Omnipresent physics in technologies and other scientific fields

from the physics knowledge in secondary/high schools

by

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Chapter 3: Modern physics laws and applications

III.1. Introduction

This chapter deals with the general presentation of some modern physics laws taught in secondary/high schools and their use in technology. Let us remind that modern physics is physics based on two major breakthroughs of the early years of the twentieth century: quantum mechanics and relativity. In secondary/high schools, mainly in the final years, the two main topics of modern physics is photoelectric effects and radioactivity which contain several laws and phenomena. This chapter deals with this two subjects with special focus on their applications in technologies. The first section deals with the photoelectric effects while radioactivity constitutes the second section.

II-2- Photoelectric laws

Photoelectric effect is the phenomenon by which electrically charged particles are released from a material when it absorbs electromagnetic radiation. The effect is often defined as the ejection of electrons from a metal plate when light falls on it. In a broader definition, the radiant energy may be infrared, visible, or ultraviolet light, X rays, or gamma rays; the material may be a solid, liquid, or gas; and the released particles may be electrons or ions (electrically charged atoms or molecules). The phenomenon was fundamentally significant in the development of modern physics because of the puzzling questions it raised about the nature of light—particle versus wavelike behavior—that were finally resolved by Albert Einstein in 1905 (Figure 3.1).

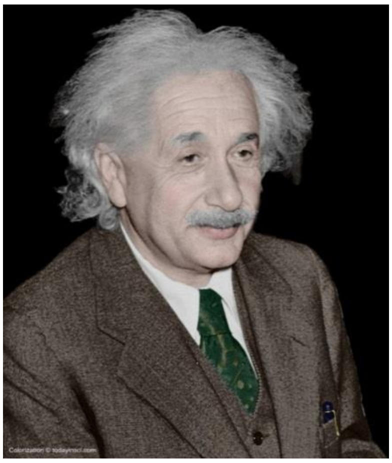

Figure 3.1: Albert Einstein

III.2.1. Formulation of the photoelectric laws and historical facts

When a light radiation of appropriate wavelength or of appropriate frequency falls on metals, electrons are emitted (Figure 3.2). This is the photoelectric effect.

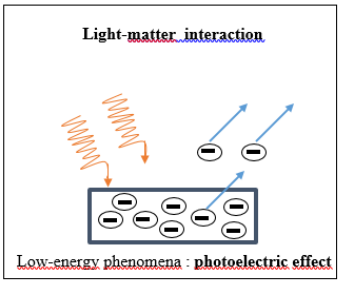

Figure 3.2: Presentation of the photoelectric effect (electrons emitted when the metal is hit by a light ray)

Electrons emitted in this manner are called photoelectrons. The effect has found use in electronic devices specialized for light detection and precisely timed electron emission.

Emission of conduction electrons from typical metals requires a few electron-volt (eV) light quanta, corresponding to short-wavelength visible or ultraviolet light.

In 1839, Alexandre Edmond Becquerel discovered the photovoltaic effect while studying the effect of light on electrolytic cells. Though not equivalent to the photoelectric effect, his work on photovoltaics was instrumental in showing a strong relationship between light and electronic properties of materials.

In 1887, Heinrich Hertz observed the photoelectric effect and reported on the production and reception of electromagnetic waves. The receiver in his apparatus consisted of a coil with a spark gap, where a spark would be seen upon detection of electromagnetic waves. He placed the apparatus in a darkened box to see the spark better. However, he noticed that the maximum spark length was reduced when inside the box. A glass panel placed between the source of electromagnetic waves and the receiver absorbed ultraviolet radiation that assisted the electrons in jumping across the gap. When removed, the spark length would increase. He observed no decrease in spark length when he replaced the glass with quartz, as quartz does not absorb UV radiation.

The discoveries by Hertz led to a series of investigations by Hallwachs, Hoor, Righi and Stoletov on the effect of light, and especially of ultraviolet light, on charged bodies. Hallwachs connected a zinc plate to an electroscope. He allowed ultraviolet light to fall on a freshly cleaned zinc plate and observed that the zinc plate became uncharged if initially negatively charged, positively charged if initially uncharged, and more positively charged if initially positively charged. From these observations he concluded that some negatively charged particles were emitted by the zinc plate when exposed to ultraviolet light.

