MODERN PHYSICS

Modern physics deals with the study of nuclear model of an atom.
An atom is the smallest particle of an element that can take part in a chemical reaction.
An atom consists of three subatomic particles and these are;-

- Protons (positively charged)
- Electrons (negatively charged)
- Neutrons (neutral/no charge)

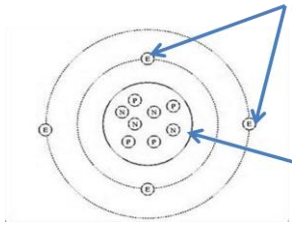
ATOMIC STRUCTURE

An atom is a basic unit of matter that consists of a central nucleus surrounded by negatively charged electrons.

THE MODEL OF AN ATOM

An atom consists of a central part known as a nucleus. This nucleus contains positive charges known as protons and neutral charges known as neutrons with 99.9% of the total mass. It also consists of negatively charged electrons located in orbits around the nucleus, and these are said to be massless.

NOTE: The number of protons in the nucleus is equal to the number of electrons around the nucleus of the atom and since they have opposite charges, the atom is said to have no charge.



Likely question: **Describe the mode of an atom.**

An atom is denoted by a symbol $^{A}_{z}X$

where A – Atomic mass
Z – Atomic number
X – Symbol of the element

TERMS USED

Mass number: Is the total number of protons and neutrons in the nucleus of an atom.
It is sometimes known as Atomic mass or Nucleon number i.e A = N + Z

Atomic number: Is the total number of protons in the nucleus of an atom i.e Z = A – N

Neutron number (N): Is the total number of neutrons in the nucleus of an atom. i.e N = A-Z

Isotopes: These are atoms of the same element with the same atomic number but different mass number.

OR These are atoms of the same element with the same number of protons but different number of neutrons.

For example: $^{35}_{17}Cl$ and $^{37}_{17}Cl$ are isotopes of chlorine

RADIOACTIVITY

Is the spontaneous disintegration of unstable nuclides to form stable ones with emission of radiations.

OR Is the spontaneous disintegration of the unstable nucleus of an atom by emission of radioactive substances.

OR This is the spontaneous disintegration of unstable nuclei emitting alpha, α, beta, β and gamma, γ radiation.

RADIOISOTOPES

These are radioactive atoms of the same element having the same atomic number but different mass number.

Substances emitted after disintegration include:-

- Alpha particles (α)
- Beta particles (β)
- Gamma rays (γ)

During disintegration energy is released and emission of an alpha or beta particle from unstable nucleus produces an atom of a different element known as a decay product which is stable.

ALPHA PARTICLE $\left(^{4}_{2}He\right)$

It is a helium nucleus having two protons and two neutrons.
When an atom decays by emission of an alpha particle, its mass number reduces by four and atomic number by two. i.e

$$^{A}_{Z}X \xrightarrow{\alpha} {}^{A-4}_{Z-2}Y + {}^{4}_{2}He + \text{energy}$$

EXAMPLES

1. Radium $^{226}_{88}Ra$ decays by emission of an alpha particle to form Radon (Rn). Write down a balanced equation for the decay. **(6 lines)**

2. An atom $^{387}_{64}X$ decays by emission of an alpha particle to give element Y. write down the composition of Y. **(8 lines)**

3. An atom $^{238}_{96}X$ decays by emission of two alpha particles to give element Y. write down a balanced equation for the decay and the composition of Y. **(8 lines)**

PROPERTIES OF ALPHA PARTICLES

- ✓ They are helium nuclei ${}^{4}_{2}\mathrm{He}$.
- ✓ They are positively charged.
- ✓ They are deflected towards the negative plate in the electric field.
- ✓ They are deflected towards the South Pole in the magnetic field.
- ✓ They carry a charge of positive two.
- ✓ They have mass (atomic number 2 and mass number 4).
- ✓ They have a less penetrating power.
- ✓ They cause ionisation of air (very ionising).

NB: **Ionisation** is the processing of gaining or losing of an electron by a charged body.

BETA PARTICLES $\left({}^{0}_{-1}e\right)$

These are electrons in nature. They change a neutron to a proton and an electron. The proton remains in the nucleus and the electron is emitted as a beta particle.
During decay, the mass number remains the same and the atomic number increases by one. i.e

$${}^{A}_{Z}\mathrm{X} \xrightarrow{\beta} {}^{A+0}_{Z+1}\mathrm{Y} + {}^{0}_{-1}e + \text{energy}$$

Examples

1. ${}^{14}_{6}\mathrm{C}$ Decays by emission of a beta particle to form nitrogen. Write a balanced decay equation. **(6 lines)**
2. ${}^{226}_{88}\mathrm{Ra}$ Decays by emission of both an alpha particle and a beta particle to form Radon and Radium respectively. Write down the equations leading to these compositions. **(6 lines)**

THE PROPERTIES OF BETA PARTICLES

1) They are electrons by nature.
2) They are negatively charged.
3) They are deflected towards the positive plate in the electric field.
4) They have a relatively high penetrating power.
5) They cause less ionization of air than alpha particles.
6) They are deflected towards the North Pole in the magnetic field.
7) They have negligible mass (no mass).

