Radioactivity

Chapter Overview

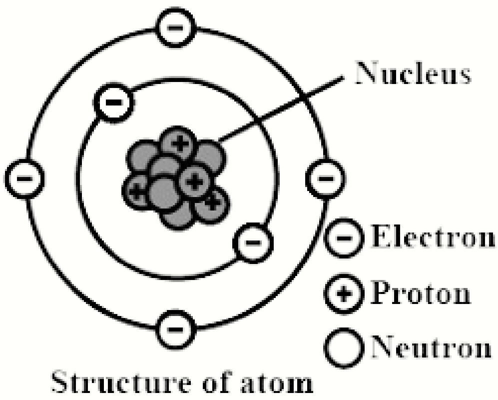
Weightage

- **Medium Weightage**
- **Memory-heavy Topic**
- **Similar to Chemistry - Atomic Structure**
- **3% of 2024 Specimen Paper**

Concepts

- **Nucleus**
- **Electron Cloud**
- **Atomic Structure**
- **Isotopes**
- **Nuclear Decay**
- **Alpha, Beta and Gamma Emission**
- **Half-life**
- **Nuclear Fusion and Fission**

Key Concepts



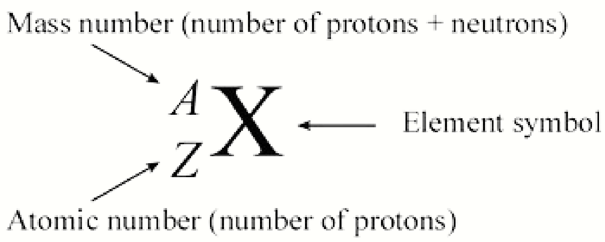
Atomic Structure

An atom consists of

- a positively charged nucleus made of positive protons and neutral neutrons
- negatively charged electrons which orbit the nucleus

The mass of the electrons are negligible, hence the mass of an atom can be approximated as the mass of its nucleus.

Subatomic particle	Location	Mass	Charge
Proton	Nucleus	1	+1
Neutron	Nucleus	1	No charge
Electron	Shells	0 (negligible)	-1



Nuclear Notation

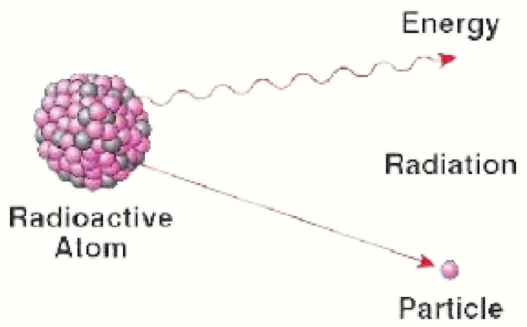
Atoms of the same element have the same number of protons. For a given nuclide (distinct nucleus):

- X is the symbol of the element
- A is the mass (nucleon) number
- Z is the atomic (proton) number

Isotopes

Isotopes are atoms of the same element that have the same number of protons (Z) but a different number of neutrons (N), resulting in a different mass number (A).

Key Concepts



Nuclear Decay

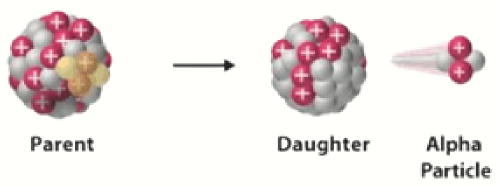
Nuclear Decay is the spontaneous and random process that occurs when an unstable nucleus transitions into a more stable state by emitting radiation.

It is a random process

- One cannot know what nucleus will decay

It is a spontaneous process

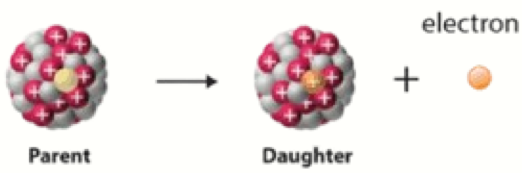
- One cannot know when nuclear decay will occur



$${}^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}He$$

Alpha Decay

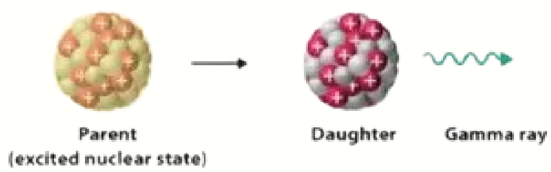
- A giant nucleus emits an alpha particle (Helium Nucleus, 2A, 2X)
- Alpha particles have positive charge and are relatively heavy
- Alpha particles have limited penetration abilities, stopped by a sheet of paper or human skin



$${}^{A}_{Z}X \rightarrow {}_{Z+1}^{A}Y + \beta^{-}$$

Beta Decay

- Emission of a beta particle (high speed electron)
- High-energy, high-speed electrons emitted
- More penetrative than alpha particles
- Can be stopped by plastic, glass or a few milimeters of Aluminium

