Radioactivity

Group 3

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1 Radioactivity

2 Introduction

Radioactivity is a phenomenon that occurs naturally in a number of substances. Atoms of the substance spontaneously emit invisible but energetic radiations, which can penetrate materials that are opaque to visible light. The effects of these radiations can be harmful to living cells but, when used in the right way, they have a wide range of beneficial applications, particularly in medicine. Radioactivity has been present in natural materials on the earth since its formation (for example in potassium-40 which forms part of all our bodies). However, because its radiations cannot be detected by any of the body's five senses, the phenomenon was only discovered 100 years ago when radiation detectors were developed. Nowadays we have also found ways of creating new man-made sources of radioactivity; some (like iodine-131 and molybdenum-99) are incidental waste products of the nuclear power industry which nevertheless have important medical applications, whilst others (for example fluorine-18) are specifically produced for the benefits of their medical use.

3 The Discovery of Radioactivity

Radioactivity was discovered in 1896 by the French physicist, Henri Becquerel working in Paris. The story of the discovery is a fascinating one which is worth telling in some detail. It gives interesting insights into how quickly and easily fundamental experiments could be done 100 years ago, compared with the lengthy processes of modern scientific research. Becquerel had succeeded his father as Professor of Physics at the Museum of Natural History in Paris. There he continued his father's investigations into the phenomenon of phosphorescence; the emission of visible light by certain substances when they are activated by exposure to a bright light source. He had assisted his father with many experiments on phosphorescence and knew that a preparation containing crystals of uranium and potassium would glow when exposed to sunlight and that this stopped quickly when it was taken into the dark.

On 20 January 1896 Becquerel attended a lecture at the French Academy of Science in Paris at which he heard Henri Poincaré describe the recent discovery of X-rays by Wilhelm Röntgen. Poincaré demonstrated how, when a beam of electrons was accelerated across a vacuum tube, visible light was emitted from the spot where the electron beam hit the glass wall (just like in a modern TV tube). This was another example of phosphorescence (although nowadays we would call it fluorescence) which others had observed before. The new discovery which Röntgen had made in 1895 was that some hitherto unknown invisible radiation was also emitted from the same spot. These became known as X-rays (X standing for the unknown). Röntgen had found that they were able to penetrate solid material and cast shadows of metal objects on photographic paper. Hearing this description, Becquerel presumed that the X-rays were associated with the phosphorescence and he wondered whether his phosphorescent crystals might also emit X-rays. He therefore conducted several experiments to check this. In each experiment he wrapped a photographic plate in light-tight paper and placed some of his crystals on the outside of the paper. This was then exposed to sunlight for several hours. Sure enough, when the plate was developed it had become blackened where the crystals had been. He found that if a thin piece of metal was placed between the crystals and the plate then this cast a shadow. These results seemed to confirm his assumption that X-rays were part of phosphorescence and he reported these results to the French Academy of Science on 24 February 1896.

Continuing his experiments, Becquerel prepared some more samples on 26 and 27 February but the weather was poor and there was insufficient sunlight to activate his crystals, so he did not use them. Instead, he left the crystals lying on the wrapped photographic plate but in a dark drawer. By Sunday 1 March the sun still had not shone in Paris, but Becquerel decided to develop his plates anyway, expecting to find only very weak images. Instead, he was amazed to find an image just as intense as when the crystals had been exposed to bright sunlight. He immediately did further experiments which confirmed that the crystals could blacken a photographic plate whether or not they were made to phosphoresce. He realized that he had accidentally discovered an entirely new phenomenon which he attributed to some form of long-lasting phosphorescence emitting invisible radiation. It is interesting to speculate what might have happened if Becquerel had chosen a different phosphorescent crystal for his experiments. He could just as easily have chosen zinc sulfate from his father's large collection of phosphorescent materials, and then he would not have found any effect on the photographic plate because zinc is not radioactive like uranium. In that case the discovery of radioactivity might well have been left to an Englishman. On 23 February 1896 Silvanus Thompson, in London, had independently performed the same experiment as Becquerel, exposing uranium crystals to sunlight whilst placed on a wrapped photographic plate. By the time that Thompson wrote to the president of the Royal Society in London to describe his results, Becquerel's initial findings had already been reported to the French Academy of Sciences. Hearing this, Thompson did no further work on the subject and thus missed the opportunity to beat Becquerel to his fortuitous discovery of 1 March. That is why we now measure radioactivity in units of megabecquerels rather than megathompsons.

