Al-Mustaqbal University
College of Health and Medical Techniques
Radiological Techniques Department

أساسيات الوقاية من الاشعاع

المحاضرة الاولى 23/9/2023

Radiation Protection Course

Lecturer

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Course Description:

This course provides a comprehensive introduction to the principles and practices of radiation protection. It is designed for university students who wish to gain a solid foundation in this critical field, relevant to various scientific disciplines, including physics, biology, medicine, and engineering. Through lectures, lab work, and practical exercises, students will learn about the sources of radiation, its biological effects, and strategies for minimizing radiation exposure.

Chapter One
Atomic & Nuclear Structure

Nuclear Structure:

Composition

1- Electron

2-Nucleus

Electronic Structure

1. Electron Orbits
2. Orbital Nomenclature
3. Binding Energy
4. Electron Transitions
5. Characteristic Radiation
6. Auger Electrons

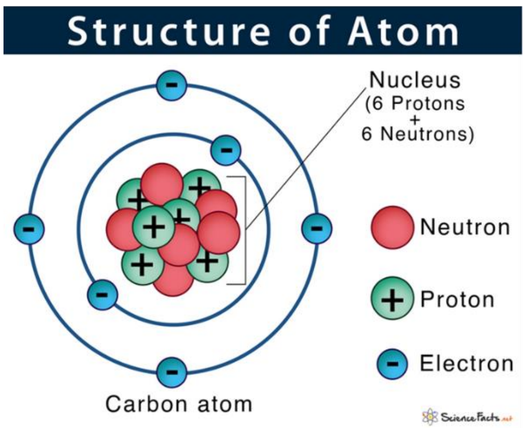
Chapter One

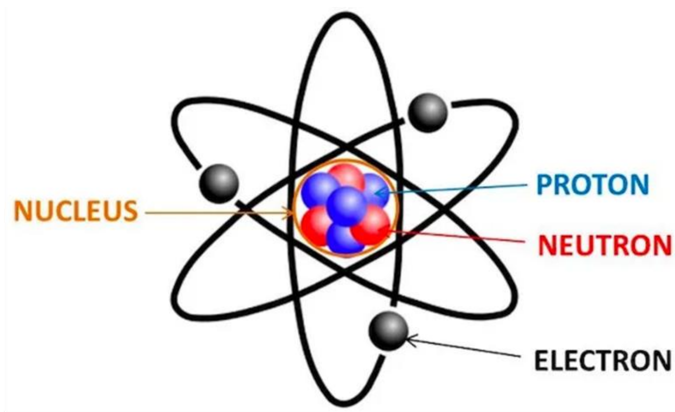
Atomic and Nuclear Structure

Composition:

1- Electron

2-Nucleus





Electronic Structure

1. Electron Orbits: Electronic orbits, also known as electron orbits or electron shells, are regions around the nucleus of an atom where electrons are most likely to be found. These orbits represent the allowed energy levels for electrons within an atom, and they are often depicted as concentric circles or more accurately, as three-dimensional electron clouds.
2. Orbital Nomenclature: Orbital nomenclature is a system used in chemistry to describe and label the different types of atomic orbitals within an atom.

