Chapter One

Introduction

1.1 Electromagnetic Spectrum

This part of the electromagnetic spectrum extents from wavelengths of 10^{-9}m down to wavelengths about 6×10^{-12}m, or frequencies between 6×10^{14} Hz and 5×10^{19} Hz.

X-ray produce profound effects on the atoms and molecules of the substances though which they are used medical diagnosis because the different absorption of X-radiation by bone and different tissues allows for a fairly well-defined pattern on a photographic film. They also, as a result of the molecular processes they induce. Cause serious damage to living tissues and organisms. It is for this reason that X-ray are used for treatment of cancer, to destroy some good tissue as well; for that reason, an exposure to large dose of X-rays may cause enough destruction to produce sickness or death.

1.2 Problem Statement:

There are a lot of applications of X-rays, either diagnosis, treatment, irradiation.

This research focuses of irradiation of food and X-ray in medical field

1.3 Objective:

The objective of this research is to study X-ray microscope. That are used for electromagnetic X-ray microscope radiation in the soft X-ray band to produce magnified images of objects.

1.4 Research methodology:

Review all topics that concern the subject such as microscope X-ray, its applications of X-ray, its radiation protection, and source of X-ray.

1.5 Thesis Layout:

This research contains five chapters: chapter one introduction, chapter Two Applications of X-ray, chapter Three X-ray Microscope, chapter Four Radiation Protection, chapter Five Conclusions and Discussion.

Chapter Two

Applications of X-ray

2.1 Introduction

X-radiation is a kind of electromagnetic radiation. X-rays are waves of X-radiation. X-rays have a shorter wavelength, and therefore more energy, than ultraviolet radiation. They have a much shorter wavelength than visible light Radiation with shorter wavelengths (more energy) than the X-ray is called Gamma radiation (γ-rays). These are all parts of the electromagnetic spectrum [1].

The wavelength of X-rays covers a wide range. Most X-rays have a wavelength in the range of 0.01 to 10 nanometers. This corresponds with frequencies in the range 30 petahertz to 30 exahertz (3×10^{16} Hz to 3×10^{19} Hz) and energies in the range 100 eV to 100 keV [1].

X-rays can go through many solid materials. For this reason, taking photograms with X-rays is used in medicine in order to see bones and other things inside the body. Sometimes the term "X-Ray" means these pictures instead of the radiation that makes them [2].

What these images show will depend on three things: Rayleigh scattering, Compton scattering and photo absorption. The images show bone because it is dense enough that X-rays are not able to pass through it. Instead, the X-rays are either absorbed or scattered. The images do not show skin and muscle, however, because these tissues are transparent enough for the X-rays to pass through them without being absorbed too much. To detect tumors, other imaging devices are used; such as magnetic resonance imaging. A computed tomography scanner combines an X-ray machine and computer to construct a three dimensional (3D) picture. This has some ability to see other things besides bone [3].

X-rays are made by hitting metal with fast-moving electrons. They are photons, tiny packets of energy that can move atoms and change chemicals in

the body. The things they do depend on the wavelength of the X-rays (or how much energy they have). X-rays with smaller energies ("soft" x-rays) cause the photoelectric effect. Mid-level energies cause Compton scattering. High-level energies ("hard" X-rays) cause pair production. X-rays used for making pictures of people have low to medium energy. Radiation therapy that treats cancer uses Compton scattering and sometimes Pair production.

There are small amounts of X-rays in the air. Like other energy in the air, X-rays can change living cells. Exposing the human body to high doses of X-rays for a long time is dangerous. It can cause cancer. However, cancer cells are hurt more easily, so X-rays are sometimes used to kill them [3].

2.2 The Source of X-ray:

2.2.1 Cyclotron Accelerator:

Cyclotron radiation is electromagnetic radiation emitted by accelerating charged particles deflected by a magnetic field. The Lorentz force on the particles acts perpendicular to both the magnetic field lines and the particles' motion through them, creating an acceleration of charged particles that causes them to emit radiation as a result of the acceleration they undergo as they spiral around the lines of the magnetic field [4].

The name of this radiation derives from the cyclotron, a type of particle accelerator used since the 1930s to create highly energetic particles for study. The cyclotron makes use of the circular orbits that charged particles exhibit in a uniform magnetic field. Furthermore, the period of the orbit is independent of the energy of the particles, allowing the cyclotron to operate at a set frequency. Cyclotron radiation is emitted by all charged particles travelling through magnetic fields, not just those in cyclotrons. Cyclotron radiation from plasma in the interstellar medium or around black holes and other astronomical phenomena is an important source of information about distant magnetic fields. The power (energy per unit time) of the emission of each electron can be calculated [4]:

$$\frac{-dE}{dt} = \sigma_t \frac{B^2 v^2}{c \mu_0} \qquad (2.1)$$

where E is energy, t is time, σ_t is the Thomson cross section (total, not differential), B is the magnetic field strength, v is the velocity perpendicular to the magnetic field, c is the speed of light and μ_0 is the permeability of free space. In the context of magnetic fusion energy, cyclotron radiation losses translate into a requirement for a minimum plasma energy density in relation to the magnetic field energy density (see Aneutronic fusion Power density and energy balance) [4].