In the period from 1888 until 1891, a detailed analysis of the photoelectric effect was performed by Aleksandr Stoletov with results reported in six publications. Stoletov invented a new experimental setup which was more suitable for a quantitative analysis of the photoelectric effect. He discovered a direct proportionality between the intensity of light and the induced photoelectric current (the first law of photo effect or Stoletov's law). He measured the dependence of the intensity of the photoelectric current on the gas pressure, where he found the existence of an optimal gas pressure corresponding to a maximum photocurrent; this property was later used for the creation of solar cells.

Many substances, besides metals, discharge negative electricity under the action of ultraviolet light. G. C. Schmidt and O. Knoblauch compiled a list of these substances. Under certain circumstances light can ionize gases. This was first reported by Philipp Lenard in 1900.

In 1899, J. J. Thomson investigated ultraviolet light in Crookes tubes. Thomson deduced that the ejected particles, which he called corpuscles, were of the same nature as cathode rays. These particles later became known as the electrons. Thomson enclosed a metal plate (a cathode) in a vacuum tube, and exposed it to high-frequency radiation. It was thought that the oscillating electromagnetic fields caused the atoms field to resonate and, after reaching a certain amplitude, caused a subatomic corpuscle to be emitted, and current to be detected. The amount of this current varied with the intensity and color of the radiation. Larger radiation intensity or frequency would produce more current.

Einstein's work predicted that the energy of individual ejected electrons increases linearly with the frequency of the light. Perhaps surprisingly, the precise relationship had not at that time been tested. By 1905, it was known that the energy of photoelectrons increases with increasing frequency of incident light and is independent of the intensity of the light. However, the manner of the increase was not experimentally determined until 1914 when Robert Andrews Millikan showed that Einstein's prediction was correct. The photoelectric effect helped to propel the then-emerging concept of wave–particle duality in the nature of light. Light simultaneously possesses the characteristics of both waves and particles, each being manifested according to the circumstances. The effect was impossible to understand in terms of the classical wave description of light, as the energy of the emitted electrons did not depend on the intensity of the incident radiation.

Consideration of these unexpected behaviors led Albert Einstein to formulate in 1905 a new corpuscular theory of light in which each particle of light, or photon, contains a fixed amount of energy, or quantum, that depends on the light frequency. In particular, a photon carries an energy E equal to

$$E= h\upsilon, \tag{3.1}$$

where υ is the frequency of the light and h is the universal constant that the German physicist Max Planck derived in 1900 to explain the wavelength distribution of blackbody radiation (the electromagnetic radiation emitted from a hot body).

The relationship may also be written in the equivalent form

$$E = hc/\lambda, \tag{3.2}$$

where c is the speed of light and λ is its wavelength, showing that the energy of a photon is inversely proportional to its wavelength.

Einstein assumed that a photon would penetrate the material and transfer its energy to an electron. As the electron moved through the metal at high speed and finally emerged from the material, its kinetic energy would diminish by an amount ϕ called the work function, which represents the energy required for the electron to escape the metal (to cross the barrier of the metal). By conservation of energy, this reasoning led Einstein to the photoelectric equation

$$E_k = h\upsilon - \phi, \tag{3.3}$$

where E_k is the maximum kinetic energy of the ejected electron.

Although Einstein's model described the emission of electrons from an illuminated plate, his photon hypothesis was sufficiently radical that it was not universally accepted until it received further experimental verification.

Further corroboration occurred in 1916 when extremely accurate measurements by the American physicist Robert Millikan verified Einstein's equation and showed with high precision that the value of the constant h used by Einstein was the same as Planck's constant.

Einstein was finally awarded the Nobel Prize in Physics in 1921 for explaining the photoelectric effect.

III.2.2. Laws of Photoelectric Emission

The fundamental laws of the photoelectric emission are the following:

i) For a given photo sensitive material, there is a minimum frequency called the threshold frequency, below which emission of photoelectrons stops completely, however great the light intensity may be.

ii) For a given photosensitive material, the photo electric current is directly proportional to the intensity of the incident radiation, provided the frequency is greater than the threshold frequency.

iii) The photoelectric emission is an instantaneous process, i.e., there is no time lag, between the incidence of radiation and the emission of photo electrons.

iv) The maximum kinetic energy of the photo electrons is directly proportional to the frequency of incident radiation, but is independent of its intensity. This follows the Einstein formula.

III.2.3. Impacts of photoelectric laws on technology

Devices based on the photoelectric effect have several desirable properties, including producing a current that is directly proportional to light intensity and a very fast response time.

