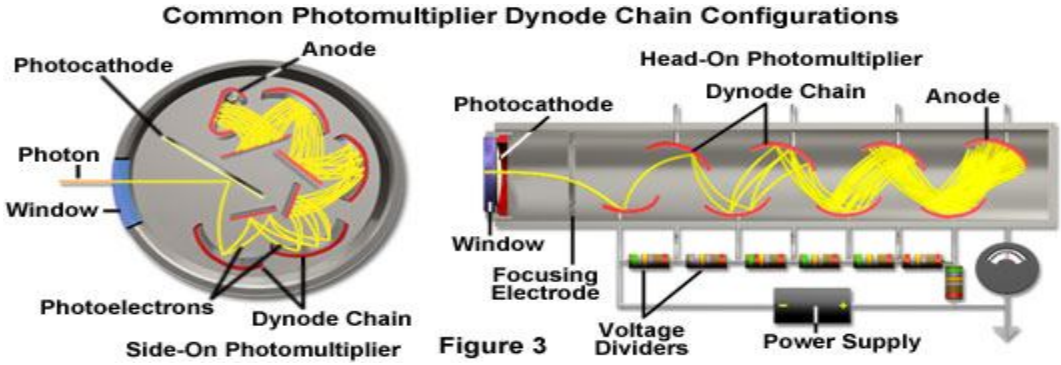


Figure-3.1b: The common photomultiplier dynode chain configurations.

3.2.5 Multichannel Analyzer(MCA)

The multichannel analyzer (MCA) is an important laboratory instrument. The multichannel analyzer (MCA) is a circuit which capable of setting of large number of individual windows (Channels) to look at complete spectrum simultaneously. The MCA can operate in several modes, including pulse-height analysis, voltage sampling, and multichannel scaling. It sorts and collects the gamma-ray pulses coming from the main amplifier to build a digital and visual representation of the pulse-height spectrum produced by the detector. MCA can measure distributions of input signals consisting of pulses. It operates in two different modes: pulse height analyzer (PHA) mode, and multichannel scaler (MCS) mode. In PHA mode, the input pulses are sorted into bins (channels) according to their amplitude, while in MCS mode they are sorted according to the time when they arrive. The MCA provides a visual display of the resulting distributions and usually can output the data to a printer or computer for further analysis.

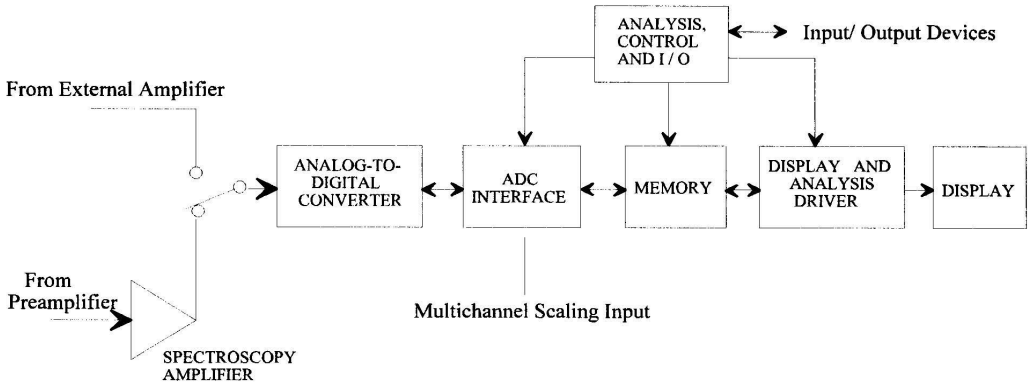


Figure-3.2: MCA functional block diagram.

Normally MCA consists of 1024 channels, and information is acquired simultaneously from each channel and displaced as an energy spectrum. In this experiment, the MCA will be used in PHA mode to investigate nuclear γ-ray spectra.

MCA are commonly used over a single channel analyzer, which uses a microprocessor technology with high speed, high density, smaller size easily computable, and semiconductor memories. The interfaces of output pores of control units are lead to cathode tube in order to display output in terms of channel verses counts.

3.3 Narrow Beam Geometry

The narrow beam geometry prevents any scattered radiation or secondary particles from reaching the detector [32]. A collimated beam of gamma radiation penetrates through varying thicknesses of the absorber to produce the narrow beam geometry. Aboutone centimeter diameteror even less than that hole was drilled into a thick lead block to create the collimator. This produces a narrow beam of γ-rays approaching the attenuator. The lead collimator was tested for any γ-ray leakage. The source was placed at certain distance away from the detector and the attenuators were placed in between the detector and the source. The distance between source and detector is varied and optimized for good attenuation. The collimated beam was then attenuated and allowed to fall on the detector after passing through the attenuator. The intensity of the attenuated beam was measured by the detector. Background counts were collected and the net count was obtained by subtracting time-normalized background counts.

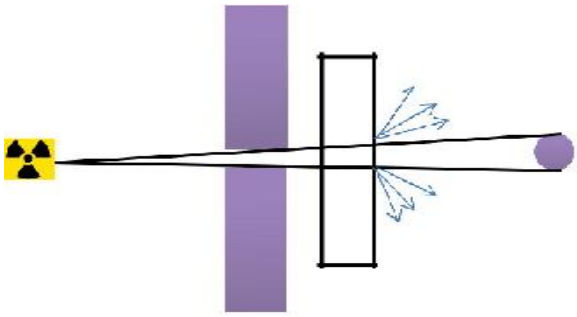


Figure-3.3: Narrow beam geometry

3.3.1 Broad Beam Geometry

In broad beam geometry, there is no collimator used as in the narrow beam geometry. Broad beam geometry allows scattered and secondary particles to reach the detector in addition to the primary beam. Ideally, every scattered and secondary particle generated in the attenuator by a primary particle will strike the detector.

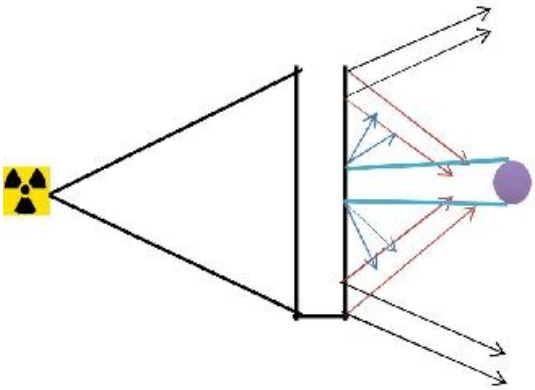


Figure-3.4: Broad beam geometry.

3.4 Experimental Techniques

In this section we describe about some details about instruments, some useful experimental quantities, etc.

The gamma ray spectrometry system finds many applications in varies research areas. Highly recommended for the various health physics labs of the nuclear power plants, an environmental survey labs and other labs for basic and applied research purposes, teaching labs of nuclear sciences and Engineering labs.

Multi-Channel Analyzer (MCA)

The multichannel analyzer (MCA) is the heart of most experimental measurements. It performs the essential functions of collecting the data, providing a visual monitor, and producing output, either in the form of final results or data for later analysis. The major requirement of MCA is for the nuclear pulse height analysis in an energy spectroscopy. The USB MCA presented here, incorporates state of art technologies such as FPGA, USB bus interface and the precision analog electronics to meet the stringent system requirements in the nuclear pulse spectroscopy. The resolution supported by the USB-MCA ranges is from 256 channels to 8K channels which is selectable via software, making it suitable for all of the spectroscopy applications from low resolution (e.g. NaI-PMT) to high resolution (e.g. HP-Ge) systems. The USB bus interface of the MCA gives an excellent connectivity with most of the new PCs and laptop computers. The PHAST application software provided with the USB-MCA, seamlessly integrates with the hardware, featuring a range of standard functions required for an acquisition and analysis.

3.5 Description, Specification Of The Constituent Units

3.5.1 Minibin And Power Supply

MINI BIN : Accommodates Six / Eight single bit modules or combination of multiple widths with an amphenol connectors. Minibin is primarily designed with an objective of conserving bench space and to achieve significant saving into cost of the Minibin based systems.

Figure-3.5: Minibin, power supply (Nuclear Instrumentation Methods)NIM module electronic setup.

3.5.2 High Voltage Unit

The High Voltage Power Supply unit supplies the necessary high voltage to the detecor and the necessary voltages to the rest of the system components. These units are usually able to supply up to 5000 V.

An output voltage variable continuously from 0V to 1500 volts.

- An output current (max) 1mA.
- Load and line regulations: Better than 0.005% of full scale.
- Indefinite over load and short circuit protections and self recovery.
- An output ripple less than 20mv.
- Dimensions : Single / Two bit module.

Figure-3.6: High Voltage Unit.

3.5.3 Spectroscopy Amplifier

The spectroscopy amplifier is a high performance nuclear pulse shaping amplifier, ideally suited for use with all kinds of detectors like germanium, silicon surface barrier and Si(Li) detectors. This is a single width NIM module with pile up rejecter (PUR), gated baseline restorer (BLR), auto threshold, diode limited unipolar output, and count rate output as some of the key features.

Figure-3.7: Spectroscopy Amplifier.

Designed into it. Some of the important applications of spectroscopy amplifier involve nuclear pulse height spectroscopy, nuclear timing spectroscopy, counting systems etc.

3.5.4 Scintillation Detectors

The wide range of NaI Scintillation Detectors of different sizes both with flat & well type crystals, to meet the requirements of wide range of users for Gamma ray spectrometry measurements. The scintillation detectors offered includes 2"x2" NaI integral assemblies with built in pre-amplifiers. These detector assemblies give excellent stability, superior performance and good resolution in the range of 8.0% to 9.5% for gamma active source Cs^{137} and of other sizes can be offered against user specific requirements also. The following table3.1 indicate the detecter types and and specifications, in the present research work we are used 2"x2" which is in bold shade.

Table 3.1 Detecter types and its specifications.

Important			**Detector Type**	
Specifications				
Flat/Well type NaI crystal	SD 151		**SD 152/SD152 W**	SD 153/ SD 153W
Crystal Sizes	1" x 1"		**2" x 2"**	3" x 3"
a. Flat crystal b. Well Size(applicable for Photo multiplier	---		**0.656" dia x 1.546" deep**	0.656" x 1.546" deep
Photo multiplier	R6095 of Hamamatsu or its equivalent		**EMI 9857 or 9266 or its equivalent**	EMI 9305 or its equivalent
Resolution (Better than)	8.5 %		**8.5 %**	9.5 %
Pre-amplifier	Built – in		**Built – in**	Built – in
Gain (Approx.)	25		**25**	25
Noise (RMS. referred to input)	Less than 50V		**Less than 50 V**	Less than 50 V
Operating Voltage	600 to 900 V		**700 to 900V**	700 to 900V
Out put	Positive Tail Pulse		**Positive Tail Pulse**	Positive Tail Pulse
Output impedance	90 Ohms		**90 Ohms**	90 Ohms
Power Requirement (Typical)	-12V @ 12 mA		**-12V @ 12 mA**	-12V @ 12 mA

3.5.5 Gamma Reference Standard Set (Gs290)

Gamma Reference Standard Set consists of a set of 5 Gamma sources evaporated and sealed on 25mm dia x 5mm plastic disc covering 6 photo peak energies in the range of 3 to 5 micro curie. A reference chart for this is given below.

Fig-3.4: Gamma Reference Standard Set with sources.

3.6 Production Of Radioisotopes

Most of the radioisotopes found in nature have relatively long half life's. They also belong to elements which are not handled well by the human body. As a result medical and research applications generally require the use of radioisotopes which are artificially produced. The type of radioisotope of value to nuclear medicine imaging should have characteristics which keep the radiation dose to the patient as possible as low. For this reason they generally have a short half life and emit only gamma rays that is no alpha or beta particle emissions. From an energy point of view the gamma ray energy should not be so low that the radiation gets totally absorbed before an emerging from the patient's body and not too high that it is difficult to detect. For this factor most of the radioisotopes used emitting gamma rays of medium energy, that is between about 100 keV and 200 keV. Finally the radioisotope needs to be an incorporated into some form of radiopharmaceutical it should also be capable of being produced in a form which is amenable to the chemical, pharmaceutical and sterile processing. The production methods considerable are nuclear fission, the radioisotope generator and nuclear bombardment.

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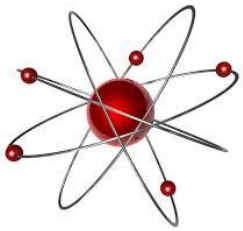
CHAPTER 4



Theory, Structure, Results, Conclusion of Amino Acids and Fatty Acids.

4] Introduction

Investigation of radiation and its effects on biologically important molecules find immense applications in the field of medical physics, radiology and radiation biophysics. Knowledge of absorption, penetration, attenuation and photon interactions with biological material such as amino acids, fatty acids, lipids and carbohydrates is essential in radiation medicine and biology, nuclear technology and space research[1]. The study of photon interactions with matter is important and the data on the transmission and absorption of X-rays and gamma rays in biological shielding and dosimetric materials assumed great significance by virtue of their diverse applications in the field of medical physics and medical biology [2]. A variety of physiological functions inside living system are performed by complex molecules such as fatty acids, carbohydrates, and proteins compose of H, C, N, and O element. Biomolucules are play a vital role in biology, chemistry etc. In this chapter we are discussed about amino acids and saturated fatty acids. Amino acids are biologically essential organic compounds which containing an amine ($-NH_2$) and carboxylic acid (-COOH) functional groups, generally along with a side-chain specific to each amino acid[3,4,5]. Amino acids are used for a plenty of applications in industry, chemical laboratory but their important use is as additives to an animal feed. 20% percent of the our human body is made up of protein. It plays a vital role in almost all biological processes and an amino acids are the building blocks of it. A large proportion of our cells, muscles and tissue is made up of an amino acids, meaning they carry out many essential bodily functions, such as giving cells their structure. They also play a key role in the transport and the storage of nutrients.

A saturated fat in which the fatty acids are all have single bonds. They are made up of long chains of carbon (C) atoms. Some carbon atoms are attached by single bonds (-C-C-) and others are by double bonds (-C=C-)[6]. Double bonds can react with hydrogen to form single bonds. In saturated fatty acids, the second bond is broken up and each half of the bond is attached to (saturated with) a hydrogen atom. Most of an animal fats are saturated. Generally the fats of plants and fish are unsaturated[6]. Saturated fats tend to have higher melting points as compare their corresponding unsaturated fats.

A large number of photon attenuation measurements and calculations have been made for different materials and the attenuation coefficient has been studied as a function of different parameters**.** The attenuation coefficient measurement studies have to give more attention to materials of biologically interest in the energy range 5-1500keV. Mass attenuation coefficient (μ_m), molar extinction coefficient and mass energy absorption coefficient (μ_{en}/ρ) of photons in matter play an important role in understanding attenuation and energy absorption. Gamma radiations in the energy region above 200keV up to about 1500keV interact with matter predominantly by photoelectric effect and Compton Effect. Hubbel [7] carried out a review of photon interaction cross section data in the medical and biological context.

It is often found convenient to represent the gamma-ray interaction properties of a composite material consisting of a number of different elements in varying proportions by an effective atomic number Z_{eff}. Which is depends on the incident energy as well as the atomic number of the constituent elements. It indicates the number of electrons of the material that actively participate in the photon-atom interaction. The Z_{eff} is used frequently in calculations of mass energy absorption coefficients and Kerma in radiation dosimetry [8]. This parameter is also used in the calculation of Compton profiles of complex materials and hence may yield valuable information about the chemical environment that surrounds the atom in a quantitative manner pointed out that there is a different atomic number for each interaction process in a complex material[9].

In order to make use of the fact that scattering and absorption of gamma-radiations are related to the density and effective atomic numbers of the material, knowledge of the mass attenuation coefficients is of prime importance And its related parameters can be derived such as the mass energy absorption coefficient, the total interaction cross- section, the effective atomic number and the effective electron density Also it measure the average number of interactions between incident photons and matter that occur in a given mass per unit area thickness of the substance encountered. Early calculations of effective atomic numbers were based on parameterization of the photon interaction cross-section by fitting data over limited ranges of photon energies and atomic number [1]. Today, using an accurate databases of photon interaction cross-sections and interpolation programs [10,11,12]. It is possible to calculate effective atomic numbers with much improved accuracy and information content over wide ranges of photon energies and elemental

composition. simple and widely used method of obtaining Z_{eff} of a composite material consisting of different elements in definite proportions is based on the determination of total attenuation coefficients for gamma-ray interactions by the transmission method. In the present work the method of deriving effective atomic numbers in composite materials was followed by using the experimental results of mass attenuation coefficients. Experimental results were compared with theoretical values. Photon energies from 1500 keV down to about 5 keV are widely used in medical and biological applications [7] especially during diagnosis and therapy. A thorough knowledge of the nature of interaction of these biologically important complex molecules such as amino acids is desirable over this energy region. Hence, in recent years this has motivated many investigators over the years to determine the total attenuation cross-sections as well as composition dependent quantities such as effective atomic numbers (Z_{eff}) and effective electron densities (N_{eff}) of such complex molecules of biological interest in this energy region by employing different methods[13-22]. There have been a number of experimental and theoretical investigations [23-26].

Theoretical values for the mass attenuation coefficients can be found in the tabulation [27]. A convenient alternative to manual calculations using tabulated data is to generate attenuation data as needed using a computer. For this purpose Berger and Hubbell [28] developed XCOM software for calculating mass attenuation coefficients or photon interaction cross-sections for any element, mixture, compound for a wide range of energies.

Selection of material for radiation shielding and protection needs an accurate assessment of interaction parameters [29]. In addition to μ_m and μ_{en}/ρ, the parameters such as Zeff (effective atomic number), σ_{tot} (total attenuation cross section), ε (molar extinction coefficient), and $\sigma_{t,el}$ (effective electronic cross section) of complex molecules of biological interest also play an important role in understanding dosimetry of photons. The determination of mass attenuation coefficients for complex biological molecules such as Lipids, Carbohydrates, Proteins, Fats and Oils composed of H, C, N and O elements in varying proportions[30]. The molar extinction coefficient for fatty acids [10,17]. Investigation of photon attenuation in elements and arbitrary materials [11,28].

There have been a great number of experimental and theoretical investigations to determine mass attenuation coefficients for complex biological molecules such as Lipids, Carbohydrates, Proteins, Fats and Oils composed of H, C, N and O elements in varying proportions investigated fatty acids in the energy region 81-1330 keV [17]. Total attenuation cross-sections for sugar and amino acids[18,19]. Recently have determined the effective atomic numbers of several bio-molecules[20,31]. Measurements on the sample containing H,C and O in the energy range 54-1333 keV have been reported by [32]. The resolution of discrepancies in tables of photon attenuation coefficients[23]. The calculation of Z_{eff} is based on the parameterization of the photon interaction cross-section by fitting data over limited ranges of photon energies and atomic number[1].The measurement of the effective atomic number[33]. Radiation mass attenuation coefficients, the atomic cross-sections, the effective atomic numbers and the molar extinction for H, C, N and O based amino acids in the energy range 122 keV to 1330 keV and then compared these experimentally evaluated parameters with theory using XCOM program.

4.1 Theory

In this section we summarize some theoretical relations that have been used for the determination of mass attenuation coefficients in the present work. When a monochromatic beam of gamma photons is incident on a target some photons are emitted due to the dominant interaction processes and therefore the transmitted beam is attenuated. The extent of attenuation depends on given elemental target. This attenuation of the beam is described by the following equation:

$$I = I_0 e^{-\mu t} \qquad (4.1)$$

Where I_0 and I are the incoming and attenuated photon intensities respectively μ (cm^{-1}) is the linear attenuation coefficient of the material and t (cm) is the sample thickness. Rearrangement of Eq. (1) yields the following equation for the linear attenuation coefficient:

$$\mu = \frac{1}{t}\ln\left(\frac{Io}{I}\right) \tag{4.2}$$

In Eq. (2) The mass attenuation coefficients μ/ρ (cm^2 g^{-1}) for the samples were obtained from Eq. (3) by using the density of the corresponding samples:

$$\mu_m = \frac{\mu}{\rho}\left(cm^2 gm^{-1}\right) = \frac{1}{\rho t}\ln\left(\frac{Io}{I}\right) \tag{4.3}$$

Where ρ (g/cm^3) is a measured density of the corresponding sample and I_0 and I are the unattenuated and attenuated photon intensities respectively.The values of μ_m were then used to determine σ_{tot} by the following relation:

$$(\sigma_{tot}) = \mu_m (M / N_A) \tag{4.4}$$

Where, M= $\sum_i n_i A_i$ is the molecular weight of the compound, N_A is the Avogadro's number, n_i is the total number of atoms in the molecule and A_i is the atomic weight of the i^{th} element in a molecule.

