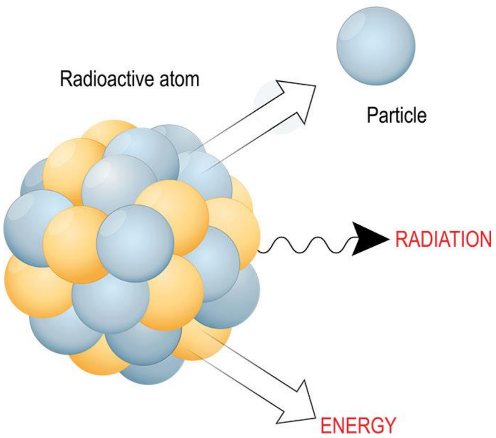

**S4 New Curriculum Physics**

## Theme: Modern physics

## Chapter 5 – Nuclear Processes




### Radioactivity

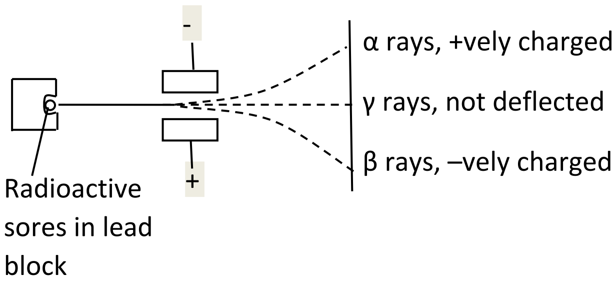
**Radioactivity** or **Radioactive decay** is the spontaneous disintegration of the unstable nucleus by the emission of alpha particle, beta particles and/or gamma rays.

**Radioactive substance** is a substance which undergoes spontaneous disintegration with emission of radiations like alpha particles, beta particles and Gamma rays.

**Radioisotope** is an isotope which undergoes spontaneous disintegration with emission of radiations like alpha particles, beta particles and Gamma rays.

### Types of radiations

There are three types of radiations given by radioactive substances. They all cause certain substances, such as zinc sulphide, to luminesce, and all ionize gases through which they pass. They differ in their response to an electric field in the manner shown in figure below:




**γ-rays**

These uncharged rays are similar to X-rays

- they have high penetrating power; being able to pass through 0.1m of metal.
- have negligible weight
- are un deflected by electric field
- ionize gases they pass through

**α-rays ($^{4}_{2}He$)**

- positively charged helium ions
- ionize gases they pass through
- deflected towards negative electric field
- have low penetrating power, for instance, they are blocked by sheet paper

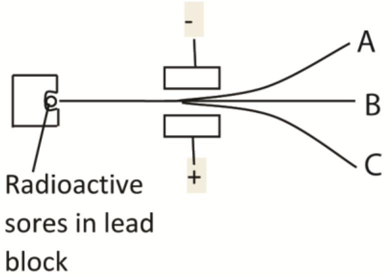
**β-rays ($^{0}_{-1}e$ or $^{0}_{-1}\beta$)**

- negatively charged
- deflected toward positive electric field
- have medium penetrating power and can penetrate a few millimeters of **plastic, glass, cardboard or aluminium**.
- ionize gases they pass through

## Trial 1

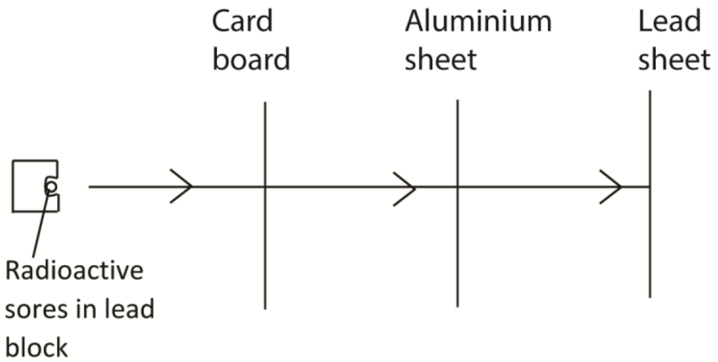
1. Which of the following are attracted towards the negative plate in electric field?
   A. Beta particles
   B. Alpha particles
   C. Gamma rays
   D. Neutrons [B]
2. State the radiations that may be emitted by a radioactive substance
   A. Alpha, gamma, X-ray
   B. Cathode rays, X-rays and beta particles
   C. Gamma, alpha and beta
   D. Cathode rays, X-rays and alpha [C]
3. What is
   (i) Alpha particle
   (ii) Beta particle
   (iii) Gamma ray

4. (a) A radioactive source decays by emission of all the three radiations. The radiations enter into electric field as shown




Name the radiations A, B, C

(b) A radioactive source which emits all the three radiations is placed in front of the cardboard, aluminium and lead sheets and arranged as shown below

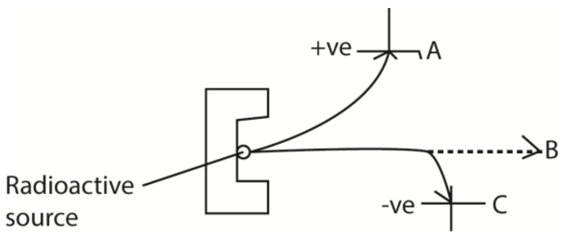



Name the radiations found between

(i) Cardboard and aluminium sheet

(ii) Aluminium sheet and lead sheet

5.




A radioactive source emits radiation which are directed between two appositively charged metal plates as shown in the figure above

(a) Name the radiations labelled A, B and C.
(b) What can you deduce about the charges of the radiations
(c) What happens when the radioactive source is completely covered with an ordinary sheet of paper?

