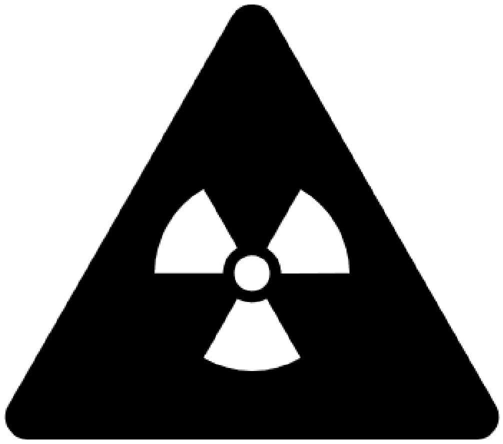
Nuclear Physics



Name ________________________________

Class ________________________________

Teacher ________________________________

L1 Development of the atomic model

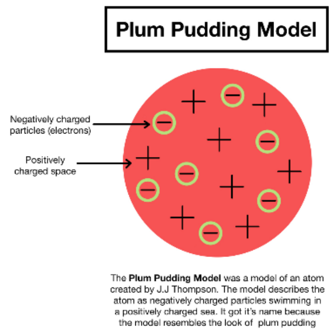
The development of the model of the atom is a fascinating journey that shows how scientific knowledge evolves with new evidence. Let's explore how our understanding of the atom has changed over time through various scientific discoveries and experiments.

Early Ideas About Atoms

Before the discovery of the electron, scientists believed that atoms were tiny, indivisible spheres. This idea was based on the work of ancient Greek philosophers like Democritus, who coined the term "atomos," meaning "indivisible." For a long time, this model went unchallenged because there was no experimental evidence to suggest otherwise.

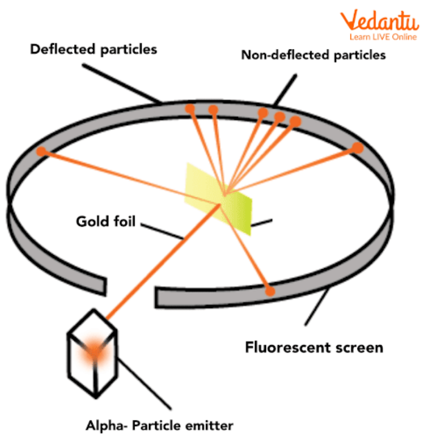
The Discovery of the Electron and the Plum Pudding Model

In the late 19th century, a scientist named J.J. Thomson discovered the electron through experiments with cathode rays. This was groundbreaking because it showed that atoms were not indivisible; they contained smaller, negatively charged particles called electrons.



To explain this new evidence, Thomson proposed the "plum pudding model" of the atom. Imagine a pudding (or a ball) of positive charge with electrons scattered throughout it, like raisins in a plum pudding. This model suggested that the positive charge was spread out over the entire atom, with electrons embedded within it.

The Alpha Particle Scattering Experiment and the Nuclear Model



However, this model was soon challenged by new experimental evidence. In 1909, Ernest Rutherford and his colleagues conducted the famous alpha particle scattering experiment. They fired alpha particles (which are positively charged) at a thin sheet of gold foil. They expected the alpha particles to pass through with only slight deflections, as predicted by the plum pudding model.

To their surprise, most alpha particles passed straight through, but some were deflected at large angles, and a few even bounced back. This unexpected result led Rutherford to conclude that the mass and positive charge of an atom are concentrated in a small, central region called the nucleus. This finding gave birth to the "nuclear model" of the atom, where electrons orbit a dense, positively charged nucleus.

Bohr's Model of the Atom

Niels Bohr, a Danish physicist, further refined the nuclear model in 1913. Bohr suggested that electrons orbit the nucleus at specific distances, or energy levels, rather than randomly. His theoretical calculations matched experimental observations, providing strong support for his model. This idea of electrons occupying fixed orbits or energy levels was a significant advancement in atomic theory.

Discovery of the Proton

Further experiments revealed more details about the nucleus. Scientists discovered that the positive charge of the nucleus is not a single entity but is made up of smaller particles called protons. Each proton carries the same amount of positive charge. This discovery helped explain why the nucleus is positively charged and how it contributes to the overall structure of the atom.

Discovery of the Neutron

About 20 years after the nuclear model was widely accepted, another crucial discovery was made by James Chadwick in 1932. Chadwick's experiments provided evidence for the existence of neutrons, particles with no charge that also reside in the nucleus. Neutrons are important because they add mass to the nucleus and help hold it together, preventing the positively charged protons from repelling each other due to their like charges.

How Scientific Models Evolve

This history of the atomic model demonstrates an important aspect of science: scientific models change and improve with new evidence. When Thomson discovered the electron, the indivisible sphere model was replaced by the plum pudding model. When Rutherford's experiment showed that the positive charge is concentrated in the nucleus, the plum pudding model was replaced by the nuclear model. Bohr’s work then refined this model by introducing specific orbits for electrons. Each of these changes was driven by new experimental evidence that required scientists to rethink their ideas about the atom.

Conclusion

The development of the atomic model shows how scientific knowledge grows and evolves. It highlights the importance of experiments and evidence in shaping our understanding of the natural world. As scientists continue to explore and experiment, our models and theories will keep improving, bringing us closer to understanding the true nature of the universe.

