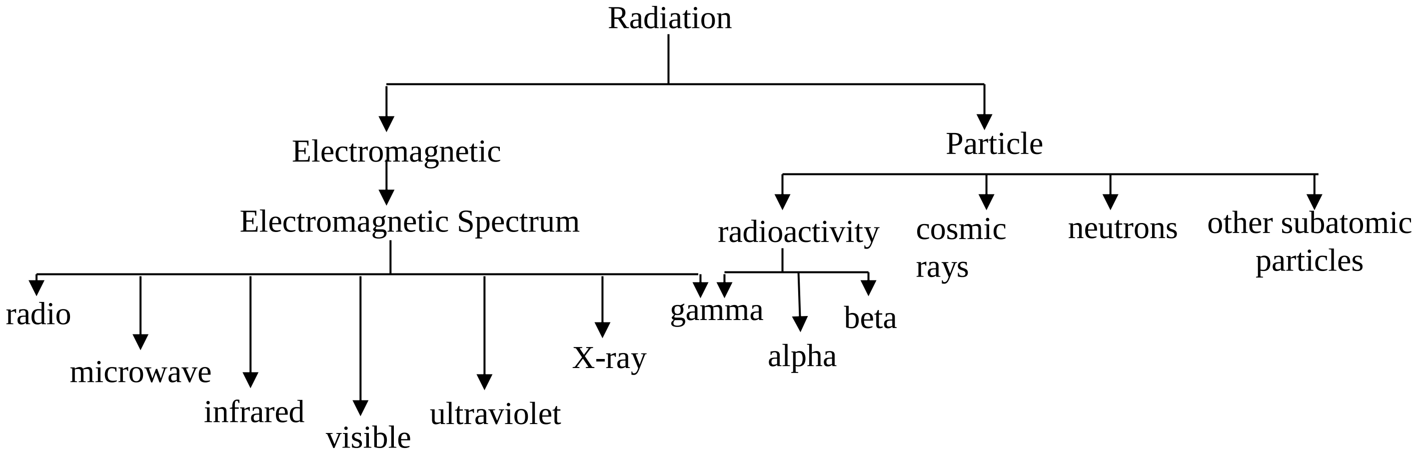
NM. How is Radiation Used to Maintain Human Health?

Physics with Synno – Radiation-Health – Lesson 1

Reference: Heinemann Physics 11 4th Edition
Chapter 16

NM.1 Radiation

There are many forms of radiation that fit into the definition.
The emission of energy as electromagnetic waves or as moving subatomic particles, especially high-energy particles which cause ionization.



NM.2 X-Rays

In 1895 Wilhelm Konrad Roentgen was studying the newly discovered 'cathode rays' that could be produced inside a glass tube. He noticed that, whenever the cathode rays were being produced a screen in the room that was coated with a special fluorescing substance would start to glow. He presumed some sort of invisible rays must have been travelling from the tube to the screen. Not knowing what these rays were, he called them **X-rays**.

X-rays are electromagnetic waves of very high frequency and very short wavelength, in the range 0.001 nm to 10 nm. Because of their high frequency, and hence high energy, they can penetrate flesh and may cause ionisation of atoms they encounter on the way through. The more dense material, such as bone, absorbs more X-radiation.




Recall that for any wave the relationship between its frequency and wavelength is given by:

$$v = \lambda f$$

where, in the case of X-rays,

v = the velocity of the X-ray (in a vacuum or air this is $c = 3.00 \times 10^{8}\ \mathrm{ms}^{-1}$)
f = frequency in hertz (Hz)
λ = wavelength in metres (m)

