Radioactivity

group 2

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Discovery of Radioactivity

In 1896, the French physicist Antoine Henri Becquerel (1852–1908) accidentally found that a uranium-rich mineral called pitchblende emits invisible, penetrating rays that can darken a photographic plate enclosed in an opaque envelope.
This ray carry energy but the energy is differ from another energy because the pitchblende emits them continuously without any energy input.
The Becquerel's rays originate in the nuclei of the atoms and have other unique characteristics.

- The emission of these rays is called nuclear radioactivity or simply radioactivity.
- The rays themselves are called nuclear radiation.
- A nucleus that spontaneously destroys part of its mass to emit radiation is said to decay .
- A substance or object that emits nuclear radiation is said to be radioactive.

there are two experimental evidence that shows Becquerel's rays is originated inside the nucleolus of an atom.

the first one is,the radiation was found with a certain element called uranium.the reason why uranium considered as a radioactive elements because radiation don't vary with chemical states.radiation does not vary with temperature, pressure, or ionization state of the uranium atom.

The huge energy emitted during each event is the second piece of evidence that the radiation cannot be atomic.
Becquerel did not vigorously pursue his discovery for very long.then In 1898, Marie Curie began her doctoral study of Becquerel's rays.She and her husband soon discovered two new radioactive elements, which she named polonium (after her native land) and radium (because it radiates).

Types of Nuclear Radiation and their Ionization and Penetration Powers

Research begun by people such as New Zealand-er Ernest Rutherford soon after the discovery of nuclear radiation indicated that different types of rays are emitted. Eventually, three types were distinguished and named alpha , beta , and gamma .
Rutherford made in his experiment the three radiation pass through in both electric and magnetic field .according to his experiment he found that The gammas are unaffected, while the alphas and betas are deflected in opposite directions, indicating the alphas are positive, the betas negative, and the gammas uncharged.he also found that alphas have a positive charge twice the magnitude of an electron,or+2qe and alphas charge to mass ratio to be several thousand times smaller than the electron's.

alpha,beta and Gama

there are three types of nuclear radiation which is alpha,beta and Gama.each of this comes through different decay process ,and composed of different particles and have unique property.

alpha particles radiation

alpha particles are a subatomic fragments that consist two neutrons and two protons.the alpha particles occur when the nucleus of an atom become unstable or when the ratio of neutron to proton is low.alpha particle radiation occur with in high atomic numbers such as uranium,radium and thorium.

when radioactive elements decayed by alpha emission the daughter nucleus of atomic number decreased by 2 and its atomic mass by 4 from its parental nucleus.

Beta particle radiation

beta radioactivity require weak nuclear force.there are two types of beta decays type.

1. **beta minus emission:-** they are energetic electron which emitted from the nucleus of an atom.it occur when the ratio of neutron to proton is high in the nucleus.as a result an excess number of neutron transform or converted in to proton and electron, then the proton remain in the nucleus while the electron ejected electrically.this process decrease the number of neutron by one and increase the number of proton by 1.
   example of beta minus atoms are tritium,cobalt-60,strontium-90,iodine-131,iodine129

2. **positron or beta plus emission :-**it occur when the nucleus contain few number of neutron.In this form, the nucleus emits a neutrino and a positron (the antimatter form of an electron). This process changes a proton in the nucleus into a neutron.

Gama particle radiation

Gama rays are high energetic,high frequency and high electromagnetic radiations.they have no charges and mass so the y almost not interact with in particles in there path.they are never absorbed.they have no charges and mass so the y almost not interact with in particles in there path. They hold the highest power of penetration. They are the most penetrating but least ionizing and very difficult to resist them from entering the body. The Gamma rays carry a large amount of energy and can also travel via thick concrete and thin lead

Ionization and penetration power

All three types of nuclear radiation produce ionization in materials, but they penetrate different distances in materials—that is, they have different ranges.
Like x rays, nuclear radiation in the form of alpha s, beta s, and gammas has enough energy per event to ionize atoms and molecules in any material. They produce ion and molecule fragments knocking electrons from them.the greater mass present the greater ionizing power.as a result gamma has the least ionizing power while the alphas have higher ionizing power. on the other side alpha has less penetration power while gammas have high penetration power.