Independent practice

1. What was the initial belief about the structure of atoms before the discovery of the electron?
2. Describe the plum pudding model proposed by J.J. Thomson.
3. What did Rutherford's alpha particle scattering experiment reveal about the atom's structure?
4. How did Niels Bohr improve upon the nuclear model of the atom?
5. What was James Chadwick's significant contribution to the atomic model?

Sentence Completion Questions

1. The plum pudding model was replaced by the nuclear model because ___________
2. The nuclear model suggested that most of the mass of an atom is concentrated in the nucleus, but ______
3. Bohr's model proposed that electrons orbit the nucleus at specific distances, and ___________

Understanding Questions

1. Explain why the discovery of the electron was significant for atomic theory.
2. How did the alpha particle scattering experiment challenge the plum pudding model?
3. Why was the discovery of neutrons important for the understanding of the atomic nucleus?

L2 Radioactive decay

Atoms are the building blocks of everything, made up of a nucleus surrounded by electrons. Most atoms are stable, but some are a bit shaky. These unstable ones try to become more stable over time, a process called radioactive decay.

Radioactive decay happens by itself and is hard to predict for each atom. When an unstable atom decays, it gives off energy called radiation, which can be tiny particles or waves. This energy release helps the atom become more stable.

Activity and Becquerel

We measure how fast this decay happens using a term called activity. It tells us the rate at which the unstable atoms are changing. If something has high activity, it means lots of atoms are changing every second.

We measure activity using a unit called the becquerel (Bq), named after the scientist who discovered radioactivity. One becquerel means one atom changing every second. For example, if something has an activity of 100 Bq, it means 100 atoms are changing every second.

Measuring Radioactivity

Scientists have tools to figure out how much radioactivity is in something. One common tool is called a Geiger-Muller tube, which counts how many times radioactive stuff zaps it each second.

Inside the tube, there's gas that gets excited when it's hit by radiation, creating an electrical signal. The device then counts these signals. How fast it counts depends on how much radioactive stuff is around and how good the detector is.

Radioactive Rocks

Some rocks have natural radioactive stuff inside them, making them a bit radioactive. This can tell us interesting things about Earth's past. The main radioactive elements in rocks are uranium, thorium, and potassium-40.

- Uranium is often found in certain rocks like granite. It changes over time, giving off radiation.
- Thorium is usually found near uranium. It also gives off radiation as it changes.
- Potassium-40 is found in many rocks. It's important for figuring out how old rocks are.

In Conclusion

Understanding radioactive decay and radiation helps us understand how tiny bits inside atoms behave when they're unstable. Activity, measured in becquerels, tells us how fast this happens. Tools like the Geiger-Muller tube help scientists measure radioactivity, which is important for many things, from medicine to making energy. When we find radioactive stuff in rocks, it helps us learn more about Earth's history. Understanding all this helps us understand the world better and helps in lots of areas of science and technology.

<u>Independent practice</u>

1. What is radioactive decay, and why does it occur?
2. Explain the concept of activity in relation to radioactive substances.
3. How is the activity of a radioactive sample measured?
4. Describe the function of a Geiger-Muller tube in detecting radioactivity.
5. What are some examples of naturally occurring radioactive elements found in rocks?

Understanding Questions:

6. How does the count-rate of a Geiger-Muller tube vary with the proximity of a radioactive source?

7. Why is it important to measure and monitor radioactivity in various contexts?

8. Can you explain why some atomic nuclei are more likely to decay than others?

9. Compare and contrast the properties of alpha, beta, and gamma radiation.

Spot and Correct Mistake:

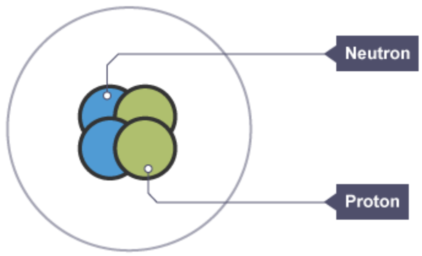
10. Identify and correct any errors in the following statement: "One becquerel represents one decay per minute."

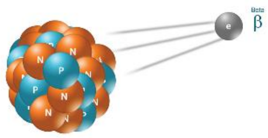
11. Locate and rectify the mistake in this statement: "Potassium-40 is commonly found in igneous rocks and has a half-life of about 1.3 million years.

L3 Types of radiation

Nuclear radiation is a fascinating aspect of physics that involves the emission of tiny particles and waves from the nucleus of an atom. To grasp this concept, let's delve into the types of nuclear radiation and their properties.

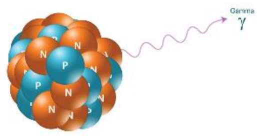
Firstly, let's talk about alpha particles (α). Imagine these particles as tiny, energetic bundles composed of two neutrons and two protons, essentially resembling the structure of a helium nucleus. Due to their relatively large size and positive charge, alpha particles can't travel very far through materials. They have a short range and can be stopped by something as thin as a sheet of paper or even human skin. However, their ionizing power, or the ability to knock electrons off atoms, is relatively high, making them useful for certain applications.





