Sudan University of Science and Technology
College of Graduate Studies

Use of Gamma Rays in the Medical Field
أستخدام أشعة جاما في المجال الطبى

A thesis submitted for partial fulfillment of the requirements of
M.Sc. in Nuclear Physics by courses and research

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Preface

قال الله سبحانة وتعالي :

(اللَّـهُ لَا إِلَـٰهَ إِلَّا هُوَ الْحَيُّ الْقَيُّومُ لَا تَأْخُذُهُ سِنَةٌ وَلَا نَوْمٌ لَّهُ مَا فِي
السَّمَاوَاتِ وَمَا فِي الْأَرْضِ مَن ذَا الَّذِي يَشْفَعُ عِندَهُ إِلَّا بِإِذْنِهِ يَعْلَمُ مَا بَيْنَ
أَيْدِيهِمْ وَمَا خَلْفَهُمْ وَلَا يُحِيطُونَ بِشَيْءٍ مِّنْ عِلْمِهِ إِلَّا بِمَا شَاءَ وَسِعَ كُرْسِيُّهُ
السَّمَاوَاتِ وَالْأَرْضَ وَلَا يَئُودُهُ حِفْظُهُمَا وَهُوَ الْعَلِيُّ الْعَظِيمُ (٢٥٥)

صدق الله العظيم

الأية(255) من سورة االبقرة

Dedication

I dedicate the research to my parents and to my family and my wife and daughter and to my tribe. to my teachers and to my colleagues candles that burn lights to others to each of the characters taught me. I dedicate this modest research wishing of God almighty to find acceptance and success.

Acknowledgements

I would first like to thanks Allah the Almighty, without his grace all this would be impossible.

Thanks extended also to SUST University, Graduate College, college of science and physics department.

Special thanks and gratitude to all of the lit candle in our ways and teachers honored in the College of science and extend my deep gratitude to the Dr. Ahmed Elhassan Elfaki, who prefers the supervision of this research has me all appreciation and respect.

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Chapter one

Research plan

1.1 Introduction:-

Since the discovery of Radium by Madame Curie in the early twentieth century, it has been the dream of medical practitioners to use radioactive emissions for treatment of human disease, indeed. Madame Curie and her coworkers found that certain superficial skin diseases underwent dramatic responses after exposure to radiation and fields of radiobiology and radiation oncology were born.

1- In the 30 years post-world war 2, many new radioisotopes were discovered and purified for medical use .In fact, medical radioisotope therapy and research has paralleled development of all other uses of atomic energy , colloidal gold and phosphorous(p-32) were some of the earliest radioisotopes used in therapy.

2- The discovery of a myriad of new radioisotopes for medical use followed rapidly ,along with new radiochemistry procedures for labeling drugs and biological agents .

The history of therapy with unsealed sources can trace its roots to the beginnings of the atomic age ,the birth of modern nuclear medicine imaging .

1.2 Problem of the research:-

Effect of gamma ray in the medical field.

1.3 Importance of the research:-

To use of the scientific applications of nuclear physics in the medical field to achieve the health benefits for people .

1.4 Objectives of the research:-

To manifest how to apply nuclear physics in the medical field that by using some applications of gamma ray for:

1-Diagnosing of human diseases

2-Treatment of human diseases

1.5 Content of the Research:-

Thesis content four Chapters, Chapter one Introduction, Chapter tow Ionizing radiation, Chapter three Gamma ray, Chapter four uses of gamma ray in the medicine.

Chapter two

Ionizing Radiation

2.1 Definition:-

Ionizing radiation: (imprecisely) called radioactivity, is electromagnetic (EM) radiation whose waves contain energy sufficient to overcome the binding energy of electron s in atom s or molecule s, thus creating ion s. The wavelength is shorter than that of ultraviolet (UV).

Ionizing radiation can occur as a barrage of photon s having a nature similar to that of visible light, but with far shorter wavelength and consequently higher frequency . This type of radiation includes X- rays and gamma- rays. More massive particles also comprise ionizing radiation if they travel at sufficient speed. These include high-speed electrons (beta particles), protons, neutrons, and helium nuclei (alpha particles). Ionizing radiation is dangerous because it damages the internal structures of living cells. This can cause cell death in high doses over a short period of time, and errors in the reproductive process (mutations) in lower doses over longer periods of time.

2.2 Types of ionizing radiation:-

The purpose of this section is to provide information on the basics of ionizing radiation for everyone.

Energy emitted from a source is generally referred to as radiation. Examples include heat or light from the sun, microwaves from an oven, X rays from an X-ray tube, and gamma rays from radioactive elements

Ionizing radiation is radiation with enough energy so that during an interaction with an atom, it can remove tightly bound electrons from the orbit of an atom, causing the atom to become charged or ionized.

Here we are concerned with only one type of radiation, ionizing radiation, which occurs in two forms - waves or particles. More information on Non-Ionizing radiation.

Forms of electromagnetic radiation. These differ only in frequency and wave length.

- Heat waves

- Radio waves
- Infrared light
- Visible light
- Ultraviolet light
- X rays
- Gamma rays

Longer wave length, lower frequency waves (heat and radio) have less energy than shorter wave length, higher frequency waves (X and gamma rays). Not all electromagnetic (EM) radiation is ionizing. Only the high frequency portion of the electromagnetic spectrum which includes X rays and gamma rays is ionizing.

2.2.1 Waves:

Most of the more familiar types of electromagnetic radiation (e.g. visible light, radio waves) exhibit “wave-like” behavior in their interaction with matter (e.g. diffraction patterns, transmission and detection of radio signals). The best way to think of electromagnetic radiation is a wave packet called a photon. Photons are chargeless bundles of energy that travel in a vacuum at the velocity of light, which is 300 000 km/sec.

2.2.2 Particulate:

Particulate radiation, consisting of atomic or subatomic particles (electrons, protons, etc.) which carry energy in the form of kinetic energy or mass in motion.

Electromagnetic radiation, in which energy is carried by oscillating electrical and magnetic fields traveling through space at the speed of light.

Alpha particles and beta particles are considered directly ionizing because they carry a charge and can, therefore, interact directly with atomic electrons through coulombic forces (i.e. like charges repel each other; opposite charges attract each other).

The neutron is an indirectly ionizing particle. It is indirectly ionizing because it does not carry an electrical charge. Ionization is caused by charged particles, which are produced during collisions with atomic nuclei.

The third type of ionizing radiation includes gamma and X rays, which are electromagnetic, indirectly ionizing radiation. These are indirectly ionizing because they are electrically neutral (as are all electromagnetic radiations) and do not interact with atomic electrons through coulombic forces.

2.2.3 Isotopes and Activity:-

Isotopes: Atoms in their normal state are electrically neutral because the total negative charge of electrons outside the nucleus equals the total positive charge of the nucleus .

Atoms with the same number of protons and different number of neutrons are called ISOTOPES. An isotope may be defined as one or two or more forms of the same element having the same atomic number (Z), differing mass numbers (A), and the same chemical properties.

These different forms of an element may be stable or unstable (radioactive). However, since they are forms of the same element, they possess identical chemical and biological properties.

The simplest atom is the hydrogen atom. It has one electron orbiting a nucleus on one proton. Any atom which has one proton in the nucleus is a hydrogen atom, like both of the ones shown here. Hydrogen-2 is called deuterium, hydrogen-3 is called tritium. However, while their chemical properties are identical their nuclear properties are quite different as only tritium is radioactive.

Activity:

- The activity of a radioisotope is simply a measure of how many atoms undergo radioactive decay per a unit of time.
- The SI unit for measuring the rate of nuclear transformations is the becquerel (Bq). The becquerel is defined as 1 radioactive disintegration per second.
- The old unit for this is the curie (Ci), in honour of Pierre and Marie Curie who discovered radium and polonium. The curie is based on the activity of 1 gram of radium-226, i.e. 3.7×10^{10} radioactive disintegrations per second.

2.2.4 Dose and Source:-

Dose:

- Only the amount of energy of any type of ionizing radiation that imparted to (or absorbed by) the human body can cause harm to health.
- To look at biological effects, we must know (estimate) how much energy is deposited per unit mass of the part (or whole) of our body with which the radiation is interacting.