Example

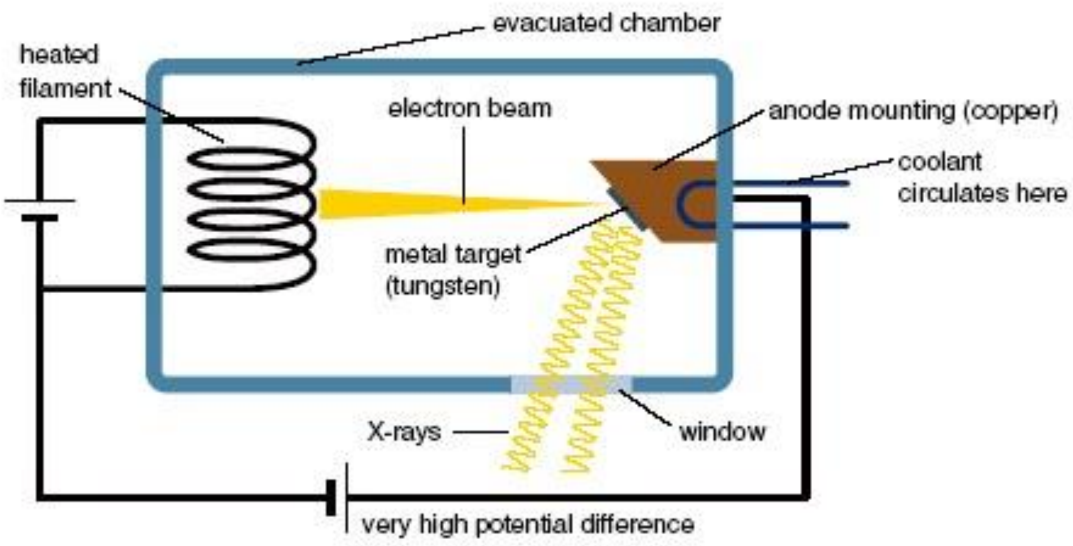
Calculate the wavelength of X-rays that have a frequency of 2.75×10^{19} Hz, if they are travelling in air.

$$v = \lambda f$$
$$3.00 \times 10^{8} = \lambda \times 2.75 \times 10^{19}$$
$$\lambda = 1.09 \times 10^{-11} m$$

The effects of overexposure to X-rays were not revealed for some time. Early scientists working with X-rays suffered hair loss, burns, skin ulcers, skin cancers and death from unprotected overuse.

NM.2.1 Producing X-rays

The production of X-rays requires very specific apparatus. The process involves the use of an evacuated glass tube and within it a filament that is heated so that it gives off electrons. Placing a positive metal target at the other end of the glass tube then accelerates these electrons. The electrons will strike the metal plate and decelerate suddenly. As they decelerate energy is given off in the form of X-rays.



NM.2.2 Energy of X-rays

Early last century Albert Einstein and Max Plank investigated a theory for the behaviour called the photon theory. This theory also applies to other forms of electromagnetic radiation such as X-rays. According to photon theory energy is carried in packet called 'photons'. They derived a formula to calculate the photon energy.

$$E = h\,f$$

where E = energy of the X-ray photon in joules (J)

h = Planck's constant = 6.62×10^{-34} J s

f = frequency in hertz (Hz)

X-rays are categorised as Soft or Hard.

Soft X-rays have lower frequency, which means lower energy and less penetrating power. Soft X-rays are used when the object being imaged is relatively thin. An example would be dental X-ray.

Hard X-rays have higher frequency, higher energy and can penetrate further. These are used when the object imaging is thicker. For example the body.

NM.3 Radioisotopes

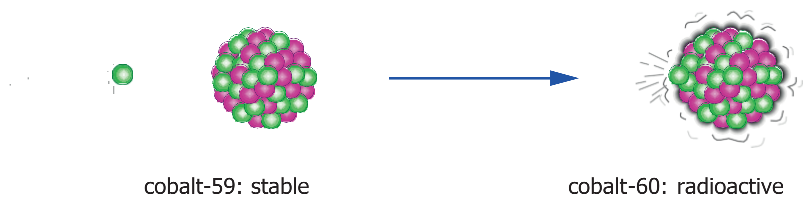
Many of the elements found in nature have isotopes of different masses due to differing numbers of neutrons in their nucleus. Some are also unstable and undergo radioactive decay, these are called radioisotopes.

NM.3.1 Producing Radioisotopes

In the early days of medical research, naturally occurring radioisotopes were used. Today most radioisotopes used in medicine are manufactured in a process called artificial transmutation, which uses neutron bombardment. Essentially neutrons are fired at an element with enough energy for it to be captured by its nucleus. This is done in a device called a cyclotron.

Cobalt-60 is produced in this way. Neutrons are fired at Cobalt-59 and one is captured by the nucleus.

$${}^{1}_{0}n + {}^{59}_{27}Co \rightarrow {}^{60}_{27}Co$$



Other radioisotopes used in medicine that are produced in this way are:

Technetium-99, which is used as a tracer. It is used to examine the function of organs and the presence of tumors.

Iodine-131, which tends to accumulate in the thyroid gland. It is used to treat or diagnose thyroid conditions.

In Australia medical radioisotopes are produced at the Australian Nuclear Science and Technology Organisation (ANSTO)

Problem Set #1: Chapter 16 Page 10 Questions 1-5, 7, 9, 10