Cyclotron radiation would likely be produced in a high altitude nuclear explosion. Gamma rays produced by the explosion would ionize atoms in the upper atmosphere and those free electrons would interact with the Earth's magnetic field to produce cyclotron radiation in the form of an electromagnetic pulse (EMP). This phenomenon is of concern to the military as the EMP may damage solid state electronic equipment [4].

Cyclotron radiation has a spectrum with its main spike at the same fundamental frequency as the particle's orbit, and harmonics at higher integral factors. Harmonics are the result of imperfections in the actual emission environment, which also create a broadening of the spectral lines. The most obvious source of line broadening is non-uniformities in the magnetic field; as an electron passes from one area of the field to another, its emission frequency will change with the strength of the field. Other sources of broadening include collisional broadening as the electron will invariably fail to follow a perfect orbit, distortions of the emission caused by interactions with the surrounding plasma, and relativistic effects if the charged particles are sufficiently energetic. When the electrons are moving at relativistic speeds, cyclotron radiation is known as synchrotron radiation [4].

The recoil experienced by a particle emitting cyclotron radiation is called radiation reaction. Radiation reaction acts as a resistance to motion in a cyclotron; and the work necessary to overcome it is the main energetic cost of accelerating a particle in a cyclotron. Cyclotrons are prime examples of systems which experience radiation reaction.

2.2.2 Linear Particle Accelerator:

A linear particle accelerator (often shortened to linac) is a type of particle accelerator that greatly increases the kinetic energy of charged subatomic particles or ions by subjecting the charged particles to a series of oscillating electric potentials along a linear beam line. Linacs have many applications: they generate X-rays and high energy electrons for medicinal purposes in radiation therapy, serve as particle injectors for higher-energy accelerators, and are used directly to achieve the highest kinetic energy for light particles (electrons and positrons) for particle physics.

The design of a linac depends on the type of particle that is being accelerated: electrons, protons or ions. Linacs range in size from a cathode ray tube (which is a type of linac) to the 3.2-kilometre-long (2.0 mi) linac at the SLAC National [5].

2.3 Construction and Operation:

A linear particle accelerator consists of the following elements:

- The particle source. The design of the source depends on the particle that is being moved. Electrons are generated by a cold cathode, a hot cathode, a photocathode, or radio frequency (RF) ion sources. Protons are generated in an ion source, which can have many different designs. If heavier particles are to be accelerated, (e.g., uranium ions), a specialized ion source is needed [5].
- A high voltage source for the initial injection of particles.
- A hollow pipe vacuum chamber. The length will vary with the application. If the device is used for the production of X-rays for inspection or therapy the pipe may be only 0.5 to 1.5 meters long. If the device is to be an injector for a synchrotron it may be about ten meters long. If the device is used as the primary accelerator for nuclear particle investigations, it may be several thousand meters long [5].
- Within the chamber, electrically isolated cylindrical electrodes are placed, whose length varies with the distance along the pipe. The length of each

electrode is determined by the frequency and power of the driving power source and the nature of the particle to be accelerated, with shorter segments near the source and longer segments near the target. The mass of the particle has a large effect on the length of the cylindrical electrodes; for example an electron is considerably lighter than a proton and so will generally require a much smaller section of cylindrical electrodes as it accelerates very quickly. Likewise, because its mass is so small, electrons have much less kinetic energy than protons at the same speed. Because of the possibility of electron emissions from highly charged surfaces, the voltages used in the accelerator have an upper limit, so this can't be as simple as just increasing voltage to match increased mass [5].

- One or more sources of radio frequency energy, used to energize the cylindrical electrodes. A very high power accelerator will use one source for each electrode. The sources must operate at precise power, frequency and phase appropriate to the particle type to be accelerated to obtain maximum device power [5].
- An appropriate target. If electrons are accelerated to produce X-rays then water cooled tungsten target is used. Various target materials are used when protons or other nuclei are accelerated, depending upon the specific investigation. For particle-to-particle collision investigations the beam may be directed to a pair of storage rings, with the particles kept within the ring by magnetic fields. The beams may then be extracted from the storage rings to create head on particle collisions.

As the particle bunch passes through the tube it is unaffected (the tube acts as a Faraday cage), while the frequency of the driving signal and the spacing of the gaps between electrodes are designed so that the maximum voltage differential appears as the particle crosses the gap. This accelerates the particle, imparting energy to it in the form of increased velocity. At speeds near the speed of light, the incremental velocity increase will be small, with the energy appearing as an increase in the mass of the particles. In portions of

the accelerator where this occurs, the tubular electrode lengths will be almost constant [5].