Finally, the values of ε were determined using the following relation:

$$\varepsilon = 0.4343 N_A \sigma_{tot} \tag{4.5}$$

4.2 Amino acids, Saturated fatty acids and its structures

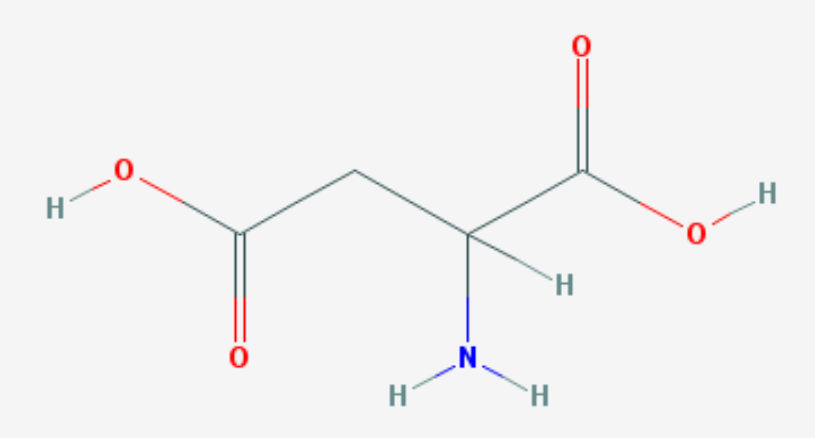
Here, the structures of amino acid and fatty acids listed from figure a-*l*

4.2.1 Amino acids

1] DL-Aspartic Acid-LR

The aspartic acid is an α-amino acid which is used in the biosynthesis of proteins. It is a semi essential for humans, meaning that the body can synthesize it from oxaloacetate. the aspartate is also a metabolite in an urea cycle and participates into gluconeogenesis. The name "aspartic acid" can refer to either enantiomer or a mixture of two[44]. These of two forms, only one, "L-aspartic acid", is directly incorporated into the proteins.

DL-Aspartic Acid-LR structure is as follow:

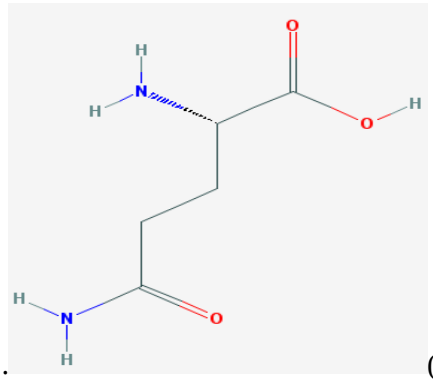


(a)

2] L-glutamine

A glutamine is the most general amino acid found in our muscles. Over the 61% of skeletal muscle is a glutamine. The glutamine consists of 19% nitrogen, making it the primary transporter of nitrogen into our muscle cells. It is a donor of carbon and nitrogen and helps restore the glycogen which restores energy. The glutamine is the most essential component of muscle proteins, and helps to repair and building of muscle and may serve to boost immune system. The L-glutamine is one of the most abundant amino acid in the bloodstream and it makes up 30-35 percent of the amino acid nitrogen in our blood.

L-glutamine structure is as follow:

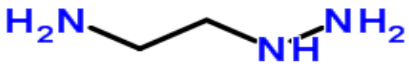


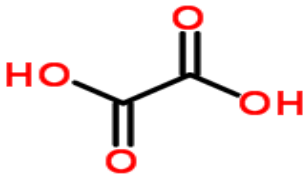
. (b)

3] Creatine Monohydrate LR

The creatine is nearly similar to protein in that it is the nitrogen containing compound. In the nutritional biochemistry area it is known as a “non-protein” nitrogen. It can be obtained in the food (typically meat and fish) or formed endogenously (in the body) from the amino acids glycine, arginine, and methionine.

Creatine monohydrate LR structure is as follow:



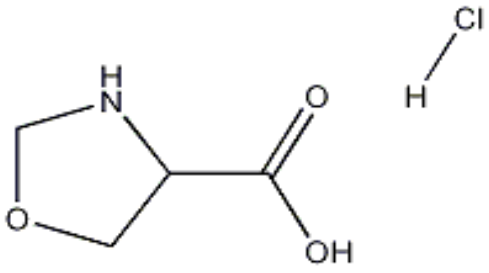


(c)

4] Creatinine Hydrochloride

The creatine is the naturally occurring chemical which found within the body, genarally in the muscles. It is also found in the certain foods and may be obtained through the supplementation. It is widely used among an athletes in a wide range of sports for the primary purpose of improving exercise performance and an increasing the muscle mass. There is scientific evidence that short term creatine use can increase the maximum power and performance in thigh intensity anaerobic repetitive work (periods of work and rest) by 5 to 15%[45].

Creatinine Hydrochloride structure is as follow:

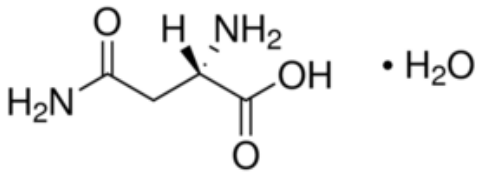


(d)

5] L-Asparagine Monohydrate

The asparagine is an α-amino acid that is also used in the biosynthesis of proteins. It contains an α-amino group and an α-carboxylic acid group, and a side chain carboxamide, by classifying it as a polar (at physiological pH), an aliphatic amino acid. It is a non essential in humans, because the body can synthesize it.

L-Asparagine Monohydrate structure is as follow:

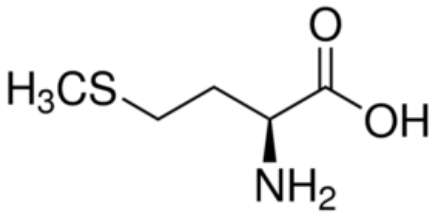


(e)

6] L-Methionine LR

The methionine is also an α-amino acid and used for the biosynthesis of proteins. It also contains an α-amino group, an α-carboxylic acid group, and a S-methyl thioether side chain, classifying it as a non-polar, an aliphatic amino acid. It is essential in humans, because the body cannot synthesize it and thus it must be obtained from the diet.

L-Methionine LR Structure as follow:



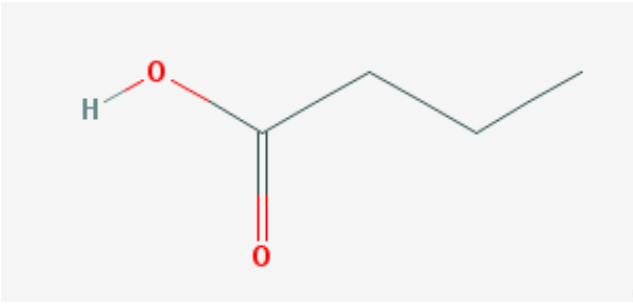
(f)

4.2.2 Saturated Fatty Acids

1) Butyric acid

The butyric acid is a fatty acid occurring in the form of esters in an animal fats. Triglyceride of butyric acid makes up 3–4% of butter. When butter goes to rancid then butyric acid is liberated from the glyceride by hydrolysis, It have an unpleasant odor. Butyric acid is the medium strong acid that reacts with the bases and the strong oxidants, and attacks many metals[3]. It is an oily, colorless liquid that is an easily soluble into the water, ethanol, and ether, and can be separated from an aqueous phase by saturation with salts such as calcium chloride. It is an oxidized to carbon dioxide and an acetic acid using the potassium dichromate and the sulfuric acid, while an alkaline potassium permanganate oxidizes it to carbon dioxide. It is also used in the preparation of various butyrate esters. As a consequence, they are used as food, the perfume additives, and an animal feed supplement due to the ability to reduce pathogenic bacterial colonization[4].

Butyric acid structure is as follow:

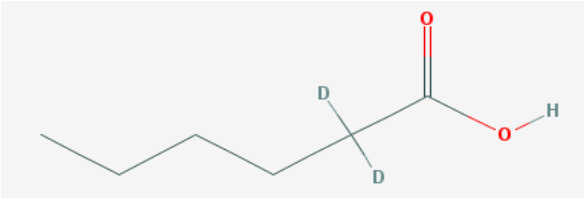


(g)

2) Caproic acid

The caproic acid is a colorless oily liquid having an odor such as fatty, cheesy, waxy, and like that of goats[5] or other barnyard animals. It is a fatty acid which found naturally in various animal fats and oils, and is one of the chemicals that gives the decomposing fleshy seed coat of the ginkgo its characteristicunpleasant odor. It is also one of the components of vanilla. The primary use of this acid is in the manufacture of its esters for an artificial flavors, and in the manufacture of hexyl derivatives, such as hexylphenols[5].

Caproic acid structure is as follow:

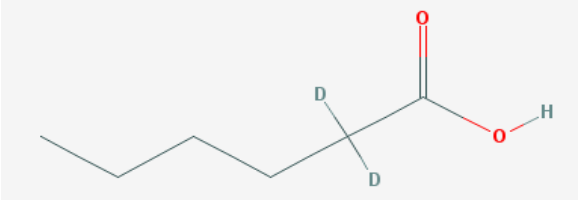


(h)

3) Enanthic acid

It is also an oily liquid with an unpleasant, rancid odor [5]. It is slightly soluble into water, but soluble into an ethanol and an ether. The methyl ester of ricinoleic acid, obtained from castor bean oil, is the main commercial precursor to heptanoic acid. It is pyrolyzed to the methyl ester of an undecenoic acid and heptanal, which is then air oxidized to the carboxylic acid. Approximately around 20,000 tons were consumed in Europe and US in 1980[6].

Enanthic acid structure is as follow:

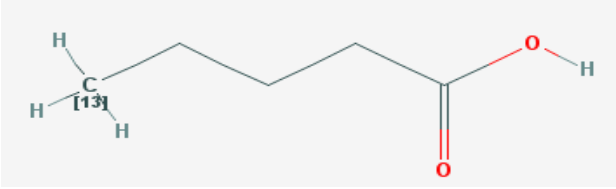


(i)

4) Valeric acid

Valeric acid is found naturally in the perennial flowering plant valerian(*Valeriana officinalis*). Its primary use is in the synthesis of its esters. The volatile esters of valeric acid tend to have pleasant odors and are used for the perfumes and cosmetics.

Valeric acid structure is as follow:

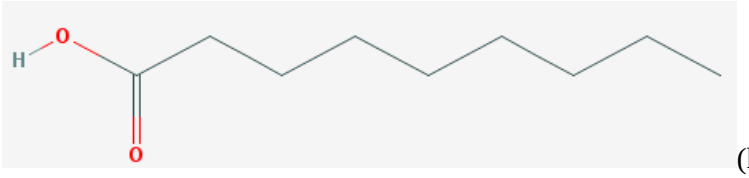


(j)

5) Pelargonic acid

It is a clear, oily liquid with also an unpleasant, rancid odor. It is nearly insoluble in water, but soluble in chloroform, ether, and hexane. The is a fatty acid which occurs naturally as esters in the oil of pelargonium. Synthetic esters, such as methyl nonanoate, are used as for the flavorings. It is also used in the preparation of plasticizers and lacquers.

Pelargonic acid structure is as follow:



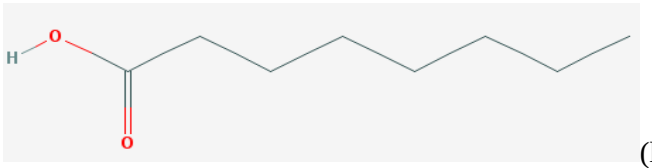
(k)

6) Caprylic acid

It is a compounds are found naturally in the milk of several mammals, and as a minor constituent of coconut oil and palm kernel oil[7]. It is an oily liquid that is minimally soluble in water with a slightly unpleasant rancid smell and taste[8]. Caprylic acid is used for commercially in the production of an esters used for perfumery and also in the manufacture of dyes. It is an antimicrobial pesticide used for as a food contact surface sanitizer in the commercial food handles establishments on dairy equipments, food processing

equipments, breweries, wineries, and beverage processing plants. It is also used for as disinfectant in health care facilities, schools/colleges, animal care/veterinary facilities, industrial facilities, office buildings, recreational facilities, restaurants, and hotels/motels. In addition, it is used as an algaecide, bactericide, and fungicide in nurseries, greenhouses, garden centers, and interiorscapes on ornamentals.

Caprylic acid structure is as follow:



(l)

4.3 Results and Discussion

The values of mean atomic number calculated from the chemical formulae of amino acids and fatty acids studied in the present work are displayed in Table 1, 5. The experimentally measured mass attenuation coefficient μ_m (cm^2/g) for the six amino acids; DL-Aspartic Acid-LR($C_4H_7NO_4$),Lglutamine($C_4H_{10}N_2O_3$),CreatineMonohydrateLR($C_4H_9N_3O_2H_2O$),Creatinine Hydrochloride ($C_4H_7N_3O.HCl$) L-Asparagine Monohydrate($C_4H_9N_3O_2H_2O$), L-Methionine LR($C_5H_{11}NO_2S$) and six fatty acids; butyric acid ($C_4H_8O_2$), caproic acid ($C_6H_{12}O_2$), enanthic acid ($C_7H_{14}O_2$), caprylic acid ($C_8H_{16}O_2$), pelargonic acid ($C_9H_{18}O_2$) and valeric acid ($C_5H_{10}O_2$) at 122,360, 511,662, 1170,1275 and 1330 keV. And the typical plot of μ_m versus energy E for DL-Aspartic Acid and butyric acid is displayed in Fig. 2, 6 and The Fig. 6.1, 6.4 also includes the variation of theoretically determined μ_m values versus energy. It is clearly seen that the mass attenuation coefficient (μ_m) depends on photon energy and decreases with increasing photon energy. The experimental (μ_m) values agree with theoretical values calculated using the XCOM program based on the mixture rule. The total experimental uncertainty of the (μ_m) values depend on the uncertainties of I_0 (without attenuation) and I (after attenuation), mass thickness measurements and counting statistics. Typical total uncertainty in the measured experimental (μ_m) values is estimated to be 2-3 %. The behavior of σ_t and ε with photon energy shows almost similar behavior to (μ_m) plots. It is clearly observed that σ_t and ε initially decrease and tend to be almost constant as a function of gamma-ray energy.

In the case if fatty acids, The values of mean atomic numbers calculated from the chemical formulae of fatty acids studied in the present work are displayed in Table 5. The experimentally measured values of μ_m (cm^2/g) for some saturated fatty acid such as butyric acid ($C_4H_8O_2$), caproic acid ($C_6H_{12}O_2$), enanthic acid ($C_7H_{14}O_2$), caprylic acid ($C_8H_{16}O_2$), pelargonic acid ($C_9H_{18}O_2$) and valeric acid ($C_5H_{10}O_2$) at 122, 356, 511, 662, 835, 1173, 1275 and 1332 keV photon energies. It is clearly seen that the μ_m depends on photon energy and decreases with increasing photon energy. The total experimental uncertainty associated with the μ_m values depend on the uncertainties of I_0 (without attenuation), I (after attenuation), mass thickness measurements and counting statistics. Typical total uncertainty in the measured experimental (μ_m) values is estimated to be 2-3%. Measured values of σ_{tot} and ε for the presently studied amino acids and fatty acids are shown in Table 3, 4 and fig.6.2, 6.3 and 6.5, 6.6, respectively. The typical plots of σ_{tot} and ε as a function of photon energy (E) are displayed in Figs.(6.2, 6.3 and 6.5, 6.6) respectively. The behavior of σ_{tot} and ε with E shows almost similar behavior μ_m versus E. Calculations of ε [17] were carried out using the XCOM program and our calculations are based on Win-XCOM which is updated version of XCOM. So, in this work more accurate results with less than 1% error are obtained.

4.4 Conclusions

1] The present experimental study has been undertaken to determine linear attenuation coefficient(μ), mass attenuation coefficient (μ_m), mass energy absorption coefficient (μ_{en}/ρ) total attenuation cross section (σ_{tot}), and molar extinction coefficient (ε) for six saturated fatty acid and six amino acid samples. It has been found that the μ_m is useful and sensitive physical quantity to determine the σ_t , ε for H, C, N and O based biological compounds.

2] The total attenuation cross sections of some amino acids with low-and medium Z elements such as DL-Aspartic Acid-LR($C_4H_7NO_4$),L-glutamine ($C_4H_{10}N_2O_3$),Creatine Monohydrate LR ($C_4H_9N_3O_2H_2O$),

Creatinine Hydrochloride ($C_4H_7N_3O.HCl$) L-Asparagine Monohydrate($C_4H_9N_3O_2H_2O$), L-Methionine LR($C_5H_{11}NO_2S$), butyric acid ($C_4H_8O_2$), caproic acid ($C_6H_{12}O_2$), enanthic acid ($C_7H_{14}O_2$), caprylic acid ($C_8H_{16}O_2$), pelargonic acid ($C_9H_{18}O_2$) and valeric acid ($C_5H_{10}O_2$) at photon energies of biomedical importance emitted by the radio isotopes namely C_o^{57},Ba^{133},Na^{22},Cs^{137} have been measured.

3] In the interaction of photons with matter, μ_m values are dependent on the physical and chemical environments of the samples. The mass attenuation coefficient (μ_m) values were found to decrease with increasing photon energies.

4.5 Theoretical Analysis

Several works on the radiological parameters such as (μ, μ_m, σ_{tot}, ε, Z_{eff}, μ_{en}/ρ, $\sigma_{t,a}$ and $\sigma_{t,el}$) have been reported in literatures [42-46](McCulloug, 1975; White, 1977; Hawkes and Jackson, 1980; Zaidi, 2000; Williamson et al., 2006; are considered complex. Since they are based on physical quantities such as mass attenuation coefficient, electron density and cross section per electron. Simple polynomial functions were used in other parameterization schemes reported for the evaluation of mass attenuation and energy-absorption coefficients.

The theoretical data can be available from various softwares available, primarily XCOM, WinXCOM, XMudat. These softwares are having advantages one over other in different manner. Many researchers have extensively studied the coherent scattering process theoretically. Hubbell and Overbo obtained the relativistic coherent (Rayleigh) scattering cross sections and they refer to numerical integration[47] (Hubbell and Overbo, 1979). The photon cross sections and mass attenuation coefficients for all elements for photon energies in the range 1 MeV to 100 GeV [48,49](Hubbell et al., 1980, 1982). Storm and Israel have tabulated photon cross sections from 1 keV to 100 MeV for elements [50](Storm and Israel, 1970). Berger and Hubbell developed the tables for the theoretical values and XCOM computer program for calculating mass attenuation coefficients for elements, compounds and mixtures for photon energies from 1 keV to 100 GeV[51].

XCOM Program

We are used this program in this work, It is a web database is provided which can be used to calculate photon cross sections for attenuation, scattering, photoelectric absorption and pair production, and total attenuation coefficients for any element, compound or mixture ($Z \leq 100$), at an energies from 1 keV to 100 GeV. XCOM Program operates in FORTRAN language(computer). The XCOM program can generate cross sections on a standard energy grid (spaced approximately logarithmically), or on a grid selected by the user, or for a mix of both grids[52]. Cross sections at energies from low to high, above and below, all absorption edges are automatically included. The program provides total cross sections and attenuation coefficients as well as partial cross sections for the following processes: incoherent scattering, coherent scattering, photoelectric absorption, and pair production in the field of the atomic nucleus and in the field of the atomic electrons. The one of the essential factor, weighting factors, that is, the fractions by weight of the constituents, are calculated by XCOM from the chemical formula entered by the user. For mixtures, however, the user must supply the fractions by weight of the various components. The program shows two forms of output:

- ✓ Tables
- ✓ Graphical display of the tabular data.

WinXCom

The WinXCom, runs under the Windows OS and provides an interface that facilitates defining, redefining and saving substances in a substance definition list. Once a substance has been defined, it can be used for defining compounds or mixtures. It is even possible to define mixtures of already defined compounds or mixtures. The substance definition list comes with a predefined list of the first hundred elements in the periodic table.

WinXCom calculates tables of cross sections for the interactions of photons with any element, compound or mixture, for photons with energies between 1keV to 100GeV. Interaction coefficients and total attenuation coefficients for compounds and mixtures are obtained as sums of corresponding quantities for atomic

constituents. The program can generate cross sections and attenuation coefficients on a standard energy grid, spaced approximately logarithmically, or on a grid selected by the user or for a mix of both grids. The program provides total cross sections and attenuation coefficients as well as partial cross section for following processes: incoherent scattering, coherent scattering, photoelectric absorption and pair production. For compounds, the quantities tabulated are partial and total mass attenuation coefficients. The total attenuation coefficient is equal to sum of interaction coefficients for the individual processes. Total attenuation coefficients without the contribution from coherent scattering are also given because they are often used in gamma-ray transport calculations.