DIFFERENCES BTN ALPHA AND BETA PARTICLES

ALPHA PARTICLES	BETA PARTICLES
1. Are helium atoms.	1. Are electrons in nature.
2. They are positively charged.	2. They are negatively charged.
3. They are deflected toward the negative plate by the electric field.	3. They are deflected toward the positive plate by the electric field.
4. They are deflected toward the south pole by the magnetic field.	4. They are deflected toward the North pole by the magnetic field.
5. They have a mass number of 4.	5. They have a mass number of zero.
6. They penetrate air but stopped by thin sheets.	6. They penetrate thin sheets but stopped by thick sheets.

SIMILARITIES OF ALPHA AND BETA PARTICLES

1) Both cause ionisation of gases.
2) Both have charges.
3) Both have penetrating power.
4) Both are deflected by the electric field.
5) Both are deflected by a magnetic field.

GAMMA RAYS (γ)

These are electromagnetic radiations of very short wave length.
Gamma rays are said to have no charge.
There is totally no change in the mass and atomic number during decay. i.e ${}^{A}_{Z}\mathrm{X} \quad \gamma \quad {}^{A}_{Z}\mathrm{Y} + \text{energy}$

PROPERTIES OF GAMMA RAYS

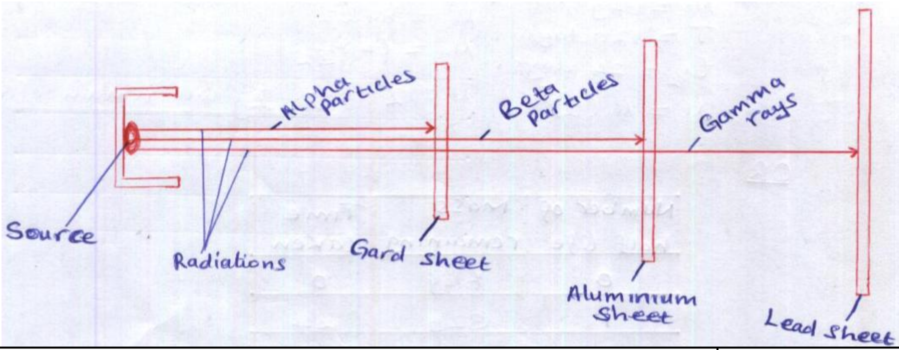
1) They are electromagnetic waves.
2) They are not deflected in the electric and magnetic fields.
3) They have a very high penetrating power.
4) They have a very low ionisation power.
5) They cause fluorescence when they strike matter.

Effect of Gamma rays: When a substance emits a gamma ray, the mass number and atomic number are not changed.

SIMILARITIES AMONG BETA, ALPHA AND GAMMARAYS

1) All cause ionisation of gases.
2) All have penetrating power.

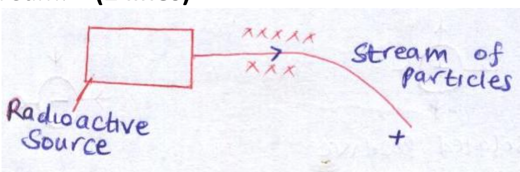
Penetration of different radioactive substances through different materials



EXERCISE

1. Which of the following are isotopes? ${}^{a}_{b}X$, ${}^{c}_{d}Y$, ${}^{b}_{a}Z$, ${}^{a}_{b}Z$, ${}^{a}_{d}Y$ and ${}^{c}_{d}X$ **(2 lines)**

2. The figure below shows a stream of particles from a radioactive source in an electric field. Identify the particles in the stream. **(2 lines)**



3. An element ${}^{246}_{98}X$ decays by emission of both an alpha and beta particle to form elements A and B respectively. Write down a combined equation for the decay and the compositions of A and B. **(8 lines)**

DETECTION OF RADIATION

Radiation can be detected using a number of detectors such as;-

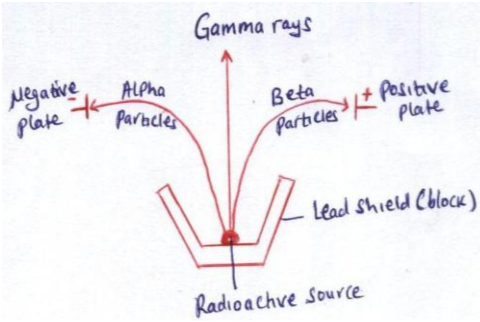
1) Ionization chamber.
2) Cloud chamber.
3) Scintillation chamber.
4) Semi-diode conductor.
5) Thermopile (thermocouple) e.t.c

General appearance of radioactive substances by a cloud chamber.

- Alpha particles appears as thick straight tracks (streams) of radiation.
- ✓ Beta particles have thin zig-zag tracks.
- While Gamma rays are seen as scattered rays not clearly identified in their shape and size.