Next up, we have beta particles (β). Picture these as high-speed electrons ejected from the nucleus when a neutron transforms into a proton. Unlike alpha particles, beta particles are much smaller and have a negative charge. They can penetrate materials more deeply than alpha particles but are still stopped by thicker barriers like aluminium foil or several millimetres of plastic. Beta particles also possess ionizing power, though not as strong as alpha particles.

Then there are gamma rays (γ), which are a form of electromagnetic radiation emitted from the nucleus. These rays are like X-rays but more energetic. Gamma rays are highly penetrating and can pass through most materials, requiring dense substances like lead or concrete to block them effectively. While they have high penetration power, gamma rays have relatively low ionizing power compared to alpha and beta particles.



Lastly, we have neutrons (n), which are electrically neutral particles found in the nucleus. Neutrons don't possess a charge, but they can still interact with other atomic nuclei, causing them to become unstable and emit radiation.

Understanding the properties of these types of radiation is crucial, especially when considering their applications and safety measures. For instance, when assessing the suitability of radiation sources for specific tasks, such as medical imaging or industrial inspections, one must consider factors like penetration through materials, range in air, and ionizing power.

Alpha particles, with their limited range and high ionizing power, are ideal for tasks requiring precise targeting, such as certain medical treatments or smoke detectors. Beta particles, while more penetrating than alpha particles, are still stopped by moderate barriers and find applications in medical therapies and thickness measurements. Gamma rays, with their ability to penetrate deeply, are invaluable in medical diagnostics like X-rays and cancer treatments, as well as in industrial radiography for inspecting materials for defects.

When evaluating the best radiation source for a given situation, it's essential to weigh the benefits against potential risks. For instance, while alpha particles are effective for treating localized cancers, they can also pose risks if not handled properly. Similarly, gamma rays offer unparalleled penetration for imaging, but excessive exposure can be harmful.

In conclusion, nuclear radiation encompasses a diverse array of particles and waves emitted from atomic nuclei. Understanding the properties of alpha particles, beta particles, and gamma rays is key to utilizing radiation effectively while ensuring safety. By applying this knowledge, scientists and engineers can harness the power of radiation for various beneficial applications while minimizing potential risks to health and the environment.

Independent practice

Comprehension Questions

1. What does an alpha particle consist of?
2. How is a beta particle created in the nucleus?
3. What kind of radiation are gamma rays, and where do they come from?
4. Describe the penetration abilities of alpha particles through materials.
5. Why are gamma rays useful in medical diagnostics?

Understanding Questions

1. Explain why alpha particles have a high ionizing power despite their limited range.
2. Compare the penetration abilities of beta particles and gamma rays.
3. Discuss the safety precautions needed when handling gamma radiation in medical settings.
4. Why are beta particles more suitable for certain medical therapies than alpha particles?
5. How does the lack of electrical charge affect the behaviour of neutrons in nuclear reactions?

Finish the Sentence Questions

1. Alpha particles can be stopped by a sheet of paper, but...
2. Gamma rays are more penetrating than beta particles because...
3. Beta particles are more suitable for certain medical therapies because...
4. Neutrons do not have a charge, and...

L4 Radioactive Decay

Nuclear equations are like special sentences in science that describe what happens when an atom undergoes radioactive decay. Let's break it down step by step!

What is Radioactive Decay?

Radioactive decay is when an unstable atom changes into a more stable one by giving off some particles or energy. This process can be represented by nuclear equations. There are different types of radioactive decay, but we'll focus on two main ones: alpha decay and beta decay.

What Are Alpha and Beta Particles?

1. **Alpha Particles (α)**:
    - An alpha particle is made up of 2 protons and 2 neutrons. This is the same as the nucleus of a helium atom.
    - It is represented by the symbol:

      $^{4}_{2}He$

2. **Beta Particles (β)**:
    - A beta particle is a high-energy, high-speed electron or positron emitted by certain types of radioactive nuclei.
    - It is represented by the symbol: $^{0}_{-1}e$

Alpha Decay

When an atom undergoes alpha decay, it loses an alpha particle. This means it loses 2 protons and 2 neutrons. Here's what happens:

- The mass number of the atom decreases by 4 (because it loses 2 protons and 2 neutrons).
- The atomic number decreases by 2 (because it loses 2 protons).

For example, let's look at uranium-238 (which has 92 protons) decaying into thorium-234:

$$^{238}_{92}U \longrightarrow ^{234}_{90}Th + ^{4}_{2}He$$

In this equation:

- Uranium-238 decays into thorium-234 .
- An alpha particle is emitted.

Beta Decay

In beta decay, a neutron in the nucleus turns into a proton and emits a beta particle (an electron or a positron). Here's the breakdown:

- The mass number stays the same (because the total number of protons and neutrons doesn't change).
- The atomic number increases by 1 (because it gains a proton).

For example, carbon-14 (which has 6 protons) decaying into nitrogen-14:

$$^{14}_{6}\text{carbon} \longrightarrow {}^{14}_{7}\text{nitrogen} + {}^{0}_{-1}\text{e}$$

In this equation:

- Carbon-14 decays into nitrogen-14.
- A beta particle is emitted.