WinXCom makes it possible to export the table of cross-sectional or mass-attenuation data to a predefined Microsoft Excel template. In this way, graphical display and further data treatment is made easy. The ability of WinXCom to calculate attenuation data for mixtures of compounds, defined by the user, comes in handy when studying for example the radiation-shielding properties of glasses[53].

XMuDat

XMuDat is a program to be used with Windows 95 or NT version for the presentation and calculation of various photon interaction coefficients [54]. Six absorbing materials can be set up individually. Each material can be composed of components chosen from the elements and further from a number of compounds and mixtures of dosimetric interest. Data for mass attenuation, mass energy transfer and mass energy absorption coefficients in a photon energy range of 1 keV to 50 MeV can be retrieved for 290 elements, compounds and mixtures.

MUA_T and MUEN_T

This program is another softwares used for the computation of mass attenuation and energy-absorption coefficients for body tissues and substitutes of arbitrary percentage-by-weight elemental composition and photon energy ranging between 1 keV (or k-edge) and 400 keV[55].

4.6 Radioactive sources

Sources of gamma rays which used in present research work is listed as follows.

1] Co^{57}

The isotope Co^{57} is produced by cyclotron irradiation of an iron. Co^{57} is used as a source in Mössbauer spectroscopy of an iron containing samples. The electron capture decay of the Co^{57} forms an excited state of the Fe^{57} nucleus, which in turn decays to the ground state with emission of a gamma ray. Measurement of the gamma ray spectrum provides information about the chemical state of the iron atom in the sample. Co^{57} is a radioactive metal that is used in medical tests; it is used as a radiolabel for vitamin B12 uptake. It is useful for the Schilling test[56]. It also useful in brachytherapy[57]. Co^{57} decays with a half-life of 270 days by electron capture.

2] Ba^{133}

The most abundant γ-ray in the decay of ^{133}Ba at 356 keV is similar in energy and emission probability to the most abundant γ-ray in the decay of ^{131}I at 364 keV. There are many uses in medical and research fields.

3] Na^{22}

Na^{22} is having energy 0.511, 1.280 MeV. Na^{22} is also a positron emitting isotope with a remarkably long half-life. It is used to create test-objects and point-sources for positron emission tomography.

4] Cs^{137}

Cs^{137}has a half life of about 30.17 years[58]. It has a number of practical uses.

- In small amounts, it is used to calibrate radiation detection equipment Geiger-Mueller counters. [59]. In larger amounts, Cs^{137} is used in medical radiation therapy devices for treating cancer; in industrial gauges that detect the flow of liquid through pipes; and in other industrial devices to measure the thickness of materials, such as paper, photographic film, or sheets of metal.
- In medicine, it is used in radiation therapy.
- In industry, it is used in flow meters, thickness gauges[59], moisture-density gauges (for density readings, with americium^{241}/beryllium providing the moisture reading)[60], and in gamma ray well

logging devices[60]. Caesium^{137} is not widely used for industrial radiography because it is quite chemically reactive, and hence difficult to handle.

- As a man-made isotope, caesium^{137} has been used to date wine and detect counterfeits[61] and as a relative dating material for assessing the age of sedimentation occurring after 1954[62].
- Cesium^{137} can be used to monitor the flow of oil in a pipeline. This isotope of cesium can also be used to treat some kinds of cancer. One procedure is to fill a hollow steel needle with cesium^{137}. The needle can then be implanted into a person's body.
- The cesium-137 gives off radiation inside the body. That radiation kills cancer cells and may help cure the disease.
- Cesium^{137} has also been approved for the irradiation of certain foods. The radiation given off by the isotope kills bacteria and other organisms that cause disease. Foods irradiated by this method last longer before beginning to spoil. Wheat, flour, and potatoes are some of the foods that can be preserved by cesium^{137} irradiation.
- One is as a getter in bulbs and evacuated tubes. The bulb must be as free from gases as possible to work properly. Small amounts of cesium react with any air left in the bulb. It converts the gas into a solid cesium compound. Cesium is called a getter because it gets gases out of the bulb.
- Cesium is also used in photoelectric cells, devices for changing sunlight into electrical energy. When sunlight shines on cesium, it excites or energizes the electrons in cesium atoms. The excited electrons easily flow away, producing an electric current.
- An very current important use of cesium today is in an atomic clock. An atomic clock is the most precise method now available for measuring time.

5] Mn^{54}

My opinion on the continued use of Manganese^{54} is that it should still be used in industry. It is used to prevent possibly harmful substances from getting into our ecosystems which could be disastrous. The benefits definitely outweigh the risks. As long as the isotope is handled using the proper equipment and is handled with care, Mn^{54} is more useful than harmful. It is used to predict the behavior of heavy metal compounds in effluents from mining waste water. Manganese^{54} is used to track heavy metals to prevent them from escaping into the environment.

6] Co^{60}

Cobalt^{60} is used in a process called industrial radiography, to inspect metal parts and welds for defects. Cobalt^{60} is also used in blast furnaces to determine times and to quantify income to measure the furnace performance. Cobalt^{60} plays an important role in the scientific community as well, from promising new stem cell research to the design and testing of items for the aerospace and nuclear energy industries. Other beneficial uses for Cobalt-60 include food preservation, sanitization of cosmetics, quarantine application of consumer products.

Other Uses

- Cobalt^{60} is ideal for industrial gauging and leveling devices
- Used by plastic manufactures to gauge the thickness of their products
- An accurate detection of explosive devices.
- To scan rail cars for cargo and unwanted passengers.
- As a tracer for cobalt in chemical reactions
- Sterilization of medical equipment[63].
- Radiation source for medical radiotherapy[64]. Cobalt therapy, using beams of gamma rays from Co^{60} teletherapy machines to treat cancer, has been widely used since the 1950s.

- Radiation source for industrial radiography[64].
- Radiation source for leveling devices and thickness gauges[64].
- Radiation source for pest insect sterilization[65].
- As a radiation source for food irradiation and blood irradiation[63].

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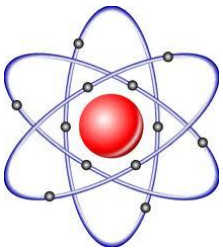
CHAPTER 5



Theory, Structure, Results, Conclusion of Sphingolipids and Polvketides

5] Introduction

The increasing actively use of gamma-active isotopes in various fields viz. reactors physics, nuclear power plants, nuclear engineering and space technology also in medical fields motivated nuclear engineers, physicist, radiologists and radiation physicists to focus on the radiation interaction with different kinds of compounds, materials for several purposes i.e. shielding, X-ray imaging and radiotherapy. This work is the basis of attenuation, absorption, penetration and photon interactions with C-, H-, N- and O- based compounds like lipids, fatty acids, amino acids. Which is important in radiation biology, nuclear research, radiation biology [1]. A living cell is a dynamic biological system composed primarily of lipids, carbohydrates, nucleic acids, and proteins that are structurally and functionally interact with many other molecules (organic and inorganic) to carry out normal cell metabolism. Among the biomolecules lipids is one of the essential for research and medical biology. So in this work we are used lipids namely; sphingolipids and polyketides for the determination of mass attenuation, molar extinction and related radiological parameters which is essential for medical diagnosis, radiation biology etc. The present research work is about effect of radiation on such types of lipids and it is rather well documented that plasma membrane of mammalian tissues are rich in sphingolipids and especially sphingoglycolipids. Sphingoglycolipids are a family of complex lipids with structures representing a large variety of carbohydrate compositions which are characteristics for a mammalian organ and can vary depending on the species of origin[2]. The glycolipids located on the surface of the cells may play a role in maintaining the functional characteristics of mammalian cells. Therefore, the study of siphingoglycolipid composition in various, radiosensitive and non-radiosensitive tissues, might indicate whether damages induced by the ionizing radiation on the plasma membrane matrix are involved in the process of cell death [3]. So in this research work we focus the effect of radiation and its absorption on lipids at medical, radiological, biological research point of view. Biological significance of sphingolipids; Sphingolipids are found in essentially all animals, plants, and fungi, also some prokaryotic organisms and viruses. They are mostly in membranes but also major constituents of the lipoproteins. Sphingolipids are divided into two main groups. The first group is the sphingophospolipids contains residues of phosphoricacid and choline (sphingomyelins) or of phosphoric acid and inositol glycoside (phytosphingolipids). The second group is the sphingoglyco lipids which contains monosaccharides, generally galactose or oligosaccharides; this group may also contain both oligosaccharides and residues of sialic acids (gangliosides)[4].Sphingolipids are found in the membranes of animal and plant cells. They are the main constituent of the myelin sheath ofmedullated nerves and of the lipids occurring in the brain. They are almost nonexistent in fat deposits. The functions of sphingolipids are still being discovered, but there are at least three, i.e., structure, recognition and the signal transduction[5]. Later studies fulfilled Thudichum's faith in the value of basic research when several genetic diseases were found to have raised amounts of sphingolipids (such as sphingomyelin in Niemann-Pick's disease and cerebrosides in Gaucher's disease) arising from defects in an enzymes responsible for sphingolipid turnover, activator proteins for such an enzymes, or lipid trafficking[6,7]. This knowledge allowed evolution of methods for diagnosis of such sphingolipid storage diseases (or 'sphingolipidoses'), trialing of families at risk, and for at least Gaucher's disease, some degree of correction of the disorder by an enzyme replacement. Progress is also being made using an inhibitors of sphingolipid synthesis, and gene replacement offers promise for the future. There are also an indications that sphingolipid analogs may be useful for prevention and treatment of disease, such as, gangliosides [8] and dietary sphingolipids protect against the colon tumorigenesis [9]. So, the relation between radiation and sphingolipids is very much essential in medical and in research context. Because the research area of an absorption, penetration, attenuation and photon interactions with the biological material like amino acids, fatty acids, lipids, vitamins, and carbohydrates is important in radiation biology and medicine, nuclear technology and space research[1]. On the other hand present in lipid research, polyketides also play an important role in medical biology. So, this work focus on the absorption of C-, H-, N- and O- based polyketides. Now a days polyketides natural products find clinical utility as antibiotics, antiparasitics, antifungals, anticancer drugs. These comprehensive pharmacological activities give continued motivation to unravel polyketide biosynthetic mechanisms to enable the discovery of novel compounds for the benefit of human health society. Many of these have infamous food-spoiling toxins and some have important therapeutics for clinical use of drugs such as erythromycin, rapamycin and lovastatin etc. Polyketides are an important group of structurally very diverse family of natural products biosynthesized by the polyketide pathway, many of which have important industrial applications in the food,

health physics and pharmaceutical industries. Because the broad class of secondary metabolites that display a diverse range of biological properties and are used extensively in human medicine[10-13]. A variety of physiological functions inside in the living system are performed by complex molecules such as fatty acids, carbohydrates and proteins compose of H-, C-, N- and O- element.

The study of photon interactions with matter is essential and the data on the transmission and an absorption of X-rays and gamma rays in the biological shielding and dosimetric materials assumed great importance by virtue of the diverse application in the field of medical physics and biology [14-16] reported μ_{en}/ρ data for elements, compound and mixtures as a function of energy of photons. A review of photon interaction cross section data in the medical and biological context[17]. Selection of material for radiation shielding and protection needs an accurate assessment of interaction parameters [18]. In addition to μ_m and μ_{en}/ρ, the parameters such as Zeff (effective atomic number), σ_{tot} (total attenuation cross section), ε (molar extinction coefficient), and $\sigma_{t,el}$ (effective electronic cross section) of complex molecules of biological interest also play an essential role in understanding dosimetry of photons. The calculation of Z_{eff} is based on the parameterization of the photon interaction cross section by fitting data over limited ranges of the photon energies and an atomic number [1,19-20] reported molar extinction coefficient for fatty acids. The investigated photon attenuation in elements and arbitrary materials[21,22]. Several related research work are published in this type of research were devoted on the investigation of above parameters[23-33]. There have been recent experimental and theoretical investigations[34-37] were devoted on the investigation of parameters. to determine Absorption coefficient, mass attenuation coefficients(μ/ρ), total attenuation cross section(σ_{tot}) and such type of radiological parameters (ε, μ_{en}/ρ, $\sigma_{m,en}$, Z_{eff}, $\sigma_{t\ a}$ $\sigma_{t\ el}$) for complex biological molecules (such as lipids, carbohydrates, proteins, fats and oils) for several polyketides using the NaI(Tl) based gamma-ray spectrometry. composed of H, C, N and O elements in varying proportions.

5.1 Sphingolipids and polyketides with structure

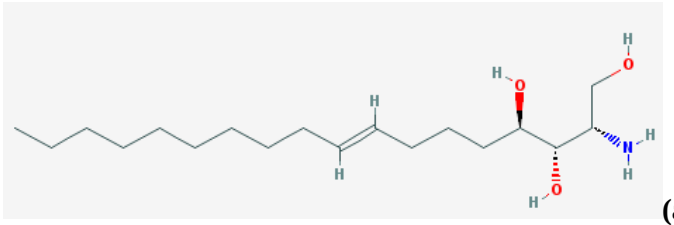
Here, the structures of Sphingholipids and Polyketides listed from figure a-*l*

5.1.1 Sphingholipids

1) Dehydrophytosphingosine

Dehydrophytosphingosine is found in pulses. It is present in the soybean phospholipids.

Dehydrophytosphingosine structure is as follow:

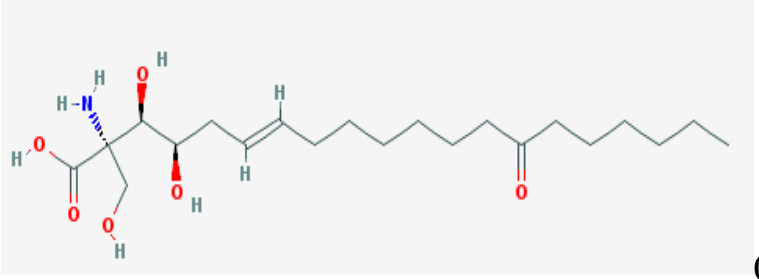


(a)

2) Myriocin

Myriocin, also called as antibiotic is an atypical amino acid and an antibiotic derived from the certainthermophilic fungi. It is a very potent inhibitor of serine palmitoyltransferase, the first step in sphingosine biosynthesis[38]. Due to this property, it is used in the biochemical research as a tool for depleting cells of a sphingolipids. It possesses immunosuppressant activity.

Myriocin structure is as follow:

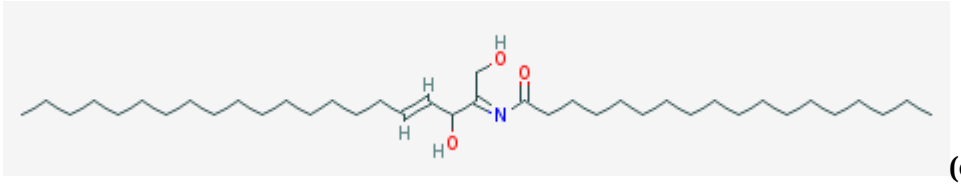


(b)

3) Hemsleyin imine A

An imine is a functional group or chemical compound which containing a C-N double bond, with the nitrogen atom attached to a hydrogen atom (H) or an organic group. If group is not a hydrogen atom, then the compound can sometimes be referred as a schiff base[39]. Imines are typically prepared by the condensation of primary amines and aldehydes and the less commonly ketones. Imines are common in nature. The vitamin B6 promotes the deamination of an amino acids via the formation of imines.

Hemsleyin imine A structure is as follow:

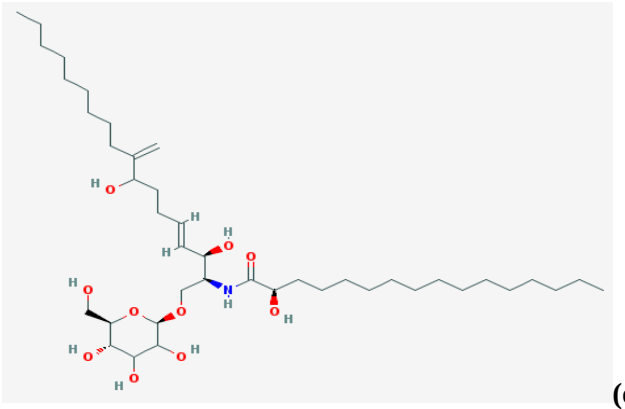


(c)

4) Termitomycesphin

Termitomycesphins A-H are the neuritogenic cerebrosides which an isolated from the mushroom termitomyces albuminosus.

Termitomycesphins structure is as follow:

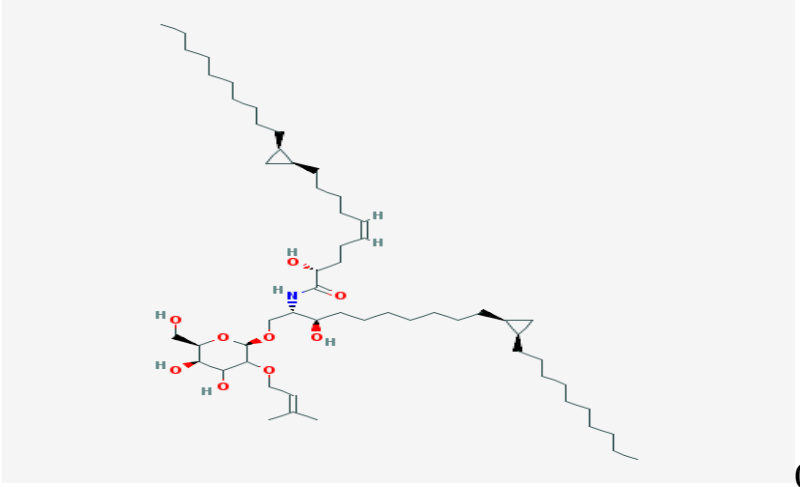


(d)

5) Plakoside A

The plakoside A, a glycosphingolipid isolated from the marine sponge plakortis simplex, has been shown to possess an immunosuppressive activity. [40] it to be inactive in an MTT assay for the cytotoxicity. Thus, plakoside A, noncytotoxic class of immuno suppressants with potential therapeutic applications and, as such, is a significant synthetic target.

Plakoside A structure is as follow:

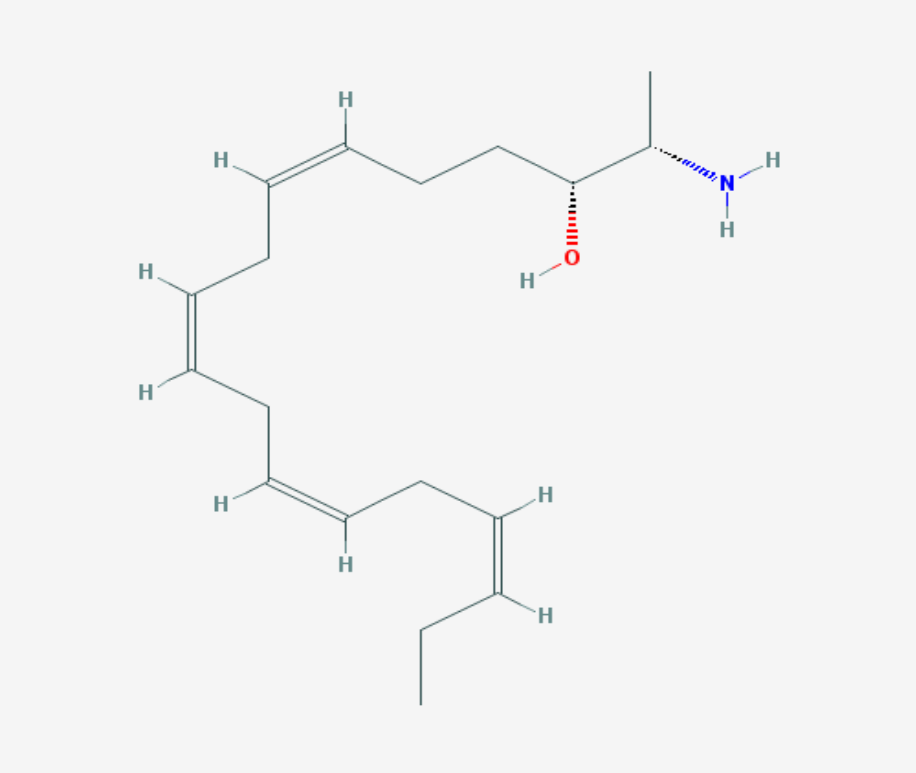


(e)

6) Obscuraminol A

An obscuraminol A is a one of the important kind of sphingholipids.Which have the following structure.