III.2.3.1. Production of electricity: photovoltaic cells

The term "photovoltaics" (PV) designates the physical process by which light energy is transformed into electricity through the transfer of photons to electrons. In general, the photovoltaic principle is similar to that of the photoelectric effect.

The photovoltaic effect manifests itself when a photon is absorbed by a material constitued of p-doped semiconductors (positive doped) and n-doped semiconductors (negative doped), called PN or NP junction. Thank to this doped process, an electric field is permanently present in the material (as a magnet possesses a permanent magnetic field). When an incident photon (light grain) interacts with the electrons, it gives its energy $h\upsilon$ to the electron which is thus liberated from the valence band and thus is submitted to the action of the intrinsic electric field. Under the action of the electric field, the electron migrates towards the superior face, thus leaving a space called hole which migrates in the opposite direction. Electrodes placed on the superior and inferior faces help to collect the electrons and makes them flow to meet the hole.

The most appropriate material used today in photovoltaics is the silicon. During its cooling, the melt silicon solidifies while forming a single cristal of large dimension. One thus cuts it into slices which will be used to form the solar cells. These cells are general uniformly blue.

Today, with the technological development, PV cells have a light yield of about 20~25%, meaning about 300Wc/m^2. The PV energy is abundant. The maintenance of PV cells is easy (removal of dust). Their life cycle is about 50 years. The electricity production is maximal when solar rays arrive perpendicularly on the cell surfaces. According to the International Agency of Energy, the World photovoltaic park was more than 500 GW at the end of 2018.

The PV cells produce continuos electrical current. To add this energy into the distribution network, one uses appropriate inverters (Figure 3.3).

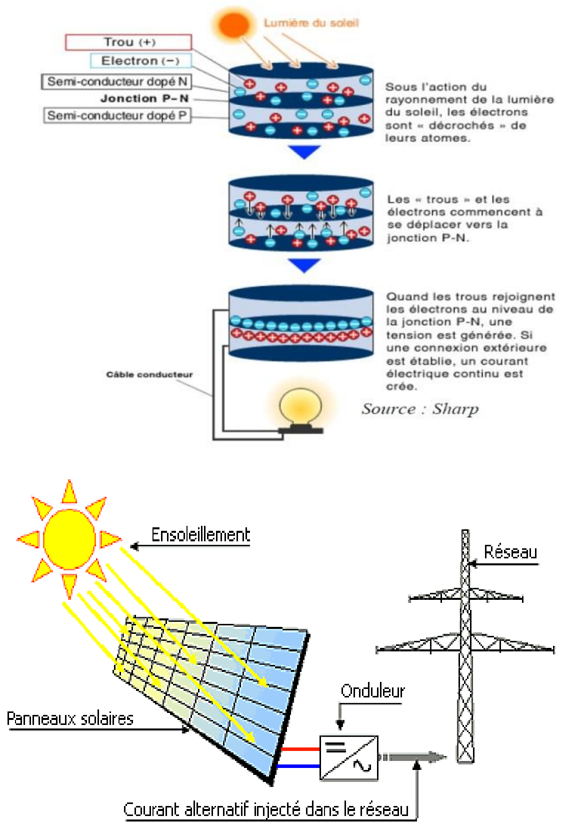

Figure 3.3 : (left) Principe of the photovoltaic effect ; (right) Schematic view of the electric distribution by a photovoltaic plant

III.2.3.2. Photodiodes

Photodiodes are used to convert light signals to electricity signals (Figure 3.4). They are also constituted of a PN junction. But they have to be electrically inversely polarized in order to reduce the noises due to electrical charges diffusion. Thus they consumed electricity before converting light into electricity.

They are used for many technological purposes and specifically in remote control devices and in optical telecommunication where they convert light messages coming from the optical fibers into electrical signals that are processed in other different forms of signals.