Biological Effects of Ionizing Radiation and Dangers of Ionizing Radiation
Biological Effects of Ionizing Radiation

The difference between ionizing and non ionizing radiation

Ionizing radiation has sufficient energy to produce ions in matter at the molecular level. If that matter is a human significant damage can result including damage to DNA and denaturation of proteins.

Non ionizing radiationis longer wavelength/lower frequency lower energy. Unlike ionizing radiation, non-ionizing radiation does not remove electrons from atoms or molecules of materials that include air, water, and living tissue.

Biological Effects of Ionizing Radiation

Radiation damage occurs via one of two ways –
Direct Damage occurs when radiation damages the DNA directly, causing ionization of the atoms in the DNA molecule. Ionisation of molecule invariably leads to its disruption.

Indirect Damage occurs when radiation interacts with non-critical target atoms or molecules, usually water. This results in the production of free radicals, which then attack other parts of the cell.

When ionizing radiation interacts with cells, it can cause damage to the cells and genetic material (i.e., deoxyribonucleic acid, or DNA). If not properly repaired, this damage can result in the death of the cell or potentially harmful changes in the DNA (i.e., mutations).

Dangers of ionizing radiation

Ionizing radiation can affect the atoms in living things, so it poses a health risk by damaging tissue and DNA in genes. has sufficient energy to affect the atoms in living cells and thereby damage their genetic material (DNA). Fortunately, the cells in our bodies are extremely efficient at repairing this damage.

When radiation passes through cellular tissue, it tonizes water molecules which change into free radicals. These radicals are highly reactive and can interact with the important genetic material in the cell, the DNA. In addition addition, the DNA may also be ionized directly. Damage caused by these interactions may be fully repaired, in which case, the cell remains viable. However, if the damage is not successfully repaired and the DNA is not restored completely, the cell may either die or mutate,Because the radiations ionize to different extents, the hazard level is also different for cach sine. The extent of the potential damage depends on several factors, **including:**

- the type of radiat
- the sensitivity of the affected tissues and organs
- the mannes and length of time exposed
- the radioactive isotopes involved
- Characteristics of the exposed perison (sach as age, gender and underlying condition).

Effective Dose

The risk of developing adverse health effects depends on the radiation dose. The higher the dose the higher is the risk of adverse effects. Absorbed dose describes the amount of energy deposited per unit mass in an object or person. The units for absorbed dose are gray (Gy, sievert (Sv) and rad; where 1Gy1J/kg and 1rad 0.01 Gy 0.01 J/kg.

1 Gy=1 is the deposit of a joule of radiation energy per kilogram of matter or tissue. 1 Sv=1 joule/kilogram a biological effect. The sievert represents the

equiv- alent biological effect of the deposit of a joule of radia- tion energy in a kilogram of human tissue

Radiation doses above 3 Gy (300 rad) can be fatal and doses above 6 Gy (600 rad) are almost certain to be fatal, with death occurring within several months (in shorter times at higher doses). For gamma rays and electrons, above 1 Gy, radiation causes a complex of symptoms, including nausea and blood changes, known as radiation sickness. For doses below 1 Sv (100 rem), there is little likelihood of radiation sickness, and the main danger is an increased cancer risk.

Nuclear Decay and Conservation Laws

Nuclear decay occurs when the nucleus of an atom is unstable and spontaneously emits energy in the form of radiation.Some nuclides are stable, apparently living forever. Unstable nuclides decay (that is, they are radioactive), eventually producing a stable nuclide after many decays. We call the original nuclide the parent and its decay products the daughters. Some radioactive nuclides decay in a single step to a stable nucleus.For example, 60Cois unstable and decays directly to 60Ni, which is stable.