An obscuraminol A structure is as follow:



(f)

5.1.2 Polyketides

1] Erythromycin

An erythromycin is an antibiotic useful for the treatment of a number of bacterial infections[41][9]. This includes the respiratory tract infections, skin infections, chlamydia infections, and syphilis. It may also be used during pregnancy to prevent group B streptococcal infection in the newborn[41], also may be used to improve delayed stomach emptying[42]. It can be given an intravenously and by mouth[41]. An eye ointment is routinely recommended after delivery to prevent an eye infections in the newborn[43]. It is generally safe in those who are allergic to penicillin [41]. An erythromycin also appears to be safe to use during pregnancy[44]. While generally regarded as safe during breastfeeding its use by the mother during the first two weeks of life may increase the risk of the pyloric stenos is in the baby[45,46]. This risk also applies if taken directly by the baby during this age[47]. An erythromycin belongs in a group of drugs called macrolide antibiotics. The macrolide antibiotics slow the growth or sometimes kill, sensitive bacteria by reducing the production of an important proteins needed by the bacteria to survive. An erythromycin is used to treat or prevent many different types of infections caused by bacteria. It is produced by a strain of saccharopolyspora erythraea (formerly streptomyces erythraeus) and belongs to the macrolide group of an antibiotics. It is basic and readily forms salts with acids. The base, the stearate salt, and the esters are poorly soluble in water.

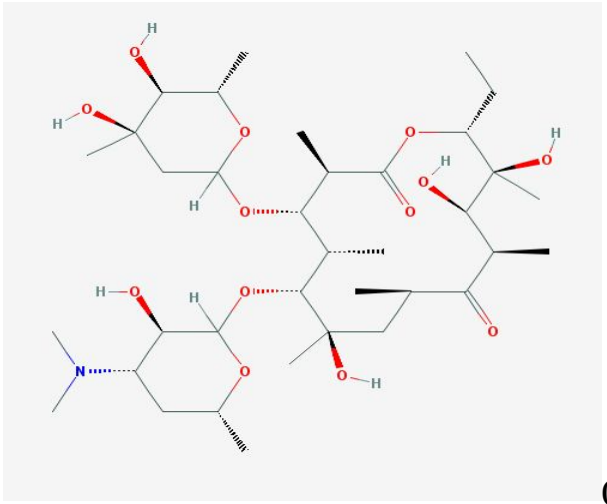
Medical uses

An erythromycin can be used to treat bacteria responsible for causing infections of the skin and an upper respiratory tract, including the streptococcus, staphylococcus, and haemophilus genera.

There are some types Erythromycin such as Erythromycin B, C, D and E which having the structure as follow,

1) Erythromycin C

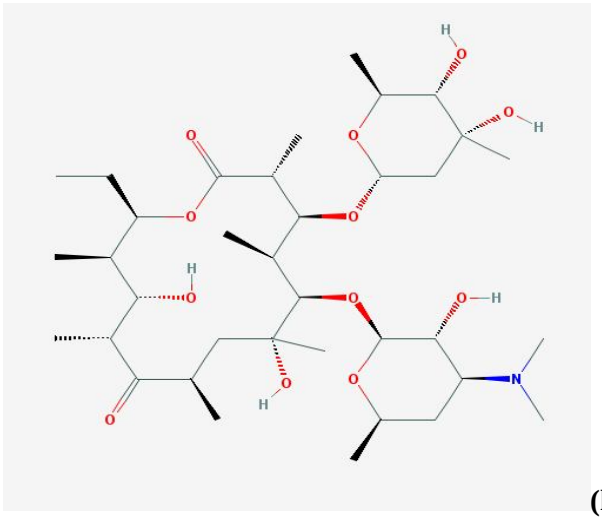
Erythromycin C structure is as follow:



(g)

2) Erythromycin D

Erythromycin D structure is as follow:

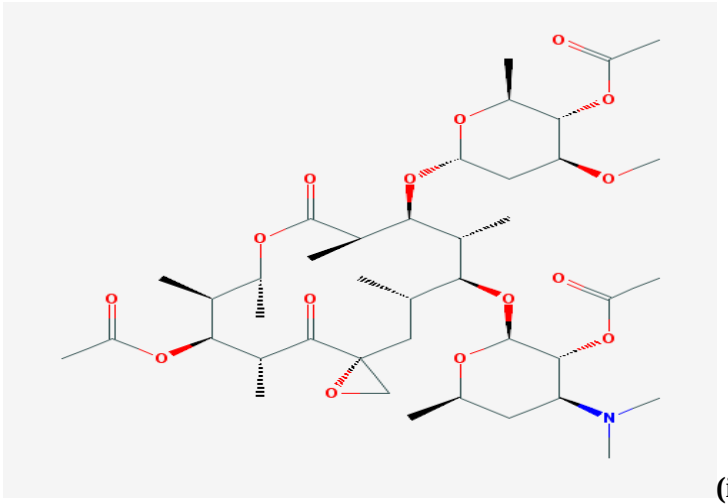


(h)

3) Troleandomycin

Troleandomycin is in a class of drugs called macrolide antibiotics. Troleandomycin is used to treat many different types of bacterial infections, such as tonsillitis, bronchitis, sinusitis, and pneumonia.

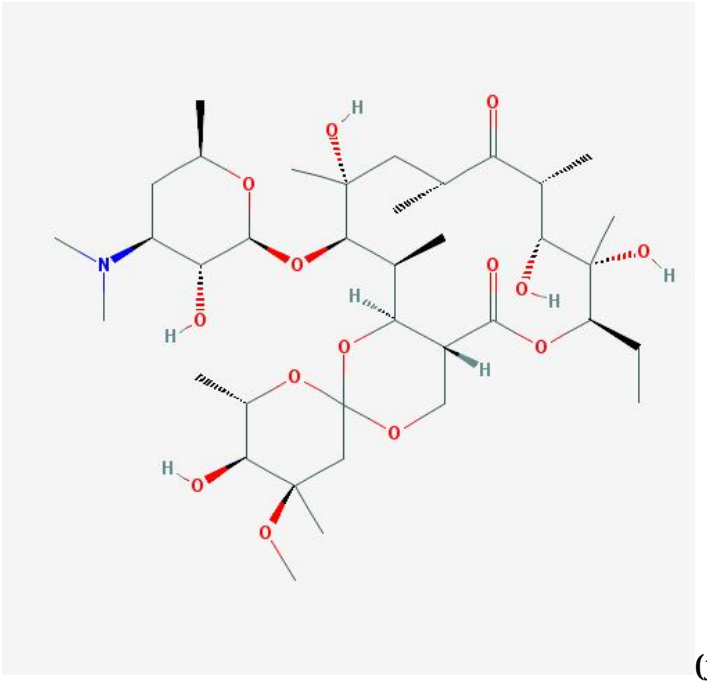
Troleandomycin structure is as follow:



(i)

4) Erythromycin E

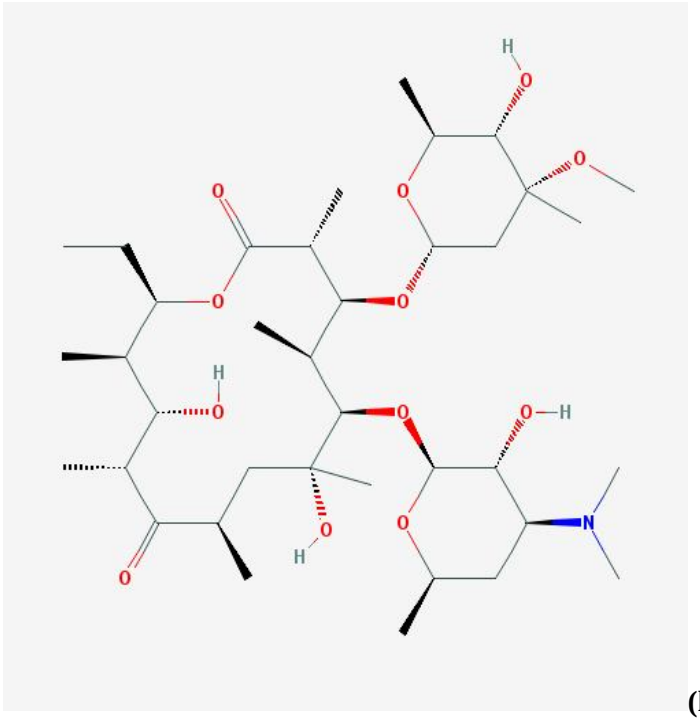
Erythromycin E structure is as follow



(j)

5) Erythromycin B

Erythromycin B structure is as follow:

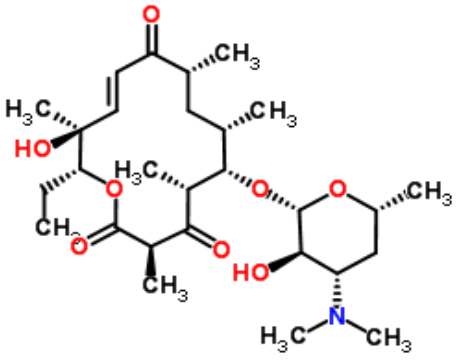


(k)

6) Pikromycin

The pikromycin was studied by Brokmann and Hekel in 1951 and was the first antibiotic macrolide to be an isolated[48]. It is derived from narbonolide, a 14-membered ring macrolide[49]. Along with the narbonolide backbone, pikromycin includes a desosamine sugar and the hydroxyl group. Although it is not a clinically useful antibiotic, it can be used as a raw material to synthesize an antibiotic ketolide compounds like ertythromycins and new epothilones[50].

Pikromycin structure is as follow:



(I)

5.2 Theory

In this section, some theoretical relations are summarized that have been used for the determination of mass absorption and related parameters in the present work. This attenuation of the beam is expressed by the some essential equations such as of linear attenuation, mass attenuation coefficient, total attenuation cross section, and molar extinction coefficient. are in previous chap.4 from equation 4.1 to 4.5. So now here, we see the remaining related formulas among the attenuation parameters.

The values of mass energy-absorption coefficient, (μ_{en}/ρ) were computed as,

$$\frac{\mu_{en}}{\rho} = (\mu_{tr}/\rho)(1-g) \qquad (5.1)$$

Where the factor 'g' represents the average fraction of the kinetic energy of secondary charged particles(produced in all the types of interactions) that is subsequently lost in radiative (photon emitting) energy-loss processes as the particles slow to rest in the medium.

The total atomic cross-sections ($\sigma_{t,a}$) using interpolation method has been determined from the following equation:

$$(\sigma_{t,a}) = \frac{1}{N_A}\sum_i f_i A_i (\mu_m)_i \qquad (5.2)$$

Similarly, effective electronic cross-section ($\sigma_{t,el}$) for the individual element is given by :

$$(\sigma_{t,el}) = \frac{1}{N_A}\sum_i \frac{f_i A_i}{Z_i}(\mu_m)_i = \frac{\sigma_{t,a}}{Z_{eff}} \qquad (5.3)$$

where $f_i = n_i / \sum_j n_j$ and Z_i are the fractional abundance and atomic number of constituent element I, respectively, n_i is the total number of atoms of the constituent element i and $\sum_j n_j$ is the total number of atoms present in the molecular formula. Finally, one of the essential quantity is the effective atomic number (Z_{eff}) using direct method can be given as,

$$(Ze_{ff}) = \frac{\sigma_{t,a}}{\sigma_{t,el}} \qquad (5.4)$$

All these radiological parameters are convenient parameters used to characterize the radiation response of a multi-element material in many technical and the medical applications. An accurate values of these physical quantities provide essential data in medical physics.

5.3 Experimental set up and measurements

The experimental set up, procedure and measurements are described for all bio-molecules which are used in this present work.

The gamma active radioactive sources ^{57}Co, ^{133}Ba , ^{22}Na, ^{137}Cs ,^{54}Mn, and ^{60}Co were used in the present investigation having energies 122, 356, 511, 662, 840, 1173, 1275 and 1332 keV emitted by the above radioactive sources were collimated and detected by the NaI (Tl) based gamma ray spectrometry. Here, gamma active ^{57}Co, ^{60}Co, ^{137}Cs sources are mainly use for radiation therapy and dosimery. For measurement of incident and transmitted photon energies a narrow beam good geometry set up was used. By proper adjustment of the distance between the detector and source (30cm < d < 50 cm), the maximum angle of scattering was under below 30 min. The signals from the detector were amplified and analyzed with 8K/13-bit multichannel analyzer. In the present study, samples of amino acids, fatty acids but fatty acids (pure liquid form), lipids; sphingolipids and polyketides are in powder form which are highly pure and by using the KBr press machine it converted into the pellet form shaped and confined in a cylindrical plastic container having the same diameter as that of sample pellets. The diameters of the samples were determined using the traveling microscope. These pellets are placed to an empty plastic container which play a role like a substrate. It was observed that the attenuation and absorption of photons beam of the empty containers were negligible. Each sample pellet was weighed in a sensitive digital balance having an accuracy 0.001 mg. The weighing was done continuously till consistent value of the mass. By using the diameter of the pellet and the mean value of the mass of the pellet, the mass per unit area was determined in each case. The thickness of sample was selected in an order to satisfy the following ideal condition as possible as far [51]: $2 < \ln (I_0 / I) < 4$.

The schematic view of an experimental set up and actual laboratory set up is displayed in Fig 7.9a and 7.9b. From the measured values of unattenuated photon intensity I_0 (with empty plastic container) and attenuated photon intensity I (including sample), the linear and mass attenuation coefficients (μ, μ_m) for all the samples of sphingolipids as well as polyketides were calculated using Eq.(4.1 and 4.2). The experimental values of mass attenuation coefficients were compare against the Win-Xcom program [22] at all photon energies of current interest which, can give the theoretical numerical data of all compounds, mixture, metal, alloys for references. Apart from multiple scattering and counting statistics, the other possible sources of an error due to the small angle scattering contribution, impurity of sample, non uniformity of the sample, photo built-up effects, dead time of the counting instrument, and pulse pile effect were an evaluated and taken care. the contribution of coherent also an incoherent scattering at such angles in the measured cross sections at an intermediate energies is negligible. Hence, no small angle scattering corrections were applied to the measured data. An error due to the impurities of sample can be high only when large percentage of high Z impurities is present in the sample. The samples bio-molecules used in the present study were of pure and no content of high Z impurities was present. Hence, sample impurity corrections were not applied to the measured data. In the present work, the uncertainty in the mass per unit area and an error due to the non uniformity of the sample is < 0.05% for all energies of an interest. The photon built-up effect was kept minimum by choosing an optimum count rate and the counting time. The photon built-up depends on the atomic number and the sample thickness, and also on the incident photon energy. It is also a consequence of the multiple scattering inside the sample. In the multichannel analyzer used in the present study, there was a built-in provision for dead time correction. The pulse piles of effects were kept minimum by selecting an optimum count rate and counting time. Here, all the radiological quantities (μ, μ_m, σ_{tot}, ε, Z_{eff}, μ_{en}/ρ, $\sigma_{t,a}$ and $\sigma_{t,el}$) are determined by using equations 4.1 to4.4 and 5.1to5.4.

5.4 Results And Discussion

The values of mean atomic numbers calculated from the chemical formulae of sphingolipids and polyketides studied in the present work are displayed in Table11,18. The experimentally measured values of μ, μ_m, σ_{tot}, ε, Z_{eff}, μ_{en}/ρ, $\sigma_{t,a}$ and $\sigma_{t,el}$ for some sphingolipids and polyketides such as Dehydrophytosphingosine ($C_{18}H_{37}NO_3$), Myriocin ($C_{21}H_{39}NO_6$), Hemsleyin imine A ($C_{39}H_{75}NO_3$), Termitomycesphin A ($C_{41}H_{77}NO_{10}$), Plakoside A ($C_{57}H_{105}NO_9$), Obscuraminol A ($C_{18}H_{31}NO$), Erythromycin C ($C_{36}H_{65}NO_{13}$), Erythromycin D ($C_{28}H_{47}NO_8$), Troleandomycin ($C_{41}H_{67}NO_{15}$), Erythromycin E ($C_{37}H_{65}NO_{14}$), Erythromycin B ($C_{37}H_{67}NO_{12}$) and Pikromycin/Amaromycin ($C_{36}H_{65}NO_{12}$) at 122, 356, 511, 662, 835, 1173, 1275 and 1332 keV photon energies. The typical plot of μ_m versus energy E for Dehydrophytosphingosine and Erythromycin D is displayed in Fig.(6.8 and 7.4) and it is also includes the variation of theoretically determined μ_m values versus energy. It is clearly seen that the μ_m depends on photon energy and decreases with increasing photon energy. The experimental (μ_m) values agree with theoretical values calculated using the Win-XCom program.

The total experimental uncertainty of the (μ_m) values depend on the uncertainties of I_0 (without attenuation), I (after attenuation), mass thickness measurements and counting statistics. Typical total uncertainty in the measured experimental (μ_m) values is estimated to be 2-3%. Measured total atomic cross section (σ_{tot}) and molar extinction coefficient (ε) values for the presently studied sphingolipids and polyketides have been displayed in Table 14, 15 and Table 21, 22, respectively. The typical plots of σ_{tot} versus E, ε versus E, μ_{en}/ρ verses E and Z_{eff} verses E for both Dehydrophytosphingosine and Erythromycin D are displayed in Fig.(6.9, 7.1, 7.2) and Fig.(7.5, 7.7, 7.8) respectively. The behavior of σ_{tot} and ε with photon energies shows almost similar behavior to (μ_m) plots. All calculations of molar extinction [55](Sandhu et al 2002) are done according to XCOM program and our calculations are based on Win-XCom which is updated version of XCOM also arrange narrow beam good geometry setup for performing experiment.

Mass energy absorption coefficient (μ_{en}/ρ) of Dehydrophytosphingosine and Erythromycin D values were determined from Eq.(5.1) by using the μ_m values of Dehydrophytosphingosine and Erythromycin D are given in Table 13, 20.The variation of μ_{en}/ρ values versus photon energy of Dehydrophytosphingosine and Erythromycin D is displayed graphically in Fig.(7.1, 7.7). It is seen from Table 15 and Fig.(7) that ε values for the present sample initially decrease and tend to be almost constant as a function of gamma-ray energy. Finally Z_{eff} of both samples are tabulated in Table 17, 24 and Fig.(7.2, 7.8) shows the typical variation of Z_{eff}, versus photon energy for Dehydrophytosphingosine and Erythromycin D sample. The present absorption data of samples compare with amino acids and fatty acids are shows the variations in absorption which is aim of the work. The present experimental study has been undertaken to get information on mass attenuation coefficient μ_m values and related parameters μ, μ_m, σ_{tot}, ε, μ_{en}/ρ and Z_{eff} for bio-molecules samples which are convenient parameters used to characterize the radiation response of a multi-element material in many technical and medical applications. Accurate values of these physical parameters provide essential data in medical physics and mainly in dosimetry. It has been found that the μ_m is useful and sensitive physical quantity to determine for above quantities and it dependent on the physical and chemical environments of the samples. The photon energies; ^{57}Co, ^{133}Ba, ^{137}Cs, ^{54}Mn, ^{60}Co, and ^{22}Na are biomedically important radioisotopes which have been used. The μ_m and related quantities were found to decrease with increasing photon energies. The measured data were compared against Win-XCom-based data and agreement is within 1%.

5.5 Conclusions

- The biological effect of ionizing radiation on human being depends on absorber dose, types of radiation alpha, beta, gamma and organs irradiated Photon entering the bodies not only lose but also they give rise energy and are finally absorbed, but also they give rise to new photons by multiple scattering gamma and X-rays are use for diagnostic in nuclear medicine, computed tomography scanning, radiography, radiotherapy, gamma knife radio surgery etc for treatment of many diseases.
- The attenuation measurements at gamma ray energies from 122–1330keV using Co^{57}, Ba^{133}, Na^{22}, Cs^{137}, Mn^{54} and Co^{60} gamma active point sources for the sphingo;ipids and polyketides shows a significant energy dependence of the parameters measured parameters.
- The results of μ, μ_m, σ_{tot}, ε, μ_{en}/ρ and Z_{eff} of biological C,H,N,O based compounds, reported in the present work, would be useful, particularly in the energy region of interest, in many medical and biological applications (e.g. for the interpretation of absorbed dose), and in radiation shielding and protection. The Z_{eff} values are useful in diagnostics, where one is generally interested in the attenuation of the X-ray beam in imaging techniques, including X-ray tomography (CAT scans).
- On the other hand, Z_{eff} would be used in radiation dosimetry and radiotherapy by means of gamma and X-ray beams, where the energy deposition of photons is important. The use of quantity Z_{eff} is important, however, when dealing with the absorbed dose in the photon energy range 3–400 keV.
- At novelty point of view using the gamma ray spectrometry we can get nearly accurate and important data of samples for radiotherapy, dosimetry by using methodology (proper way and long time span) which is used in the present work.