- Additional magnetic or electrostatic lens elements may be included to ensure that the beam remains in the center of the pipe and its electrodes.
- Very long accelerators may maintain a precise alignment of their components through the use of servo systems guided by a laser beam [5].

2.4 Applications of X-ray:

2.4.1 X-ray in Medical Field:

Since Rontgen's discovery that X-rays can identify bone structures, X-rays have been used for medical imaging. The first medical use was less than a month after his paper on the subject [6]. Up until 2010, 5 billion medical imaging studies have been conducted worldwide. Radiation exposure from medical imaging in 2006 made up about 50% of total ionizing radiation exposure in the United States [7].

2.4.2 Projectional Radiographs:

Projectional radiography is the practice of producing two-dimensional images using x-ray radiation. Bones contain much calcium, which due to its relatively high atomic number absorbs x-rays efficiently. This reduces the amount of X-rays reaching the detector in the shadow of the bones, making them clearly visible on the radiograph. The lungs and trapped gas also show up clearly because of lower absorption compared to tissue, while differences between tissue types are harder to see [8].

Projectional radiographs are useful in the detection of pathology of the skeletal system as well as for detecting some disease processes in soft tissue. Some notable examples are the very common chest X-ray, which can be used to identify lung diseases such as pneumonia, lung cancer, or pulmonary edema, and the abdominal x-ray, which can detect bowel (or intestinal) obstruction, free air (from visceral perforations) and free fluid (in ascites). X-rays may also be used to detect pathology such as gallstones (which are rarely radiopaque) or kidney stones which are often (but not always) visible.

Traditional plain X-rays are less useful in the imaging of soft tissues such as the brain or muscle [8].

Dental radiography is commonly used in the diagnoses of common oral problems, such as cavities.

In medical diagnostic applications, the low energy (soft) X-rays are unwanted, since they are totally absorbed by the body, increasing the radiation dose without contributing to the image. Hence, a thin metal sheet, often of aluminium, called an X-ray filter, is usually placed over the window of the X-ray tube, absorbing the low energy part in the spectrum. This is called *hardening* the beam since it shifts the center of the spectrum towards higher energy (or harder) x-rays [8].

To generate an image of the cardiovascular system, including the arteries and veins (angiography) an initial image is taken of the anatomical region of interest. A second image is then taken of the same region after an iodinated contrast agent has been injected into the blood vessels within this area. These two images are then digitally subtracted, leaving an image of only the iodinated contrast outlining the blood vessels. The radiologist or surgeon then compares the image obtained to normal anatomical images to determine whether there is any damage or blockage of the vessel [8]. See fig (2.1)

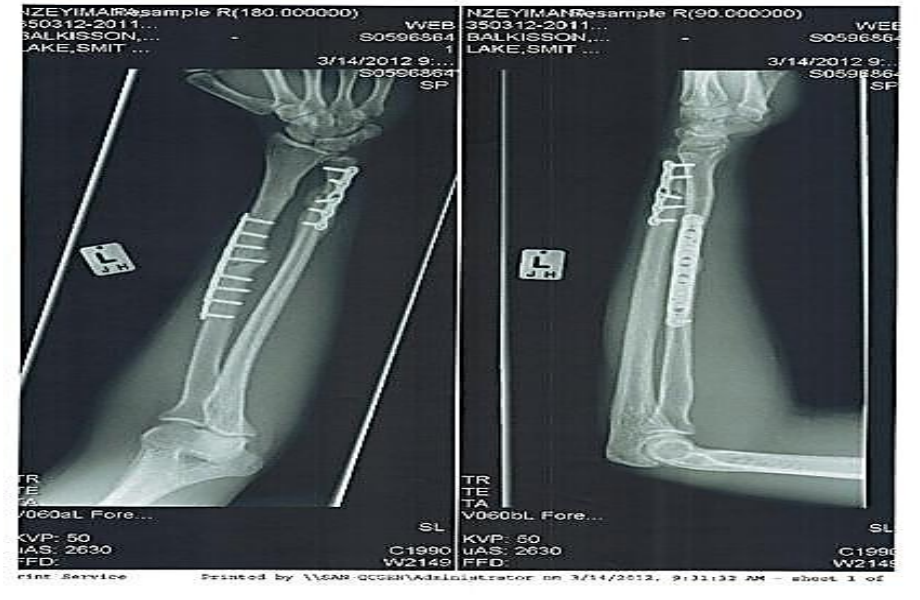

Fig (2.1): Diagnosis by X-ray

2.4.3 Computed Tomography:

Computed tomography (CT scanning) is a medical imaging modality where tomographic images or slices of specific areas of the body are obtained from a large series of two-dimensional X-ray images taken in different directions [9]. These cross-sectional images can be combined into a three-dimensional image of the inside of the body and used for diagnostic and therapeutic purposes in various medical disciplines.