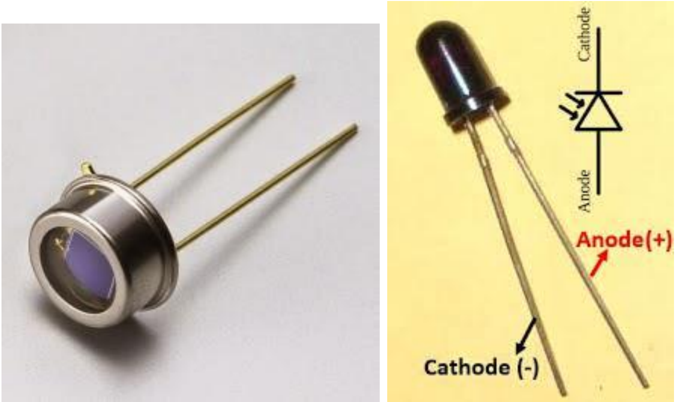

Figure 3.4: Photodiodes and symbol

III.3. Radioactivity laws

III.3.1. Definition of radioactivity and some historical facts

Radioactivity was first discovered in 1896 by the French scientist Henri Becquerel while working on phosphorescent materials (materials which when exposed to radiation emit light even after the radiation has ceased). These materials glow in the dark after exposure to light, and Becquerel thought that the glow produced in cathode ray tubes by x-rays might somehow be connected with phosphorescence. So he tried wrapping a photographic plate with a black paper and placing various phosphorescent minerals on them. All results were negative until he tried using uranium salts. The result with these compounds was a deep blackening of the plate.

However, it soon became clear that the blackening of the plate had nothing to do with phosphorescence because the plate blackened when the mineral was kept in the dark. Also non-phosphorescent salts of uranium and even metallic uranium blackened the plate. Clearly there was some new form of radiation that could pass through paper that was causing the plate to blacken (in some literature, it is indicated that Becquerel accidentally discovered radioactivity. At first, it seemed that the new radiation was similar to the then recently discovered X-rays. However further research by Becquerel, Marie Curie, Pierre Curie, Ernest Rutherford and others discovered three different types of radioactivity, namely alpha decay, beta decay, and gamma decay. These researchers also discovered that many other chemical elements (or their isotopes) are radioactive.

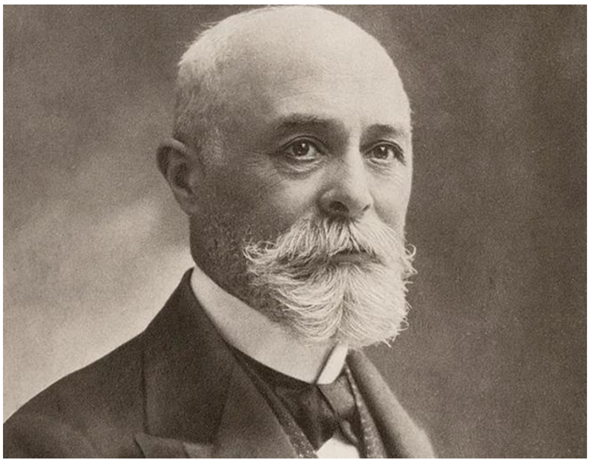

Figure 3.5 : Henri Becquerel (1852- 1908), discover of radioactivity and Nobel prize co-winner for radioactivity discovery (with the Marie and Pierre Curie)

Figure 3.6: Marie Currie (1867-1934), then Pierre (1859-1906) and Marie Curie in their laboratory, co-winners of the Nobel Prize for radioactivity discovery (with Becquerel).

Becquerel (Figure 2.5) was awarded the Nobel Prize in Physics in 1903 for the discovery of radioactivity, alongside Marie and Pierre Curie (Figure 2.6), for their works to explain the radioactivity. The standard international unit for measuring radioactivity is today named the Becquerel in his honor.

The Curie eventually outstripped Henri Becquerel when it came to radioactivity research. They were the ones who introduced the term “radioactive." They showed that uranium ore contained at least two substances more radioactive than uranium itself, both previously unknown to science. These were radium, derived from the Latin for ray, and polonium, named for Marie's native Poland, then under Russian control. The Curie went on to work with so much radiation (and make so many key discoveries) that there was a concern after Marie's death from aplastic anemia in 1934 that her skeleton might be radioactive. When tested during a exhumation in 1995, it was not the case, although her papers still are (Pierre had died much earlier, in 1906, after an accident with a horse cart).

III.3.2. Types of radioactivity

The "Radiation" is the name of the particles emitted as the result of radioactivity. The three most common types of radiation (or decay) are alpha (α), beta (β) and gamma (γ) radiation.

- *α-decay* –a helium nucleus ($^{4}_{2}He$) is emitted : Alpha radiation consists of two protons and two neutrons, equivalent to the nucleus of a helium (He) atom; that is, helium without its two electrons. Because of the combination of this particle sizable mass and +2 electrical charge, these particles do not move very far from the nuclei that emit them. They interact strongly with most matter and can do serious biological damages if ingested (swallowed).