Balancing Nuclear Equations

When writing nuclear equations, it's important to balance them. This means making sure that both the total mass numbers and the atomic numbers are the same on both sides of the equation.

- **Mass number**: The total number of protons and neutrons.
- **Atomic number**: The number of protons.

For example:

Alpha decay of polonium-210:

$$^{210}_{84}\text{Po} \longrightarrow {}^{210}_{82}\text{Pb} + {}^{4}_{2}\text{He}$$

Beta decay of thorium-234:

$$^{234}_{90}\text{Th} \longrightarrow {}^{234}_{91}\text{Pa} + {}^{0}_{-1}\text{e}$$

Gamma Radiation

Sometimes, when a nucleus decays, it emits energy in the form of gamma rays (γ\gammaγ). Unlike alpha and beta particles, gamma rays are just energy and do not have mass or charge. Therefore, gamma emission doesn't change the mass number or atomic number of the nucleus.

Summary

- **Alpha Decay**: Mass number decreases by 4, atomic number decreases by 2.
- **Beta Decay**: Mass number stays the same, atomic number increases by 1.
- **Gamma Emission**: No change in mass number or atomic number.

Understanding these basic principles will help you write and balance nuclear equations correctly. It's like solving a puzzle where you make sure the pieces (protons and neutrons) match up on both sides

Independent practice

Comprehension Questions

1. What are the three main types of radiation emitted during radioactive decay?
2. Describe an alpha particle and its effect on the nucleus when emitted.
3. What happens to a neutron in the nucleus during beta decay?
4. How does the emission of gamma rays affect the mass and charge of a nucleus?
5. Explain why balancing nuclear equations is important.

Understanding Questions

1. Why does alpha decay decrease both the mass and charge of the nucleus?
2. In beta decay, why does the mass of the nucleus remain unchanged even though a neutron turns into a proton?
3. Given the symbol $^{4}_{2}He$, explain what each number represents in an alpha particle.
4. How can you tell if a nuclear equation is balanced?
5. What are the differences between alpha, beta, and gamma radiation in terms of mass and charge?

Spot and Correct Mistakes

1. Statement: In alpha decay, a nucleus emits a particle with 2 protons and 3 neutrons, decreasing its mass and charge.
2. Statement: During beta decay, the mass number of the nucleus increases.
3. Statement: Gamma rays are emitted and they decrease the charge of the nucleus.
   - **Correction:** Gamma rays do not change the charge of the nucleus; they only carry away energy.
4. Statement: In the nuclear equation $^{14}_{6}C \rightarrow ^{14}_{8}N + ^{0}_{-1}e,$, the atomic number increases by 2.
5. Statement: An alpha particle is represented by the symbol $^{4}_{2}H.$.

L5 Half life

Radioactive Decay is Random

To start, let's talk about radioactive decay. This is the process by which unstable atoms lose energy by emitting radiation. This happens because the nucleus of the atom is not stable and needs to become more stable. The key thing to remember here is that radioactive decay is **random**. This means we can't predict exactly when a specific atom will decay. Imagine you have a huge collection of atoms - some might decay immediately, while others might take a long time. This randomness is similar to flipping a coin; you can't predict the result of a single flip, but if you flip a lot of coins, you expect about half to be heads and half to be tails over time.

What is a Half-Life?

Now, let's introduce the concept of a **half-life**. The half-life of a radioactive isotope is the time it takes for half of the radioactive atoms in a sample to decay. It's also the time it takes for the activity, or count rate, of the sample to reduce to half its initial level.

Think of it like this: if you start with 100 radioactive atoms, after one half-life, about 50 of those atoms will have decayed, leaving 50 still radioactive. After another half-life, 25 of those remaining radioactive atoms will decay, leaving 25. This process continues, with each half-life reducing the number of radioactive atoms by half.

The Random Nature and Half-Life

Because radioactive decay is random, we use half-life to describe the behavior of large numbers of atoms. Even though we can't say when a specific atom will decay, we can be very precise about how a large group of atoms will behave over time.

For instance, if a radioactive isotope has a half-life of 10 years, this means that every 10 years, the number of radioactive atoms in a sample will be halved. If you start with 1000 atoms, after 10 years, about 500 will remain. After another 10 years, about 250 will remain, and so on.

Determining the Half-Life

To determine the half-life of a radioactive isotope, you need some information about how the count rate changes over time. For example, if you measure the activity of a sample and find that it drops from 1000 counts per minute to 500 counts per minute in 5 years, you can say the half-life is 5 years because the activity has halved in that time.

Calculating the Net Decline (HT Only)

For students looking for a deeper understanding, we can calculate the net decline in radioactive emissions after a given number of half-lives. This is often expressed as a ratio.

Let's say you want to find out how much of a radioactive isotope remains after 3 half-lives. You start with a whole sample, which is represented as 1. After one half-life, you have 1/2 of the original amount. After two half-lives, you have 1/2 of that remaining amount, which is 1/4 of the original. After three half-lives, you have 1/2 of that remaining amount, which is 1/8 of the original.

So, after 3 half-lives, the ratio of the remaining radioactive substance to the original amount is 1:8.