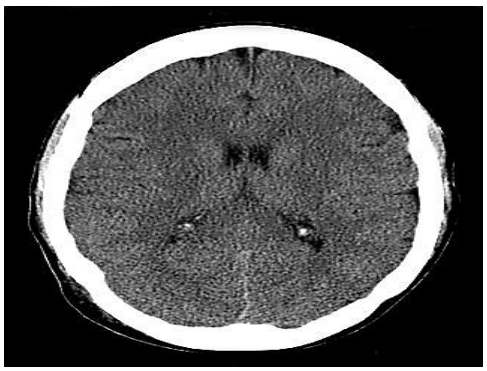

Fig (2.2): Computed Tomography

Fluoroscopy is an imaging technique commonly used by physicians or radiation therapists to obtain real-time moving images of the internal structures of a patient through the use of a fluoroscope. In its simplest form, a fluoroscope consists of an X-ray source and a fluorescent screen, between which a patient is placed. However, modern fluoroscopes couple the screen to an X-ray image intensifier and CCD video camera allowing the images to be recorded and played on a monitor. This method may use a contrast material. Examples include cardiac catheterization (to examine for coronary artery blockages) and barium swallow (to examine for esophageal disorders) [9]. See fig (2.2)

2.5 Radiotherapy:

Radiation therapy or radiotherapy is therapy using ionizing radiation, generally as part of cancer treatment to control or kill malignant cells and normally delivered by a linear accelerator. Radiation therapy may be curative in a number of types of cancer if they are localized to one area of the body. It

may also be used as part of adjuvant therapy, to prevent tumor recurrence after surgery to remove a primary malignant tumor [10].

The use of X-rays as a treatment is known as radiation therapy and is largely used for the management (including palliation) of cancer. it requires higher radiation doses than those received for imaging alone. X-rays beams are used for treating skin cancers using lower energy x-ray beams while higher energy beams are used for treating cancers within the body such as brain, lung, prostate, and breast [11].

2.6 Food Irradiation:

Food irradiation is the process of exposing foodstuffs to ionizing radiation. Ionizing radiation is energy that can be transmitted without direct contact to the source of the energy (radiation) capable of freeing electrons from their atomic bonds (ionization) in the targeted food. This treatment is used to preserve food, reduce the risk of food borne illness, prevent the spread of invasivepests, and delay or eliminate sprouting or ripening. Irradiated food does not become radioactive. The radiation can be emitted by a radioactive substance or generated electrically [12].

Irradiation is used to create safe foods for people at high risk of infection or for conditions where food must be stored for long periods of time and or proper storage conditions are not available. Foods that can tolerate irradiation at sufficient doses are treated to ensure that the product is completely sterilized. This is most commonly done with rations for astronauts, special diets for hospital patients.

Irradiation is used to create shelf stable products. Since irradiation reduces the populations of spoilage microorganisms and because pre-packed food can be irradiated, the packaging prevents recontamination into the final product [13].

Irradiation is used to reduce post-harvest losses. It reduces populations of spoilage micro-organisms in the food and can slow down the speed at which enzymes change the food and therefore slows spoilage, ripening, and inhibits sprouting (e.g. of potato, onion and garlic) [14].

Food is also irradiated to prevent the spread of invasive pest species through trade in fresh vegetables and fruits [14].

Chapter Three

X-ray Microscope

3.1 Introduction:

An X-ray microscope uses electromagnetic radiation in the soft X-ray band to produce magnified images of objects. Since X-rays penetrate most objects, there is no need to specially prepare them for X-ray microscopy observations.

3.2 X-ray Microscope:

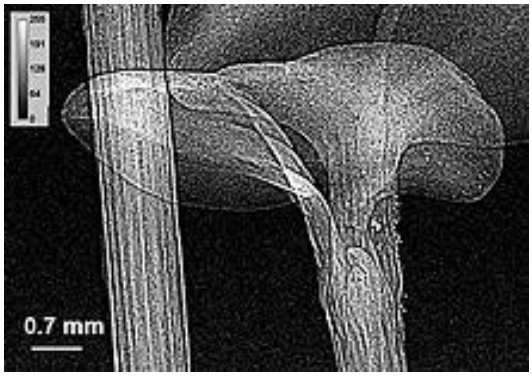

Fig (3.1): X-ray microscopy image of a living 10-days-old canola plant [15].

Unlike visible light, X-rays do not reflect or refract easily, and they are invisible to the human eye. Therefore, the basic process of an X-ray microscope is to expose film or use a charge-coupled device (CCD) detector to detect X-rays that pass through the specimen. It is a contrast imaging technology using the difference in absorption of soft X-rays in the water window region (wavelengths: 2.34-4.4 nm, energies: 280-530 eV) by the carbon atom (main element composing the living cell) and the oxygen atom (main element for water) [15].