- *β-decay*: Beta radiation is the emission of a negatively charged electron or the emission of positron (particle with the same mass as the electron, but with a positive electric charge). Being smaller, these particles are more penetrating than alpha radiation. They also impact on the health.

- *γ-deca*y – high energy (hundreds of keV or more) photons are emitted : Gamma radiation is the emission of electromagnetic energy from the nucleus rather than particles. These emissions are similar to X-rays, except that the latter do not originate in nuclei. This radiation is useful in medical applications, but are also highly dangerous since it can penetrate deep into biological matter.

III.3.3. Energy released from a radioactivity reaction

Nuclear reactions, like chemical reactions, are accompanied by an energy release. The energy changes in nuclear reactions, however, are enormous compared with those of even the most energetic chemical reactions. In this section, we describe the relationship between mass and energy in nuclear reactions and show how very small changes in mass that accompany nuclear reactions result in the release of enormous amounts of energy. The relationship between mass (m) and energy (E) is expressed in the following Einstein's equation:

$$E = mc^2 \tag{3.5}$$

where c is the speed of light (2.998×108 m/s), E and m are expressed in units of Joule and kilograms, respectively.

Einstein first derived this relationship in 1905 as part of his special theory of relativity: the mass of a particle is directly proportional to its energy. Thus according to Einstein, every mass has an associated energy, and similarly, any reaction that involves a change in energy must be accompanied by a change in mass. This implies that all exothermic reactions should be accompanied by a decrease in mass, and all endothermic reactions should be accompanied by an increase in mass. Given the law of conservation of mass, how can this be true? The solution to this apparent contradiction is that chemical reactions are indeed accompanied by changes in mass, but these changes are simply too small to be detected.

Let us consider the radioactive decay of ^{14}C to ^{14}N and an electron (a β particle). The equation is written as

$$^{14}\mathrm{C} \rightarrow {}^{14}\mathrm{N} + {}^{0}_{-1}\beta \tag{3.6}$$

The total change in mass during the reaction is therefore the difference between the mass of a neutral ^{14}N atom (14.003074 amu) and the mass of a ^{14}C atom (14.003242 amu):

Δm=mass (products)-mass(reactants)= -0.000168 uma.

This is for one nucleus of carbone 14. If we consider one mole of this carbon (meaning about 14 g of this carbon), then the difference in mass when the radioactivity takes place is about 1.68 × 10^{-7} kg. Although, this look very small, its conversion into energy following the Einstein's formula gives an energy release of

$$\Delta E=(\Delta m)*c^2=1.51 \times 10^7 \text{ kJ}. \tag{3.7}$$

Imagine that this energy is released in a hall of 20 m x20 m x 5 m=2000 m^3 filled of air. Then the air temperature will increase of about

$$\Delta T = \Delta E/m_{air}\, c_{air} = 57\ 730.5\ °C \tag{3.8}$$

where m_{air} and c_{air} are respectively the air mass and air specific heat. This is a huge temperature variation and all beings (biological and material) will be burnt and transformed into ashes or gas.

III.3.4. The radioactivity decay law

The radioactive decay law states that the probability per unit time that a nucleus will decay is a constant, independent of time. This constant is called the decay constant and is denoted by λ, "lambda". The radioactive decay of certain number of atoms (mass) is exponential in time and is given by the following mathematical expression:

$$N(t) = N_0 e^{-\lambda t} \tag{3.9}$$

N_0 is the number of radioactive nuclei in the sample at the initial time and N is the number of radioactive nuclei at any subsequent time t.

In radioactivity calculations, we are more interested in the decay rate R ($= -\dfrac{dN}{dt}$) than in N itself. This rate gives us the number of nuclei decaying per unit time. Even if we do not know the number of nuclei in the sample, by simply measuring the number of emissions of α, β or γ particles in 10 or 20 seconds, we can calculate the decay rate. The decay rate is thus mathematically equal to

$$R = \lambda N_0 e^{-\lambda t} \quad \text{or} \quad R = R_0 e^{-\lambda t} \tag{3.10}$$

This is an alternative form of the law of radioactive decay. R is also called the activity. It can be rewritten as follows

$$R = \lambda N \tag{3.11}$$

The SI unit for measurement of activity is 'Becquerel' and is defined as,
1 Becquerel = 1 Bq = 1 decay per second
An older unit, the Curie, is still in common use:
1 Curie = 1 Ci = 3.7×10^{10} Bq (decays per second)

The half-life $T_{1/2}$ is the time at which both R and N are reduced to half of their initial values. It is given by the following relation:

$$T_{1/2} = \frac{\ln 2}{\lambda} \qquad (3.12)$$

III.3.5. Radioactivity technological applications

III.3.5.1. In medicine:

- **Diagnosis:**

For the diagnosis of diseases, radiography, scintigraphy and tracer methods are based on radioactivity.