K shell 1st shell = 2 electron , n=1

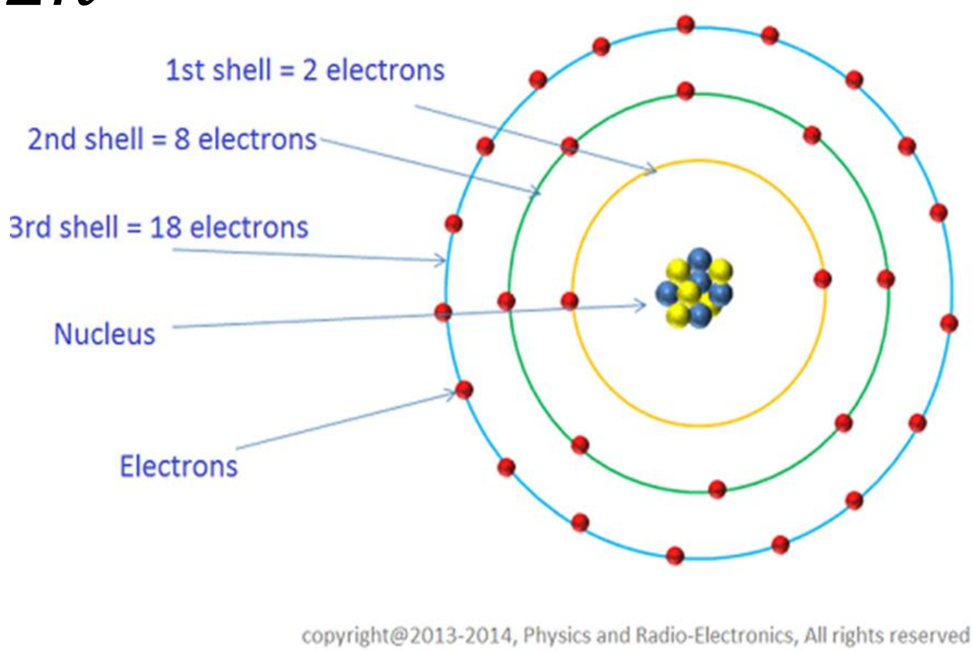
L shell 2nd shell = 8 electron , n=2

M shell 3rd shell =18 electron, n=3

N shell 4th shell =32 electron , n=4

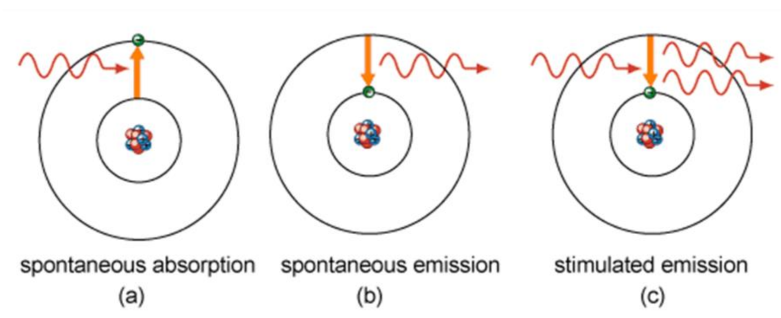
O shell 5th shell = 50 electron , n=5

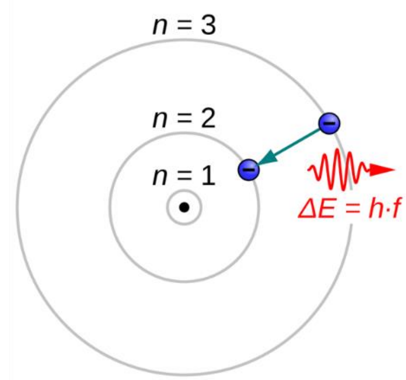
$$2n^2$$



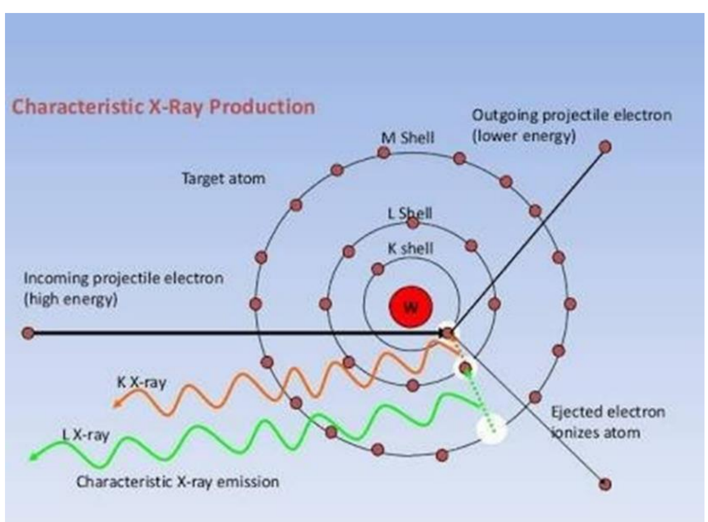
Binding Energy: amount of energy required to separate a particle from a system of particles or to disperse all the particles of the system and Electron binding energy, also called ionization potential, is the energy required to remove an electron from an atom, a molecule, or an ion.