Early X-ray microscopes by Paul Kirkpatrick and Albert Baez used grazing incidence reflective optics to focus the X-rays, which grazed X-rays off parabolic curved mirrors at a very high angle of incidence. An alternative method of focusing X-rays is to use a tiny Fresnel zone plate of concentric gold or nickel rings on a silicon dioxide substrate. Sir Lawrence Bragg

produced some of the first usable X-ray images with his apparatus in the late 1940s.

In the 1950s Sterling Newberry produced a shadow X-ray microscope which placed the specimen between the source and a target plate, this became the basis for the first commercial X-ray microscopes from the General Electric Company [15]. See fig (3.1)

3.2.1 Advanced Light Source:

The Advanced Light Source (ALS) in Berkeley, California, is home to XM-1, a full field soft X-ray microscope operated by the Center for X-ray Optics and dedicated to various applications in modern nanoscience, such as nonmagnetic materials, environmental and materials sciences and biology. XM-1 uses an X-ray lens to focus X-rays on a CCD, in a manner similar to an optical microscope. XM-1 held the world record in spatial resolution with Fresnel zone plates down to 15 nm and is able to combine high spatial resolution with a sub-100ps time resolution to study [16].

The ALS is also home to the world's first soft x-ray microscope designed for biological and biomedical research. This new instrument, XM-2 was designed and built by scientists from the National Center for X-ray Tomography. XM-2 is capable of producing 3-dimensional tomograms of cells [16].

3.2.2 Scanning Transmission:

Sources of soft X-rays suitable for microscopy, such as synchrotron radiation sources, have fairly low brightness of the required wavelengths, so an alternative method of image formation is scanning transmission soft X-ray microscopy. Here the X-rays are focused to a point and the sample is mechanically scanned through the produced focal spot. At each point the transmitted X-rays are recorded with a detector such as a proportional counter or an avalanche photodiode [17]. This type of Scanning Transmission X-ray

Microscope (STXM) was first developed by researchers at Stony Brook University and was employed at the National Synchrotron Light Source at Brookhaven National Laboratory [17].

3.2.3 Resolution:

The resolution of X-ray microscopy lies between that of the optical microscope and the electron microscope. It has an advantage over conventional electron microscopy in that it can view biological samples in their natural state. Electron microscopy is widely used to obtain images with nanometer to sub-Angstrom level resolution but the relatively thick living cell cannot be observed as the sample has to be chemically fixed, dehydrated, embedded in resin, and then sliced ultra-thin. However, it should be mentioned that cryo-electron microscopy allows the observation of biological specimens in their hydrated natural state, albeit embedded in water ice. Until now, resolutions of 30 nanometer are possible using the Fresnel zone plate lens which forms the image using the soft x-rays emitted from a synchrotron. Recently, the use of soft x-rays emitted from laser-produced plasmas rather than synchrotron radiation is becoming more popular [17].

3.2.4 Analysis:

Additionally, X-rays cause fluorescence in most materials, and these emissions can be analyzed to determine the chemical elements of an imaged object. Another use is to generate diffraction patterns, a process used in X-ray crystallography. By analyzing the internal reflections of a diffraction pattern (usually with a computer program), the three-dimensional structure of a crystal can be determined down to the placement of individual atoms within its molecules. X-ray microscopes are sometimes used for these analyses because the samples are too small to be analyzed in any other way [17].

3.3 X-ray absorption Spectroscopy:

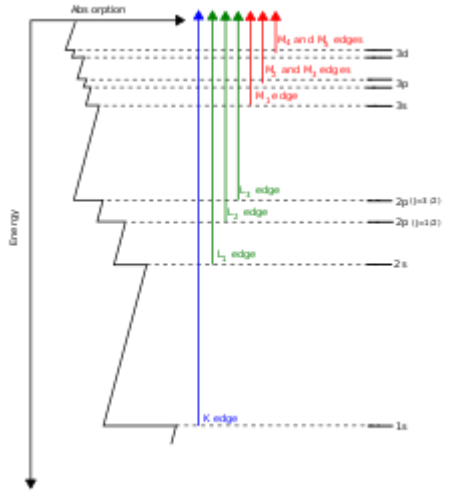

Figure 3.2: Transitions that contribute to XAS edges

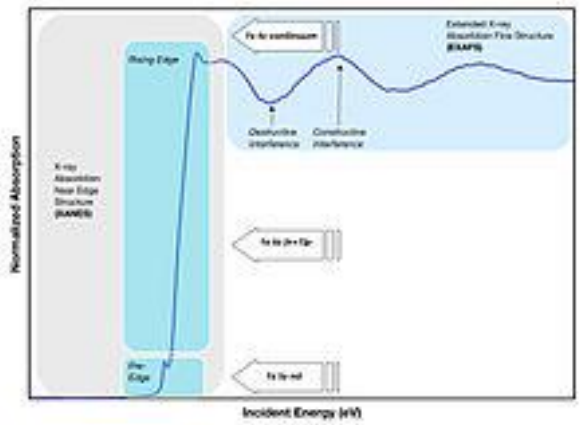

Figure 3.3: Three regions of XAS data

X-ray absorption spectroscopy (XAS) is a widely used technique for determining the local geometric and/or electronic structure of matter. The experiment is usually performed at synchrotron radiation sources, which provide intense and tunable X-ray beams. Samples can be in the gas-phase, solution, or condensed matter (i.e. solids) [18].