- ❖ With proper knowledge of the attenuation parameters and buildup of photons in human organs and tissues, energy-absorption in the human body can be carefully controlled. The experimental data will also help in estimating safe dose levels for radiotherapy patients. For people working with gamma radiation and X-rays, especially at reactors and nuclear power plants, the present studies on the energy-absorption factor of human organs and tissues will help them to take proper precautions.
- ❖ The molar extinction coefficient and total attenuation cross sections, of some sphingolipids and polyketides are having biomedical importance. In the interaction of photons with matter.

The major objectives of the present investigation were as follows:

1. Formulation of comprehensive and consistent set of formulas for the linear attenuation, mass attenuation coefficient, attenuation cross section, molar extinction coefficient, mass energy absorption, effective atomic number should be valid for all types of materials and for a wide range of photon energies above 1 keV and far into the GeV range.
2. Application of these comprehensive and consistent set of formulas to a variety of materials: biological molecules and organic compounds.
3. To develop a procedure to facilitate the formulation of tissue substitutes for a wide range of applications (for example: dosimetric phantoms, radiographic test objects, dosimeter components, radiotherapy etc.) for photon interactions.
4. Computation and analysis of energy-absorption for bioactive materials in the energy range 1 keV – 100 MeV.

The research objectives specified above have been fulfilled along with some other additional objectives. The following conclusions may be drawn from the systematic investigations outlined in the present thesis.

5.6 Applications of present work

1. The formulas, derived in the present work, are valid for all types of materials and for all photon energies in an extended range above 1 keV, and can be of great practical usefulness. Most of the methods used in the past are valid in limited ranges of energy and atomic number.
2. The results on Z_{eff} and other parameters of biological compounds reported in the present work, would be useful, particularly in the energy region of interest, in many medical and biological applications (e.g. for the interpretation of absorbed dose), and in radiation shielding and protection.
3. The Z_{eff} values are useful in diagnostics, where one is generally interested in the attenuation of the X-ray beam in imaging techniques, including X-ray tomography (CAT scans). also would be used in radiation dosimetry and radiotherapy by means of X-ray beams, where the energy deposition of photons is important. Radiotherapy, however, is usually performed with photons in the MeV energy range especially for low- and medium-Z materials e.g. human organs/tissues.
4. Gamma rays and X-rays are extensively used in the medical field for diagnosis and treatment of many diseases, such as cancer. With proper knowledge of the buildup of photons in human organs and tissues, energy-absorption in the human body can be carefully controlled. The results will also help in estimating safe dose levels for radiotherapy patients.
5. For people working with X-rays and gamma radiation, especially at reactors and nuclear power plants, the present studies on the energy-absorption coefficient of human organs and tissues will help them to take proper precautions, taking into account the photon buildup in human organs and tissues.

5.7 Scope for future research

1. To the best of our knowledge, all experimental work has been done in the intermediate energy range, i.e. around 1 MeV, where Compton scattering is the main interaction process, It is very interesting to have an experimental data at energies where Z_{eff} is rapidly varying with energy.
2. In present work, data interpreted is in energy range 122-1330keV which is normally useful in medical field. In other hand, if we select the radioactive source samples having energy above 1330keV and below 100keV then it is very much different aspect which is also essential in medical as well as other

fields. The combination following two points is very much essential research area for future work point of view.

a) The various radioisotopes; mainly useful in medical and industry area. b) With having high efficiency, accuracy and sensitive detectors such as Hp-Ge photon detectors.

3. For any possible effect of chemical bonding on the photon interaction cross-sections and the effective atomic numbers of the biological molecules. Such studies could stimulate further theoretical developments, in particular close to absorption edges.

5.8 Current Scenario(National/International)

National status: This type of research work attenuation properties and radiological data of bio-molecule carried out in BARC, Punjab, Mysore, Gulbarga, and Gurunanak University.

International status: Attenuation parameter carried out by several international research organizations such as Australian Defense Scientific Service, American Physical Society, National Bureau Standard and National Institute of Standards and Technology.

5.9 Motivation

The biological effect of ionizing radiation on human being depends on absorber dose, types of radiation alpha, beta, gamma and organs irradiated Photon entering the bodies not only lose but also they give rise energy and are finally absorbed, but also they give rise to new photons by multiple scattering gamma and X-rays are use for diagnostic in nuclear medicine, computed tomography scanning, radiography, radiotherapy, gamma knife radio surgery etc for treatment of many diseases.

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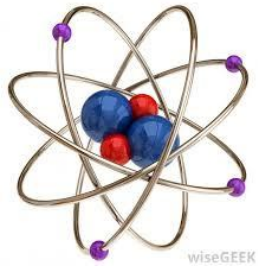
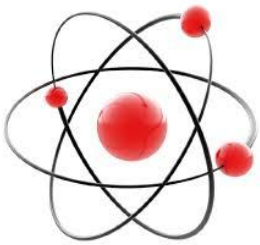


Figures and Tables



6.1 Amino Acids Tables and Figures

Table 1.The mean atomic numbers calculated from the chemical formula for amino acids.

Amino acids	Molar mass (g/mol)	Chemical Formula	Mean atomic number, Z
DL-Aspartic Acid-LR	133.10	$C_4H_7NO_4$	4.38
L-glutamine	146.15	$C_4H_{10}N_2O_3$	3.90
Creatine Monohydrate LR	149.15	$C_4H_9N_3O_2H_2O_2$	3.81
Creatinine Hydrochloride	149.58	$C_4H_7NO_3HCl$	4.59
L-Asparagine Monohydrate	150.13	$C_4H_9N_3O_2H_2O$	4.00
L-Methionine LR	161.22	$C_5H_{11}NO_2S$	4.10

Table-2: Mass attenuation coefficient μ_m (cm^2/gm) of amino acids.

Sr. No.	Amino acids	122keV		356keV		511keV		662keV		1170keV		1275keV		1330 keV	
		Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo
1.	DL-Aspartic Acid-LR	0.141	0.153	0.091	0.105	0.082	0.089	0.071	0.078	0.062	0.069	0.046	0.054	0.045	0.053
2.	L-glutamine	0.142	0.155	0.092	0.106	0.084	0.091	0.074	0.081	0.058	0.065	0.048	0.056	0.044	0.052
3.	Creatine Monohydrate LR	0.142	0.155	0.093	0.107	0.085	0.092	0.075	0.082	0.058	0.065	0.052	0.060	0.051	0.059
4.	Creatinine Hydrochloride	0.147	0.160	0.090	0.104	0.082	0.089	0.073	0.080	0.055	0.062	0.050	0.058	0.049	0.057
5.	L-Asparagine Monohydrate	0.141	0.154	0.093	0.107	0.085	0.092	0.075	0.082	0.058	0.065	0.050	0.058	0.048	0.056
6.	L-Methionine LR	0.148	0.161	0.094	0.108	0.085	0.092	0.075	0.082	0.057	0.064	0.052	0.060	0.051	0.059

Table-3: Atomic cross-sections, σ_t (barn/mole) of amino acids.

Sr No.	.Amino acids	122keV		356keV		511keV		662keV		1170keV		1275keV		1330 keV	
		Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo
1.	DL-Aspartic Acid-LR	31.149	33.800	20.103	23.200	18.115	19.660	15.685	17.230	13.696	15.240	10.162	11.930	09.941	11.710
2.	L-glutamine	34.446	37.600	22.317	25.710	20.376	22.070	17.950	19.650	14.069	15.770	11.643	13.580	10.673	12.610
3.	Creatine Monohydrate LR	35.150	38.370	23.022	26.490	21.042	22.780	18.566	20.300	14.358	16.090	12.872	14.850	12.625	14.610
4.	Creatinine Hydrochloride	36.495	39.720	22.340	25.870	20.358	22.100	18.123	19.860	13.654	15.390	12.413	14.460	12.165	14.230
5.	L-Asparagine Monohydrate	34.885	38.380	23.174	26.660	21.180	22.930	18.688	20.430	14.452	16.200	12.459	14.450	11.960	13.950
6.	L-Methionine LR	39.603	43.080	25.162	28.900	22.753	24.620	20.076	21.940	15.258	17.130	13.919	16.060	13.652	15.790

Table-4: Comparison of measured and calculated values of molar extinction coefficient ε (cm^2/mole) of amino acids at different photon energies.

Sr. No.	Amino acids	122keV		356keV		511keV		662keV		1170keV		1275keV		1330 keV	
		Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.
1.	DL-Aspartic Acid-LR	8.8440	8.1504	6.0705	5.2601	5.1442	4.7399	4.5083	4.1041	3.9876	3.5836	3.1215	2.6589	3.0640	2.6011
2.	L-glutamine	9.8541	9.0131	6.7272	5.8394	5.7748	5.3315	5.1416	5.6967	4.1263	3.6812	3.5533	3.0465	3.2995	2.7926
3.	Creatine Monohydrate LR	10.0398	9.1973	6.9313	6.0239	5.9606	5.5058	5.3116	4.8579	4.2101	3.7569	3.8856	3.3680	3.8228	3.3034
4.	Creatinine Hydrochloride	10.3931	9.5492	6.7691	5.8454	5.7826	5.3268	5.1965	4.7420	4.0269	3.5727	3.7835	3.2479	3.7234	3.1830
5.	L-Asparagine Monohydrate	10.0424	9.1275	6.9458	6.0637	5.9998	55419	5.3457	4.8898	4.2388	3.7815	3.7809	3.2600	3.6501	3.1294
6.	L-Methionine LR	11.2722	10.3625	7.5619	6.5838	6.4420	5.9535	5.7408	5.2530	4.4822	3.9924	4.2022	3.6420	4.1316	3.5721

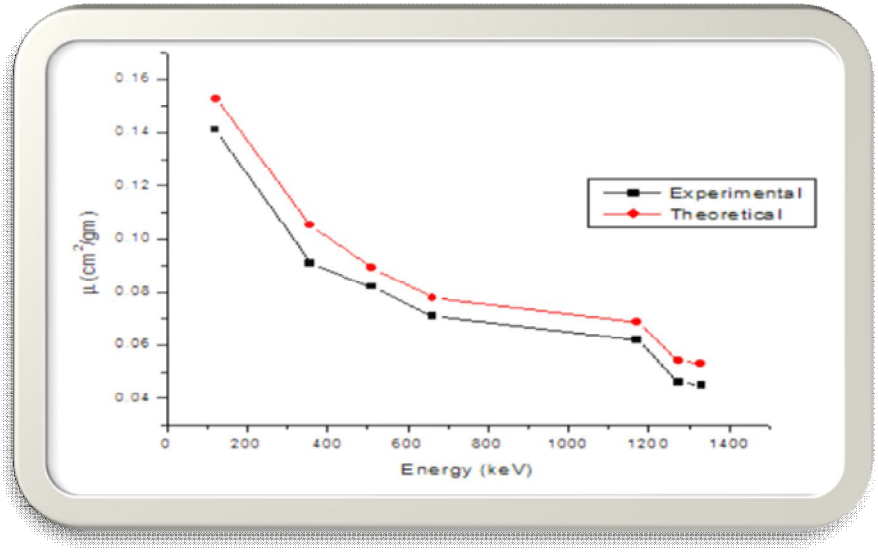


Figure-6.1: Plots of mass attenuation coefficient (μ_m) versus photon energy for DL-Aspartic Acid-LR ($C_4H_7NO_4$).

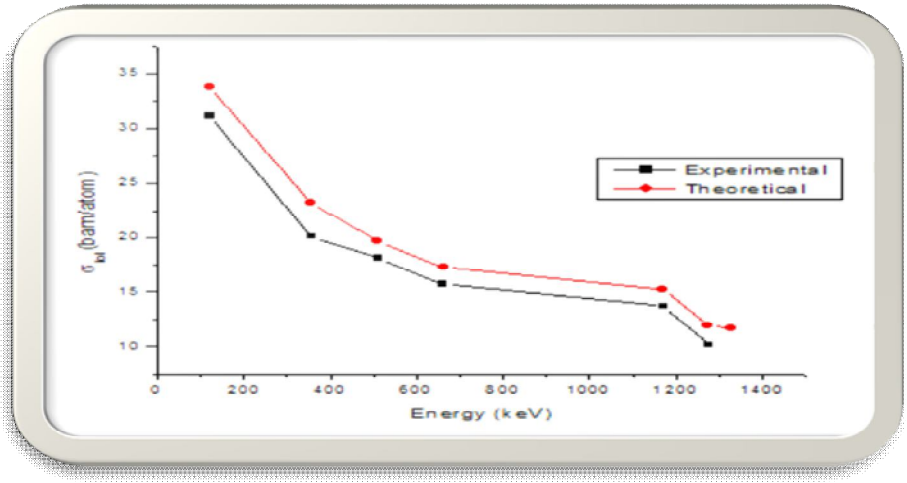


Figure-6.2: Plots of total attenuation cross section (σ_{tot}) versus photon energy for DL-Aspartic Acid-LR ($C_4H_7NO_4$).

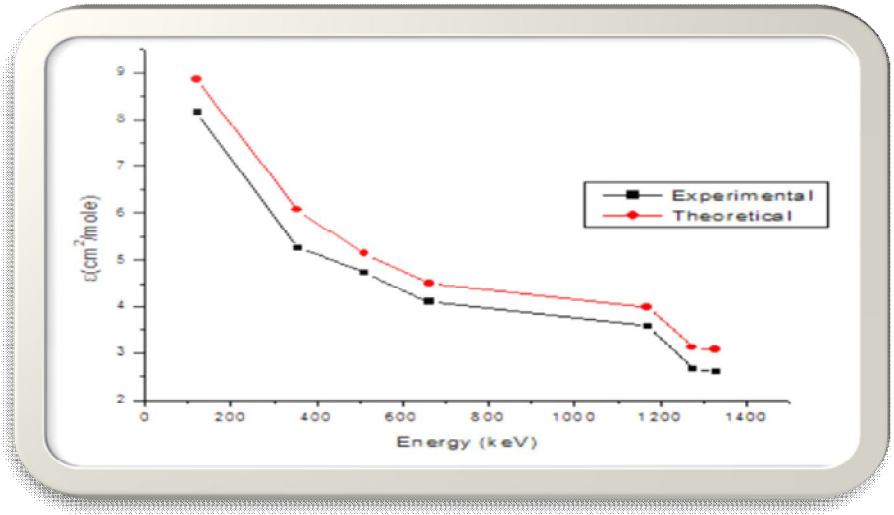


Figure-6.3: Plots of molar extinction coefficient (ε) versus photon energy for DL-Aspartic Acid-LR ($C_4H_7NO_4$).

6.2 Fatty acids Tables and Figures

Table-5: Mean atomic numbers (Z) calculated from the chemical formula for fatty acids.

Saturated fatty acids	Molar mass (g/mol)	Chemical Formula	Mean atomic number, Z
Butyric acid	088.105	($C_4H_8O_2$)	3.42
Caproic acid	116.158	($C_6H_{12}O_2$)	3.20
Enanthic acid	130.185	($C_7H_{14}O_2$)	3.13
Caprylic acid	144.212	($C_8H_{16}O_2$)	3.07
Pelargonic acid	158.239	($C_9H_{18}O_2$)	3.03
Valeric acid	169.517	($C_5H_{10}O_2$)	3.29

Table-6: Comparison of measured and calculated values of mass attenuation coefficient μ_m (cm^2/g) of fatty acids at different photon energies. The calculated values are based on Win-XCOM program.

Sr. No.	Fatty acids	122keV		356keV		511keV		662keV		835keV		1173keV		1275keV		1332 keV	
		Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo	Exp.	Theo.
1.	Butyric acid	0.156	0.157	0.107	0.108	0.090	0.091	0.079	0.081	0.077	0.078	0.069	0.070	0.060	0.061	0.059	0.060
2.	Caproic acid	0.157	0.159	0.107	0.109	0.09	0.092	0.08	0.082	0.077	0.079	0.068	0.070	0.053	0.055	0.052	0.054
3.	Enanthic acid	0.157	0.159	0.107	0.109	0.09	0.092	0.08	0.082	0.077	0.079	0.069	0.071	0.053	0.055	0.053	0.055
4.	Caprylic acid	0.158	0.160	0.107	0.109	0.091	0.092	0.080	0.082	0.077	0.079	0.069	0.071	0.053	0.055	0.053	0.055
5.	Pelargonic acid	0.158	0.160	0.107	0.109	0.091	0.093	0.081	0.083	0.080	0.082	0.077	0.079	0.071	0.073	0.053	0.055
6.	Valeric acid	0.156	0.158	0.107	0.109	0.089	0.091	0.076	0.078	0.079	0.081	0.068	0.070	0.053	0.055	0.052	0.054

Table-7: Comparison of measured and calculated values of total attenuation cross section σ_{tot} (barn/atom) of saturated fatty acids at different photon energies.

Sr. No.	Fatty acids	122keV		356keV		511keV		662keV		835keV		1173keV		1275keV		1332 keV	
		Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo	Exp.	Theo.
1.	Butyric acid	22.8128	22.9590	15.6472	15.7934	13.1612	13.3074	11.5526	11.8451	11.2601	11.4064	10.0902	10.2365	8.7741	8.9203	8.6279	8.7741
2.	Caproic acid	18.2369	18.4692	12.4289	12.6613	10.4542	10.6866	9.2927	9.5250	8.9442	9.1765	7.8987	8.1311	6.1564	6.3887	6.0402	6.2725
3.	Enanthic acid	20.4391	20.6995	13.9298	14.1902	11.7167	11.9770	10.4148	10.5752	10.0242	10.2846	8.9828	9.2431	6.8998	7.1602	6.8998	7.1602
4.	Caprylic acid	22.7855	23.0739	15.4307	15.7191	13.1233	13.2675	11.5369	11.8254	11.1043	11.3927	9.9506	10.2390	7.6432	7.9316	7.6432	7.9316
5.	Pelargonic acid	25.0017	25.3182	16.9315	17.2480	14.3997	14.7162	12.8173	13.1338	12.6591	12.9756	12.1844	12.5009	11.2349	11.5514	8.3866	8.7031
6.	Valeric acid	26.4447	26.7837	18.1383	18.4774	15.0870	15.4261	12.8833	13.2223	13.3918	13.7309	11.5272	11.8662	8.9844	9.3234	8.8149	9.1539

Table-8: Comparison of measured and calculated values of molar extinction coefficient ε (cm^2/mole) of saturated fatty acids at different photon energies.

Sr. No.	Fatty acids	122keV		356keV		511keV		662keV		835keV		1173keV		1275keV		1332 keV	
		Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo	Exp.	Theo.
1.	Butyric acid	5.9689	6.0074	4.0941	4.1325	3.4436	3.4820	3.0227	3.0993	2.9462	2.9845	2.6401	2.6784	2.2957	2.3341	2.2574	2.2958
2.	Caproic acid	4.7716	4.8326	3.2520	3.3129	2.7353	2.7962	2.4314	2.4923	2.3402	2.4011	2.0667	2.1275	1.6108	1.6716	1.5804	1.6412
3.	Enanthic acid	5.3479	5.4162	3.6447	3.7130	3.0656	3.1339	2.7250	2.7932	2.6228	2.6910	2.3503	2.4185	1.8053	1.8735	1.8053	1.8874
4.	Caprylic acid	5.9618	6.0375	4.0374	4.1130	3.4337	3.4715	3.0186	3.0942	2.9054	2.9810	2.6035	2.6791	1.9998	2.0754	1.9998	2.0754
5.	Pelargonic acid	6.5417	6.6247	4.4301	4.5131	3.7676	3.8506	3.3536	3.4366	3.3122	3.3951	3.1880	3.2709	2.9396	3.0225	2.1943	2.2772
6.	Valeric acid	6.9192	7.0082	4.7459	4.8347	3.9475	4.0363	3.3709	3.4597	3.5039	3.5928	3.0160	3.1049	2.3507	2.4395	2.3064	2.3952

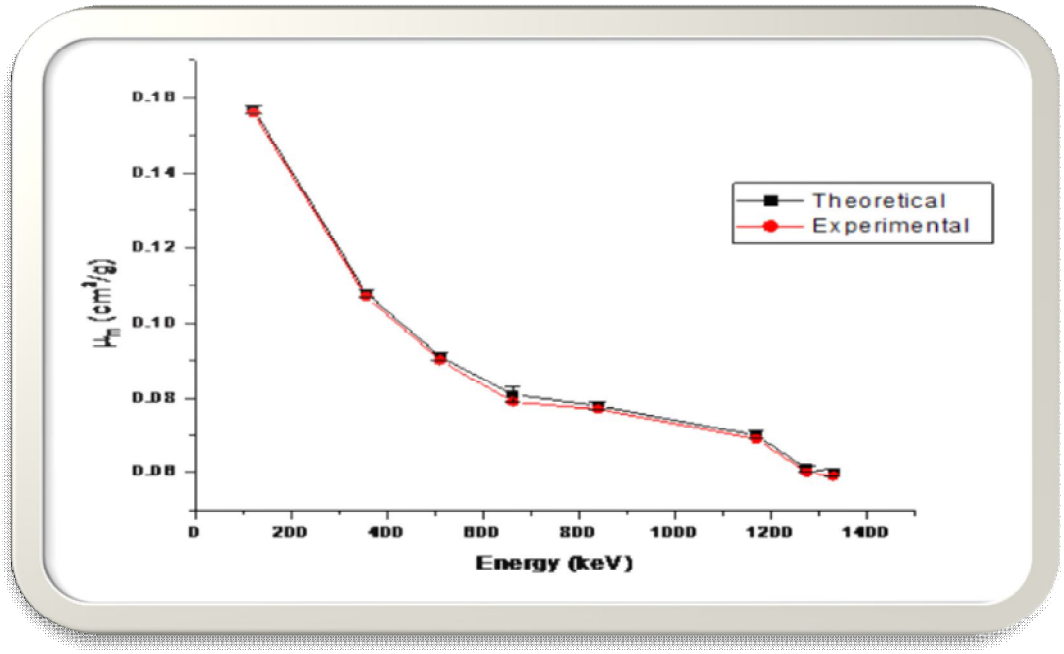


Figure-6.4: Plot of mass attenuation coefficient (μ_m) versus photon energy for butyric acid ($C_4H_8O_2$).