- The international (SI) unit of measure for absorbed dose is the gray (Gy), which is defined as 1 joule of energy deposited in 1 kilogram of mass. The old unit of measure for this is the rad, which stands for "radiation absorbed dose." - 1 Gy = 100 rad.
- Equivalent dose – the biological effect depends not only on the amount of the absorbed dose but also on the intensity of ionization in living cells caused by different type of radiations.
- Neutron, proton and alpha radiation can cause 5-20 times more harm than the same amount of the absorbed dose of beta or gamma radiation.
- The unit of equivalent dose is the sievert (Sv). The old unit of measure is the rem. - 1 Sv = 100 rem.

Source:

Ionizing radiation is generated through nuclear reactions, nuclear decay, by very high temperature, or via acceleration of charged particles in electromagnetic fields. Natural sources include the sun, lightning and supernova explosions. Artificial sources include nuclear reactors, particle accelerators, and x-ray tubes.

2.3 penetration of ionizing radiation:-

Ionizing radiation takes a few forms: Alpha, beta, and neutron particles, and gamma and X-rays. All types are caused by unstable atoms, which have either an excess of energy or mass (or both). In order to reach a stable state, they must release that extra energy or mass in the form of radiation (fig-1).

2.3.1 Alpha Radiation:-

Alpha radiation occurs when an atom undergoes radioactive decay, giving off a particle (called an alpha particle) consisting of two protons and two neutrons (essentially the nucleus of a helium-4 atom), changing the originating atom to one of an element with an atomic number 2 less and atomic weight 4 less than it started with. Due to their charge and mass, alpha particles interact strongly with matter, and only travel a few centimeters in air (fig-2). Alpha particles are unable to penetrate the outer layer of dead skin cells, but are capable, if an alpha emitting substance is ingested in food or air, of causing serious cell damage. Alexander Litvinenko is a famous example. He was poisoned by polonium-210, an alpha emitter, in his tea.

2.3.2 Beta Radiation:-

Beta radiation takes the form of either an electron or a positron (a particle with the size and mass of an electron, but with a positive charge) being emitted from an atom. Due to the smaller mass, it is able to travel further in air, up to a few meters, and can be stopped by a thick piece of plastic, or even a stack of paper (fig-3). It can penetrate skin a few centimeters, posing somewhat of an external health risk. However, the main threat is still primarily from internal emission from ingested material.

2.3.3 Gamma Radiation:-

Gamma radiation, unlike alpha or beta, does not consist of any particles, instead consisting of a photon of energy being emitted from an unstable nucleus. Having no mass or charge, gamma radiation can travel much farther through air than alpha or beta, losing (on average) half its energy for every 500 feet. Gamma waves can be stopped by a thick or dense enough layer material (fig-4), with high atomic number materials such as lead or depleted uranium being the most effective form of shielding.

2.3.4 X-Rays:-

X-rays are similar to gamma radiation, with the primary difference being that they originate from the electron cloud. This is generally caused by energy changes in an electron, such as moving from a higher energy level to a lower one, causing the excess energy to be released. X-Rays are longer wavelength and (usually)lower energy than gamma radiation, as well (fig-5).

2.3.5 Neutron Radiation:-

Lastly, Neutron radiation consists of a free neutron, usually emitted as a result of spontaneous or induced nuclear fission. Able to travel hundreds or even thousands of meters in air, they are however able to be effectively stopped if blocked by a hydrogen-rich material, such as concrete or water (fig-6). Not typically able to ionize an atom directly due to their lack of a charge, neutrons most commonly are indirectly ionizing, in that they are absorbed into a stable atom, thereby making it unstable and more likely to emit off ionizing radiation of another type. Neutrons are, in fact, the only type of radiation that is able to turn other materials radioactive.

2.4 Physical effects:-

2.4.1 Nuclear effects:-

Neutron radiation, alpha radiation, and extremely energetic gamma (> ~20 MeV) can cause nuclear transmutation and induced radioactivity. The relevant mechanisms are neutron activation, alpha absorption, and photodisintegration. A large enough number of transmutations can change macroscopic properties and cause targets to become radioactive themselves, even after the original source is removed.

2.4.2 Chemical effects:-

Ionization of molecules can lead to radiolysis (breaking chemical bonds), and formation of highly reactive free radicals. These free radicals may then react chemically with neighboring materials even after the original radiation has stopped. Ionizing radiation can disrupt crystal lattices in metals, causing them to become amorphous, with consequent swelling, material creep, and embrittlement. Ionizing radiation can also accelerate existing chemical reactions such as polymerization and corrosion, by contributing to the activation energy required for the reaction. Optical materials darken under the effect of ionizing radiation.

High-intensity ionizing radiation in air can produce a visible ionized air glow of telltale bluish-purplish color. The glow can be observed, e.g., during criticality accidents, around mushroom clouds shortly after a nuclear explosion, or inside of a damaged nuclear reactor like during the Chernobyl disaster.

Monatomic fluids, e.g. molten sodium, have no chemical bonds to break and no crystal lattice to disturb, so they are immune to the chemical effects of ionizing radiation. Simple diatomic compounds with very negative enthalpy of formation, such as hydrogen fluoride will reform rapidly and spontaneously after ionization.

2.4.3 Electrical effects:-

Ionization of materials temporarily increases their conductivity, potentially permitting damaging current levels. This is a particular hazard in semiconductor microelectronics employed in electronic equipment, with subsequent currents introducing operation errors or even permanently damaging the devices. Devices intended for high radiation environments such as the nuclear industry and extra atmospheric (space) applications may be made *radiation hard* to resist such effects through design, material selection, and fabrication methods.

Proton radiation found in space can also cause single-event upsets in digital circuits.

The electrical effects of ionizing radiation are exploited in gas-filled radiation detectors, e.g. the Geiger-Muller counter or the ion chamber.

2.4.4 Health effects:-

In general, ionizing radiation is harmful and potentially lethal to living beings but can have health benefits in radiation therapy for the treatment of cancer and thyrotoxicosis.

Most adverse health effects of radiation exposure may be grouped in two general categories:

- deterministic effects (harmful tissue reactions) due in large part to the killing/ malfunction of cells following high doses; and
- stochastic effects, i.e., cancer and heritable effects involving either cancer development in exposed individuals owing to mutation of somatic cells or heritable disease in their offspring owing to mutation of reproductive (germ) cells [1].

The human body cannot sense ionizing radiation except in very high doses, but the effects of ionization can be used to characterize the radiation. Parameters of interest include disintegration rate, particle flux, particle type, beam energy, dose rate, and radiation dose.

If the radiation type is not known then it can be determined by differential measurements in the presence of electrical fields, magnetic fields, or varying amounts of shielding.

The International Commission on Radiological Protection manages the International System of Radiological Protection, which sets recommended limits for dose uptake. Dose values may represent absorbed, equivalent, effective, or committed dose. The monitoring and calculation of doses to safeguard human health is called dosimetry and is undertaken within the science of health physics. Key measurement tools are the use of dosimeters to give the external effective dose uptake and the use of bio-assay for ingested dose. The article on the sievert summarizes the recommendations of the ICRU and ICRP on the use of dose quantities and includes a guide to the effects of ionizing radiation as measured in sieverts, and gives examples of approximate figures of dose uptake in certain situations.

The committed dose is a measure of the stochastic health risk due to an intake of radioactive material into the human body. The ICRP states "For internal exposure, committed effective doses are generally determined from an assessment of the intakes of radionuclides from bioassay measurements or other quantities. The radiation dose is determined from the intake using recommended dose coefficients [2].

2.5 Uses:-

Ionization radiation has many industrial, military, and medical uses. Its usefulness must be balanced with its hazards, a compromise that has shifted over time. For example, at one time, assistants in shoe shops used X-rays to check a child's shoe size, but this practice was halted when the risks of ionizing radiation were better understood [3].

Neutron radiation is essential to the working of nuclear reactors and nuclear weapons. The penetrating power of x-ray, gamma, beta, and positron radiation is used for medical imaging, nondestructive testing, and a variety of industrial gauges. Radioactive tracers are used in medical and industrial applications, as well as biological and radiation chemistry. Alpha radiation is used in static eliminators and smoke detectors. The sterilizing effects of ionizing radiation are useful for cleaning medical instruments, food irradiation, and the sterile insect technique. Measurements of carbon-14, can be used to date the remains of long-dead organisms (such as wood that is thousands of years old).