XAS data is obtained by tuning the photon energy using a crystalline monochromatic to a range where core electrons can be excited (0.1-100 keV photon energy). The name of the edge depends upon which core electron is excited: the principal quantum numbers n = 1, 2, and 3, correspond to the K-,

L-, and M-edges, respectively. For instance, excitation of a 1s electron occurs at the K-edge, while excitation of a 2s or 2p electron occurs at an L-edge (Fig 3.2) [18].

There are three main regions found on a spectrum generated by XAS data (Fig3.3):

1. The "absorption threshold" determined by the transition to the lowest unoccupied states:

a) The states at the Fermi energy in metals giving a "rising edge" with an arc tangent shape;

b) The bound core excitons in insulators with a Lorentzian line-shape (they occur in a pre-edge region at energies lower than the transitions to the lowest unoccupied level).

2. The X-ray Absorption Near-Edge Structure XANES introduced in 1980 and later in 1983 called also NEXAFS (Near-edge X-ray Absorption Fine Structure) which are dominated by core transitions to quasi bound states (multiple scattering resonances) for photoelectrons with kinetic energy in the range from 10 to 150 eV above the chemical potential, called "shape resonances" in molecular spectra since they are due to final states of short life-time degenerate with the continuum with the Fano line-shape. In this range multi-electron excitations and many-body final states in strongly correlated systems are relevant [19].

3. In the high kinetic energy range of the photoelectron the scattering cross-section with neighbor atoms is weak and the absorption spectra are dominated by EXAFS (Extended X-ray Absorption Fine Structure) where the scattering of the ejected photoelectron of neighboring atoms can be approximated by single scattering events. After it was shown in 1985 that multiple scattering theory can interpret both XANES and EXAFS the experimental analysis focusing on both regions is called XAFS [29].

XAS is a type of absorption spectroscopy from a core initial state with a well-defined symmetry therefore the quantum mechanical selection rules select the symmetry of the final states in the continuum which usually are mixture of multiple components. The most intense features are due to electric-dipole allowed transitions (i.e. $\Delta\ell = \pm 1$) to unoccupied final states.

XAS methodology can be broadly divided into four experimental categories that can give complementary results to each other: Metal K-edge, metal L-edge, ligand K-edge, and EXAFS [19].

3.4 Applications:

XAS is a technique used in different scientific fields including molecular and condensed matter physics, materials science and engineering, chemistry, earth science, and biology. In particular, its unique sensitivity to the local structure, as compared to x-ray diffraction, have been exploited for studying [19]:

- Amorphous solids and liquid systems
- Solid solutions
- Doping and ion implantation materials for electronics
- Local distortions of crystal lattices
- Organometallic compounds
- Metalloproteins
- Metal clusters
- Catalysis
- Vibrational dynamics
- Ions in solutions
- Speciation of elements
- Liquid water and aqueous solutions [19].

Chapter Four

Radiation Protection

4.1 Introduction:

Radiation protection, sometimes known as **radiological protection**, is defined by the International Atomic Energy Agency (IAEA) as "The protection of people from harmful effects of exposure to ionizing radiation, and the means for achieving this". The IAEA also states "The accepted understanding of the term radiation protection is restricted to protection of people. Suggestions to extend the definition to include the protection of non-human species or the protection of the environment are controversial" [20].

4.2 Radiation protection

Ionizing radiation is widely used in industry and medicine, and can present a significant health hazard. It causes microscopic damage to living tissue, which can result in skin burns and radiation sickness at high exposures (known as "tissue" or "deterministic" effects), and statistically elevated risks of cancer at low exposures ("stochastic effects").

Fundamental to radiation protection is the reduction of expected dose and the measurement of human dose uptake. For radiation protection and dosimetry assessment the International Committee on Radiation Protection (ICRP) and International Commission on Radiation Units and Measurements (ICRU) have published recommendations and data which is used to calculate the biological effects on the human body, and set regulatory and guidance limits. [20]

The ICRP recommends, develops and maintains the International System of Radiological Protection based on evaluation of the body of scientific studies available. The recommendations it makes flow down to national regulators,

which have the opportunity to incorporate them into law. This is shown in the accompanying diagram.