By the end of 1896 Becquerel's interest in his new discovery seems to have waned as he could see little more of interest to do and Röntgen's X-rays seemed to have many more applications. However in 1897 he was joined by a young research student, Marie Curie, who wished to study for her doctorate. Marie soon discovered that another element, thorium, also exhibited the same emission of Becquerel rays as uranium and she suggested the term 'radioactivity' for the phenomenon. She also discovered the important fact that the radioactivity was a property of the atoms themselves and it was not changed by any physical or chemical processes through which the material went. She was later joined by her husband, Pierre, and together they discovered that the mineral pitchblende contained two even stronger radioactive substances, which they called polonium and radium. After years of painstaking purification, they were able to separate sufficient polonium and radium to demonstrate that these were both previously unknown elements. In 1903 Henri Becquerel, Marie Curie, and Pierre Curie were jointly awarded the Nobel prize in physics for their work on radioactivity. Later Marie Curie was also awarded the 1911 Nobel prize in Chemistry for her discovery of radium.

4 Medical Applications of Radioactivity

4.1 Learning Objectives

By the end of this section, you will be able to:

- Describe how nuclear imaging works (e.g., radioisotope imaging, PET)
- Describe the ionizing effects of radiation and how they can be used for medical treatment

4.2 Section Key Terms

- Anger camera
- Rad
- Radiopharmaceutical
- Therapeutic ratio
- Relative biological effectiveness (RBE)
- Roentgen equivalent man (rem)
- Tagged

4.3 Medical Applications of Nuclear Physics

Applications of nuclear physics have become an integral part of modern life. From the bone scan that detects one cancer to the radioiodine treatment that cures another, nuclear radiation has diagnostic and therapeutic effects on medicine.

4.3.1 Medical Imaging

A host of medical imaging techniques employ nuclear radiation. What makes nuclear radiation so useful? First, γ radiation can easily penetrate tissue; hence, it is a useful probe to monitor conditions inside the body. Second, nuclear radiation depends on the nuclide and not on the chemical compound it is in, so that a radioactive nuclide can be put into a compound designed for specific purposes. When that is done, the compound is said to be tagged. A tagged compound used for medical purposes is called a radiopharmaceutical. Radiation detectors external to the body can determine the location and concentration of a radiopharmaceutical to yield medically useful information. For example, certain drugs are concentrated in inflamed regions of the body, and their locations can aid diagnosis and treatment. Another application utilizes a radiopharmaceutical that the body sends to bone cells, particularly those that are most active, to detect cancerous tumors or healing points. Images can then be produced of such bone scans. Clever use of radioisotopes determines the functioning of body organs, such as blood flow, heart muscle activity, and iodine uptake in the thyroid gland. For instance, a radioactive form of iodine can be used to monitor the thyroid, a radioactive thallium salt can be used to follow the bloodstream, and radioactive gallium can be used for cancer imaging.