Practical Example

Let's take an example. Suppose you have a radioactive isotope with a half-life of 2 years. You start with 80 grams of this isotope. After 2 years (one half-life), you’ll have 40 grams remaining. After another 2 years (four years total, two half-lives), you'll have 20 grams remaining. After 6 years (three half-lives), you'll have 10 grams remaining.

By understanding the concept of half-life and the random nature of radioactive decay, you can predict how a large group of radioactive atoms will behave over time, even though you can't predict the behavior of any single atom. This concept is very important in fields like medicine, archaeology, and environmental science, where knowing how long a radioactive material remains active is crucial.

Independent practice

Comprehension Questions

1. What does it mean when we say that radioactive decay is random?
2. Define the term "half-life" in the context of radioactive decay.
3. If a sample starts with 200 radioactive atoms, how many atoms are expected to remain after one half-life?
4. How does the activity (count rate) of a radioactive sample change over time?
5. What information do you need to determine the half-life of a radioactive isotope?

Understanding Questions

1. Explain why we use the concept of half-life to describe the decay of radioactive isotopes.
2. Describe how the randomness of radioactive decay affects our ability to predict the decay of individual atoms versus large groups of atoms.
3. If a radioactive isotope has a half-life of 5 years, how much of the isotope remains after 15 years?
4. How would you calculate the net decline of a radioactive sample after 4 half-lives?
5. Why is it important to understand the half-life of a radioactive isotope in practical applications like medicine or archaeology?

Spot and Correct Mistakes

1. Statement: "After two half-lives, all of the radioactive atoms in a sample will have decayed."
2. Statement: "The half-life of a radioactive isotope changes depending on the size of the sample."
3. Statement: "The activity of a radioactive sample increases over time as more atoms decay."

L6 Radioactive contamination and irradiation

Radioactive contamination and irradiation might sound similar, but they are actually quite different. Let's break down these concepts to make them easier to understand.

What is Radioactive Contamination?

Radioactive contamination occurs when unwanted radioactive materials, which contain radioactive atoms, end up on other materials. Imagine you have a clean table and someone accidentally spills a powder that contains radioactive atoms on it. Now, the table is contaminated with radioactivity.

Why is Contamination Hazardous? The danger from radioactive contamination comes from the decay of radioactive atoms. As these atoms decay, they release energy in the form of radiation. There are different types of radiation, including alpha particles, beta particles, and gamma rays. The type of radiation emitted determines how dangerous the contamination is. For example:

Alpha particles can be very harmful if ingested or inhaled, but they can't penetrate the skin.

Beta particles can penetrate the skin but usually don't go much deeper.

Gamma rays can pass through the body and are the most penetrating and potentially harmful type of radiation.

What is Irradiation?

Irradiation is the process of exposing an object to nuclear radiation. Unlike contamination, the object being irradiated does not become radioactive itself. Think of it like getting an X-ray at the doctor’s office. The machine sends out radiation that passes through your body to create an image, but you don't become radioactive from the X-ray.

Comparing Hazards: Contamination vs. Irradiation

Understanding the difference between contamination and irradiation is crucial for handling them safely.

Contamination: The primary hazard comes from the radioactive material itself, which continues to emit radiation until it decays completely. This means that contaminated objects or areas can remain hazardous for a long time.

Irradiation: The hazard comes from being exposed to radiation from a source. Once the exposure stops, there is no lingering radiation on the object or person that was irradiated. For example, after you leave the X-ray room, you are no longer exposed to radiation.

Safety Precautions

To protect against the hazards of radioactive sources used in irradiation, certain precautions are necessary:

Shielding: Using materials like lead or concrete to block or reduce radiation exposure.

Distance: Keeping a safe distance from the radiation source can reduce exposure.

Time: Minimizing the amount of time spent near a radiation source reduces the dose of radiation received.

Protective clothing: Wearing special suits, gloves, and masks can protect against contamination.

Importance of Sharing Scientific Findings

Scientists conduct studies to understand the effects of radiation on humans better. It is important for their findings to be published and shared with other scientists. This allows for:

Peer Review: Other scientists review the research to check for errors, ensuring that the findings are accurate and reliable.

Collaboration: Sharing results can lead to new ideas and improvements in safety protocols.

Public Safety: Accurate information helps develop guidelines and regulations that protect people from radiation hazards.

In summary, while both radioactive contamination and irradiation involve nuclear radiation, they differ in how they affect objects and people. Contamination involves radioactive material sticking to surfaces, posing a long-term hazard, while irradiation involves exposure to radiation without making the object radioactive. Understanding these differences helps in taking the right precautions to stay safe.

Independent practice

Comprehension Questions

1. What is radioactive contamination?
2. What types of radiation can be emitted by radioactive materials, and how do they differ in terms of danger?
3. How does irradiation differ from radioactive contamination?
4. Why is it important for scientific findings about the effects of radiation to be shared and published?
5. What are some precautions that can be taken to protect against the hazards of radioactive sources?

Understanding Questions

1. Explain why an object that has been irradiated does not become radioactive itself.
2. Describe a scenario where radioactive contamination could occur and explain the potential hazards.
3. How do alpha particles, beta particles, and gamma rays differ in their ability to penetrate materials and their potential danger to humans?
4. Why is it important to minimize the time spent near a radiation source?
5. What role does peer review play in ensuring the safety and accuracy of scientific research on radiation?