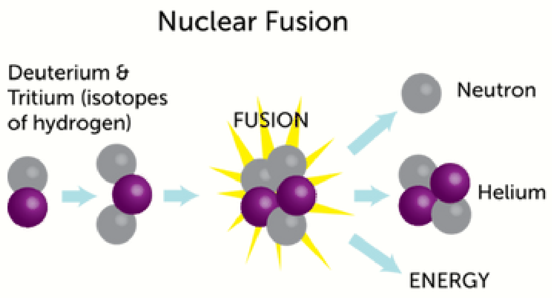


$${}^{Am}_{Z}X \rightarrow {}^{A}_{Z}X + {}^{0}_{0}\gamma$$

Gamma Decay

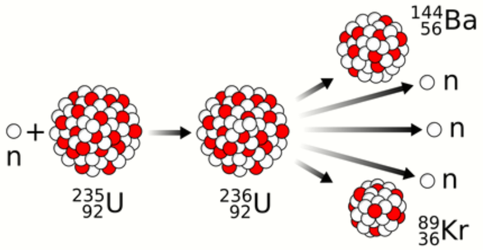
- Emission of a Gamma Photon, a form of high-energy electromagnetic radiation
- Electromagnetic radiation of very high frequency and energy. They are neutral and highly penetrative
- Requires dense materials such as lead or several centimeters of concrete to shield against them

Key Concepts



Nuclear Fusion

Nuclear Fusion is the process in which two smaller nuclei combine to form a heavier nucleus. A small amount of mass is lost, accompanied by a release of energy.



Nuclear Fission

Nuclear fission is the process of splitting a nucleus into two or more smaller nuclei, along with the release of a large amount of energy. The energy produced in fission is substantial, and is the basis for nuclear power plants.

Applications

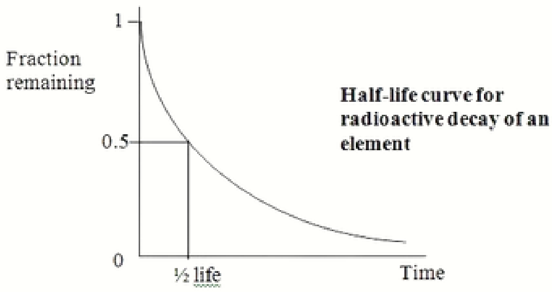
$$N(t) = N_0 \left(\frac{1}{2}\right)^{\frac{t}{t_{1/2}}}$$

$N(t)$ = quantity remaining
N_0 = initial quantity
t = elapsed time
$t_{1/2}$ = half-life of the substance

Half-Life

Half-life is the time taken for half the radioactive nuclei in a sample to decay.
It is the measure of stability of a radioactive material. The greater the half-life, the more stable the nuclei.

It can be expressed through this formula.



Using Tables and Graphs

If you're given a table or graph with various time points and remaining amounts of radioactive sample, you can determine the half-life by identifying the time it takes for the sample to halve.

Medical Treatments

Radioactive materials are used in treatments such as radiotherapy for cancer and imaging procedures like PET scans.

Nuclear Energy

Nuclear reactors harness the energy released from controlled fission of radioactive elements like Uranium.

Applications

$$N(t) = N_0 \left(\frac{1}{2}\right)^{\frac{t}{t_{1/2}}}$$

$N(t)$ = quantity remaining
N_0 = initial quantity
t = elapsed time
$t_{1/2}$ = half-life of the substance

Background Radiation

Background Radiation is the standard radiation levels that are present in our environment. It is called background radiation because it forms a baseline level of radiation exposure that is inescapable.

Sources of Background Radiation

- **Cosmic Radiation: comes from the sun and other celestial bodies**
- **Man-made sources: medical X-rays, nuclear power plants, etc.**
- **Internal Radiation: our own bodies contain naturally occurring radioactive isotopes such as Carbon-14 and Potassium-40**

Dangers and Precautions

Dangers: Prolonged exposure to radioactive materials can damage living tissues, increasing the risk of cancer and other health issues.

Precautions: Proper shielding, using remote handling tools and maintaining distance can reduce the risk of danger.

Definitions

Radioactivity	A spontaneous process where unstable atomic nuclei emit particles or electromagnetic radiation to attain a stable state
Protons	Positively charged particles and are one of the primary components that define the identity of an element.
Electron Cloud	Surrounding the nucleus is a cloud of electrons, which are subatomic particles carrying a negative electric charge. Electrons are much lighter than protons and neutrons, and they occupy various energy levels or "shells" around the nucleus. The distribution and behavior of these electrons determine the atom's chemical properties
Proton Number	The proton number, also known as the atomic number (Z), is the number of protons in the nucleus of an atom
Nucleon Number	The nucleon number, also known as the mass number (A), is the total number of protons and neutrons in an atom's nucleus.
Isotopes	Isotopes are atoms of the same element that have the same number of protons (Z) but a different number of neutrons (N), resulting in a different mass number (A).
Nuclear Decay	Nuclear decay is both a random and spontaneous process that occurs when an unstable nucleus transitions to a more stable state by emitting radiation. Here's a deeper look into these concepts:
Randomness	The randomness in nuclear decay means that it is impossible to predict exactly when a specific nucleus will decay.
Spontaneity	The spontaneity of nuclear decay means that the process happens by itself without needing any external trigger.

Definitions

Background Radiation	Background radiation refers to the natural and artificial sources of ionizing radiation that are present in our environment. It's called "background" radiation because it forms a baseline level of radiation exposure that is virtually inescapable.
Half-Life	The time taken for half the radioactive nuclei in a sample to decay. It's a measure of the stability of a radioactive material.
Nuclear Fusion	Nuclear Fusion is the process in which two smaller nuclei combine to form a heavier nucleus. A small amount of mass is lost, accompanied by a release of energy.
Nuclear Fission	Nuclear fission is the process of splitting a nucleus into two or more smaller nuclei, along with the release of a large amount of energy. The energy produced in fission is substantial, and is the basis for nuclear power plants.