4.3 Protection Groups:

Radiation protection can be divided into *occupational radiation protection*, which is the protection of workers, *medical radiation protection*, which is the protection of patients, and *public radiation protection*, which is protection of individual members of the public, and of the population as a whole. The types of exposure, as well as government regulations and legal exposure limits are different for each of these groups, so they must be considered separately [21].

4.4 Factors in Dose Uptake:

There are three factors that control the amount, or dose, of radiation received from a source. Radiation exposure can be managed by a combination of these factors:

4.4.1 Time: Reducing the time of an exposure reduces the effective dose proportionally. An example of reducing radiation doses by reducing the time of exposures might be improving operator training to reduce the time they take to handle a source.

4.4.2 Distance: Increasing distance reduces dose due to the inverse square law. Distance can be as simple as handling a source with forceps rather than fingers.

4.4.3 Shielding: The term 'biological shield' refers to a mass of absorbing material placed around a reactor, or other radioactive source, to reduce the radiation to a level safe for humans. The effectiveness of a material as a biological shield is related to its cross-section for scattering and absorption, and to a first approximation is proportional to the total mass of material per unit area interposed along the line of sight between the radiation source and the region to be protected. Hence, shielding strength or "thickness" is conventionally measured in units of g/cm^2.

The radiation that manages to get through falls exponentially with the thickness of the shield. In x-ray facilities, walls surrounding the room with the x-ray generator may contain lead sheets, or the plaster may contain barium sulfate. Operators view the target through a leaded glass screen, or if they must remain in the same room as the target, wear lead aprons. Almost any material can act as a shield from gamma or x-rays if used in sufficient amounts.

Practical radiation protection tends to be a job of juggling the three factors to identify the most cost effective solution [21].

4.5 Regulation of Dose Uptake:

In most countries a national regulatory authority works towards ensuring a secure radiation environment in society by setting dose limitation requirements that are generally based on the recommendations of the International Commission on Radiological Protection (ICRP). These use the following overall principles:

- **Justification:** No unnecessary use of radiation is permitted, which means that the advantages must outweigh the disadvantages.
- **Limitation:** Each individual must be protected against risks that are far too large through individual radiation dose limits [21].
- **Optimization:** Radiation doses should all be kept as low as reasonably achievable. This means that it is not enough to remain under the radiation dose limits. As permit holder, you are responsible for ensuring that radiation doses are as low as reasonably achievable, which means that the actual radiation doses are often much lower than the permitted limit.

4.6 ALARA Principle:

ALARA P is an acronym for an important principle in exposure to radiation and other occupational health risks and stands for "*As Low As Reasonably Practicable*".[23] The aim is to minimize the risk of radioactive exposure or other hazard while keeping in mind that some exposure may be acceptable in order to further the task at hand. The equivalent term **ALARA**, *"As Low As Reasonably Achievable",* is more commonly used outside the UK [22].

4.7 Shielding:

Shielding reduces the intensity of radiation depending on the thickness. This is an exponential relationship with gradually diminishing effect as equal slices of shielding material are added. A quantity known as the halving-thicknesses is used to calculate this.

The effectiveness of a shielding material in general increases with its atomic number, called *Z*, except for neutron shielding which is more readily shielded by the likes of neutron absorbers and moderators such as compounds of boron e.g. boric acid, cadmium, carbon and hydrogen respectively [22].

4.7.1 X-ray Shielding:

In most cases, high-density materials are more effective than low-density alternatives for blocking or reducing the intensity of radiation. However, low-density materials can compensate for the disparity with increased thickness, which is as significant as density in shielding applications. Lead is particularly well-suited for lessening the effect of gamma rays and x-rays due to its high atomic number. This number refers to the amount of protons within an atom, so a lead atom has a relatively high number of protons along with a corresponding number of electrons. These electrons block many of the gamma and x-ray particles that try to pass through a lead barrier and the degree of protection can be compounded with thicker shielding barriers.

However, it is important to remember that there is still potential for some rays making it through the shielding, and that an absolute barrier may not be possible in many situations [22].

Chapter Five

Conclusions and Discussion

5.1 Discussion:

X-ray microscope uses electromagnetic radiation in the soft X-ray band to produce magnified images of objects and to produce 3-dimensional image

5.2 Conclusion:

The medical X-ray macbines need low voltages need not exceeding 150 kV this is because any voltage exceeding this limit causes tissue damage or it may do some unknown biological hazards. It is important to know that, variation in voltages need different film types and different low exposure time in addition to different appropriatc voltage.

5.3 Recommendations:

I suggest further study could be done in the future in the

- Use of x-ray in currying of the tumours
- Used of computers to display information on the screen under appropriate software. It is replacing the x-ray film.

References:

[1] "RTAB: the Rayleigh scattering database". Lynn Kissel. 2000-09-02. Retrieved 2012-11-08.