Electron Transitions: Electronic transitions occur in atoms and molecules due to the absorption or emission of electromagnetic radiation.

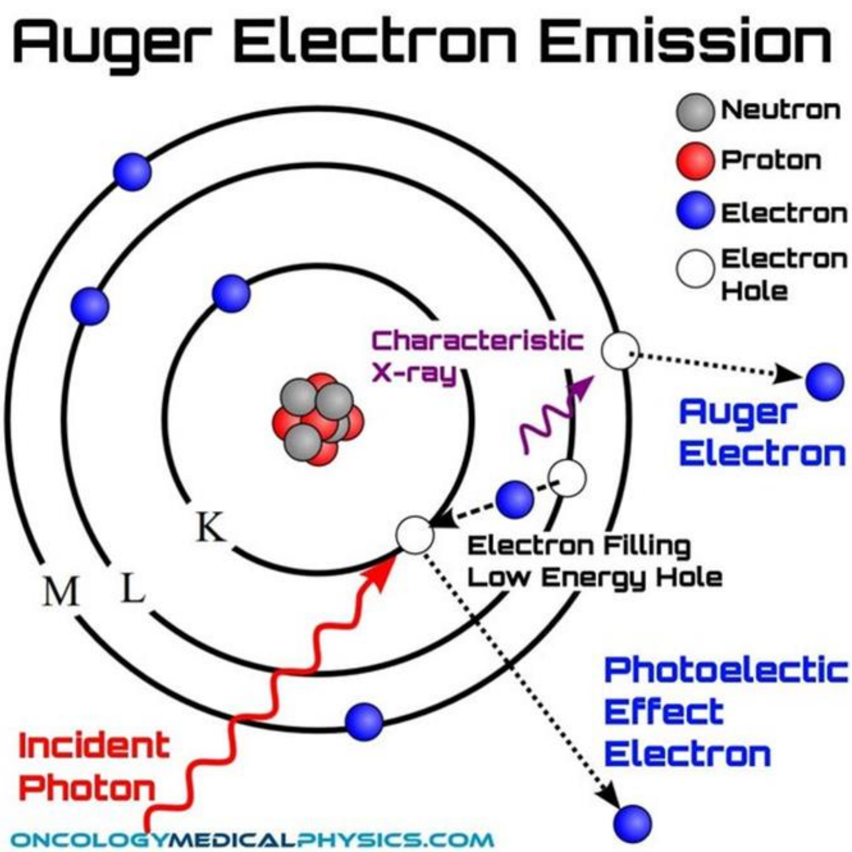




Characteristic Radiation: This energy emission happens when a fast-moving electron collides with a K-shell electron, the electron in the K-shell is ejected (provided the energy of the incident electron is greater than the binding energy of K-shell electron) leaving behind a 'hole'. An outer shell electron fills this hole (from the L-shell, M-shell, etc.) with an emission of a single x-ray photon, sometimes called a characteristic photon, with an energy level equivalent to the energy level difference between the outer and inner shell electron involved in the transition.



Auger Electrons: Auger electrons are electrons that are emitted when an electron from a higher energy level falls into a vacancy in an inner shell. The process usually occurs when the atom is bombarded with high energy electrons. If the collision ejects an inner-shell electron, an electron from a higher level will quickly drop to this lower level to fill the vacancy. But sometimes the energy is transferred to another electron, which is ejected from the atom. This second ejected electron is called an Auger electron, after one of its discoverers, the French physicist Pierre Auger.