The radiography uses the X rays. A radioactive nucleus placed in an apparatus transforms the X-rays in electrons and thus provided an image of the zone under analysis.

The technetium 99m, which emits gamma radiations, is used in radiography to produce images of the skeleton, of muscle, brain, thyroid, lungs, liver, kidney, spinal cord, etc. It also helps to visualize infections on different organs (figure 3.7).

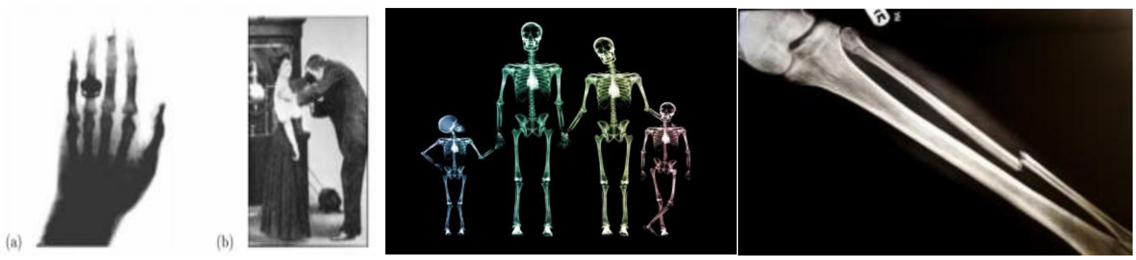

Figure 3.7: (left) (a) Radiography of the arm of Röntgen's wife; (b) Radiographic analysis of the chest at the beginning of the 20th century. The X rays tube is placed behind the patient and the doctor observes the transmitted signal using a fluorescent screen. (Middle) A family photograph from X rays. (right) Fracture detected by X rays.

For the scintigraphy, small quantities of radioactive substances are injected into the biological organ (Figure 3.8). These substances fixed themselves more on the biological organ if it functions appropriately. If not, the fixation will be limited. But the reverse can be observed where the diseased organs accumulate more the radioactive element. This is for instance the case of Phosphorus 32 which is useful in the identification of malignant tumors because cancerous cells tend to accumulate phosphate more than normal cells do.

Figure 3.8: A scintigraphy apparatus and the thyroid image from a scintigraphy

For the tracer methods, it is known that radioactive atoms are easy to detect because of the radiation they emit and which can be measured using detection devices such as gamma-ray spectrometers and proportional counters. Thus in medicine and research, this property is used to follow the progression of a molecule in a biological organ. This can help in the detection of stenosis of the blood vessels. This can also show how a biological organ reacts when the radionuclide arrives at its level (thus see the efficiency of a drug). The main radioisotopes used as tracers are iodine-131, phosphorus-32, and technetium-99*m*.

- **Radiotherapy or treatment by radiations:**

Radioisotopes such as cobalt-60 and cesium-137 are widely used to treat cancer. They can be administered selectively to malignant tumors and so minimize damage to neighbouring healthy tissue.

There, the radiation emitted destroy the cancer cells.

The iodine 131 emits beta radiation and is used for the treatment of the hyperthyroid and cancers of the thyroid.

III.3.5.2. Production of electricity

Some radioisotopes are used to produce electricity in what is called a nuclear reactor. A nuclear reactor is also known as atomic pile. It initiates and controls a self-sustained nuclear chain reaction to generate electricity (Figure 3.9). The radioisotopes used in nuclear reactor are the Uranium and Plutonium which disintegrate in two (fission) with the emission of energy and a large amount of heat. When one nucleus disintegrates, it emits high (velocity) energy neutrons which hit other nucleus and thus provoke their disintegration. A chain reaction takes places.

The heat created by fission turns the water into steam, whose pressure acts on a turbine to produce carbon-free electricity.

The device is specially controlled to avoid the radiation going out the nuclear reactor.

The heat produced is sometimes used to propel ship in the sea (nuclear marine propulsion).