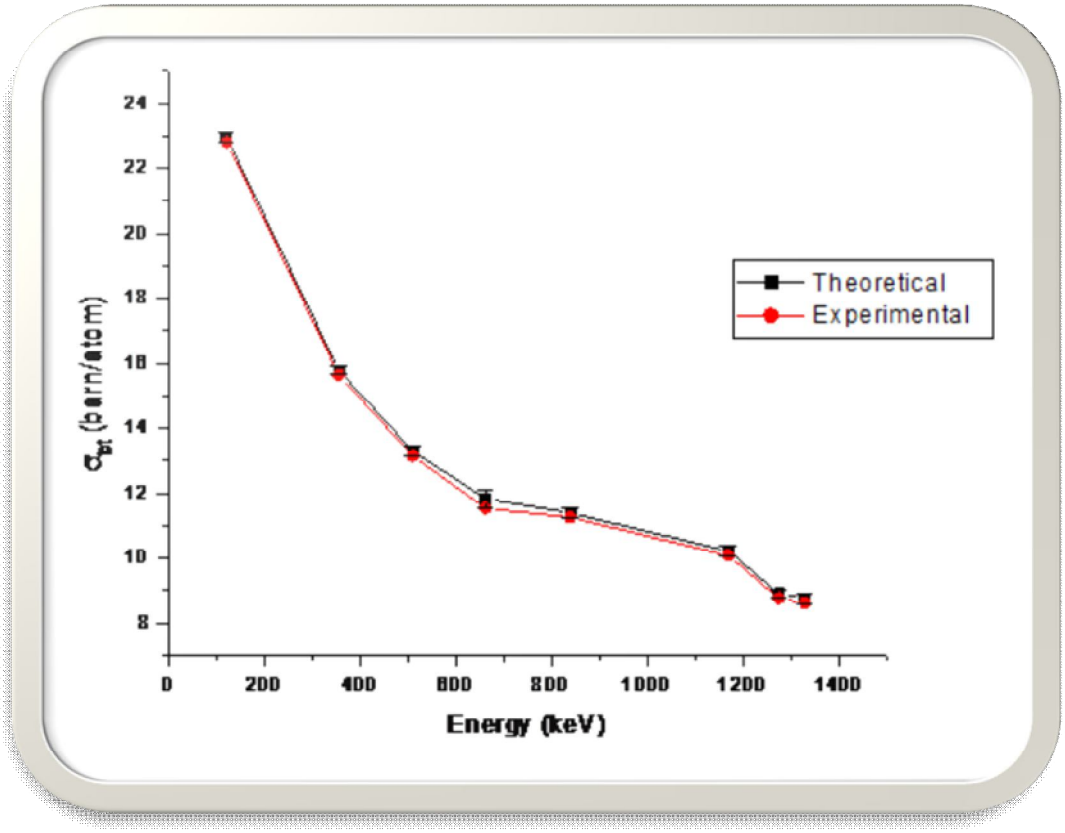


Figure-6.5: Plots of total attenuation cross section (σ_{tot}) versus photon energy for butyric acid ($C_4H_8O_2$).

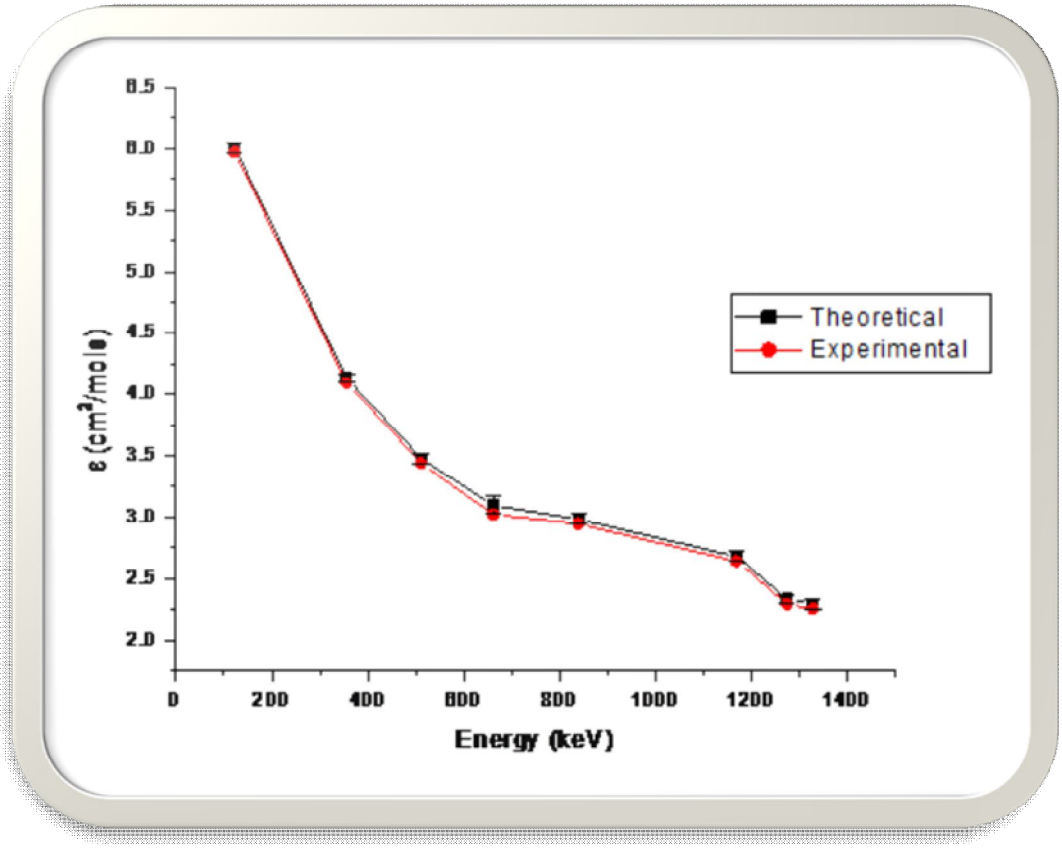


Figure-6.6: Plots of molar extinction coefficient (ε) versus photon energy for butyric acid ($C_4H_8O_2$).

6.3 Sphingolipids Tables and Figures

Table-9: Mean atomic numbers (Z) calculated from the chemical formula for sphingolipids.

Sphingolipids	Molar mass (g/mol)	Chemical Formula	Mean atomic number, Z
Dehydrophytosphingosine	315.28	$(C_{18}H_{37}NO_3)$	3.11
Myriocin	401.28	$(C_{21}H_{39}NO_6)$	3.31
Hemsleyin imine A	605.57	$(C_{39}H_{75}NO_3)$	2.89
Termitomycesphin	743.55	$(C_{41}H_{77}NO_{10})$	3.19
Plakoside A	947.78	$(C_{57}H_{105}NO_9)$	3.06
Obscuraminol A	277.24	$(C_{18}H_{31}NO)$	3.05

Table-10: Comparison of measured and calculated values of mass attenuation coefficient (μ (cm^2/g)) of sphingolipids at different photon energies.

Sr. No.	Sphingolipids	122keV		356keV		511keV		662keV		835keV		1173keV		1275keV		1332 keV	
		Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo	Exp.	Theo.
1.	Dehydrophytosphingosine	0.153	0.155	0.105	0.108	0.086	0.087	0.081	0.083	0.073	0.074	0.061	0.063	0.059	0.060	0.065	0.059
2.	Myriocin	0.175	0.177	0.120	0.123	0.103	0.105	0.096	0.095	0.084	0.085	0.074	0.071	0.067	0.068	0.065	0.067
3.	Hemsleyin imine A	0.146	0.144	0.099	0.100	0.088	0.086	0.076	0.078	0.068	0.069	0.060	0.059	0.057	0.056	0.054	0.055
4.	Termitomycesphin	0.173	0.174	0.123	0.121	0.102	0.104	0.092	0.093	0.084	0.083	0.073	0.071	0.069	0.068	0.064	0.067
5.	Plakoside A	0.175	0.176	0.118	0.123	0.101	0.105	0.089	0.095	0.088	0.085	0.074	0.072	0.067	0.068	0.066	0.067
6.	Obscuraminol A	0.147	0.148	0.100	0.103	0.087	0.088	0.082	0.080	0.072	0.071	0.058	0.060	0.058	0.057	0.057	0.056

Table-11: Comparison of measured and calculated values of mass attenuation coefficient (μ_m cm^2/g) of sphingolipids at different photon energies.

Sr. No.	Sphingolipids	122keV		356keV		511keV		662keV		835keV		1173keV		1275keV		1332 keV	
		Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo	Exp.	Theo.
1.	Dehydrophytosphingosine	0.158	0.160	0.109	0.112	0.089	0.090	0.084	0.086	0.076	0.077	0.063	0.065	0.061	0.062	0.059	0.061
2.	Myriocin	0.156	0.158	0.107	0.110	0.092	0.094	0.086	0.085	0.075	0.076	0.066	0.064	0.060	0.061	0.058	0.060
3.	Hemsleyin imine A	0.163	0.161	0.110	0.112	0.098	0.096	0.085	0.087	0.076	0.077	0.067	0.066	0.064	0.063	0.060	0.062
4.	Termitomycesphin	0.158	0.159	0.112	0.111	0.093	0.095	0.084	0.085	0.077	0.076	0.067	0.065	0.063	0.062	0.059	0.061
5.	Plakoside A	0.158	0.159	0.107	0.111	0.091	0.095	0.081	0.086	0.080	0.077	0.077	0.065	0.071	0.062	0.053	0.061
6.	Obscuraminol A	0.158	0.159	0.108	0.111	0.094	0.095	0.088	0.086	0.078	0.077	0.063	0.065	0.063	0.062	0.062	0.061

Table-12: Comparison of measured and calculated values of total attenuation cross section (σ_{tot} barn/atom) of sphingolipids at different photon energies.

Sr. No.	Sphingolipids	122keV		356keV		511keV		62keV		835keV		1173keV		1275keV		1332 keV	
		Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo	Exp.	Theo.
1.	Dehydrophytosphingosine	82.6811	83.7277	57.0395	58.6094	46.5735	47.0968	43.9570	45.0036	39.7706	40.2939	32.9678	34.1440	31.9212	32.4445	30.8746	31.9212
2.	Myriocin	103.9022	105.2343	71.2663	73.2644	61.2757	62.6077	57.2794	56.6134	49.9530	50.6190	43.9586	42.6265	39.9624	40.6284	38.6303	39.9624
3.	Hemsleyin imine A	163.8343	161.8241	110.5630	112.5733	98.5016	96.4914	85.4350	87.4453	76.3890	77.3941	67.3429	66.3378	64.3276	63.3224	60.3071	62.3173
4.	Termitomycesphin	194.9936	196.2277	138.2233	135.7550	114.7747	117.2429	103.6675	104.9016	95.0285	93.7943	82.6871	80.2188	77.7506	76.5164	72.8140	75.2823
5.	Plakoside A	248.5522	250.1253	168.3233	174.6158	143.1535	149.4459	127.4223	135.2879	125.8492	121.1298	105.3987	102.2525	95.9600	97.5331	94.3869	95.9600
6.	Obscuraminol A	72.7052	73.1654	49.6972	51.0777	43.2550	43.7152	40.4940	39.5737	35.8924	35.4323	28.9900	29.9104	28.9900	28.5299	28.5299	28.0697

Table-13: Comparison of measured and calculated values of molar extinction coefficient (ε cm^2/mol) of sphingolipids at different photon energies.

Sr. No.	Sphingolipids	122keV		356keV		511keV		662keV		835keV		1173keV		1275keV		1332 keV	
		Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo	Exp.	Theo.
1.	Dehydrophytosphingosine	21.6343	21.9081	14.9249	15.3357	12.1864	12.3233	11.5017	11.7756	10.4063	10.5433	8.6263	8.9001	8.3524	8.4894	8.0786	8.3524
2.	Myriocin	27.1870	27.5355	18.6475	19.1703	16.0333	16.3819	14.9877	14.8134	13.0706	13.2449	11.5022	11.1536	10.4565	10.6308	10.1080	10.4565
3.	Hemsleyin imine A	41.5538	42.0798	28.6668	29.4558	23.4069	23.6699	22.0919	22.6179	19.9879	20.2509	16.5689	17.0949	16.0429	16.3059	15.5169	16.0429
4.	Termitomycesphin	51.0219	51.3448	36.1674	35.5216	30.0319	30.6777	27.1256	27.4485	24.8651	24.5422	21.6358	20.9900	20.3441	20.0212	19.0525	19.6983
5.	Plakoside A	65.0360	65.4477	44.0434	45.6899	37.4574	39.1039	33.3412	35.3993	32.9296	31.6948	31.6948	26.7553	29.2250	25.5204	21.8159	25.1088
6.	Obscuraminol A	19.0240	19.1444	13.0037	13.3649	11.3181	11.4385	10.5956	10.3548	9.3916	9.2712	7.5855	7.8263	7.5855	7.4651	7.4651	7.3447

Table-14: Comparison of measured and calculated values of mass energy absorption coefficient (μ_{en}/ρ cm^2/g) of sphingolipids at different photon energies.

Sr. No.	Sphingolipids	122keV		356keV		511keV		662keV		835keV		1173keV		1275keV		1332 keV	
		Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo	Exp.	Theo.
1.	Dehydrophytosphingosine	0.2873	0.2910	0.2030	0.2061	0.1672	0.1657	0.1547	0.1583	0.1401	0.1417	0.1160	0.1196	0.1129	0.1147	0.1087	0.1122
2.	Myriocin	0.2219	0.2248	0.1564	0.1590	0.1287	0.1287	0.1193	0.1221	0.1080	0.1093	0.0895	0.9233	0.0870	0.0884	0.0838	0.0866
3.	Hemsleyin imine A	0.2899	0.2937	0.2046	0.2079	0.1686	0.1671	0.1560	0.1597	0.1413	0.1430	0.1170	0.1207	0.1138	0.1156	0.1096	0.1132
4.	Termitomycesphin	0.2851	0.2871	0.2066	0.2008	0.1730	0.1735	0.1534	0.1552	0.1408	0.1387	0.1224	0.1186	0.1156	0.1137	0.1078	0.1113
5.	Plakoside A	0.2873	0.2893	0.1988	0.2042	0.1707	0.1748	0.1490	0.1582	0.1474	0.1416	0.1417	0.1196	0.1313	0.1146	0.0976	0.1122
6.	Obscuraminol A	0.2852	0.2871	0.1991	0.2025	0.1746	0.1733	0.1606	0.1569	0.1425	0.1405	0.1150	0.1186	0.1154	0.1136	0.1132	0.1112

Table-15: Comparison of measured and calculated values of effective atomic number (Z_{eff}) of sphingolipids at different photon energies

Sr. No.	Sphingolipids	122keV		356keV		511keV		662keV		835keV		1173keV		1275keV		1332 keV	
		Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo	Exp.	Theo.
1.	Dehydrophytosphingosine	5.4941	5.4964	5.4458	5.4328	5.4195	5.4303	5.4257	5.4307	5.4234	5.4311	5.4214	5.4305	5.4036	5.4053	5.4154	5.4322
2.	Myriocin	5.5940	5.5920	5.5460	5.5327	5.5253	5.5304	5.5300	5.5308	5.5239	5.5312	5.5255	5.5308	5.5025	5.5073	5.5271	5.5322
3.	Hemsleyin imine A	5.4493	5.4469	5.3628	5.3856	5.3656	5.3831	5.3830	5.3835	5.3759	5.3839	5.3821	5.3840	5.3570	5.3587	5.3797	5.3850
4.	Termitomycesphin	5.5403	5.5380	5.4764	5.4777	5.4695	5.4753	5.4753	5.4757	5.4683	5.4761	5.4719	5.4762	5.4473	5.4517	5.4720	5.4772
5.	Plakoside A	5.4978	5.4954	5.4219	5.4356	5.4270	5.4332	5.4333	5.4336	5.4260	5.4340	5.4313	5.4342	5.4065	5.4095	5.4298	5.4350
6.	Obscuraminol A	5.5388	5.5370	5.4757	5.4812	5.4720	5.4790	5.4783	5.4794	5.4731	5.4798	5.4768	5.4791	5.4556	5.4569	5.4759	5.4808

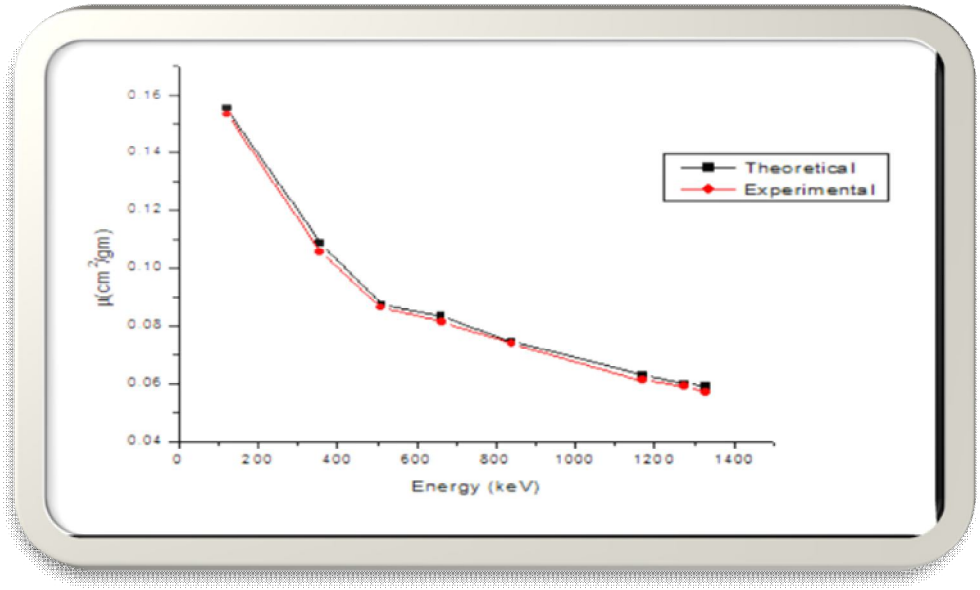


Figure-6.7: Plot of μ versus photon energy for Dehydrophytosphingosine ($C_{18}H_{37}NO_3$).