Finish the Sentences

1. Scientists need to share their findings about radiation effects because...
2. An object exposed to nuclear radiation does not become radioactive but..

L7 Background radiation – Triple only

Background Radiation: Understanding the Invisible Energy Around Us

Imagine living in a world where invisible energy particles are constantly zipping through you and everything around you. This might sound like science fiction, but it's real! This invisible energy is called radiation, and the kind that's always present in our environment is known as background radiation.

What is Background Radiation?

Background radiation is the small amount of radiation that we are exposed to all the time. It comes from both natural and man-made sources.

Natural Sources of Background Radiation

1. **Rocks and Soil:** Many rocks and soil contain small amounts of radioactive materials like uranium, thorium, and radon. These elements slowly break down, releasing radiation into the environment.
2. **Cosmic Rays:** Space is full of energetic particles. When these particles crash into the Earth's atmosphere, they produce cosmic rays. Although our atmosphere and magnetic field protect us from most of this radiation, some still reaches us on the ground.

Man-Made Sources of Background Radiation

1. **Nuclear Weapons Testing:** In the past, countries tested nuclear weapons by exploding them in the atmosphere. This released radioactive particles that spread around the world.
2. **Nuclear Accidents:** Accidents at nuclear power plants, like the ones in Chernobyl and Fukushima, released large amounts of radiation into the environment. Even though these events are rare, they add to the background radiation.

Radiation Dose

The amount of radiation you are exposed to is called a radiation dose. Scientists measure this dose in units called sieverts (Sv). Since a sievert is a large amount, doses are often measured in millisieverts (mSv), where 1000 millisieverts equals 1 sievert.

How Background Radiation Varies

The level of background radiation can change depending on where you are and what you do.

1. **Location:** Some places naturally have higher levels of background radiation. For example, if you live in an area with lots of granite, a type of rock rich in uranium, you might get a higher dose of radiation. People who live at higher altitudes are also exposed to more cosmic rays because there's less atmosphere to protect them.
2. **Occupation:** Certain jobs expose people to higher levels of radiation. For instance, airline pilots and flight attendants get more cosmic radiation because they spend a lot of time flying at high altitudes. Workers in nuclear power plants or medical professionals using X-rays also receive higher doses.

Why Understanding Background Radiation Matters

Knowing about background radiation helps us understand what is normal and what is not. By measuring and monitoring radiation levels, scientists can keep track of any changes that might indicate a problem, such as a nuclear accident. It also helps in creating guidelines for safety in various occupations to ensure people are not exposed to harmful levels of radiation.

Independent Practice

Comprehension Questions

1. What are the two main sources of background radiation?
2. How do cosmic rays contribute to background radiation?
3. Why do some occupations expose people to higher levels of radiation?
4. What unit is used to measure radiation dose, and how is it related to millisieverts?
5. Why is it important to monitor background radiation levels?

Understanding Questions

1. Explain why people living at higher altitudes are exposed to more background radiation.
2. Describe how nuclear accidents can increase background radiation levels.
3. What are some natural sources of radiation found in rocks and soil?
4. How does our atmosphere protect us from cosmic rays?

Find the Mistake Questions

1. Statement: Background radiation only comes from natural sources like rocks and soil.
2. Statement: Radiation dose is measured in millilitres (mL).
3. Statement: Only people who work in nuclear power plants are exposed to higher levels of radiation.
4. Statement: Cosmic rays are particles that come from the Earth's atmosphere.

L8 Half life – Triple only

What is a Radioactive Isotope?

A radioactive isotope, or radionuclide, is an atom that has an unstable nucleus. This instability causes the nucleus to lose energy by emitting radiation in the form of particles or electromagnetic waves. This process is called radioactive decay.

What is a Half-Life?

The half-life of a radioactive isotope is the time it takes for half of the atoms in a sample to decay. After one half-life, only half of the original radioactive atoms remain; after two half-lives, only a quarter of the original atoms are left, and so on. Half-lives can vary greatly among different isotopes, from fractions of a second to millions of years.

Examples of Half-Lives

To better understand half-lives, let's look at two examples:

1. **Carbon-14**: This isotope has a half-life of about 5,730 years. It's commonly used in carbon dating to determine the age of ancient artifacts.
2. **Uranium-238**: This isotope has a half-life of about 4.5 billion years. It's one of the isotopes used to estimate the age of the Earth.

Why Do Half-Lives Vary?

The length of an isotope's half-life depends on the stability of its nucleus. Isotopes with very unstable nuclei decay quickly and have short half-lives. Those with more stable nuclei decay slowly and have long half-lives. The differences in nuclear stability arise from the balance of forces within the nucleus.

Hazards of Radioactive Materials

The dangers posed by radioactive materials depend largely on their half-lives and the type of radiation they emit.

1. **Short Half-Lives**: Isotopes with short half-lives decay rapidly, releasing a lot of radiation in a short period. This can make them very dangerous if not handled properly, but the risk diminishes quickly as they decay. For example, **Iodine-131** has a half-life of about 8 days and is used in medical treatments. It poses a significant hazard initially but becomes much less dangerous after a few weeks.
2. **Long Half-Lives**: Isotopes with long half-lives release radiation more slowly. Although they are less immediately dangerous, they remain hazardous for much longer periods. **Plutonium-239**, with a half-life of 24,100 years, can remain dangerous for hundreds of thousands of years, posing a long-term environmental hazard.