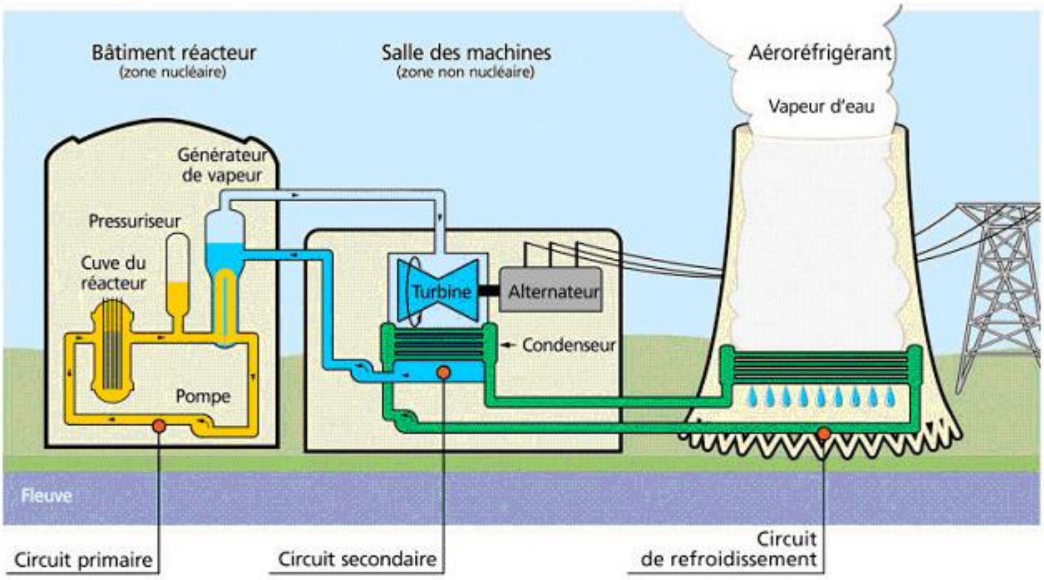

Figure 3.9 : Structure of a nuclear reactor

The fumes which come out from the nuclear reactors (Figure 3.10) are water vapors from the water used to cool the secondary circuit in which are the turbines producing electricity through their rotation. The primary circuit is that of the nuclear source. These fumes are not toxic because the system is made so as to make the primary circuit isolated from the secondary circuit.

Figure 3.10 : Cooling circuit of a nuclear reactor

Small radioisotope batteries (atomic batteries, nuclear batteries) are devices which use energy from the decay of radioactive isotopes to generate electricity (Figure 3.11). Their radioisotope sources are plutonium 239 or cobalt 60. The difference with the nuclear reactors is that they do not use a chain reaction. Moreover, their size is small compare to that of the nuclear reactors. They have the advantage that they function without special care during many years. They are used in space engines such as satellites.

Figure 3.11: Nuclear or atomic batteries

III.3.5.3. Nuclear weapons

One of the first uses of radioactivity was military. Today, several developed countries have nuclear arms of different types.

A nuclear weapon is based either on the fission of radioelements (fission bomb) or on the combination of fission and fusion reactions (thermonuclear weapon). Their war action is the explosion they produce leading a huge destructive force. They are called atomic bomb or nuclear bomb or warheads. They are weapons of mass destruction.

Their principle is similar to that of the electricity plant described above with the difference that the heat or energy produced is not used to warm the water for the turbine, but is directly set out in an explosive manner. They use uranium and plutonium. The chain reaction being almost instantaneous, a huge amount of energy is released instantaneously and devastate all material and biological beings in a large area.

This is what happens in Nagasaki and Hiroshima during the second World war when the United States of America launched two atomic bombs in these two Japanese cities.

The Hiroshima bomb had a thin shape and was named “Little Boy” (Figure 3.12). It used uranium 235. The fission of only one kilogram of uranium 235 released energy equivalent to approximately 15,000 kT (or tons of TNT). We note that 1 kT=4 184 000 000 000 Joule.

The Nagasaki bomb has a round and flat shape and was called “Fat Man”. It used plutonium 239 and the fission of about one kilogram is thought to have released destructive energy equivalent to about 21,000 kT.