2.6 Background radiation:-

Background radiation comes from both natural and man-made sources (Artificial sources) .The global average exposure of humans to ionizing radiation is about 3 mSv (0.3 rem) per year, 80% of which comes from nature. The remaining 20% results from exposure to man-made radiation sources, primarily from medical imaging. Average man-made exposure is much higher in developed countries, mostly due to CT scans and nuclear medicine.

Natural background radiation comes from five primary sources: cosmic radiation, solar radiation, external terrestrial sources, radiation in the human body, and radon [4].

2.7 Radiation exposure:-

There are three standard ways to limit exposure:

1. **Time**: For people exposed to radiation in addition to natural background radiation, limiting or minimizing the exposure time will reduce the dose from the radiation source.
2. **Distance**: Radiation intensity decreases sharply with distance, according to an inverse-square law (in an absolute vacuum).

3. **Shielding**: The effectiveness of a material in shielding radiation is determined by its half-value thicknesses, the thickness of material that reduces the radiation by half. This value is a function of the material itself and of the type and energy of ionizing radiation. Some generally accepted thicknesses of attenuating material are 5 mm of aluminum for most beta particles, and 3 inches of lead for gamma radiation [5].

2.8 Occupational exposure:-

Occupationally exposed individuals are controlled within the regulatory framework of the country they work in, and in accordance with any local nuclear licence constraints. These are usually based on the recommendations of the ICRP. The International Commission on Radiological Protection recommends limiting artificial irradiation. For occupational exposure, the limit is 50 mSv in a single year with a maximum of 100 mSv in a consecutive five-year period.

The radiation exposure of these individuals is carefully monitored with the use of dosimeters and other radiological protection instruments which will measure radioactive particulate concentrations, area gamma dose readings and radioactive contamination. A legal record of dose is kept.

Examples of activities where occupational exposure is a concern include:

- Airline crew (the most exposed population)
- Industrial radiography
- Medical radiology and nuclear medicine [6][7]
- Uranium mining
- Nuclear power plant and nuclear fuel reprocessing plant workers
- Research laboratories (government, university and private)

2.9 Public exposure:-

Medical procedures, such as diagnostic X-rays, nuclear medicine, and radiation therapy are by far the most significant source of human-made radiation exposure to the general public. Some of the major radio nuclides used are I-131, Tc-99m, Co^{60}, Ir^{192}, and Cs^{137}. The public also is exposed to radiation from consumer products, such as tobacco (polonium-210), combustible fuels (gas, coal, etc.), televisions, luminous watches and dials (tritium), airport X-ray systems, smoke detectors (americium), electron tubes, and gas lantern mantles (thorium).

Of lesser magnitude, members of the public are exposed to radiation from the nuclear fuel cycle, which includes the entire sequence from processing uranium to the disposal of the spent fuel [8].

Chapter three

Gamma Ray:-

3.1 History of Discovery:-

Gamma ray (also called gamma radiation), denoted by the lower-case Greek letter gamma (γ or), is extremely high-frequency electromagnetic radiation and therefore consists of high-energy photons [9].

The first gamma ray source to be discovered historically was the radioactive decay process called gamma decay .In this type of decay ,an excited nucleus emits a gamma ray almost immediately upon formation . Paul Villard, a French chemist and physicist, discovered gamma radiation in 1900,while studying radiation emitted from radium . Villard knew that his described radiation was more powerful than previously described types of rays from radium, which included beta rays, first noted as “radioactivity” by Henri Becquerel in 1896 , and alpha rays, discovered as a less penetrating from of radiation by Rutherford, in 1899.However, Villard did not consider naming them as a different fundamental type [10][11]. Villard's radiation was recognized as being of a type fundamentally different from previously named rays, 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 [12].

The “rays” emitted by radioactive elements were named in order of their power to penetrate various materials, using the first three letters of the Greek alphabet: alpha rays as the least penetrating, followed by beta rays, followed by gamma rays as the most penetrating. Rutherford also noted that gamma rays were not deflected (or at least, not *easily* deflected) by a magnetic field, another property making them unlike alpha and beta rays.

Gamma rays were first thought to be particles with mass, like alpha and beta rays. Rutherford initially believed that they might be extremely fast beta particles, but their failure to be deflected by a magnetic field indicated that they had no charge [13]. In 1914,gamma rays were observed to be reflected from crystal surfaces, proving that they were electromagnetic radiation [13]. Rutherford and his coworker Edward Andrade measured the wavelengths of gamma rays from radium, and found that they were similar to X-rays, but with shorter wavelengths and (thus) higher frequency. This was eventually recognized as giving them also more energy per photon, as soon as the latter term became generally accepted. A gamma decay was then understood to usually emit a single gamma photon.

3.2 Sources of gamma rays:-

Natural sources of gamma rays on Earth include gamma decay from naturally occurring radioisotopes such as potassium-40, and also as a secondary radiation from various atmospheric interactions with cosmic ray particles. Some rare terrestrial natural sources that produce gamma rays that are not of a nuclear origin, are lightning strikes and terrestrial gamma-ray flashes, which produce high energy emissions from natural highenergy voltages. Gamma rays are produced by a number of astronomical processes in which very high-energy electrons are produced. Such electrons produce secondary gamma rays by the mechanisms of bremsstrahlung, inverse Compton scattering and synchrotron radiation. A large fraction of such astronomical gamma rays are screened by Earth's atmosphere and must be detected by spacecraft. Notable artificial sources of gamma rays include fission such as occurs in nuclear reactors, and high energy physics Sources of gamma ray experiments, such as neutral pion decay and nuclear fusion.

3.3 General characteristics :-

The distinction between X-rays and gamma rays has changed in recent decades. Originally, the electromagnetic radiation emitted by X-ray tubes almost invariably had a longer wavelength than the radiation (gamma rays) emitted by radioactive nuclei [14]. Older literature distinguished between X- and gamma radiation on the basis of wavelength, with radiation shorter than some arbitrary wavelength, such as 10−11 m, defined as gamma rays [15]. However, with artificial sources now able to duplicate any electromagnetic radiation that originates in the nucleus, as well as far higher energies, the wavelengths characteristic of radioactive gamma ray sources vs. other types, now completely overlap. Thus, gamma rays are now usually distinguished by their origin: X-rays are emitted by definition by electrons outside the nucleus, while gamma rays are emitted by the nucleus [16][17][18] . Exceptions to this convention occur in astronomy, where gamma decay is seen in the afterglow of certain supernovas, but other high energy processes known to involve other than radioactive decay are still classed as sources of gamma radiation.

3.4 Units of measure and exposure:-

The measure of gamma rays' ionizing ability is called the exposure:

The coulomb per kilogram (C/kg) is the SI unit of ionizing radiation exposure, and is the amount of radiation required to create 1 coulomb of charge of each polarity in 1 kilogram of matter.

The röntgen (R) is an obsolete traditional unit of exposure, which represented the amount of radiation required to create 1 esu of charge of each polarity in 1 cubic centimeter of dry air. 1 röntgen = 2.58×10^{-4} C/kg.

However, the effect of gamma and other ionizing radiation on living tissue is more closely related to the amount of energy deposited rather than the charge. This is called the absorbed dose:

The gray (Gy), which has units of (J/kg), is the SI unit of absorbed dose, and is the amount of radiation required to deposit 1 joule of energy in 1 kilogram of any kind of matter.

The rad is the deprecated CGS unit, equal to 0.01 J deposited per kg. 100 rad = 1 Gy.

The equivalent dose is the measure of the biological effect of radiation on human tissue. For gamma rays, it is equal to the absorbed dose.

The sievert (Sv) is the SI unit of equivalent dose, which for gamma rays is numerically equal to the gray (Gy).

The rem is the deprecated CGS unit of equivalent dose. For gamma rays it is equal to the rad or 0.01 J of energy deposited per kg. 1 Sv = 100 rem [19].