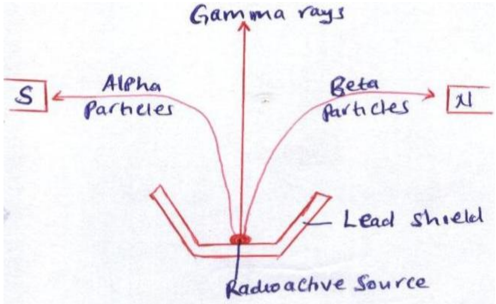
EFFECTS OF ELECTRIC AND MAGNETIC FIELDS ON RADIOACTIVE SOURCES

a) **Electric field**



In the electric field some particles are deflected to the positive plate (Beta), Negative plate (Alpha) and the other not deflected (Gamma rays).

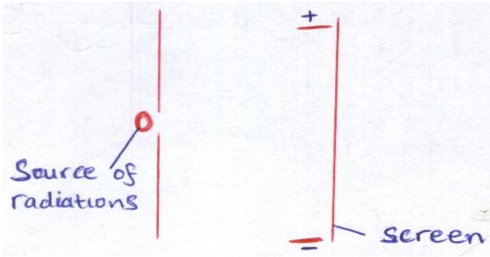
b) Magnetic field



In the magnetic field some particles are deflected towards the south pole (alpha) others towards the North pole (Beta) and others are not deflected (Gamma rays).

EXERCISE

The figure below shows an arrangement for studying the effect of an electric field on moving particles and rays. Sketch on the diagram the path taken by Alpha particles, Beta particles and Gamma rays.



USES OF RADIOACTIVITY

a) **MEDICAL USES**

- ✓ Detection of broken bones.
- ✓ Detection of cancer cells and treating.
- ✓ Detection of blood volume.
- ✓ Sterilization of medical equipments and parked food to kill bacteria.
- ✓ For therapeutic purposes to produce biological changes in tissues.

b) INDUSTRIAL AND AGRICULTURAL USE

- ✓ In the manufacture of nuclear energy.
- ✓ Detection in leakages in pipes.
- ✓ Investigating the rate of fertilizer intake in plants.
- ✓ In the manufacture of sensors e.g smoke detectors.
- ✓ Detecting the rate of wear and tear of machine parts e.g piston ring.
- ✓ Manufacture of genetically modified food and animals with faster growth rates and bigger size.
- ✓ Controlling thickness of papers and steel during manufacture.
- ✓ In carbon dating to determine the age of fossils (remains of old plants and animals by Archeologists).

DANGERS OF RADIOACTIVITY

- ➢ It causes heart failure.
- ➢ It causes skin burns.
- ➢ It causes infertility more so in women.
- ➢ It causes environmental damage i.e bombs
- ➢ It induces unwanted mutations leading to leukemia and genetic damage.

PRECUATIONS/MINIMISING DANGERS OF RADIOACTIVITY

- ✓ Keep the exposure time to radiation as minimal as possible.
- ✓ Avoid swallowing or inhaling of radioisotopes by use of masks during experiments.
- ✓ Using tongs or protective gloves when handling radioisotopes and not pointing them towards humans.
- ✓ During radiations treatment e.g in medicine, use short lived isotopes so that they decay away from the body in a short time.

ACTIVITY (A)

This is the number of atoms disintegrating per second.

i.e $A = \lambda N$

Where λ – wave length

N – number of active atoms present.

HALF LIFE

This is the time taken for a substance to decay to a half its original mass.

OR: This is the time taken for half the number of radioactive particles of a given element to disintegrate or decay.

DETERMINTION OF HALF LIFE

(i) **Using the expression**

If N_o is the original value of a radioactive element and N is the mass of a radioactive element remaining at any time T,

then ; $N = N_o \left(\frac{1}{2}\right)^{T/t}$

Where N – final mass (mass remaining)

N_o – initial mass (original mass)

T – total time taken

t – half life

This is applicable to unstable values.

Examples

1. The half life of Uranium is 24 days, calculate the mass of Uranium which remains after 120 days if the initial mass is 64g. **(8 lines)**

2. A radioactive material has a half life of 4hours. If the initial mass of the substance is 9.6g, calculate the;
   (i) Mass remaining after 24 hours. **(6 lines)**
   (ii) Mass decayed after 24 hours. **(2 lines)**

3. Radioactive material has a half life of 2.5hours. If after 7.5hours 0.82g remains, calculate the initial mass of the radioactive material. **(8 lines)**

4. A radioactive material has a half life of 1.5 years. If the initial mass of the substance is 12.8g, calculate the time taken for the material to decay to 0.8g. **(8 lines)**

5. 7.8g of a radioactive substance undergoes decay and after 32hours 0.4875g remains. Calculate the half life of the radioactive substance. **(8 lines)**

Using a table

Example

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Exercise

1. A radioactive element has half life of 4 minutes given that the original count rate is 256 counts per minute,

(i) Find the total time taken to reach a count rate of 16 counts per minute. **(5 lines)**

(ii) What fraction of the original number of atoms will be left by the time the count rate is 16 counts per minute. **(5 lines)**

2. A radioactive material of mass 8 grams has half life of 20 days. Find how much of it will decay after 60 days. **(6 lines)**

Using the graph

We can use a graph to determine the half life by considering the average of the countable rate time as below.

A graph of count rate against time.