Once a radioactive compound has been ingested, a device like that is used to monitor nuclear activity. The device, called an Anger camera or gamma camera, uses a piece of lead with holes bored through it. The gamma rays are redirected through the collimator to narrow their beam and are then interpreted using a device called a scintillator. The computer analysis of detector signals produces an image. One of the disadvantages of this detection method is that there is no depth information (i.e., it provides a two-dimensional view of the tumor as opposed to a three-dimensional view), because radiation from any location under that detector produces a signal. An Anger or gamma camera consists ofEYU:

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\section{B. What is Radioactive Dating?}

Radioactive dating is a method of dating rocks and minerals using radioactive isotopes. This method is useful for igneous and metamorphic rocks, which cannot be dated by the stratigraphic correlation method used for sedimentary rocks. Over 300 naturally-occurring isotopes are known. Some do not change with time and form stable isotopes (i.e., those that form during chemical reactions without breaking down). The unstable or more commonly known radioactive isotopes break down by radioactive decay into other isotopes. Radioactive decay is a natural process and comes from the atomic nucleus becoming unstable and releasing bits and pieces. These are released as radioactive particles (there are many types). This decay process leads to a more balanced nucleus and when the number of protons and neutrons balance, the atom becomes stable.

This radioactivity can be used for dating, since a radioactive 'parent' element decays into a stable 'daughter' element at a constant rate. The rate of decay (given the symbol lambda)is the fraction of the 'parent' atoms that decay in unit time. For geological purposes, this is taken as one year. Another way of expressing this is the half-life period (given the symbol T). The half-life is the time it takes for half of the parent atoms to decay. The relationship between the two is:

\[T = \frac{0.693}\lambda} \]

How is this radioactivity measured? Many different radioactive isotopes and techniques are used for dating. All rely on the fact that certain elements (particularly uranium and potassium) contain a number of different isotopes whose half-life is exactly known and therefore the relative concentrations of these isotopes within a rock or mineral can measure the age. For an element to be useful for geochronology (measuring geological time), the isotope must be reasonably abundant and produce daughter isotopes at a good rate. Either a whole rock or a single mineral grain can be dated. Some techniques place the sample in a nuclear reactor first to excite the isotopes present, then measure these isotopes using a mass spectrometer (such as in the argon-argon scheme). Others place mineral grains under a special microscope, firing a laser beam at the grains which ionizes the mineral and releases the isotopes. The isotopes are then measured within the same machine by an attached mass spectrometer.

\section{C.localized application of radioactive dating}

Radioactive dating, also known as radiometric dating, is a technique used to determine the age of materials such as rocks, minerals, fossils, and archaeological artifacts based on the decay of radioactive isotopes. Some of the key uses of radioactive dating include: Determining the age of rocks and minerals: Radioactive dating is commonly used in geology to determine the age of rocks and minerals. By measuring the ratio of parent isotopes to daughter isotopes in a sample, scientists can calculate how long it has been since the material formed.Dating archaeological artifacts: Radioactive dating is used by archaeologists to determine the age of artifacts and archaeological sites. By dating materials such as bones, pottery, and charcoal found at a site, researchers can establish a chronology for the site and the artifacts it contains.Dating fossils: Radioactive dating is used to determine the age of fossils, helping scientists understand the evolutionary history of life on Earth. By dating the rocks and minerals surrounding a fossil, researchers can estimate its age and place it in the context of the geological timescale.Studying the Earth's history: Radioactive dating is essential for studying the history of the Earth, including the timing of major geological events such as volcanic eruptions, mountain-building processes, and changes in climate.Tracing the movement of fluids: Radioactive dating can be used to trace the movement of fluids through rocks and minerals. By analyzing the distribution of parent and daughter isotopes in a sample, scientists can infer the pathways and rates of fluid flow in the Earth's crust.Dating meteorites: Radioactive dating is used to determine the ages of meteorites, providing insights into the formation and early history of the solar system.Assessing environmental contamination: Radioactive dating can be used to assess the impact of human activities on the environment, such as radioactive contamination from nuclear accidents or the disposal of radioactive waste.

\section{D.academic application }

Academic applications of radio activity Radioactivity has numerous academic applications across various fields: \section{Nuclear Physics}: It's fundamental in understanding nuclear structure, decay processes, and interactions, crucial for advancements in nuclear physics research.

\section{Medicine:} Radioactive isotopes are used in medical imaging techniques like PET scans, SPECT scans, and gamma cameras for diagnosing diseases and studying physiological processes.