3.5 Properties:-

3.5.1 Shielding:--

Shielding from gamma rays requires large amounts of mass, in contrast to alpha particles, which can be blocked by paper or skin, and beta particles, which can be shielded by foil. Gamma rays are better absorbed by materials with high atomic numbers and high density, although neither effect is important compared to the total mass per area in the path of the gamma ray. For this reason, a lead shield is only modestly better (20–30% better) as a gamma shield than an equal mass of another shielding material, such as aluminum, concrete, water or soil; lead's major advantage is not in lower weight, but rather its compactness due to its higher density. Protective clothing, goggles and respirators can protect from internal contact with or ingestion of alpha or beta emitting particles, but provide no protection from gamma radiation from external sources.

The higher the energy of the gamma rays, the thicker the shielding made from the same shielding material is required. Materials for shielding gamma rays are typically measured by the thickness required to reduce the intensity of the gamma rays by one half (the half value layer or HVL). For example, gamma rays that require 1 cm (0.4″) of lead to reduce their intensity by 50% will also have their intensity reduced in half by 4.1 cm of granite rock, 6 cm (2½″) of concrete, or 9 cm (3½″) of packed soil. However, the mass of this

much concrete or soil is only 20–30% greater than that of lead with the same absorption capability. Depleted uranium is used for shielding in portable gamma ray sources, but here the savings in weight over lead are larger, as portable sources' shape resembles a sphere to some extent, and the volume of a sphere is dependent on the cube of the radius; so a source with its radius cut in half will have its volume reduced by a factor of eight, which will more than compensate uranium's greater density . In a nuclear power plant, shielding can be provided by steel and concrete in the pressure and particle containment vessel, while water provides a radiation shielding of fuel rods during storage or transport into the reactor core. The loss of water or removal of a "hot" fuel assembly into the air would result in much higher radiation levels than when kept under water [20].

3.5.2 Matter interaction:-

When a gamma ray passes through matter, the probability for absorption is proportional to the thickness of the layer, the density of the material, and the absorption cross section of the material. The total absorption shows an exponential decrease of intensity with distance from the incident surface:

$$I(x) = I_0 . e^{-\mu x}$$

where x is the thickness of the material from the incident surface, $\mu = n\sigma$ is the absorption coefficient, measured in cm−1, n the number of atoms per cm^3 of the material (atomic density) and σ the absorption cross section in cm^2.

As it passes through matter, gamma radiation ionizes via three processes: the

photoelectric effect, Compton scattering, and pair production.

Photoelectric effect: This describes the case in which a gamma photon interacts with and transfers its energy to an atomic electron, causing the ejection of that electron from the atom. The kinetic energy of the resulting photoelectron is equal to the energy of the incident gamma photon minus the energy that originally bound the electron to the atom (binding energy). The photoelectric effect is the dominant energy transfer mechanism for X-ray and gamma ray photons with energies below 50 keV (thousand electron volts), but it is much less important at higher energies.

Compton scattering: This is an interaction in which an incident gamma photon loses enough energy to an atomic electron to cause its ejection, with the remainder of the original photon's energy emitted as a new, lower energy gamma photon whose emission direction is different from that of the incident gamma photon, hence the term "scattering". The probability of Compton scattering decreases with increasing photon energy. Compton scattering is thought to be the principal absorption mechanism for gamma rays in the intermediate energy range 100 keV to 10 MeV.

Compton scattering is relatively independent of the atomic number of the absorbing material, which is why very dense materials like lead are only modestly better shields, on a *per weight* basis, than are less dense materials.

Pair production: This becomes possible with gamma energies exceeding 1.02 MeV, and becomes important as an absorption mechanism at energies over 5 MeV. By interaction with the electric field of a nucleus, the energy of the incident photon is converted into the mass of an electron-positron pair. Any gamma energy in excess of the equivalent rest mass of the two particles (totaling at least 1.02MeV) appears as the kinetic energy of the pair and in the recoil of the emitting nucleus.

At the end of the positron's range, it combines with a free electron, and the two annihilate ,and the entire mass of these two is then converted into two gamma photons of at least 0.51 MeV energy each (or higher according to the kinetic energy of the annihilated particles).

The secondary electrons (and/or positrons) produced in any of these three processes frequently have enough energy to produce much ionization themselves.

Additionally, gamma rays, particularly high energy ones, can interact with atomic nuclei resulting in ejection of particles in photodisintegration, or in some cases, even nuclear fission (photofission).

3.5.3 Light interaction:-

High energy (from 80 GeV to ~10 TeV) gamma rays arriving from far-distant quasars are used to estimate the extragalactic background light in the universe: The highest-energy rays interact more readily with the background light photons and thus the density of the background light may be estimated by analyzing the incoming gamma ray spectra [21][22].

3.5.4 Gamma ray production:-

Gamma rays can be produced by a wide range of phenomena, both nuclear and non-nuclear.

Radioactive decay (gamma decay): Gamma rays are produced during gamma decay, which normally occurs after other forms of decay occur, such as alpha or beta decay. An excited nucleus can decay by the emission of an α or β particle. The daughter nucleus that results is usually left in an excited state. It can then decay to a lower energy state by emitting a gamma ray photon, in a process called gamma decay.

The emission of a gamma ray from an excited nucleus typically requires only 10−12 seconds. Gamma decay may also follow nuclear reactions such as neutron capture, nuclear fission, or nuclear fusion. Gamma decay is also a mode of relaxation of many excited states of atomic nuclei following other types of radioactive decay, such as beta decay, so long as these states possess the necessary component of nuclear spin. When high-energy gamma rays, electrons, or protons bombard materials, the excited atoms emit

Characteristic "secondary" gamma rays, which are products of the creation of excited nuclear states in the bombarded atoms.

In certain cases, the excited nuclear state that follows the emission of a beta particle or other type of excitation may be more stable than average, and is termed a metastable excited state, if its decay takes (at least) 100 to 1000 times longer than the average 10−12 seconds. The rate of gamma decay is also slowed when the energy of excitation of the nucleus is small [23].

An emitted gamma ray from any type of excited state may transfer its energy directly to any electrons, but most probably to one of the K shell electrons of the atom, causing it to be ejected from that atom, in a process generally termed the photoelectric effect (external gamma rays and ultraviolet rays may also cause this effect). The photoelectric effect should not be confused with the internal conversion process, in which a gamma ray photon is not produced as an intermediate particle (rather, a "virtual gamma ray" may be thought to mediate the process).

Gamma rays, X-rays, visible light, and radio waves are all forms of electromagnetic radiation. The only difference is the frequency and hence the energy of those photons. Gamma rays are generally the most energetic of these, although a broad overlap with X ray energies occurs. An example of gamma ray production follows:

First 60Co decays to excited 60Ni by beta decay emission of an electron of 0.31 MeV. Then the excited 60Ni decays to the ground state by emitting gamma rays in succession of 1.17 MeV followed by 1.33 MeV.

$$ {}^{60}_{27}Co \longrightarrow {}^{60}_{28}\mathrm{Ni}^{*} + \mathrm{e}^{-} + \mathrm{v}_{\mathrm{e}} + \gamma + 1.17MeV $$

$$ {}^{60}_{28}Ni^{*} \longrightarrow {}^{60}_{28}Ni + \gamma + 1.33MeV $$

Another example is the alpha decay of 241Am to form 237Np; which is followed by gamma emission. In some cases, the gamma emission spectrum of the daughter nucleus is quite simple, (e.g. 60Co/60Ni) while in other cases, such as with (241Am/237Np and 192Ir/192Pt),the gamma emission spectrum is complex, revealing that a series of nuclear energy levels exist.

Gamma rays from sources other than radioactive decay:A few gamma rays in astronomy are known to arise from gamma decay but most do not. Photons from astrophysical sources that carry energy in the gamma radiation range are often explicitly called gamma-radiation. In addition to nuclear emissions, they are often produced by sub-atomic particle and particle-photon interactions. Those include electron -positron annihilation, neutral pion decay, bremsstrahlung, inverse Compton scattering and synchrotron radiation.

Terrestrial thunderstorms: Thunderstorms can produce a brief pulse of gamma radiation called a terrestrial gamma-ray flash. These gamma rays are thought to be produced by high intensity static electric fields accelerating electrons, which then produce gamma rays by bremsstrahlung as they collide with and are slowed by atoms in the atmosphere. Gamma rays up to 100 MeV can be emitted by terrestrial thunderstorms, and were discovered by space-borne observatories.