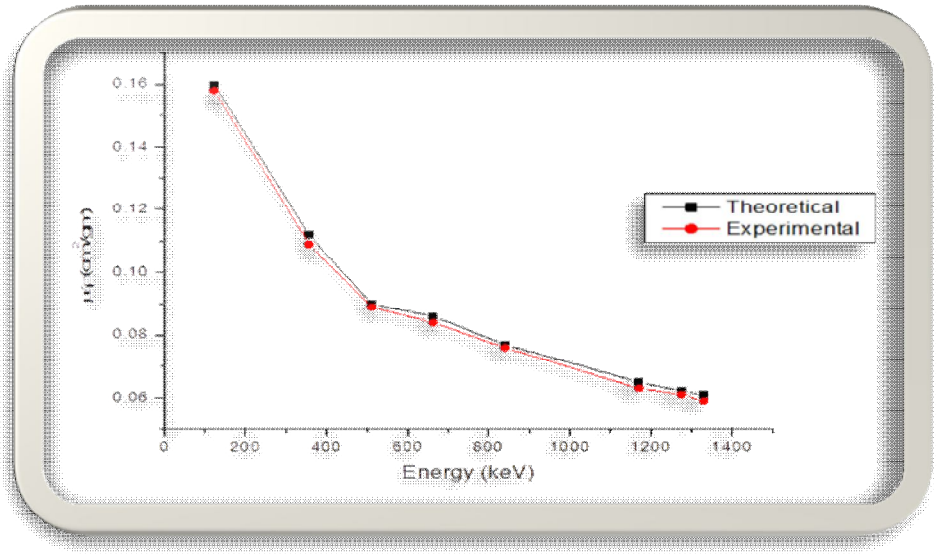


Figure-6.8: Plot of μ_m versus photon energy for Dehydrophytosphingosine ($C_{18}H_{37}NO_3$).

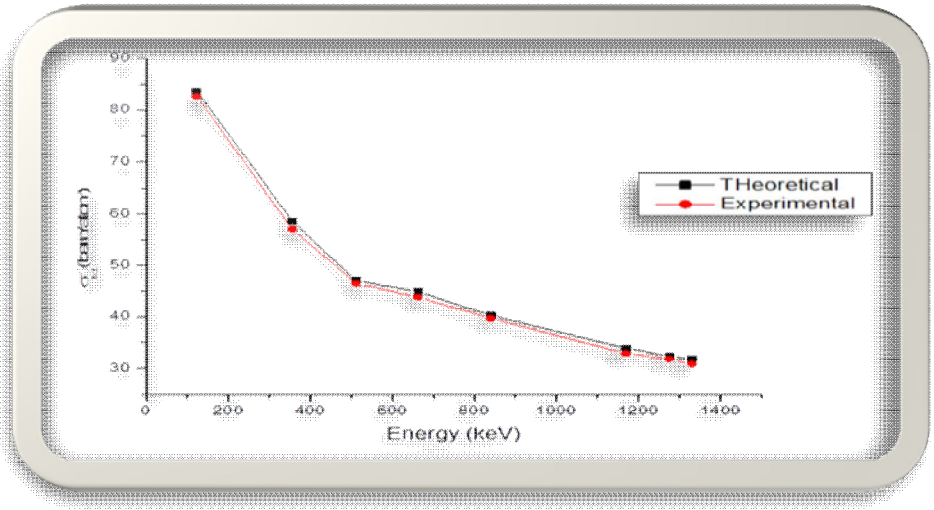


Figure-6.9: Plots of σ_{tot} versus photon energy for Dehydrophytosphingosine ($C_{18}H_{37}NO_3$).

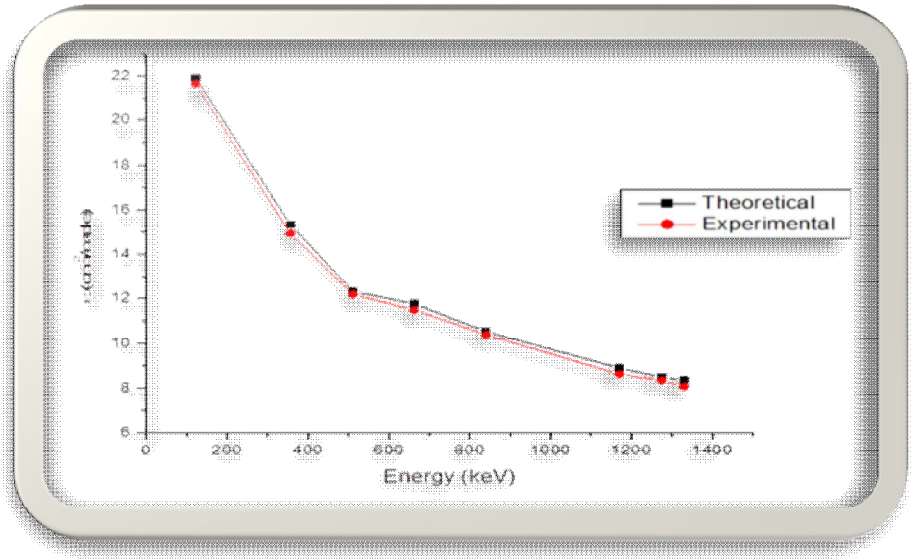


Figure-7: Plots of ε versus photon energy for Dehydrophytosphingosine ($C_{18}H_{37}NO_3$).

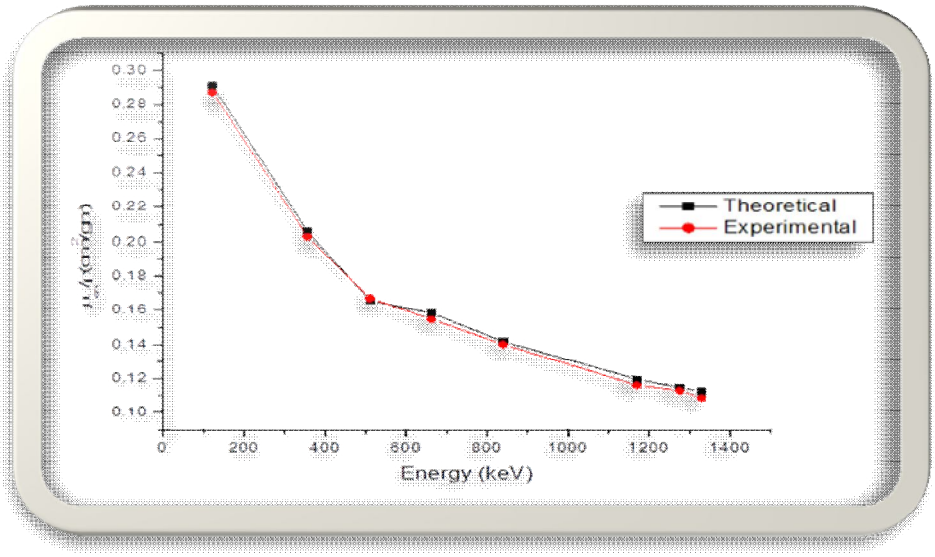


Figure-7.1: Plot of μ_{en}/ρ versus photon energy for Dehydrophytosphingosine ($C_{18}H_{37}NO_3$).

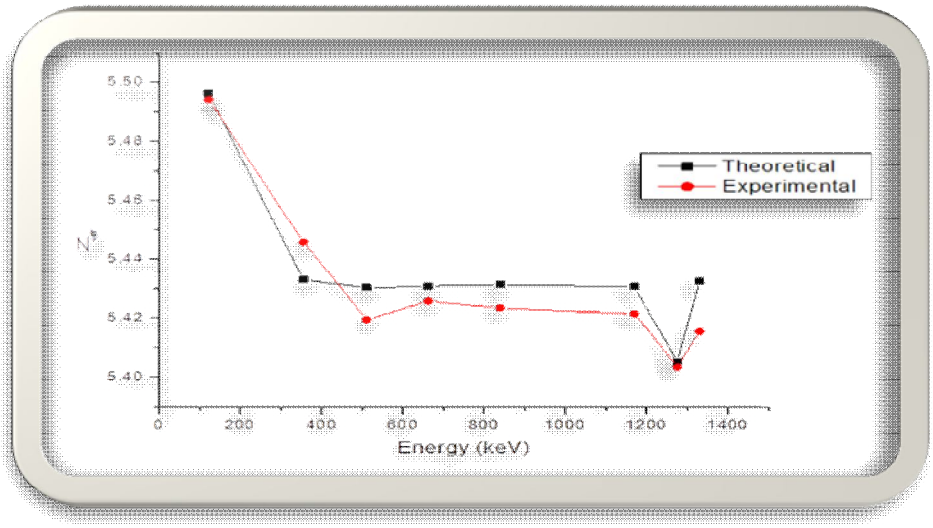


Figure-7.2: Variation of Z_{eff} with photon energy for Dehydrophytosphingosine ($C_{18}H_{37}NO_3$).

6.4 Polyketides Tables and figures

Table-16: Mean atomic numbers (Z) calculated from the chemical formula for polyketides.

Polyketides	Molar mass (g/mol)	Chemical Formula	Mean atomic number, Z
Troleandomycin	813.45	$(C_{41}H_{67}NO_{15})$	4.51
Pikromycin/Amaromycin	525.33	$(C_{36}H_{65}NO_{12})$	4.21
Erythromycin B	717.47	$(C_{37}H_{67}NO_{12})$	4.17
Erythromycin E	747.44	$(C_{37}H_{65}NO_{14})$	4.17
Erythromycin D	703.45	$(C_{28}H_{47}NO_{8})$	4.16
Erythromycin C	719.45	$(C_{36}H_{65}NO_{13})$	3.40

Table-17: Comparison of measured and calculated values of mass attenuation coefficient (μ (cm^2/g)) of polyketids at different photon energies.

Sr.No.	Polyketides	122keV		356keV		511keV		662keV		835keV		173keV		1275keV		1332 keV	
		Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo	Exp.	Theo.
1.	Erythromycin C	0.174	0.175	0.119	0.122	0.103	0.105	0.093	0.094	0.086	0.084	0.072	0.071	0.070	0.068	0.065	0.066
2.	Erythromycin D	0.176	0.175	0.120	0.122	0.103	0.105	0.096	0.094	0.082	0.084	0.070	0.071	0.067	0.068	0.064	0.066
3.	Troleandomycin	0.183	0.186	0.127	0.129	0.112	0.111	0.098	0.099	0.091	0.090	0.076	0.075	0.075	0.073	0.069	0.070
4.	Erythromycin E	0.175	0.177	0.125	0.123	0.103	0.105	0.093	0.094	0.083	0.084	0.076	0.074	0.070	0.068	0.066	0.067
5.	Erythromycin B	0.178	0.175	0.119	0.122	01065	0.105	0.091	0.094	0.082	0.084	0.072	0.071	0.070	0.068	0.063	0.066
6.	Pikromycin OR Amaromycin	0.174	0.172	0.117	0.119	0.102	0.103	0.093	0.092	0.084	0.082	0.069	0.070	0.066	0.067	0.063	0.066

Table-18: Comparison of measured and calculated values of mass attenuation coefficient (μ/ρ cm^2/g) of polyketids at different photon energies.

Sr.No.	Polyketides	122keV		356keV		511keV		662keV		835keV		1173keV		1275keV		1332 keV	
		Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo	Exp.	Theo.
1.	Erythromycin C	0.156	0.157	0.107	0.109	0.092	0.094	0.083	0.084	0.077	0.075	0.065	0.064	0.063	0.061	0.058	0.059
2.	Erythromycin D	0.158	0.157	0.108	0.109	0.092	0.094	0.086	0.084	0.074	0.075	0.063	0.064	0.060	0.061	0.058	0.059
3.	Troleandomycin	0.153	0.155	0.106	0.108	0.094	0.093	0.082	0.083	0.075	0.079	0.063	0.071	0.061	0.055	0.059	0.055
4.	Erythromycin E	0.155	0.157	0.111	0.109	0.092	0.093	0.083	0.084	0.074	0.075	0.068	0.066	0.061	0.061	0.059	0.060
5.	Erythromycin B	0.159	0.157	0.107	0.109	0.095	0.094	0.082	0.084	0.074	0.074	0.065	0.064	0.063	0.061	0.057	0.059
6.	Pikromycin OR Amaromycin	0.159	0.157	0.107	0.109	0.093	0.094	0.085	0.084	0.077	0.075	0.063	0.064	0.060	0.061	0.058	0.060

Table-19: Comparison of measured and calculated values of total attenuation cross section (σ_{tot} barn/atom) of polyketids at different photon energies.

Sr.No.	Polyketides	122keV		356keV		511keV		662keV		835keV		1173keV		1275keV		1332 keV	
		Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo	Exp.	Theo.
1.	Erythromycin C	186.401	187.596	127.852	130.242	109.929	112.318	99.175	100.370	92.005	89.616	77.667	76.472	75.277	72.887	69.303	70.498
2.	Erythromycin D	184.595	183.427	126.179	127.347	107.486	109.822	100.476	98.139	86.456	87.624	73.604	74.772	70.099	71.267	67.762	68.931
3.	Troleandomycin	206.705	209.407	143.207	145.909	126.995	125.644	110.783	112.134	102.677	101.326	86.465	85.114	85.114	82.411	78.835	79.709
4.	Erythromycin E	192.412	194.895	137.792	135.309	114.206	115.447	103.034	104.275	91.861	93.103	84.413	81.930	76.965	75.723	73.241	74.482
5.	Erythromycin B	189.465	187.082	127.502	129.885	113.202	112.011	97.711	100.095	88.179	89.370	77.454	76.262	75.071	72.688	67.921	70.304
6.	Pikromycin OR Amaromycin	138.729	136.984	93.358	95.103	81.143	82.015	74.163	73.290	67.183	65.438	54.968	55.840	52.350	53.223	50.605	52.350

Table-20: Comparison of measured and calculated values of molar extinction coefficient (ε cm^2/mole) of polyketids at different photon energies.

Sr.No.	Polyketides	122keV		356keV		511keV		662keV		835keV		1173keV		1275keV		1332 keV	
		Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo	Exp.	Theo.
1.	Erythromycin C	36.299	35.843	24.428	24.884	21.231	21.460	19.405	19.177	17.579	17.122	14.382	14.611	13.698	13.926	13.241	13.698
2.	Erythromycin D	48.301	47.995	33.016	33.321	28.124	28.736	26.290	25.679	22.622	22.927	19.259	19.565	18.342	18.647	17.730	18.036
3.	Troleandomycin	54.086	54.793	37.471	38.178	33.229	32.876	28.987	29.341	26.866	26.512	22.624	22.270	22.270	21.563	20.503	20.856
4.	Erythromycin E	50.346	50.996	36.054	35.405	29.883	30.208	26.959	27.284	24.036	24.361	22.087	21.437	20.138	19.813	19.164	19.489
5.	Erythromycin B	49.575	48.951	33.362	33.985	29.620	29.308	25.567	26.190	23.072	23.384	20.266	19.954	19.643	19.019	17.772	18.395
6.	Pikromycin OR Amaromycin	36.299	35.843	24.428	24.884	21.231	21.460	19.405	19.177	17.579	17.122	14.382	14.611	13.698	13.926	13.241	13.698

Tabl- 21: Comparison of measured and calculated values of mass energy absorption coefficient (μ_{en}/ρ cm^2/g) of polyketids at different photon energies.

Sr.No.	Polyketides	122keV		356keV		511keV		662keV		835keV		1173keV		1275keV		1332 keV	
		Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo	Exp.	Theo.
1.	Erythromycin C	0.2709	0.2726	0.1892	0.1927	0.1640	0.1676	0.1487	0.1502	0.1385	0.1349	0.1176	0.1158	0.1142	0.1105	0.1052	0.1070
2.	Erythromycin D	0.2786	0.2768	0.1941	0.1958	0.1663	0.1700	0.1562	0.1526	0.1350	0.1368	0.1156	0.1174	0.1102	0.1120	0.1066	0.1085
3.	Troleandomycin	0.2521	0.2554	0.1786	0.1819	0.1595	0.1578	0.1399	0.1416	0.1303	0.1286	0.1104	0.1087	0.1089	0.1054	0.1003	0.1021
4.	Erythromycin E	0.2630	0.2664	0.1923	0.1888	0.1605	0.1622	0.1455	0.14733	0.1303	0.1321	0.1205	0.1170	0.1100	0.1083	0.1048	0.1066
5.	Erythromycin B	0.2823	0.2787	0.1935	0.1971	0.1729	0.1711	0.1499	0.1536	0.1358	0.1377	0.1200	0.1181	0.1164	0.1127	0.1054	0.1091
6.	Pikromycin OR Amaromycin	0.2762	0.2727	0.1896	0.1931	0.1658	0.1676	0.1523	0.1505	0.1385	0.1349	0.1140	0.1158	0.1088	0.1106	0.1052	0.1088

Table-22: Comparison of measured and calculated values of effective atomic number (Z_{eff}) of polyketids at different photon energies.

Sr.No.	Polyketides	122keV		356keV		511keV		662keV		840keV		1170keV		1275keV		1330 keV	
		Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.
1.	Erythromycin C	5.6108	5.6126	5.5840	5.5539	5.5433	5.5516	5.5479	5.5520	5.5448	5.5524	5.5418	5.5524	5.5257	5.5289	5.5381	5.5334
2.	Erythromycin D	5.5956	5.5974	5.5641	5.5384	5.5276	5.5361	5.5324	5.5365	5.5293	5.5369	5.5266	5.5369	5.5102	5.5132	5.5225	5.5379
3.	Troleandomycin	5.6571	56587	5.6360	5.6042	5.5940	5.6021	5.5987	5.6024	5.5958	5.6028	5.5927	5.6029	5.5779	5.5810	5.5896	5.6038
4.	Erythromycin E	5.6308	5.6326	5.6081	5.5750	5.5648	5.5728	5.5692	5.5732	5.5662	5.5736	5.5629	5.5736	5.5473	5.5506	5.5596	5.5746
5.	Erythromycin B	5.5929	5.5946	5.5598	5.5359	5.5250	5.5336	5.5299	5.5339	5.5268	5.5343	5.5242	5.5344	5.5078	5.5107	5.5200	5.5354
6.	Pikromycin OR Amaromycin	5.6244	5.6262	5.5964	5.5709	5.5604	5.5687	5.5651	5.5691	5.5626	5.5695	5.5598	5.5693	5.5447	5.5472	5.5559	5.5704

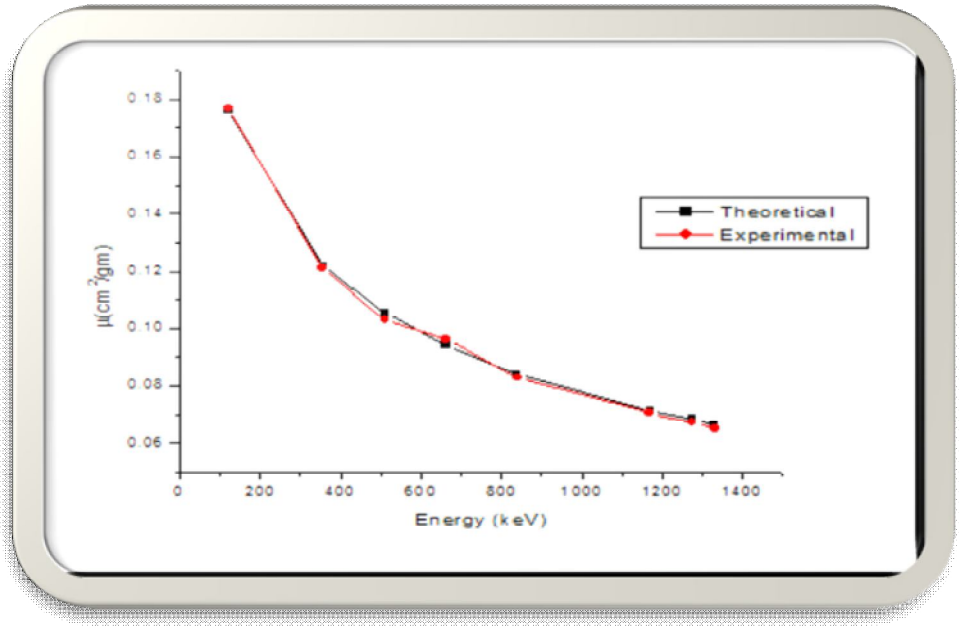


Figure-7.3: Plot of μ versus photon energy for Erythromycin D ($C_{28}H_{47}NO_8$).