Chapter Two

Classification of ionizing radiation

Natural Background Sources:

1- Cosmic Radiation: The earth, and all living things on it, are constantly bombarded by radiation from space, similar to a steady drizzle of rain. Charged particles from the sun and stars interact with the earth's atmosphere and magnetic field to produce a shower of radiation, typically beta and gamma radiation.

The dose from cosmic radiation varies in different parts of the world due to differences in elevation and to the effects of the earth's magnetic field.

2- Terrestrial Radiation: Long-wave electromagnetic radiation originating from Earth and its atmosphere. It is the radiation emitted by naturally radioactive materials on Earth including uranium, thorium, and radon.

Radioactive material found in: Soil ,Water, Vegetation.

3- Internal Radiation:

a- Potassium-40

b- Carbon-14

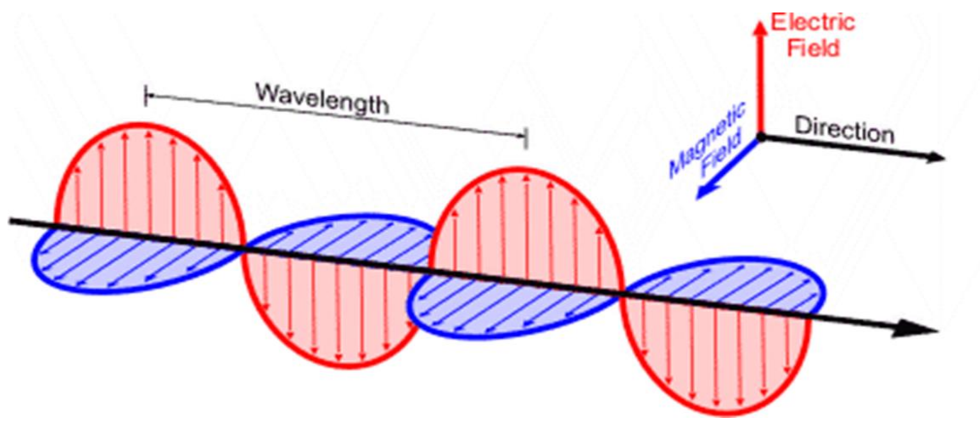
c- Lead-210

Human-made (artificial) sources:

Man-made radiation sources result in exposures: Medical Sources, Diagnostic x-rays Nuclear medicine procedures (iodine-131, cesium-137, and others).

Type of radiation

Electromagnetic Radiation: Electromagnetic radiation is an electric and magnetic disturbance traveling through space at the speed of light (3 × 108 m/s). It contains neither mass nor charge but travels in packets of radiant energy called photons, or quanta. Examples of EM radiation include radio waves and microwaves, as well as infrared, ultraviolet, gamma, and x-rays.



Electromagnetic radiation travels in a waveform at a constant speed. The wave characteristics of EM radiation are found in the relationship of velocity to wavelength (the straight line distance of a single cycle) and frequency (cycles per second, or hertz, Hz), expressed in the formula

$c=\lambda\nu$, $E=h$□ *where* h=Planck's constant

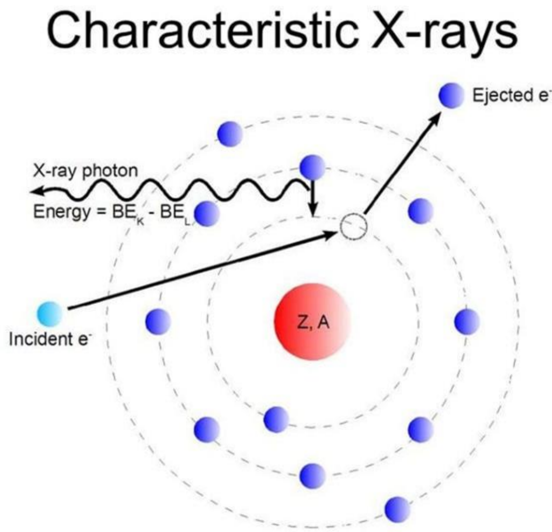
where c = velocity, λ = wavelength, and □ = frequency.