This raises the possibility of health risks to passengers and crew on aircraft flying in or near thunderclouds [24].

Pulsars and magnetars: The gamma ray sky is dominated by the more common and longer-term production of gamma rays that emanate from pulsars within the Milky Way. Sources from the rest of the sky are mostly quasars. Pulsars are thought to be neutron stars with magnetic fields that produce focused beams of radiation, and are far less energetic, more common, and much nearer sources (typically seen only in our own galaxy) than are quasars or the rarer gamma-ray burst sources of gamma rays.

Quasars and active galaxies: More powerful gamma rays from very distant quasars and closer active galaxies are thought to have a gamma ray production source similar to a particle accelerator. High energy electrons produced by the quasar, and subjected to inverse Compton scattering, synchrotron radiation, or bremsstrahlung, are the likely source of the gamma rays from those objects. It is thought that as a supermassive black hole at the center of such galaxies provides the power source that intermittently destroys stars and focuses the resulting charged particles into beams that emerge from their rotational poles. When those beams interact with gas, dust, and lower energy photons they produce X-rays and gamma rays.

Gamma-ray bursts: The most intense sources of gamma rays are also the most intense sources of any type of electromagnetic radiation presently known. They are the "long duration burst" sources of gamma rays in astronomy ("long" in this context, meaning a few tens of seconds), and they are rare compared with the sources discussed above. By contrast, "short" gamma-ray bursts, which are not associated with supernovae, are thought to produce gamma rays during the collision of pairs of neutron stars, or a neutron star and a black hole. Such bursts last two seconds or less, and are of far lower energy than the "long" bursts (only sources in our galaxy are detectable for that reason) [25].

3.6 Health effect:-

Gamma rays cause damage at a cellular level and are penetrating, causing diffuse damage throughout the body. However, they are less ionizing than alpha or beta particles, which are less penetrating.

Low levels of gamma rays cause a stochastic health risk, which for radiation dose assessment is defined as the probability of cancer induction and genetic damage. High doses produce deterministic effects, which is the severity of acute tissue damage that is certain to happen. These effects are compared to the physical quantity of the absorbed dose measured by the unit gray (Gy) [26].

Chapter four

Uses of gamma rays in the medicine:-

4.1 Sterilizing equipment:

Nuclear radiation is used in medicine to sterilize equipment, to help in diagnosis and to treat cancer with gamma rays.

Gamma rays are high energy electromagnetic waves which are only stopped by thick lead .This means they can easily pass through medical equipment, such as syringes.

As gamma rays pass through the packaging they will inactivate viruses and kill bacteria .As long as the equipment remains in a sealed plastic pack it will remain sterile.

4.1.1Tracers:

Radioactive tracers are used to investigate a patient's body without the need for surgery. Gamma emitters and sometimes beta emitters are used .This is because gamma rays and beta particles can pass through skin, whereas alpha particles cannot.

A small amount of radioactive material is put into patient's body .The radiographer puts a detector around the body to detect any gamma rays or beta particles that pass out of the patient's body.

Nuclear radiation can damage cells. To avoid possible harm to the patient, it is important that medical tracers do not stay active in the body for long periods.

The source used is either a beta or gamma emitter .Radioisotopes with short half-lives are chosen to make sure that the tracer does not stay radioactive in the body for long periods. The radioisotopes may be chemically on the test being carried out.

The radioactive tracer is put into the body by one of the following ways:

By an injection

By ingestion (eating a solid with the tracer in it or drinking a liquid with the tracer in it)

The tracer is given enough time to move around the body before a radiographer positions a radiation detector outside the body .This produces a picture showing where the tracer has accumulated .

Tracers and markers in medicine:-

The tracers used in medicine are complex organic molecules specifically chosen for their affinity for the organ under examination. These molecules are ‘marked’ by the presence of a radioactive nucleus, and are often injected intravenously. On these skeletal scans, we can see the areas where a diphosphate marked with technetium 99 has built up, indicating the possible presence of metastasis. This particular marker is very popular in gamma cintigraphy. If order to trace the journey of a specific molecule, one can replace a stable atom with a radioactive **isotope** (such as replacing hydrogen with tritium), and follow the trail left by the radiation. This process is known as radioactive ‘marking’ rather than ‘tracing’, as the isotope in question is merely playing the part of an identifying sticker. For instance, a radioisotope like cobalt-60 would be called a tracer if used to trace the behaviour of cobalt in a chemical process. On the contrary, we would talk of marking with cobalt 60 in a metallurgical process whereby steel balls are coated with this radioisotope so as to highlight the flow of these steel balls. The distinction between markers and tracers, however, is a vague one for the non-specialist, and one is often taken for the other.

Thanks to radioactive isotopes it is now possible to follow the process of a specific chemical or particle without altering the structural, chemical or hydrodynamic properties of the substance. In the same way, it has been possible to monitor the radioactive fallout and the residual pollution of the nuclear tests and of the Chernobyl accident.

4.2 Gamma Cameras:-

'Gamma cameras' or scintillation cameras are pieces of apparatus which allow radiologists to carry out scintigraphy scans', tests which provide detailed diagnoses about the functioning of the thyroid, the heart, the lungs and many other parts of the body. Scintigraphy scans get their name from the ability of some crystals (such as sodium iodide) to scintillate (in other words, emit sparks) when exposed to radiation.

4.2.1 Double-headed gamma camera:

This gamma camera is equipped with two heads capable of detecting the presence of radiation. The lower head is partly concealed under the bed, and the whole apparatus can be moved along horizontally to obtain a full-body scintigraphy. By doubling the number of gamma rays used, a face scintigraphy can be performed at the same time as a back scintigraphy for the same amount of radioisotope ingested. By comparison with a PET scanner, a gamma camera requires much less equipment and is more easy to set up. A large number of hospitals make use of them for this reason.

The procedure involves giving the patient a radiopharmaceutical molecule marked with a gamma-emitting radioisotope. Once the molecule fixed on the target organ or tissue, the highly penetrative emitted gamma rays easily escape from the body and leave their mark on the detection panels. The molecule which is followed around the body is carefully chosen with respect to the body part under examination. A very small quantity of radioactive isotope is all that is needed, as the detection systems are sensitive enough to register the decay of individual atoms.

For gamma rays emitted by technetium atoms, 140 keV of energy will be deposited in the scintillatiors.

As its name indicates, a 'gamma camera' detects scintillations produced by gamma rays emitted by a radioactive marker. Once a large number of these scintillations have been observed, the radioactive molecules emitting these gamma rays can be located.

Thanks to computer technology, complex calculations can be performed very quickly to convert the detected radiation into information that is useful for radiologists. The images, created in a fraction of a second, allow doctors to follow the spread of the radioisotope throughout a patient's body in real time. This allows for highly detailed pictures of the heart contraction, or of the filtration of blood plasma in the kidneys. A gamma camera scintigraphy can also be used to form images of the skeleton, by injecting patients with a radioactive solution which attaches itself onto the bones. This is often how skeletal metastases are detected.

The scintillation camera was invented by the American physicist H.O. Anger in Berkeley in 1957. It has since revealed itself to be an irreplaceable tool in a wide range of different diagnoses. Unquestionably the preferred piece of equipment in the field of nuclear medicine, there were 14,000 of them in the world by 1996 and much more now.

4.2.2 Nuclear Scintigraphies:-

The word '**scintigraphy**' comes from the 'scintillations' that are produced by gamma rays in certain crystals, and which are the basis of scintigraphic technique.

Scintigraphy is used in the radioactive departments of numerous hospitals and clinics, institutions which have been granted specific authorisation to make use of radioactive sources. As radiation therapy uses sources which are not contained in protective casings, the regulations which surround this branch of medicine are especially strict.

4.2.3 Radiology and nuclear imagery:-

In traditional radiology, one measures the relative absorption of X-Rays passing through the body. In nuclear imagery, a handful of radioactive atoms (carefully chosen to latch on to the relevant organ) are injected into the body, and the gamma rays they emit from inside are detected so as to measure the concentration of radioisotope in the organ in question (fig-7).