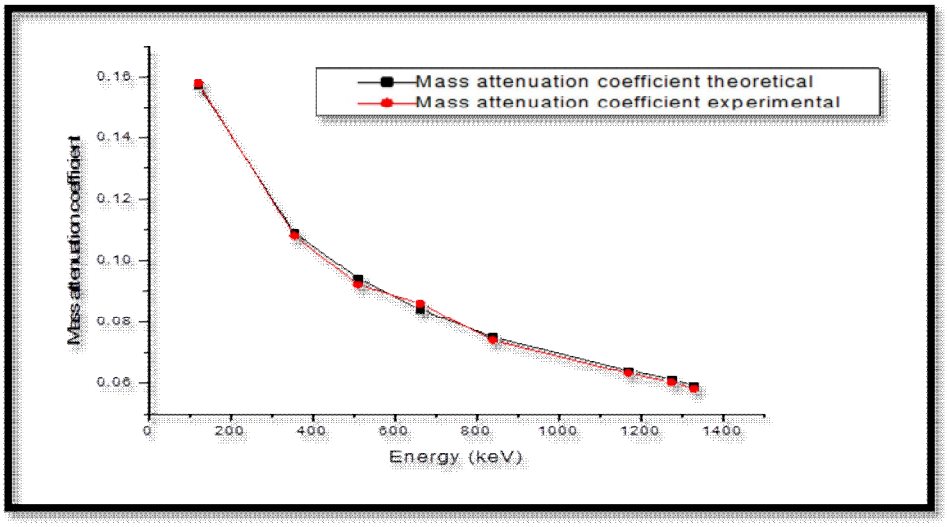


Figure-7.4: Plot of μ_m versus photon energy for Erythromycin D ($C_{28}H_{47}NO_8$).

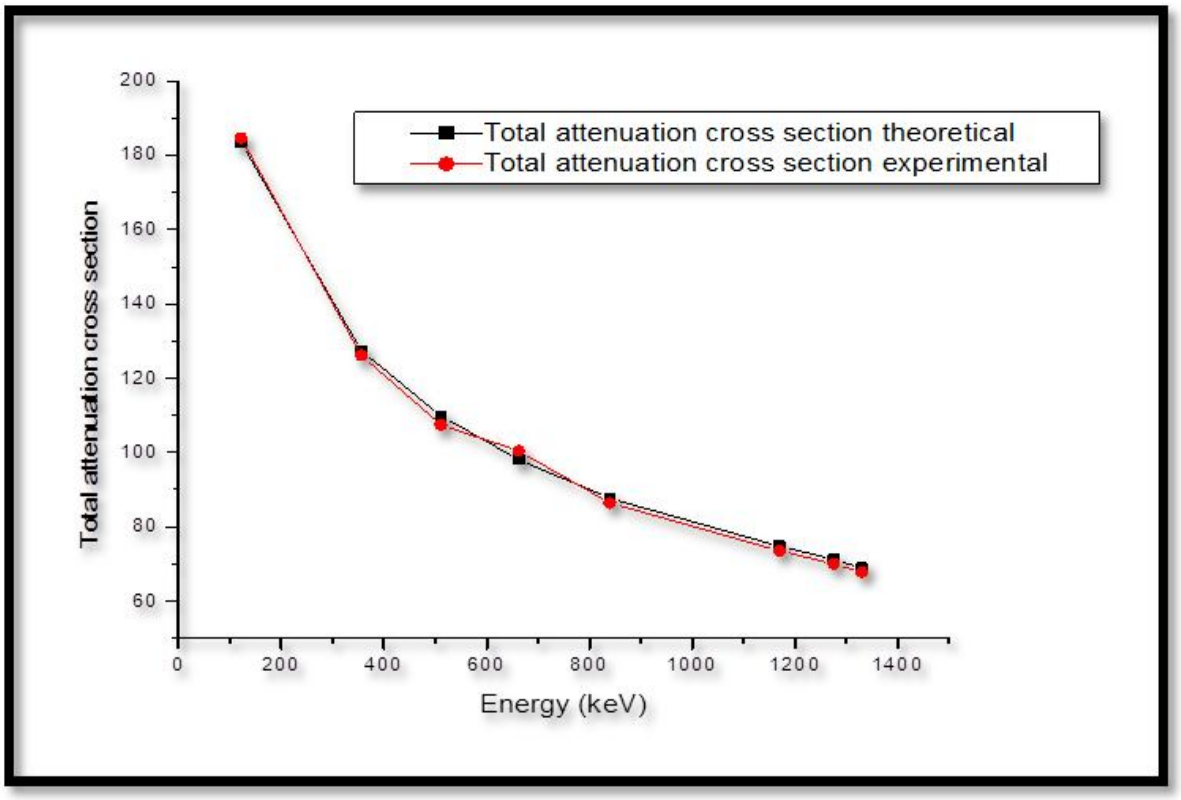


Figure-7.5: Plot of σ_{tot} versus photon energy for Erythromycin D ($C_{28}H_{47}NO_8$).

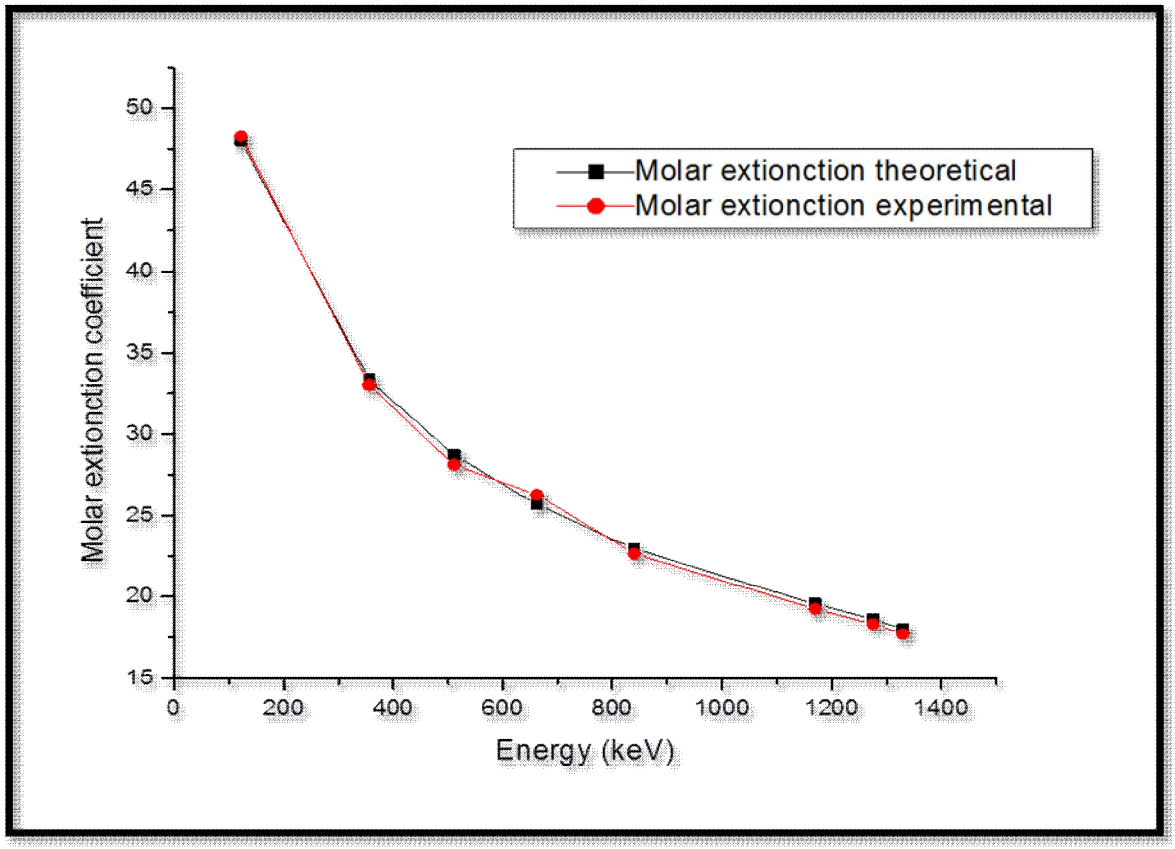


Figure-7.6: Plot of ε versus photon energy for Erythromycin D ($C_{28}H_{47}NO_8$).

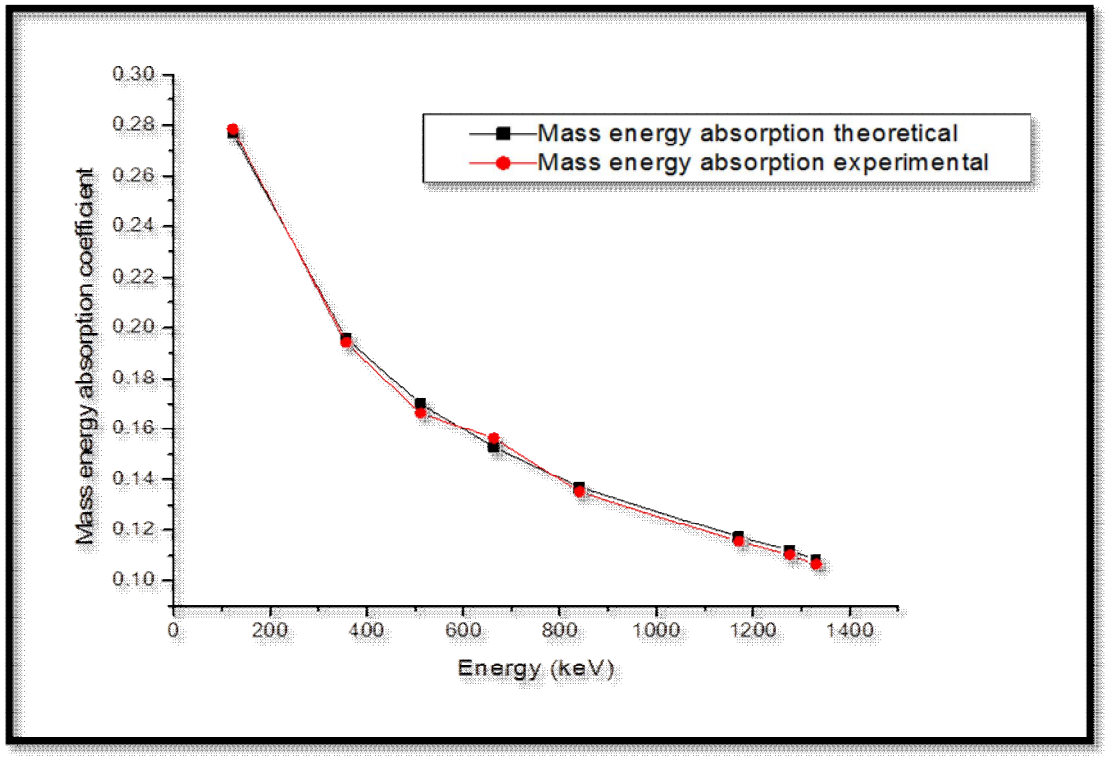


Figure-7.7: Plot of μ_{en}/ρ versus photon energy for Erythromycin D ($C_{28}H_{47}NO_8$).

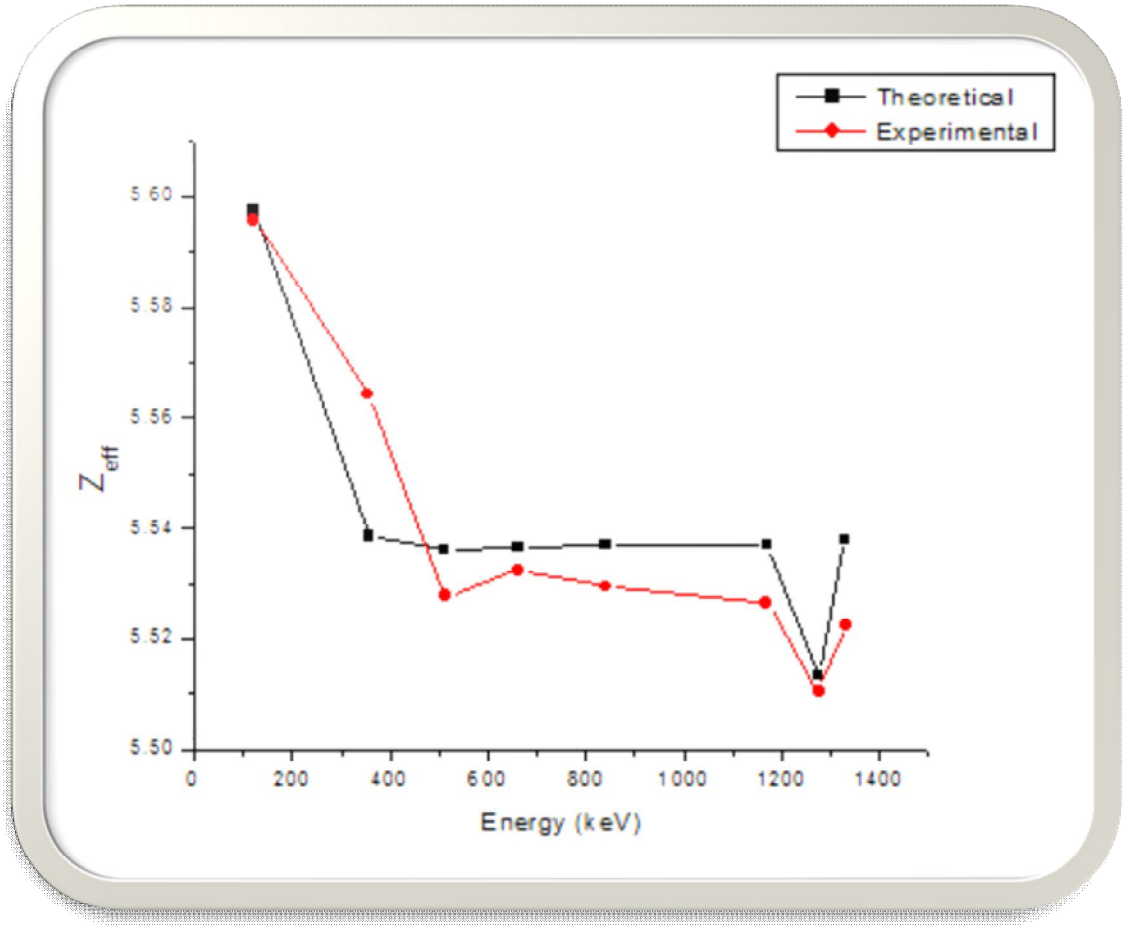


Figure-7.8: Variation of Z_{eff} with photon energy for Erythromycin D ($C_{28}H_{47}NO_8$).

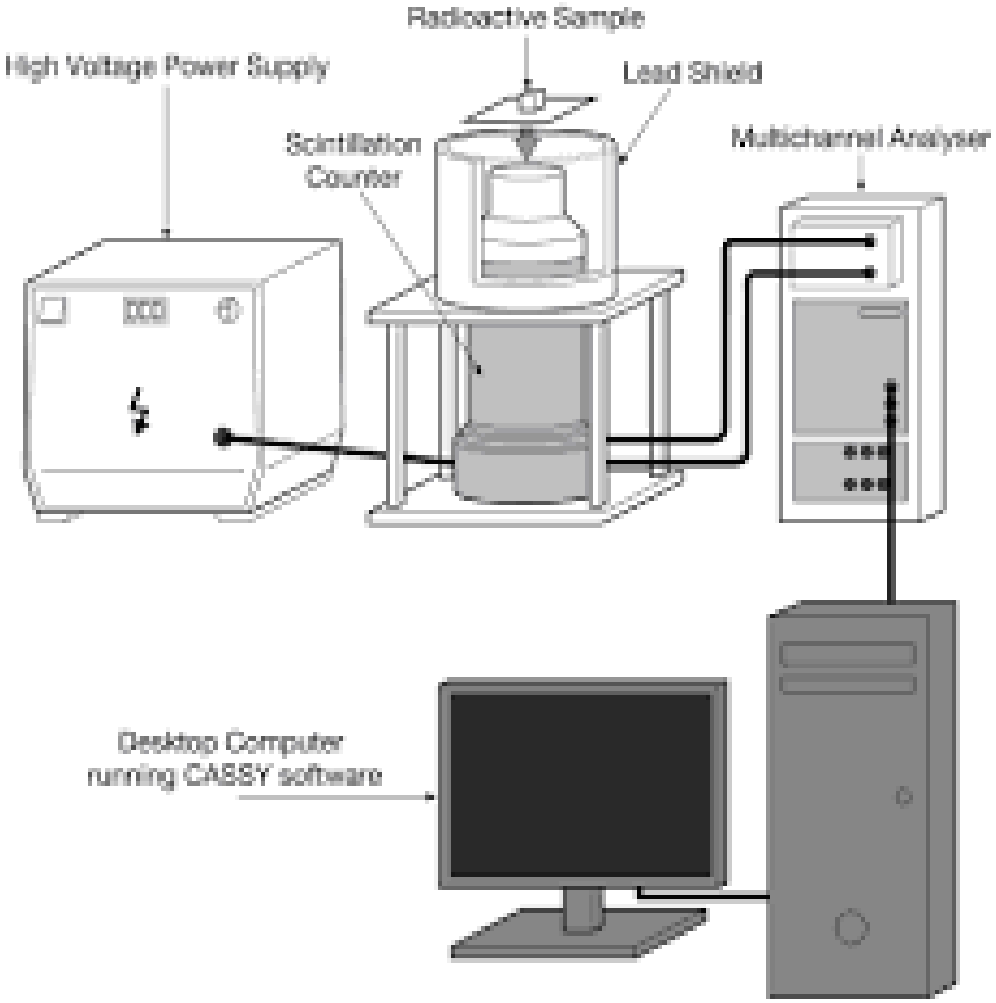


Figure-7.9a: The schematic view of Scintillation counter.

Figure-7.9b: The actual experimental setup of Scintillation counter in laboratory.

Table-23: Gama isotopes with an energy and half lifes.

Gamma Isotope	Energy Mev	Nominal Activity	Half life
Co-57	0.123	2-5 µci	273 Days
Ba-133	0.36 (Main)	2-5 µci	7.5 years
Cs-137	0.662	2-5 µci	30 years
Co - 60	1.17; 1.33	2-5 µci	5.3 years
Na-22	0.511;1,280	2-5 µci	2.6 years
Mn-54	0.840	2-5 µci	313 days

Figure-7.9c: The actual photograph of Photomultiplier tube.

ABOUT THE BOOK

A smooth progression of the need drive goal motivated cycle and one's role expectations don not always occurs in reality. Within every individual there are usually (1) a number of competing needs and roles, (2) a variety of ways that drives and roles can be expressed, (3) many types of barriers which can occur between the drive and the goal, and (4) both positive and negative aspects attached to desired goals. These complicate the human adaptation process in both work and family roles often results in conflict. The dynamics of interactive behavior of police personnel at individual, interpersonal, group and organizational level and the resulting conflict, plat an increasing important role in the analysis and study of police organization behavior. Although conflict and stress are conceptually similar, their effects in intraindividual level differs in frustration, role conflict and ambiguity. The broader organizational perspective of conflict can be found in both the classical and modern structures. Traditionally, the management of organizational conflict was based on simplistic assumptions where as modern approach is to assume the inevitability of conflict, recognize that it is not always bad for the organizations, and try to manage it effectively rather than merely try to eliminate it. Work family conflict, is an inter-role conflict in which work and family domain mutually incompatible, the participation of one role makes difficulties in the performance of other role. The need of balancing the two main domain pressures deserves the psychological wellbeing of human force, are discussed in this book. The antecedents and outcomes of work family conflict are enlisted along with the appropriate coping strategies. The exclusive role pressures of policing, the profession which are constantly affected by unsocial working hours and negative exposures are discussed here. This book has the potential to contribute to the research literature as well as the policing practice by identifying the most critical factors leading to work-to- family confAs a teacher and researcher, nothing is more gratifying than to get your point of view successfully across to your students. You get immense satisfaction when students score well in your subject. This book is designed for teaching, learning and prime introduction to radiological aspects in research view to students at advanced undergraduate or beginning graduate and postgraduate level, this textbook also provides an overview of nuclear physics before they delve into more specialized volumes. Physical concepts, mathematical formulation and observational data are combined in a balanced way to provide a unified treatment. Topics such as radiation measurements, detectors, essentials biomaterials, application and radiological physics behind between them provides prime importance which nicely arranged in chapter wise. While the emphasis is on developing the fundamentals thoroughly and recent important discoveries are highlighted at every stage.

The book coming out of eight years of teaching and research experience is highly lucid and students will pleasure to read. The book shows the necessity of safe and proper use of dose while dealing with. Gamma rays and X-rays are extensively used in the medical field for diagnosis and treatment of many diseases, such as cancer. With proper knowledge of the buildup of photons in human organs and tissues, energy-absorption in the human body can be carefully controlled. The results will also help in estimating safe dose levels for radiotherapy patients and For people who working with X-rays and gamma radiation, especially at reactors and nuclear power plants, the present studies on the energy-absorption coefficient of human organs and tissues will help them to take proper precautions, taking into account the photon buildup in human organs and tissues. Such studies could stimulate further theoretical and experimental developments, in particular close to absorption edges. It is hoped researchers would find it stimulating and engage themselves in optimizing this approach for practical applications in bio-nuclear physics. The contents have been arranged to emphasize the chronological evolution of the concepts.

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