Because the velocity is constant, any increase in frequency results in a subsequent decrease in wavelength. Therefore, wavelength and frequency are inversely proportional.

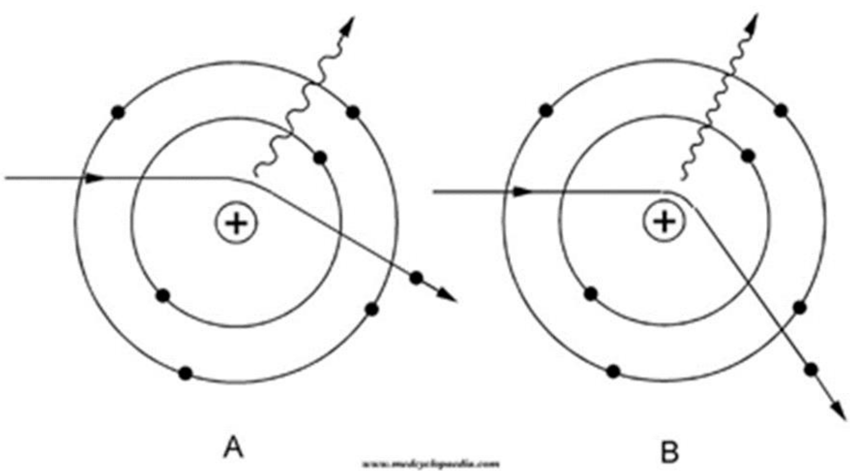
1- **Ionizing electromagnetic radiation**: refers to a specific type of electromagnetic radiation that has enough energy to ionize atoms or molecules, meaning it can remove one or more electrons from them, creating charged particles (ions). This ionization process occurs because the energy of the radiation is sufficient to overcome the binding energy that holds electrons within an atom or molecule. 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 radiation.

a- X-rays: are produced through a process called X-ray radiation or X-ray emission. This phenomenon occurs when high-energy electrons interact with matter, typically heavy metals like tungsten, and release X-ray photons. The process of X-ray production can be described in two primary ways: characteristic X-rays and Bremsstrahlung X-rays.

1-Characteristic X-rays: This type of X-ray production occurs when high-energy electrons knock inner-shell (core) electrons out of their atomic orbits, leaving behind vacancies. Electrons from higher energy levels then fill these vacancies, emitting X-ray photons in the process. The energy of these emitted X-ray photons is specific to the difference in energy levels between the shell from which the electron was displaced and the shell to which the electron transitions. The resulting X-ray photons have discrete energies and are characteristic of the element involved.



2-Bremsstrahlung: is electromagnetic radiation produced by the deceleration of a charged particle when deflected by another charged particle, typically an electron by an atomic nucleus. The moving particle loses kinetic energy, which is converted into a photon, thus satisfying the law of conservation of energy. The term is also used to refer to the process of producing the radiation. Bremsstrahlung has a continuous spectrum, which becomes more intense and whose peak intensity shifts toward higher frequencies as the change of the energy of the decelerated particles increases. The maximum radiation frequency is related to the kinetic energy of the electrons by the relationship. $E=h\nu\_max$