Scintigraphy scans involve the injection of a radiopharmaceutical product into the body - a radioactive source which will attach itself to an organ whose functions are of interest. It is for this reason that this field is referred During an X-ray scan, detectors are set up to measure the number of X-rays which pass through the patient's body. In a scintigraphy scan, detectors are set up to count the number of rays emitted from the source located inside the patient. These measurements are carried out by sensitive gamma-cameras or PET-scanners.

Scintigraphy scans today can be carried out on the lungs, the thyroid gland, the skeleton, the heart, the kidneys and even the brain. The procedures surrounding these exams differ depending on which organ is to be scanned, though the choices made as to the nature of the radiopharmaceutical product and the means of ingestion are also taken into account. When it comes to a cardiac scintigraphy, for instance, it is important to see the heart at two stages: at rest, and while pumping blood around the body. For this reason two separate scintigraphic scans need to be carried out.

4.2.4 Bone Scintigraphies:

Bone scintigraphy is based on the fixation in the bony structures of phosphate molecules tagged with technetium-99m.The radiopharmaceutical is injected intravenously and no special preparation is needed before the patient examination. The technetium-99m tracer travels through the blood and its uptake by the skeleton is maximal after three hours, which imposes an equivalent waiting period between injection and passage under the gamma camera.

“Whole body” bone scintigraphy**:**

This bone scan shows the fixation the of radioactive technetium isotope on the entire skeleton with views from the front (left) and back (right). Bone scans require at least two and a half hours to allow time for radiopharmaceutical injected to fixe to the bone. Scans of the entire skeleton, as for the search for bone metastases, require a scan “whole body

Several types of diagnostics are available:

-Scintigraphic planar images focused on a specific region (the gamma camera is immobilized for several minutes over the region to examine, the knee for example);

-Whole body scintigraphic images, to visualize the tracer fixation throughout the skeleton (the search for bone metastases, for example);

-A tomography exam completing planar images and increasing diagnosis accuracy;

-A complete examination in three phases: study of the vascularization (scintigraphic images performed just after injection) followed by a tissue study and finally a bone scan.

4.3 Gamma Knife:

Designed specifically for the brain, Gamma Knife radiosurgery replaces the surgeon’s scalpel with multiple narrow beams of radiation targeted to a specific area. Contrary to its name, there is no knife. No incisions are involved in this proven procedure. Patients are typically in and out of the hospital in a day’s time and back to their normal routines.

Gamma Knife is an alternative to traditional brain surgery and whole brain radiation therapy for the treatment of complex, difficult brain conditions. Leading centers around the world choose Gamma Knife for its accuracy and documented outcomes.

Gamma Knife radiosurgery is a highly effective, non-surgical outpatient treatment that replaces scalpels with radiation beams, targeted to a specific area, literally killing the offending tissue. Patients are in and out of the hospital in a day's time – and back to their normal routines immediately – with no incision.

Gamma Knife is a non-invasive stereotactic radiosurgery instrument that involves no scalpel or incision – it is not a knife at all. Instead, Gamma Knife uses up to 201 precisely focused beams of radiation to control malignant and nonmalignant tumors, as well as vascular and functional disorders in the brain, without harming surrounding healthy tissue.

Patients are typically in and out of the hospital in a day’s time – and back to their normal routines soon after treatment. Gamma Knife radiosurgery may be used in place of, or in addition to, traditional surgery or whole brain radiation, depending on a patient’s diagnosis (fig-8).

4.3.1 Gamma Knife Treatment Options:

Most people will never have to face the need for brain surgery or whole brain radiation therapy, but for those who do, it’s reassuring to know that there is a non-invasive, high-precision treatment. Gamma Knife can be used in place of, or in addition to, traditional surgery or whole brain radiation

Gamma Knife Alone: Because of its accuracy and clinical effectiveness, Gamma Knife is a preferred treatment for patients seeking a less invasive option. In an increasing number of cases, Gamma Knife is used as an alternative to surgery or whole brain radiation.

Gamma Knife may follow traditional surgery or whole brain radiation to further treat any residual tumor remaining after surgery or in the event of a recurrence after other therapies. In addition, Gamma Knife has become a well- documented secondary treatment option used in conjunction with chemotherapy and other radiation. Unlike whole brain radiation therapy, Gamma Knife treatments can be repeated if necessary.

Gamma Knife is not a knife, but rather a sophisticated system that can be used to replace brain surgery or whole brain radiation in some situations. It uses a single, high dose of gamma radiation delivered via up to 201 individual beams which intersect at a single spot with the accuracy of less than one-tenth of a millimeter (about the thickness of a sheet of paper).

A Gamma Knife procedure can be used to treat targets even in the most critical, difficult-to-access areas of the brain without delivering significant radiation doses to healthy normal brain tissue. Referred to as "surgery without a scalpel," the Gamma Knife procedure does not require the surgeon to open the skull.

On the day of treatment, the patient may be given light sedation. Next, local anesthesia is used to secure a head frame to the patient’s head. The frame is used in conjunction with an imaging procedure to accurately locate the target. With the frame in place, the patient undergoes an MRI or CT scan, or in the case of an arteriovenous malformation (AVM), angiography, in order to locate the lesion in the brain to be treated. Using the imaging procedure, the treating team can define the position of the lesion(s) inside the patient’s head/. While the patient rests, the treatment team (which typically consists of a neurosurgeon, radiation oncologist and physicist) create a treatment plan. This takes from 30 to 90 minutes to complete, depending upon the geometry and location of the target(s). When the individual treatment plan is completed, the patient lies on the Gamma Knife couch so that their head is precisely positioned for treatment. The patient is then moved automatically, into the machine, and treatment begins. Treatment typically lasts from 20 minutes to 2 hours, during which time the patient feels and hears nothing. At the completion of the treatment, the patient is automatically moved out of the machine, and the head frame is removed. The patient usually goes home at this point, but may remain in the hospital overnight for observation on occasion.

Gamma Knife is typically completed in a single-day with patients arriving in the morning and able to return home later in the day. Occasionally, physicians may choose to deliver the treatment over a few days.

The Gamma Knife is not an experimental form of treatment. It is a highly effective method of treating brain tumors and neurological and functional disorders and its use is supported by two decades of clinical research published in the mainstream medical literature.

Developed in 1968, it has been used in the treatment of over 850,000 patients. There are over 2,500 peer reviewed publications describing the use of the Gamma Knife in an array of clinical conditions including brain tumors, vascular malformations, movement disorders and facial pain.

The results reported by Gamma Knife centers are typically as good as achievable with other techniques, frequently with lower complication rates.

4.3.2 Studies have been done to show its effectiveness:

The number of peer-reviewed, published scientific articles documenting patient outcomes with Gamma Knife far outweighs any other form of stereotactic radiosurgery. Gamma Knife centers have published more than 2,500 papers and have treated more than 850,000 patients worldwide during the last 40 years. The fact that 74% of all published radiosurgery literature including most of the multicenter radiosurgery studies is based on the use of the Gamma Knife is especially significant given that both Gamma Knife and Linac-based radiosurgery systems were introduced in the same era.

Gamma Knife used in over 70,000 patients every year.

There might be mild pain from administration of the local anesthetic used during placement of the head frame (similar to the sensation of having blood drawn). Patients have reported that they feel a pressure sensation when the frame is applied.

After the treatment session is finished, the head frame is removed. Sometimes there is a little bleeding from where the pins contact the patient's head. Pressure is applied to stop the bleeding and a bandage may be used to keep the pin sites clean. It is usually recommended that the patient refrain from physical activity over the next 18 to 24 hours.

The effects of Gamma Knife radiosurgery occur over a period of time that can range from several weeks to several years, depending on the condition being treated.

Gamma Knife treatment can be given more than once

4.3.3 The Advantages of Gamma Knife:-

- **Noninvasive** – Despite its name, there is no knife. It's called Gamma Knife because of the surgical precision and effectiveness. However, there's no incision, no blood and no complications that occur with surgery.
- **Proven** – Studies show that local control—meaning the specific tumor treated does not come back—exceeds an average of 85% for the management of tumors in any brain location.
- **High Dose of Evidence** – Over 2,500 medical papers have been published on Gamma Knife surgery, and 800,000 patients have been treated worldwide. Other types of radiation treatment often claim to be as accurate and effective, but they don't have the data and proven results of Gamma Knife.
- **Accurate** – There is no other radiation treatment system as precise and accurate as Gamma Knife.