\section{Radiation Therapy: }Radioactive sources are used in radiation therapy to treat cancer by targeting and destroying cancerous cells while minimizing damage to healthy tissue.

\section{Archaeology and Geology:} Radioactive dating methods like carbon dating (for organic materials) and uranium-lead dating (for rocks) help determine the age of artifacts and geological formations.

\section{Environmental Science:} Radioactive tracers are employed to study environmental processes such as ocean currents, atmospheric circulation, and groundwater flow. \section{Materials Science: }Radioactive isotopes are used as tracers to analyze material properties, study corrosion processes, and investigate the behavior of materials under extreme conditions.

\section{Agriculture}: Radioactive isotopes are utilized to study plant uptake of nutrients, optimize fertilizer use, and track the movement of pollutants in soil and water. \section{Forensics: }Radioactive isotopes can be used as markers to trace the source of substances in forensic investigations, such as tracking illegal drug trafficking routes. These are just a few examples of how radioactivity contributes to academic research and applications in various disciplines. Radioactivity has numerous academic applications across various fields.

Here are the keys Physics and Chemistry Nuclear Physics \section{research }Investigates the properties and behaviors of atomic nuclei using radioactive isotopes.

\section{Radio chemistry: }Studies the chemistry of radioactive materials, including the chemical effects of radiation on matter. Medicine Nuclear Medicine: Utilizes radioactive tracers for diagnostic imaging (e.g., PET and SPECT scans) and treatment (e.g., radiotherapy for cancer).Radiopharmaceuticals: Develops and uses radioactive compounds in medical diagnostics and treatments.

\section{Biology Radiobiology:} Examines the effects of ionizing radiation on living organisms, including DNA damage and repair mechanisms.Tracer Studies: Uses radioactive isotopes to trace biochemical pathways and understand metabolic processes.

\section{Environmental Science Radiometric Dating:} Employs isotopes such as carbon-14 for dating archaeological, geological, and hydrogeological samples.Environmental Monitoring: Tracks the distribution and impact of radioactive contaminants in the environment. Geology and Archaeology Geochronology: Uses radioactive decay to date rocks and minerals, providing insights into Earth's history.Archaeometry: Applies radiocarbon dating to determine the age of archaeological artifacts. Engineering Non-Destructive Testing: Uses gamma radiography to inspect materials and structures for internal defects without damaging them.

\section{Radiation Shielding Design}: Studies and designs materials and structures to protect against harmful radiation.

\section{Agriculture Food Irradiation: }Uses radiation to preserve food by killing bacteria and pests, extending shelf life.

\section{Mutation Breeding: }Induces mutations in plants to develop new and improved crop varieties. Education Teaching and Demonstration: Uses radioactive sources in laboratory experiments to teach principles of nuclear physics and chemistry.

\section{Research Projects: }Provides students with opportunities to conduct research involving radioisotopes and radiation detection techniques. Space Exploration Radioisotope Thermoelectric Generators (RTGs): Uses radioactive decay to provide long-lasting power for spacecraft and planetary probes.

\section{Radiation Studies: }Investigates the effects of cosmic radiation on astronauts and spacecraft materials. These applications the diverse and critical roles that radioactivity plays in advancing scientific knowledge and technology across disciplines.

\section{E.industrial application }Industrial Uses There are many industrial uses of radioactive materials, including material density evaluation, product sterilization, quality control, static elimination, and electricity generation. The radiation sources used for these processes include radiation-producing machines and sealed-source radioactive materials, to name two

Industrial radiography Industrial radiography is a method of inspecting materials for seeing hidden flaws by using the ability of short X-rays, gamma rays and neutrons to penetrate various materials. It is a major element of non-destructive testing. Industrial radiography for non-destructive testing is used to inspect, among others, concrete and a wide variety of welds, such as those in gas and water pipelines, storage tanks and structural elements. It can identify cracks or flaws that may not be otherwise visible. These characteristics have made non-destructive testing a key tool for quality control, safety and reliability.