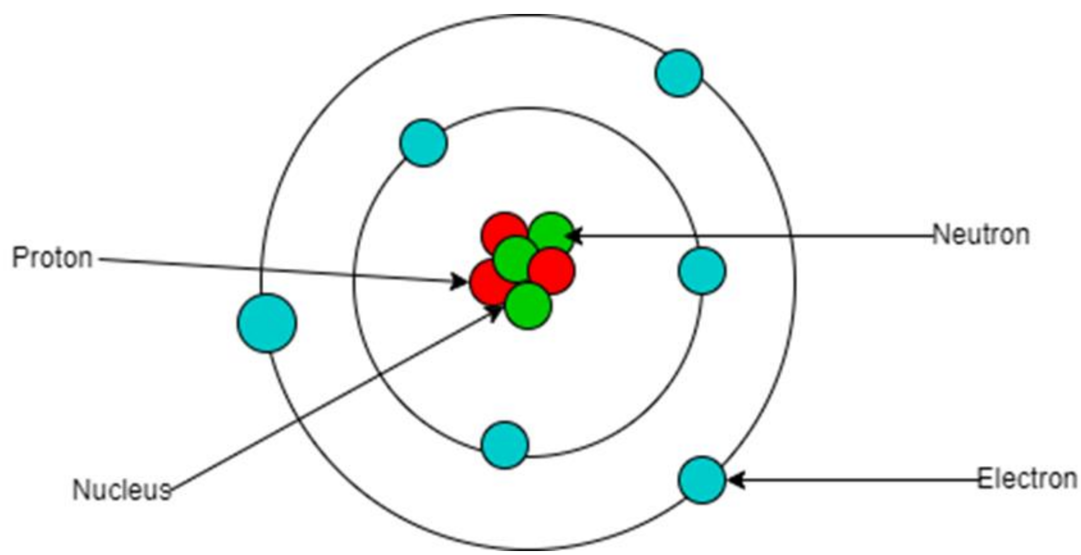


b- Gamma Radiation: is a form of ionizing electromagnetic radiation that is extremely high in energy and short wavelengths, making them highly penetrating and dangerous to living organisms.

X-rays and gamma rays have the same basic properties but come from different parts of the atom. X-rays are emitted from processes outside the nucleus, but gamma rays originate inside the nucleus. They also are generally lower in energy and, therefore less penetrating than gamma.

Nuclear Structure

1- Compositions: The nucleus of an atom is the central region of an atom where the majority of the mass is concentrated. The nucleus of an atom consists of two types of particles, positively charged particles called protons and neutrally charged particles called neutrons. Protons + Neutrons in an atom represent the nucleus of an atom. The nucleus of an atom is represented by zXA, where X is the nucleus of an atom, Z is the atomic number and A is the mass number.



Terms Related to the Nucleus of an Atom

Nucleons: Protons and neutrons which are present in the nuclei of atoms are collectively known as nucleons.

Atomic Number: The number of protons in the nucleus is called the atomic number of the element. It is denoted by Z.

Mass Number: The total number of protons and neutrons (collectively known as nucleons) present in a nucleus is called the mass number of the element. It is denoted by A.

Nuclear Mass: The total mass of the protons and neutrons present in a nucleus is called nuclear mass.

Number of protons in an atom = Number of electrons in an atom = Z

Number of nucleons in an atom = A

Number of neutrons in an atom N = A – Z

A proton has a positive charge Q_p= 1.6×10-19 C and mass m_p = 1.6726×10-27kg

A neutron has no charge and its mass m_n = 1.6749×10-27kg

No electrons are present inside the nucleus.

2- Non-ionizing radiation: Non-ionizing electromagnetic radiation refers to a type of electromagnetic radiation that does not have enough energy to ionize atoms or molecules.

is all around us and comes from both natural and human-made sources. It includes electric and magnetic fields, radio waves, microwaves, infrared, ultraviolet,