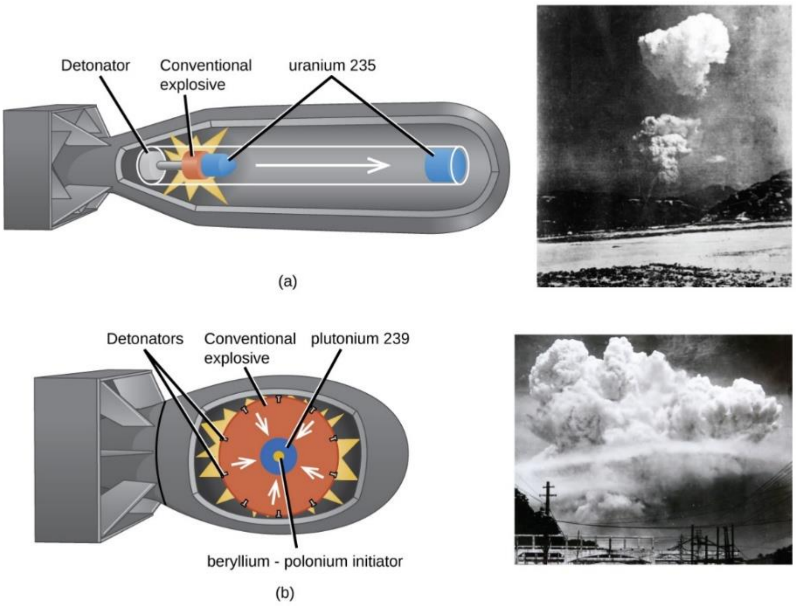

Figure 3.12: In (a) The nuclear fission bomb that destroyed Hiroshima on August 6, 1945, consisted of two subcritical masses of U-235, where conventional explosives were used to fire one of the subcritical masses into the other, creating the critical mass for the nuclear explosion. (b) The plutonium bomb that destroyed Nagasaki on August 12, 1945, consisted of a hollow sphere of plutonium that was rapidly compressed by conventional explosives. This led to a concentration of plutonium in the center that was greater than the critical mass necessary for the nuclear explosion.

An atomic bomb contains several pounds of fissionable material, ${}^{235}_{92}U$ or ${}^{239}_{94}Pu$, a source of neutrons, and an explosive device for compressing it quickly into a small volume. When fissionable material is in small pieces, the proportion of neutrons that escape through the relatively large surface area is high, and a chain reaction does not take place. When the small pieces of fissionable material are brought together quickly to form a body with a mass larger than the critical mass, the relative number of escaping neutrons decreases, and a chain reaction and explosion result.

III.3.5.4. Archeology by dating

In archeology and ethnology, the radioactive decay law helps to determine the date of any objet that exists in the earth. This is done by comparing the remaining level of radioactivity which still remains in the object to the level it has initially. This method has helped to better determine the chronological sequence of past events by enabling to date more accurately fossils and artifacts from 500 to 50,000 years old. As indicated above, the principle is simple. For each object, one knows its Carbon 14 content when it is active. This means its radioactive activity. After it ceases to be active (for instance, the bones of an animal or a part of tree that has been cut down), the radioactive carbon continues to decay. Measuring its present radioactive activity, one can date the object using the exponential decay law. Using that method, it has been possible to determine the ages of various rocks and rock formations (geochronology) or the ages of animal or human fossils to be able to determine the ages they were living in the earth (archeology).

III.3.5.5. In industries

- In agro-industries, the use of radioactivity to ionize fresh food (vegetables and cereals) has appeared to be a technique for the elimination of insects, parasites and bacteria. The gamma rays (coming from Cobalt 60 or Cesium 137), the X rays and high velocity electrons beams coming from radioelements are used. This also reduces the ripening process and inhibits the germination. This gives way for a good and long conservation of these vegetables and cereals. This technique is also used to pasteurize fish and beef for long conservation.
- The radioactivity is also used to protect arts by destroying insects, bacteria and micro-organisms as in the case the fresh food protection as described above.
- In the same way, sterilization of chirurgical instruments can be done using radiations from a radioelement.
- Thanks to the penetration of radiation, one also determines the defects in some materials using the radiography. For instance, to verify that the soldering has been well conducted.

III.4. Conclusion

This chapter has been devoted to the photoelectric effects and radioactivity and their applications. These are the two main topics of modern physics that are learned in secondary/high schools in Cameroon and several African countries. The applications in technology have been described so as to inform the students on this large field of physics which is the essence of modern technologies. The students who will continue their studies in the field of physics will find several other applications and see how they impact our daily lives.