Comparing Hazards

To understand why different half-lives result in different hazards, consider the following scenarios:

- **Short-Term Exposure**: If you're exposed to a radioactive isotope with a short half-life, the immediate danger is high because it releases a lot of radiation quickly. However, if you can avoid exposure for a short period, the danger decreases rapidly as the isotope decays.
- **Long-Term Exposure**: An isotope with a long half-life poses a lower immediate risk but a significant long-term hazard. Continuous exposure, even to low levels of radiation, can be harmful over time. Long-lived isotopes can contaminate environments for extended periods, requiring careful management and containment.

Practical Applications and Safety

Different half-lives have practical implications in various fields:

- **Medicine**: Short-lived isotopes are used in diagnostic imaging and cancer treatment. Their quick decay means that they can target diseased cells without remaining in the body for long.
- **Archaeology**: Long-lived isotopes like Carbon-14 are used to date ancient objects, helping us understand historical timelines.
- **Energy**: Long-lived isotopes like Uranium-238 are used in nuclear power. Managing the long-term waste from these processes is crucial to prevent environmental contamination.

Conclusion

Understanding the half-life of radioactive isotopes helps us appreciate the varying risks associated with radioactive materials. Isotopes with short half-lives can be very dangerous initially but become safe relatively quickly, while those with long half-lives pose less immediate danger but require long-term safety measures. By understanding these concepts, we can use radioactive materials safely and effectively in medicine, industry, and research.

<u>Independent practice</u>

Comprehension Questions

1. What is a radioactive isotope and how does it differ from a stable isotope?
2. Explain what a half-life is and how it affects the amount of radioactive material over time.
3. Describe the differences in hazards between isotopes with short half-lives and those with long half-lives.
4. How is Carbon-14 used in archaeology, and why is its half-life suitable for this purpose?
5. Why is it important to manage and contain isotopes with long half-lives, like Plutonium-239, in the environment?

Understanding Questions

1. Why do isotopes with short half-lives pose a higher immediate danger than those with long half-lives?
2. How can the different half-lives of isotopes influence their practical applications in medicine and energy?
3. What would happen if an isotope used in medical treatment had a very long half-life? How would this affect the patient?

Re-write questions

4. Rewrite the following sentence to correct the mistake: "An isotope with a long half-life releases a lot of
5. Rewrite the following sentence to correct the mistake: "Uranium is used in dating ancient artifacts because of its long half-life."
6. Rewrite the following sentence to correct the mistake: "A radioactive isotope used in medical treatments remains dangerous for a long time because it decays slowly."

L9 Uses of radiation – Triple only

Nuclear radiation might sound like something out of a science fiction movie, but it's actually a very important tool in modern medicine. Let's explore how it works and why it's so useful.

What is Nuclear Radiation?

Nuclear radiation comes from the nucleus, or centre, of an atom. It can be in the form of particles (like alpha and beta particles) or waves (like gamma rays). These forms of radiation have high energy, which means they can penetrate materials and even our bodies. Because of this ability to pass through things, scientists and doctors use nuclear radiation for various medical purposes.

Exploring Internal Organs

One of the coolest uses of nuclear radiation is helping doctors see inside our bodies without needing to cut us open. This is called medical imaging. Here's how it works:

1. **Tracer Injection**: A small amount of radioactive substance, known as a tracer, is injected into your body. This tracer travels through your bloodstream and collects in specific organs or tissues.
2. **Gamma Camera**: Special cameras, called gamma cameras, detect the radiation emitted by the tracer. These cameras then create images showing where the tracer has travelled.

For example, if doctors want to examine your heart, they can use a tracer that collects in the heart tissue. The gamma camera will take pictures of the heart, showing how well it's working and if there are any blockages in the blood vessels.

This method is very useful because it provides detailed images that help doctors diagnose problems quickly and accurately.

Controlling or Destroying Unwanted Tissue

Nuclear radiation is also used to treat certain medical conditions, particularly cancer. This process is called radiation therapy. Here's how it helps:

1. **Targeted Treatment**: High doses of radiation are directed at cancerous cells. Because these cells grow and divide rapidly, they are more vulnerable to radiation than normal cells.
2. **Cell Damage**: The radiation damages the DNA inside the cancer cells, which prevents them from growing and dividing. Eventually, these cells die off.

Radiation therapy is carefully planned to target only the cancer cells and minimize damage to healthy tissues. Doctors use imaging techniques to precisely aim the radiation beams.

Evaluating the Risks

Even though nuclear radiation is a powerful tool in medicine, it comes with risks. Let's look at some of the concerns and how they are managed:

1. **Radiation Exposure**: High levels of radiation can damage healthy cells and increase the risk of cancer. That's why the amount of radiation used in medical procedures is strictly controlled and kept as low as possible.
2. **Side Effects**: Patients undergoing radiation therapy might experience side effects, such as skin irritation or fatigue. However, these are usually temporary and can be managed with proper care.