- **One treatment** – The noninvasive Gamma Knife can isolate and deliver a high dose of radiation to one or more locations in the brain during a single treatment session.
- **Fast recovery** – Most people leave the hospital the same day and resume normal activities.
- **Minimal side effects** – Few people experience of a mild headache, which can be treated with an over-the-counter pain reliever. There is no loss of hair or nausea, as with some treatments.
- **Flexible** – Because it’s noninvasive, Gamma Knife can be used to treat tumors or other disorders in surgically inaccessible areas of the brain, such as the brain stem.
- **Repeatable** – Patients who develop new or growth of an existing tumor can be treated again with Gamma Knife [27].

4.4 Discussion :-

The discovery of radiation and radionuclides for use in medicine has led to more diverse and effective prevention, diagnostic and treatment options for many health conditions.

Diseases like cancer that were once considered unmanageable and fatal can now be diagnosed earlier and treated more effectively using nuclear techniques, giving patients a fighting chance and, for many, a significant chance for a cure. These methods are more important than ever as high-mortality diseases like cancer or cardiovascular diseases are on the rise and are among the leading health threats globally.

The IAEA has worked for over 50 years to promote the use of nuclear techniques in medicine by collaborating with its Member states and other organizations through projects, programmes and agreements. The Agency's aim is to help build Member states' capacities in this field in order to support the provision of high-quality health care worldwide, particularly in developing countries. Since the IAEA began its work in human health, the use of nuclear techniques in medicine has become one of the most widespread peaceful applications of atomic energy.

Nuclear Medicine:

Nuclear medicine is a field of medicine that uses a trace amount of radioactive substances called radioisotopes for the diagnosis and treatment of many health conditions such as certain types of cancer, and neurological and heart diseases.

In nuclear medicine, radionuclides which emit gamma rays are used to provide diagnostic information about the body and also provide the treatment technique.

The applications of gamma rays in this field are as follows.

Gamma ray is often used to kill living organisms, in a process called irradiation. Applications of this include sterilization of medical equipment (as an alternative to autoclaves or chemical means), the removal of decay-causing bacteria from many foods and the prevention of the sprouting of fruit and vegetables to maintain freshness and flavor.

Despite their cancer-causing properties, gamma rays are also used to treat some types of cancer, since the rays kill cancer cells also. In the procedure called gamma knife surgery, multiple concentrated beams of gamma rays are directed to the growth in order to kill the cancerous cells. The beams are aimed from different angles to concentrate the radiation on the growth while minimizing damage to surrounding tissues.

Gamma rays are also used for diagnostic purposes in nuclear medicine in imaging techniques. A number of different gamma-emitting radioisotopes are used. The most common gamma emitter used in medical applications is the nuclear isomer technetium-90m which emits gamma rays in the same energy range as diagnostic X-rays. When this radionuclide tracer is administered to a patient, a gamma camera can be used to form an image of the radioisotope's distribution by detecting the gamma radiation emitted. Depending on which molecule has been labeled with the tracer, such techniques can be employed to diagnose a wide range of conditions (for example, the spread of cancer to the bones via bone scan).

4.5 Conclusion and Recommendations:-

By the completion of this study, I recommend using of gamma camera and gamma knife (applications of gamma ray in the medical field) in Sudan for the following reasons:

1- Gamma Knife has become a preferred option for treating complex and “inoperable” tumors. It is often used as an alternative to surgery and/or whole brain radiation and in some cases is combined with those treatments.

While Gamma Knife was originally applied to patients with only a single brain metastasis as an alternative to craniotomy and removal, evidence indicates that disease control is possible in more than 80% of patients who undergo Gamma Knife radiosurgery alone for metastatic brain cancer.

The key to the success of Gamma Knife is its ability to accurately focus many beams of high-intensity gamma radiation to converge on one or more tumors. Each individual beam is relatively low energy, so the radiation has virtually no affect on healthy brain tissue.

2- Radionuclide imaging (Gamma camera) is the most important application of radioactivity in nuclear medicine. Radionuclide imaging laboratories are found in almost every hospital, performing hundreds and even thousands of imaging procedures per month in larger institutions

The gamma camera has thus become the most widely used nuclear-imaging instrument for clinical applications.

References:-

[1].The International Commission on Radiological Protection (ICRP) publication 103 paragraph 55.

[2]. "Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII Phase 2". Publication date 2006. National Academy of Science. Retrieved 2013-11-11.

[3].The International Commission on Radiological Protection (ICRP) publication 103 - Paragraph 144.

[4]. Lewis, Leon; Paul E Caplan (January 1, 1950). "THE SHOE-FITTING FLUOROSCOPE AS A RADIATION HAZARD". California Medicine **72** (1): 26–30 [27]. PMC 1520288. PMID 15408494.

[5] .United Nations Scientific Committee on the Effects of Atomic Radiation (2000). "Annex B". Sources and Effects of Ionizing Radiation. vol. 1. United Nations. p. 121. Retrieved 11 November 2012.

[6]. Mortazavi, S.M.J.; P.A. Karamb (2005). "Apparent lack of radiation susceptibility among residents of the high background radiation area in Ramsar, Iran: can we relax our standards?". Radioactivity in the Environment **7**: 1141–1147. doi:10.1016/S1569-4860(04)07140-2. ISSN 1569-4860.

[7]. Sohrabi, Mehdi; Babapouran, Mozhgan (2005). "New public dose assessment from internal and external exposures in low- and elevated-level natural radiation areas of Ramsar, Iran". Proceedings of the 6th International Conference on High Levels of Natural Radiation and Radon Areas **1276**: 169–174. doi:10.1016/j.ics.2004.11.102.

[8]. "Health Risks | Radon | US EPA". Epa.gov. Retrieved 2012-03-05.

[9]. Camphausen KA, Lawrence RC. "Principles of Radiation Therapy" in Pazdur R, Wagman LD, Camphausen KA, Hoskins WJ (Eds) Cancer Management: A Multidisciplinary Approach. 11 ed. 2008.

[10].The International Commission on Radiological Protection (ICRP) report 103".

[11]. P. Villard. (1900) "Sur le rayonnement du radium," Comptes rendus, vol. 130, pages 1178-1179.

[12]. L'Annunziata, Michael F. (2007). Radioactivity: introduction and history. Amsterdam, Netherlands: Elsevier BV. pp. 55–58. ISBN 978-0-444-52715-8.

[13]. Rutherford named γ rays on page 177 of: E. Rutherford (1903) "The magnetic andelectric deviation of the easily absorbed rays from radium," Philosophical Magazine,Series 6, vol. 5, no. 26, pages 177-187.

[14]. "Rays and Particles" . Galileo.phys.virginia.edu. Retrieved 2013-08-27.

[15]. Dendy, P. P.; B. Heaton (1999). Physics for Diagnostic Radiology . USA: CRC Press. p. 12. ISBN 0-7503-0591-6.

[16]. Charles Hodgman, Ed. (1961). CRC Handbook of Chemistry and Physics, 44th Ed. USA:Chemical Rubber Co. p. 2850.

[17]. Feynman, Richard; Robert Leighton; Matthew Sands (1963). The Feynman Lectures on Physics, Vol.1. USA: Addison-Wesley. pp. 2–5. ISBN 0-201-02116-1.

[18]. L'Annunziata, Michael; Mohammad Baradei (2003). Handbook of RadioactivityAnalysis . Academic Press. p. 58. ISBN 0-12-436603-1.

[19]. Grupen, Claus; G. Cowan; S. D. Eidelman; T. Stroh (2005). Astroparticle Physics.Springer. p. 109. ISBN 3-540-25312-2.

[20]. Shaw, R. W.; Young, J. P.; Cooper, S. P.; Webb, O. F. (1999). "Spontaneous Ultraviolet Emission from 233Uranium/229Thorium Samples". Physical Review Letters **82** (6): 1109– 1111. Bibcode:1999PhRvL.82.1109S . doi:10.1103/PhysRevLett.82.1109 .

[21]. "Gamma-Ray Telescopes & Detectors" . NASA GSFC. Retrieved 2011-11-22.