[2] David Attwood. "3". *Soft X-rays and extreme ultraviolet radiation*. Cambridge University Press. ISBN 978-0-521-65214-8, 1999.

[3] Jerrold T. Bushberg, J. Anthony Seibert, Edwin M. Leidholdt, and John M. Boone. *The essential physics of medical imaging*. Lippincott Williams & Wilkins. p. 38, 42. ISBN 978-0-683-30118-2, 2002.

[4] *Monreal, Benjamin. "Single-electron cyclotron radiation". Physics Today. 69 (1): 70. doi:10.1063/pt.3.3060, June 2016.*

[5] G. Ising: *Prinzip einer Methode zur Herstellung von Kanalstrahlen hoher Voltzahl.* In: *Arkiv för Matematik, Astronomi och Fysik.* Band 18, Nr. 30, 1924, S. 1–4.

[6] *Spiegel PK. "The first clinical X-ray made in America—100 years". American Journal of Roentgenology. Leesburg, VA: American Roentgen Ray Society. 164 (1): 241–243. doi:10.2214/ajr.164.1.7998549. ISSN 1546-3141. PMID 7998549, 1995.*

[7] Medical Radiation Exposure Of The U.S. Population Greatly Increased Since The Early 1980s, Science Daily, March 5, 2009.

[8] *Roobottom CA, Mitchell G, Morgan-Hughes G. "Radiation-reduction strategies in cardiac computed tomographic angiography". Clin Radiol. 65 (11): 859–67. doi:10.1016/j.crad.2010.04.021. PMID 20933639, 2010.*

[9] *Herman, Gabor T. Fundamentals of Computerized Tomography: Image Reconstruction from Projections (2nd ed.). Springer. ISBN 978-1-85233-617-2, 2009.*

[10] Advances in kilovoltage x-ray beam dosimetry in doi:10.1088/0031-9155/59/6/R183

[11] Back to the future: the history and development of the clinical linear accelerator in doi:10.1088/0031-9155/51/13/R20.

[12] Food Irradiation – A technique for preserving and improving the safety of food, WHO, Geneva, 1991.

[13] *Loaharanu, Paisan. "Food irradiation: Facts or fiction?." (PDF). IAEA Bulletin (32.2): 44–48. Retrieved March 3, 2014*

[14] Martin, Andrew. Spinach and Peanuts, with a Dash of Radiation. New York Times. February 1, 2009.

[15] Karunakaran, Chithra; Lahlali, Rachid; Zhu, Ning; Webb, Adam M.; Schmidt, Marina; Fransishyn, Kyle; Belev, George; Wysokinski, Tomasz; Olson, Jeremy; Cooper, David M. L.; Hallin, Emil. "Factors influencing real time internal structural visualization and dynamic process monitoring in plants using synchrotron-based phase contrast X-ray imaging". Scientific Reports. 5: 12119. Bibcode:2015NatSR...512119K. doi:10.1038/srep12119. PMC 4648396. PMID 26183486, 2015.

[16] Coherent X-Ray scanning microscopy at PETRA III reached 10 nm resolution (June 2012). Hasylab.desy.de. Retrieved on 2015-12-14.

[17] Kamijo N, Suzuki Y, Awaji M, et al"Hard X-ray microbeam experiments with a sputtered-sliced Fresnel zone plate and its applications". J Synchrotron Radiat. 9 (Pt 3): 182–6. doi:10.1107/S090904950200376X. PMID 11972376, . May 2002.

[18] Penner – HAHN j.E. X-ray absorption spectroscopy. University of Michigan, Ann Arbor, MI, USA.

[19] Cramer, S.P; Jencho; Yocum, M; Ceorge, G N. Nucl. Instrum Methods phys. Res. Sect A.Accel. Spectrom. Dect. Assoc.

[20] IAEA Safety Glossary - draft 2016 revision.

[21] "Biological shield". United States Nuclear Regulatory Commission. Retrieved 13 August 2010.

[22] national regulatory authority that coined the term, in turn derived from its enabling legislation: Health and Safety at Work etc. : "Risk management: ALARP at a glance". London: Health and Safety Executive. Retrieved 13 February 2011. 'ALARP' is short for 'as low as reasonably practicable'. Act 1974.

Appendix

Electromagnetic Pulse	(EMP)
Radio frequency	(RF)
Computed tomography	(CT)
Charge Coupled device	(CCD)
Advanced Light Source	(ALS)
Scanning Transmission X-ray Microscope	(STXM)
X-ray absorption spectroscopy	(XAS)
X-ray Absorption Near-Edge Structure	(XANES)
Extended X-ray Absorption Fine Structure	(EXAFS)
International Atomic Energy Agency	(IAEA)
International Committee on Radiation Protection	(ICRP)
International Commission on Radiation Units and Measurements	(ICRU)
As Low As Reasonably Achievable	(ALARA)