Alpha decay

Alpha decay is a nuclear decay process where an unstable nucleus changes to another element by shooting out a particle composed of two protons and two neutrons.
In alpha decay, a 4He nucleus simply breaks away from the parent nucleus, leaving a daughter with two fewer protons and two fewer neutrons than the parent examples of alpha decays are 238U and 239Pu.

$$^{238}_{92}U \rightarrow ^{234}_{90}Th + ^{4}_{2}\alpha$$

$$Pu^{239}_{94} \xrightarrow[\text{24,000 years}]{} U^{235}_{92} + He^{4}_{2}$$

(alpha particle)

If you examine the periodic table of the elements, you will find that Th has Z=90 , two fewer than U, which has Z=92 . Similarly, in the second decay equation, we see that U has two fewer protons than Pu, which has Z=94. The general rule for alpha decay is best written in the format

$$^{A}_{Z}XN$$

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If a certain nuclide is known to alpha decay its alpha decay equation is

$$^{A}_{Z}XN. = ^{A-2}_{Z-2}YN - 2. + ^{4}_{2}He2.$$

where Y is the nuclide that has two fewer protons than X,
It is instructive to examine conservation laws related to alpha decay. for instance when we see in the above equation the charges are conserved the linear momentum also conserved.If the nucleus is at rest when it decays, its momentum is zero. In that case, the fragments must fly in opposite directions with equal-magnitude momenta so that total momentum remains zero. This results in the alpha particle carrying away most of the energy.the energy produced in the decay comes from conversion of a fraction of the original mass.

Beta decay
There are actually two types of beta decay. the first one is an ordinary beta decay which is called β^-.the nagative indicate that represents an electron emitted in nuclear beta decay. Cobalt-60 is a nuclide that β^-decays in the following manner:

$$^{60}Co = ^{60}Ni + \beta\bar{+}neutrino$$

The **neutrino** is a particle emitted in beta decay that was unanticipated and is of fundamental importance.the neutrino was discovered after beta decay was known to involve electron emissions.Neutrinos are nearly mass less, have no charge, and do not interact with nucleons via the strong nuclear force.they travel at the speed of light.since they have no charges they are not electronmagnetic wave which means the couldn't interact by EM wave they interact through weak nuclear force.However, neutrinos do carry energy, angular momentum and linear momentum away from a beta decay.
It was discovered, When accurate measurements of beta decay were made, then it became apparent that energy, angular momentum, and linear momentum were not accounted for by the daughter nucleus and electron alone. Either a previously unsuspected particle was carrying them away, or three conservation laws were being violated.
The neutrino also reveals a new conservation law.We propose that the number of members of the electron family is constant in any process or any closed system. In our example of beta decay, there are no members of the electron family present before the decay, but after, there is an electron and a neutrino. So electrons are given an electron family number of +1 . The neutrino in β^- decay is an electron's antineutrino, given the symbol ν $^-$e
where $\nu$is a neutrino and the e indicate it related to electron and the bar indicate that it is antimatter. The electron's antineutrino ν^-e, being antimatter, has an electron family number of –1.then The total is zero, before and after the decay. The new conservation law, obeyed in all circumstances, states that the total

electron family number is constant.
the negative beta decay equation became

$$ {}_{Z}^{A}XN. = {}_{Z+1}^{A}YN - 1. + \beta\bar{+}\bar{\nu} $$

where Y is the nuclide having one more proton than X

The second type of beta decay is β+decays.decay. Certain nuclides decay by the emission of a positive electron. This is anti electron or positron decay.

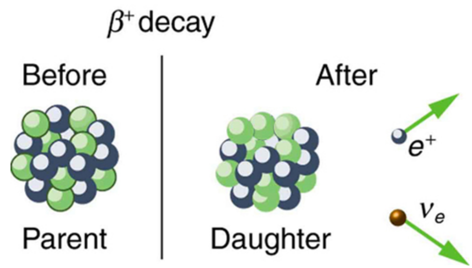

Figure 1:

The antielectron is often represented by the symbol e+, but in beta decay it is written as β+ to indicate the antielectron was emitted in a nuclear decay.Antielectrons are the antimatter counterpart to electrons,
its β+decay equation is

$$ {}_{Z}^{A}XN. = {}_{Z-1}^{A}YN + 1. + \beta\bar{+}\nu $$

where Y is the nuclide having one less proton than X (to conserve charge) and ν is the symbol for the electron's neutrino, which has an electron family number of +1.
generally in beta decay one of the proton of the atom decayed in to one neutron ,positron and neutrino.