[22]. Bock, R. K.; et al. (2008-06-27). "Very-High-Energy Gamma Rays from a DistatQuasar: How Transparent Is the Universe?". Science **320** (5884): 1752–1754.arXiv:0807.2822Bibcode:2008Sci...320.1752M . doi:10.1126/science.1157087 .ISSN 0036-8075.PMID 18583607 .

[23]. Domínguez, Alberto; et al. (2015-06-01). "All the Light There Ever Was". Scientific American. Vol. 312 no. 6. pp. 38–43. ISSN 0036-8075 .

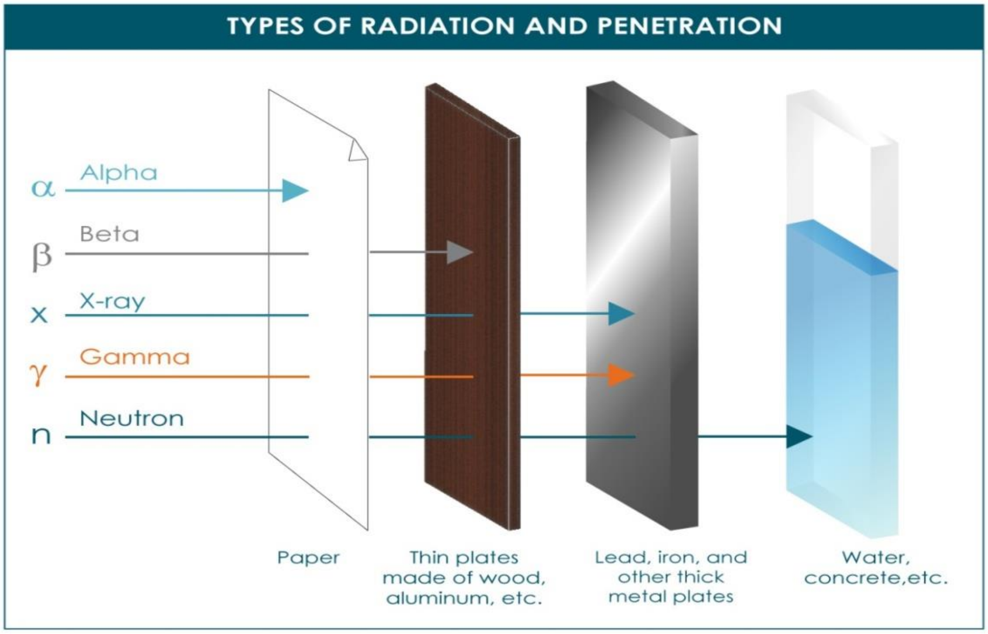
[24]. Gamma decay review Accessed Sept. 29, 2014

[25]. Smith, Joseph; David M. Smith (August 2012). "Deadly Rays From Clouds". Scientific American. Vol. 307 no. 2. pp. 55–59. Bibcode:2012SciAm.307b..54D .doi:10.1038/scientificamerican0812-54.

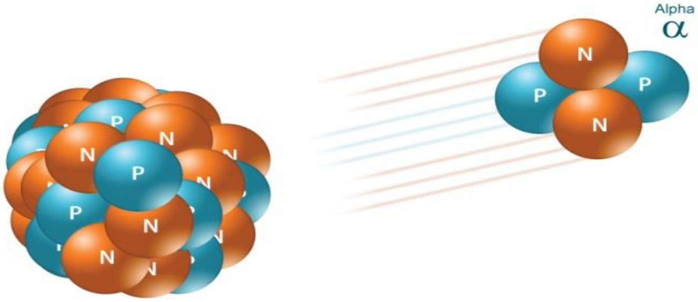
[2**6]**.The International Commission on Radiological Protection (ICRP) report 103 para 104 and 105.

[27].Simmons GH: The Scintillation Camera. New York, Society of Nuclear Medicine, 1988.

Appendix:-

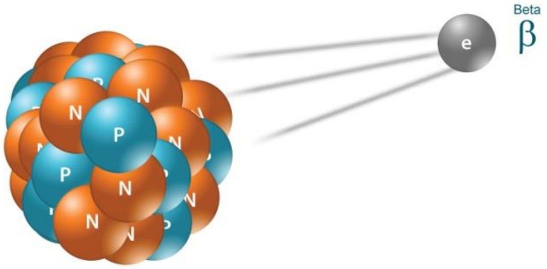


(Fig-1) Types of Radiation and Penetration

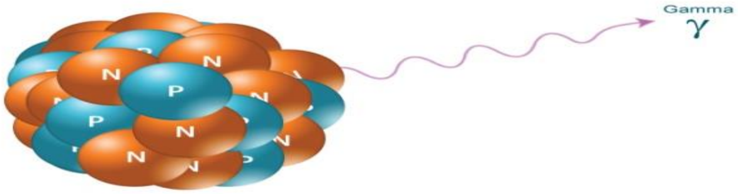


(fig-2) Alpha radiation: The emission of an alpha particle from the nucleus of an atom.

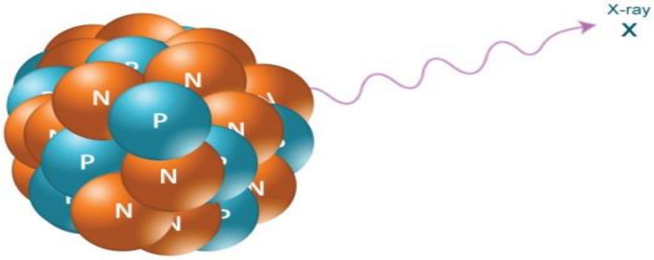
(fig-1) Types of Radiation and Penetration



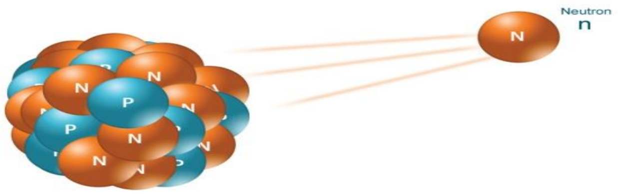
(Fig-3) Beta radiation: The emission of a beta particle from the nucleus of an atom.



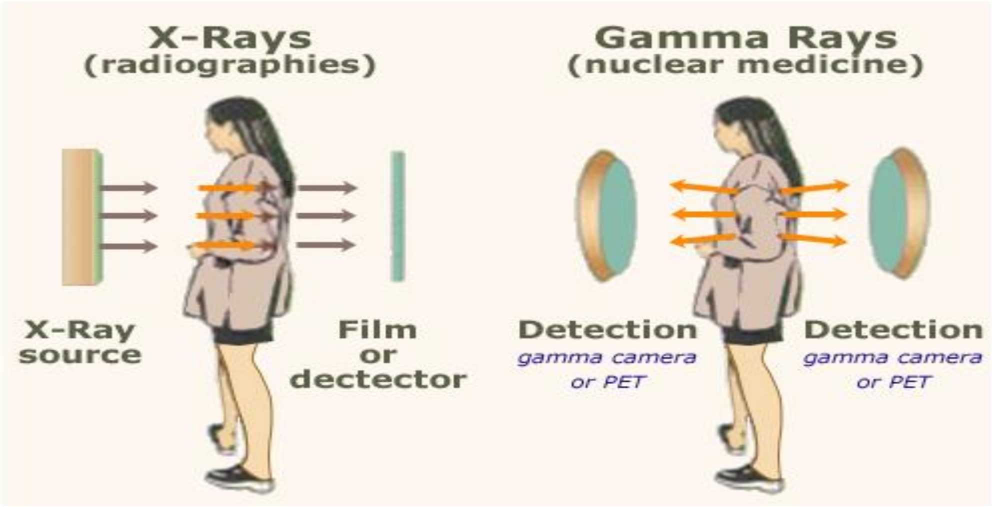
(fig-4) Gamma radiation: The emission of an high-energy wave from the nucleus of an atom.



(fig-5) X-Rays:The emission of a high energy wave from the electron cloud of an atom.



(fig-6) Neutron radiation: The emission of a neutron from the nucleus of an atom.



(fig-7) X-Rays & Gamma Rays.

(fig-8) Gamma Knife.