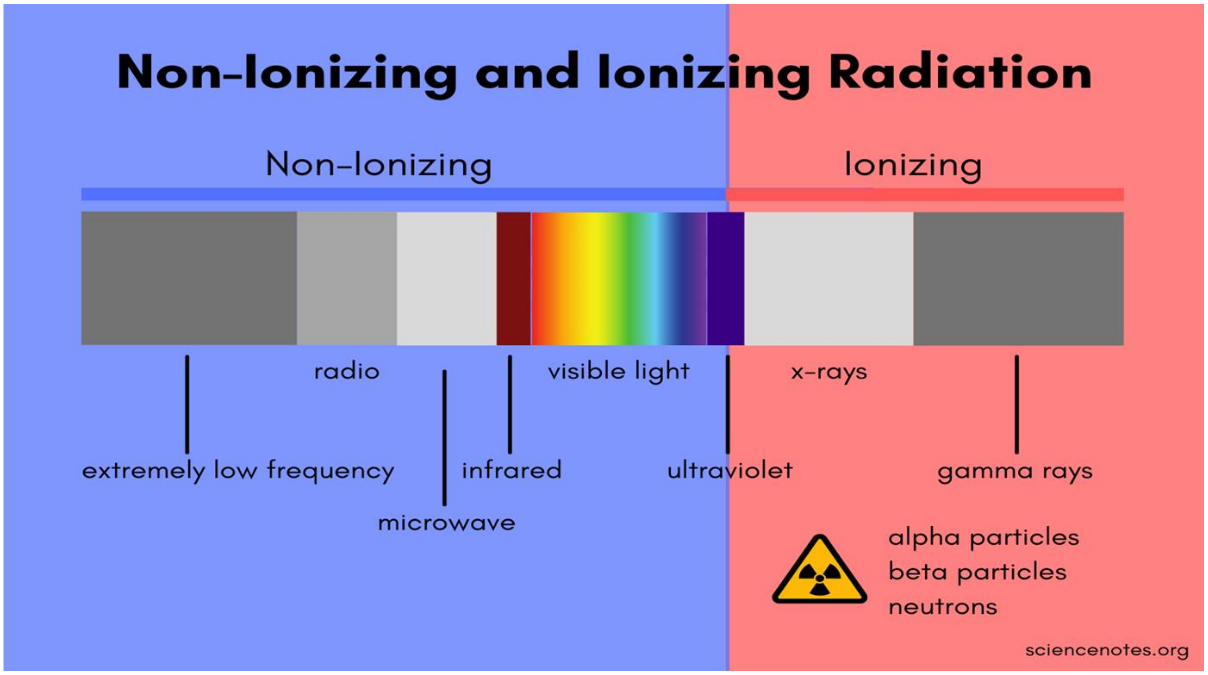


Table summarizing the key differences between ionizing and non-ionizing radiation:

Characteristic	Ionizing Radiation	Non-Ionizing Radiation
Definition	Can ionize atoms/molecules, creating charged particles (ions).	Cannot ionize atoms/molecules; excites electrons without ionization.
Examples	Alpha particles, beta particles, gamma rays, X-rays, certain cosmic rays.	Radio waves, microwaves, infrared radiation, visible light, UV radiation (to some extent), ELF electromagnetic fields
Energy	High energy levels; penetrates matter deeply.	Lower energy levels; limited penetration through matter.
Health Risk	Considered more harmful; can damage DNA and biological molecules, leading to cancer and radiation sickness.	Generally considered less harmful, but high exposure to certain types (e.g., UV) can cause skin damage, increase cancer risk, or have other adverse effects
Common Uses	Medical imaging (X-rays), radiation therapy, industrial radiography, nuclear power generation	Communication (radio waves, microwaves), cooking (microwaves), heating (infrared), lighting (visible light), sterilization, some medical treatments.

Particle Radiation

Particle radiation refers to a type of ionizing radiation composed of tiny, high-energy particles. Unlike electromagnetic radiation, which includes photons (such as X-rays and gamma rays), particle radiation consists of actual particles that can carry both energy and mass. Particle radiation is made up of any subatomic particles, such as protons, neutrons, and high-speed electrons, capable of causing ionization. Alpha and beta particles are two of the more common types of particle radiation. They come from the nuclei of radioactive atoms through radioactive decay.

Some common examples of particle radiation include:

1- Light charged particles: [beta particles β (Electrons e^- and Positron e^+)] m_e=0.00054858 amu =9.1093837 × 10^{-31} kg .

2- Heavy charged particles: [Alpha Particles α] $\boldsymbol{m_\alpha}$=**4.001506179127 *amu***, Protons p m_p=1.00727647and heavier ions].

2- Uncharged particles: (Neutrons n $\boldsymbol{m_n}$=**1.00866491588** amu)