Doctors and scientists evaluate the benefits and risks of using nuclear radiation in each case. They consider factors like the patient's overall health, the type and stage of the disease, and the expected outcomes. The goal is to maximize the benefits (like diagnosing or treating a condition) while minimizing any potential harm.

Independent Practice

Comprehension Questions

1. What is nuclear radiation and what are its two main forms?
2. How do doctors use nuclear radiation to explore internal organs?
3. What is a tracer and how does it work in medical imaging?
4. Describe how radiation therapy is used to treat cancer.
5. What are some of the risks associated with the use of nuclear radiation in medicine?

Understanding Questions

1. Why is a gamma camera important in medical imaging involving nuclear radiation?
2. How does radiation therapy target cancer cells more effectively than normal cells?
3. What factors do doctors consider when evaluating the risks and benefits of using nuclear radiation in a medical procedure?

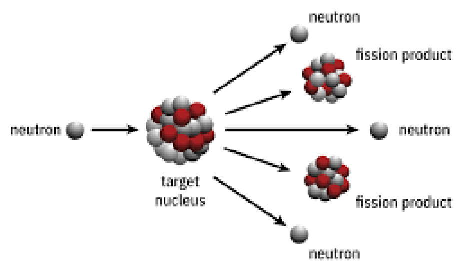
Finish the Sentence Questions

1. Doctors use a small amount of radioactive substance in imaging because...
2. Nuclear radiation can be very helpful in medicine, but...
3. Radiation therapy damages the DNA of cancer cells, therefore...

L10 Fission and Fusion – Triple only

Nuclear fission is a process where a large and unstable atomic nucleus splits into two smaller nuclei, releasing a lot of energy. Imagine you have a big Lego tower that's wobbly and unstable. If you hit it just right, it might break apart into two smaller towers, releasing a lot of energy in the form of falling Lego pieces.

How Does Nuclear Fission Happen?



1. **Absorbing a Neutron**: For fission to happen, the unstable nucleus, like uranium or plutonium, first absorbs a neutron. Think of the neutron as a tiny particle that, when added to the nucleus, makes it so unstable that it splits.
2. **Splitting**: The nucleus then splits into two smaller nuclei. These smaller pieces are called fission products, and they are roughly the same size.
3. **Emitting Particles**: Along with the smaller nuclei, the fission process emits two or three more neutrons and gamma rays. Gamma rays are a type of high-energy radiation.
4. **Releasing Energy**: All the fission products, including the neutrons and gamma rays, have a lot of kinetic energy. This is energy due to motion, like a ball rolling down a hill.
5. **Chain Reaction**: The emitted neutrons can go on to hit other unstable nuclei, causing them to split too. This can start a chain reaction, where more and more nuclei keep splitting.

Controlling the Chain Reaction

In a nuclear reactor, the chain reaction is controlled to manage the energy released. Imagine it like a controlled bonfire where you add just enough wood to keep it burning steadily, not too fast or too slow.

In contrast, a nuclear weapon causes an uncontrolled chain reaction. This is like adding so much wood to the bonfire that it creates a huge, uncontrollable blaze, leading to an explosion.

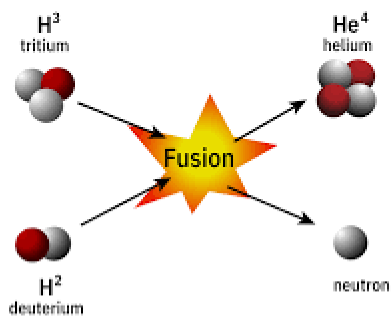
Understanding Diagrams

When you see diagrams of nuclear fission, look for the following parts:

- A large nucleus (like uranium or plutonium)
- An incoming neutron
- The nucleus splitting into two smaller nuclei
- Emitted neutrons and gamma rays

What is Nuclear Fusion?

Nuclear fusion is the opposite of fission. Instead of splitting a large nucleus, fusion involves joining two small nuclei to form a larger one.



How Does Nuclear Fusion Happen?

1. **Joining Nuclei**: In fusion, two light nuclei, like hydrogen atoms, come very close together and combine to form a heavier nucleus, such as helium.

2. **Mass to Energy**: During this process, a tiny amount of the mass of the nuclei is converted into energy. This is the energy of radiation, which can include light and heat.

Fusion in the Sun

Fusion is the process that powers the sun and other stars. In the core of the sun, hydrogen nuclei fuse together to form helium, releasing a tremendous amount of energy. This energy travels to Earth as sunlight, which we see and feel as warmth.

Comparing Fission and Fusion

- **Fission**: Splitting of a large nucleus, releases neutrons, and can cause a chain reaction. Controlled in reactors, uncontrolled in bombs.
- **Fusion**: Joining of small nuclei, converts some mass into energy, and powers the sun.

Key Takeaways

- **Energy Release**: Both processes release a lot of energy, but through different methods.
- **Control**: Fission can be controlled (like in reactors) or uncontrolled (like in bombs). Fusion, while incredibly powerful, is harder to control and is still being researched for practical use on Earth.
- **Natural vs. Man-Made**: Fusion powers stars naturally, while fission is often harnessed in man-made reactors or weapons.

Understanding these concepts helps us grasp how the universe works, from the power of the sun to the energy we use in our daily lives.