Gamma decay

Gamma decay is the simplest form of nuclear decay it is the emission of energetic photons by nuclei left in an excited state by some earlier process.Protons and neutrons in an excited nucleus are in higher orbitals, and they fall to lower levels by photon emission.Nuclear excited states have lifetimes typically of only about 1014 s, an indication of the great strength of the forces pulling the nucleons to lower states. The γ decay equation is simply

$$ {}_{Z}^{A}XN. ={}_{Z}^{A} YN. + \gamma 1 \ + \gamma 2 \ .... $$

where the asterisk indicates the nucleus is in an excited state. There may be one or more γ s emitted, depending on how the nuclide de-excites.

Radiation Detectors

A radiation detector is a device that measures the ionization of radiations (i.e., creating electrons and positively charged ions), such as beta radiation, gamma radiation, and alpha radiation with the matter. There are different types of radiation detectors,
The first direct detection of radiation was Becquerel's fogged photographic plate. Photographic film is still the most common detector of ionizing radiation, being used routinely in medical and dental x rays.

1. **Scintillators:**A scintillator is a general term for substances that emit fluorescence when exposed to radiations of high energy it is a type of phosphor. When a radiation collides with this substance, it absorbs its energy and internal electrons move from the ground state (stable state) to the excited state. When this electron returns to the original stable state, it releases its energy in the form of light emission (visible light or ultraviolet light), and this phenomenon called scintillation.
   The incident radiation can be measured quantitatively by photo-electrically converting/amplifying the emitted fluorescence with a photo multiplier tube (PMT). Scintillation detectors represent the best means for detecting gamma or x-radiation and are the second- most common detector type after G-M tubes. They have the ability to distinguish between alpha, beta, and gamma radiation, and can be configured to produce correspondingly different sounds through a meter.

2. **Geiger counter:**A Geiger counter, also known as the Geiger-Muller tube, is used to quickly detect and measure radiation. It exploits the natural process of ionization to detect and measure radiation. When exposed to radioactive radiations, the stable gas within the chamber ionizes. This generates an electrical current that the counter records over a period of 60 seconds. When ionization occurs and the current is produced, a speaker clicks and a reading is given often in millisieverts (mSv). The central wire in between a gas-filled tube at high voltage is used to collect the ionization produced by incident radiation. Geiger counters can detect alpha, beta, and gamma radiation. However, they cannot differentiate which one is beta, or gamma or alpha radiation.

The Half-Life

Half-life (symbol $t\frac{1}{2}$) is the time required for a quantity (of substance) to reduce to half of its initial value. The term is commonly used in nuclear physics to describe how quickly unstable atoms undergo radioactive decay or how long stable atoms survive. A half-life is the time taken for something to halve its quantity. The term is most often used in the context of radioactive decay, which occurs when unstable atomic particles lose energy. Twenty-nine elements are known to be capable of undergoing this process.

The number of any radiouctive parent nuclei decreases with time since it emits radiation in the form of $\alpha$and β emissions. The decay of a particular nucleus cannot be predicted and is not affected by physical influences like temperature. The rate of isotope decay depends on two factors.