Other non-destructive testing Non-destructive testing methods are used in industry to evaluate the integrity and properties of material or components without causing damage to the tested object. Aside from industrial radiography, four of the most common methods are: ultrasonic radiography; and liquid penetrant, magnetic particle and eddy current inspections. Non-destructive testing is a key tool for quality control, safety and reliability. the use of non-destructive testing technology to maintain the stringent quality control standards for the safe operation of nuclear and other industrial installations. It helps its Member States train staff in applying the technology and provides necessary equipment. While there are hundreds of methods available, the most common are: Industrial radiography, which uses short X-rays, gamma rays and neutrons to penetrate materials; Ultrasonic radiography, which uses mechanical vibrations similar to sound waves; Liquid penetrant inspection, which can locate surface-breaking defects in non-porous materials; Magnetic particle inspection, which can detect surface and slightly subsurface discontinuities in ferromagnetic materials; and Eddy current testing, which uses electromagnetic induction to detect flaws in conductive materials. In addition, non-destructive testing programme has led to the establishment of national teams that provide services to industries, training centres and certifying bodies that are responsible for the training and certification of personnel involved in non-destructive testing. In many institutions, these efforts have led to a state of self-sufficiency in this area of technology.

Nucleoni gauging Nucleonic gauges are measuring and analysis instruments exploiting the interaction between ionising radiation and matter. Industry around the world uses this technology to control and improve product quality by optimising processes and saving energy and materials. Several hundred thousand nucleonic control systems are operating in industry worldwide. Since the technology has the key advantage that direct contact with the material is not needed, the instruments are particularly suited for use at high-speed production lines or systems operating at extreme temperatures. Nucleonic control systems can be used for either static or continuous measuring applications. Some nucleonic gauges do not use radiation sources but are based on measuring the natural radiation of an examined material. Nucleonic measurement systems also allow for the visualization of internal structures of objects and flows through different technologies such as Computed Tomography (CT). The two most commonly used gauge systems are transmission and backscatter. These systems measure the material without destroying it or changing its properties.

The high-energy gamma radiation can penetrate the walls of sealed containers, which allows for material inside to be measured without opening the containers. Most nucleonic control systems have a larger sampling volume than that of other physical techniques, which is usually also much larger than assays (analytical sampling techniques) normally collected for laboratory analysis. The systems are robust and usually versatile in their application to different materials and processes. The nucleonic control systems technology competes well with conventional techniques in many areas. This includes such international priority sectors of industry as mining and mineral ore processing; environmental monitoring; paper and plastics industries; cement and civil engineering industries; and oil and gas industries. As the benefits in these sectors are sizable, new applications and techniques used in the design, calibration, quality control and operation of the technology is on-going.

Medical sterilization Radiation kills germs that can cause disease and neutralizes other harmful organisms. Sterilization with ionizing radiation inactivates microorganisms very efficiently and, when used for product wrapping, ensures that healthcare products are safe and can be relied upon.

Sterilizing medical products Radiation is a safe and cost-effective method for sterilizing single-use medical devices such as syringes and surgical gloves. One of its key advantages is that it allows already-packaged products to be sterilized. A variety of life-saving equipment is sterilized with radiation. More than 160 gamma irradiation plants around the world are operating to sterilize medical devices. Around 12 million m3 of medical devices are sterilized by radiation annually. More than 40 per cent of all single-use medical devices produced worldwide are sterilized with gamma irradiation.

5 conclusion

Radioactivity is a natural phenomenon that has a wide range of applications in science, medicine, and industry. It is used to generate electricity, detect and treat cancer, date archaeological artifacts, and sterilize food and medical supplies. Radioactivity is also essential for the functioning of many natural processes, such as the carbon cycle and the formation of new elements in stars. However, radioactivity can also be harmful to humans if it is not properly controlled. Radiation exposure can cause a variety of health problems, including cancer, birth defects, and radiation sickness. Therefore, it is important to weigh the benefits and risks of radioactivity carefully before using it in any applications.