1. The total number of undecayed nuclei present in the system. That is, on doubling the average number of undecayed nuclei must double the rate of decay

2. The stability of the isotope. Some isotopes decay more rapidly than others. The rate of decay gives the number of nuclei that decay per second

In general, the decay rate, called the activity, A, is given by

$$A=\Delta N/\Delta t=-\lambda N$$

- The negative sign shows the decrease in the number of the radioactive nuclei with time.
- N is the number of undecayed nuclei at the subsequent time t.
- The decay constant λ of a radioactive nuclide is defined as its probability of decay per unit time; having SI unit s1. It is a positive rate also called the exponential decay constant, disintegration constant, rate constant, or transformation constant.

its SI unit is becquerel(Bq) when 1Bq = 1 decay per second .it also have other unit which is curie(Ci)
the quantity of the parent radioactive nuclei is subjected to its exponential decay since it decrease in proportional to its current value.the exponetial decay value is given by

$$N=Noe^{-}\lambda^{t}$$

. **Quantum Tunneling**

Quantum tunneling is a phenomenon in which particles penetrate a potential energy barrier with a height greater than the total energy of the particles. The phenomenon is interesting and important because it violates the principles of classical mechanics. Quantum tunneling is important in models of the Sun and has a wide range of applications, such as the scanning tunneling microscope and the tunnel diode. Also Quantum tunnelling is defined as a quantum mechanical process where wavefunctions can penetrate through a potential barrier. The transmission through the potential barrier can be finite and relies exponentially on the barrier width and barrier height. The wave functions have the genuine probability of disappearing on one side and reappearing on the remaining side. The first derivative of the wave functions is continuous. In the steady-state case, the probability flux in the forward trajectory is spatially uniform. No wave or particle is eliminated. Tunnelling happens with barriers of thickness about 1–3 nm and smaller. Quantum tunnelling cannot be explained through the laws of classical mechanics, where a dense potential barrier needs potential energy. It has a crucial role in physical processes such as nuclear fusion. It's been used in quantum computing, tunnel diodes and scanning tunnelling microscopes. The quantum phenomenon was theorised in the early 20th century, and it was accepted as a practical physical phenomenon in the mid-century.

Quantum tunnelling is forecasted to create physical limits to the dimensions of the transistors employed in microelectronics. This is due to electrons' ability to tunnel transistors that are too small. Tunnelling can be understood through the concepts of Heisenberg's uncertainty principle. In other words, the uncertainty in the precise location of electromagnetic particles permits these particles to break the laws of classical physics and propagate in space without going over the potential energy boundary. Both tunnelling and uncertainty principle are mutually compatible as they consider a quantum body as both wave and particle simultaneously.
Quantum tunnelling falls under the domain of quantum mechanics. To understand the phenomenon, particles attempting to travel across a potential barrier can be compared to a ball trying to roll over a hill. Quantum mechanics and classical mechanics differ in their treatment of this scenario.
Classical mechanics predicts that particles that do not have enough energy to classically surmount a barrier cannot reach the other side. Thus, a ball without sufficient energy to surmount the hill would roll back down. In quantum mechanics, a particle can, with a small probability, tunnel to the other side, thus crossing the barrier. The reason for this difference comes from treating matter as having properties of waves and particles.

Applications of Quantum Tunnelling

1. **Scanning Tunnelling Microscope**
   Heinrich Rohrer and Gerd Binning developed scanning tunnelling microscopes (STM). It is a type of microscope that helps to observe objects at atomic levels. It functions by utilising the connection between quantum tunnelling with distance. STM analyses the surface by using a sharp conducting tip that can differentiate characteristics smaller than 0.1 nm with a 0.01 nm depth resolution. So, individual atoms can be consistently imaged and manipulated.

2. **Nuclear Fusion**
   Quantum tunnelling is a crucial part of nuclear fusion. The average temperature of a star's core is usually not sufficient for atomic nuclei to over-

come the Coulomb barrier and kick start thermonuclear fusion. The tunnelling increases the chances of infiltrating this barrier. Though the probability is still low, the huge number of nuclei in the stellar core is enough to drive a steady fusion reaction.

3. **Electronics**
   Tunnelling is a frequent source of current leakage in very-large-scale integration (VLSI) electronics. The VLSI electronics experience substantial power loss and heating effects that cripple such devices. It is usually considered the lower threshold on how microelectronic device elements can be created. Tunnelling is also a basic technique employed to set the floating gates in flash memory. Cold emission, tunnel junction, quantum-dot cellular automata, tunnel diode, and tunnel field-effect transistors are some of the main electronic processes or devices that use quantum tunnelling.