## Balancing nuclear equations

The sum of protons and the mass number on the either side of the equation should be equal.

(i) Emission of an alpha particle

When a nucleus of an element decays with emission of an alpha particle, its atomic number and mass number decrease by 2 and 4 respectively, i.e.

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

**Example 1**

$^{6}_{3}\text{Li} + \, ^{1}_{0}\text{n} \rightarrow \, ^{3}_{1}\text{H} + \, \mathbf{^{4}_{2}He}$

(ii) Emission of a beta particle

When a nucleus of an element decays with emission of a beta particle, its atomic number increase by 1 while its atomic mass does not change, i.e.

$^{A}_{Z}X \longrightarrow \; _{Z+1}^{\;\;A}Y + \; _{-1}^{\;\;0}e$

**Example 2**

$^{214}_{83}\text{Bi} \rightarrow \, _{-1}^{\;\;0}\text{e} + \, \mathbf{^{214}_{84}po}$

(iii) Emission of γ rays

When a nucleus of an element decays with emission of gamma ray, its atomic mass and mass number do not change, i.e.

$^{A}_{Z}X \longrightarrow \; ^{A}_{Z}X + \gamma$

## Trial 2

1. Element X emits radiation r and forms element Y as given in the equation.
   $^{A}_{Z}X \longrightarrow \; _{Z+1}^{\;\;A}Y + r$
   Where A and Z are mass number and atomic mass respectively, the radiation r is
   A. Alpha particle
   B. Beta particle
   C. Gamma rays
   D. X-ray [B]
2. Radium nucleus $^{226}_{88}Ra$ decays to Radon (Rn) by alpha particle emission. What is the equation for the reaction?
   A. $^{226}_{88}Ra \longrightarrow \; ^{3}_{2}He + \, ^{223}_{86}Rn$
   B. $^{226}_{88}Ra \longrightarrow \; ^{4}_{2}He + \, ^{222}_{86}Rn$
   C. $^{4}_{2}He + \, ^{222}_{86}Rn \longrightarrow \; ^{226}_{88}Ra$
   D. $^{226}_{88}Ra \longrightarrow \; ^{1}_{0}n + \, ^{225}_{88}Ra$ [B]
3. The following equation represent part of radioactive series
   $^{234}_{90}Th \longrightarrow X + radiaton$
   Substance X and the radiation in the equation above are
   A. $^{234}_{91}Pa + gamma$
   B. $^{230}_{90}Th + beta$
   C. $^{230}_{90}Th + gamma$
   D. $^{234}_{91}Pa + beta$ [D]

4. When uranium 235 is bombarded with a neutron, it splits according to the equation
   $^{235}_{92}U + ^{1}_{0}n \longrightarrow ^{M}_{N}P + ^{92}_{36}Kr + 3^{1}_{0}n$
   M and N on P represent
   Find the value of
   (i) M [141]
   (ii) N [56]

5. $^{24}_{11}Na \longrightarrow ^{A}_{Z}Y + ^{0}_{-1}B$
   A radioisotope of sodium atom decays by emission of beta particle as shown above. Find the value of

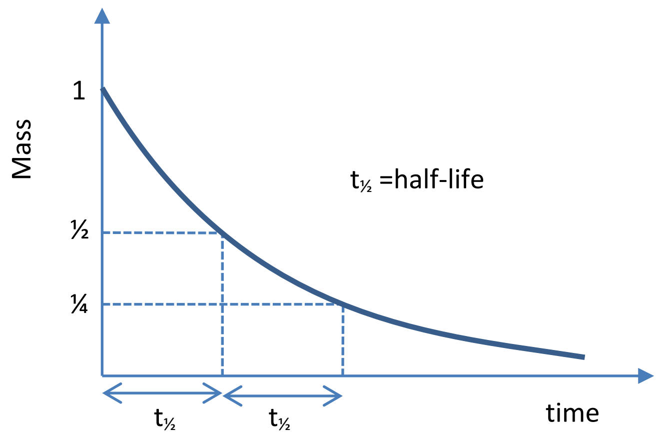
   (i) A [24]
   (ii) Z. [12]

6. $^{60}_{27}Co$ is a radioactive isotope of cobalt which emits a beta particle and very high gamma rays to form element X. Write a balance equation for nuclear reaction.
   [$^{60}_{27}Co \longrightarrow ^{60}_{28}Ni + ^{0}_{-1}B$
7. The symbol $^{235}_{92}U$ denotes a uranium nucleus
   (a) What is the meaning of
      (i) 235 ……………………………………..
      (ii) 92 ………………………………………
   (b) Write down a balanced nuclear equation showing the decay of $^{235}_{92}U$ to a nuclide X by emission of an alpha particle.[ $^{231}_{92}X$]

**Half-life of radioactive element**

Half-life ($t_{\frac{1}{2}}$) of a radioactive decay is the time taken by the mass of radioactive isotope to reduce to half of its initial mass.

The half life of a radioactive decay can be obtained from a graph mass of the substance aganst time; for example, the decay of 1g of the substance below



### Example 3

A radioactive material of mass 8g has a half-life of 20days. Find how much of the material will decay after 60days.

Solution

Method 1

Every after 20 days the material reduces to half its original mass

8g $\xrightarrow{\text{20days}}$ 4g $\xrightarrow{\text{20days}}$ 2g $\xrightarrow{\text{20days}}$ 1g

1g remains after 60 days

Therefore (8 -1) = 7g decay in 60days

Method 2

Number of half-lifes, = $\frac{60}{20} = 3$

Mass that remains after 3 half-lifes = $\frac{8}{2^3} = 1g$

Mass that decayed = 8 – 1 = 7g

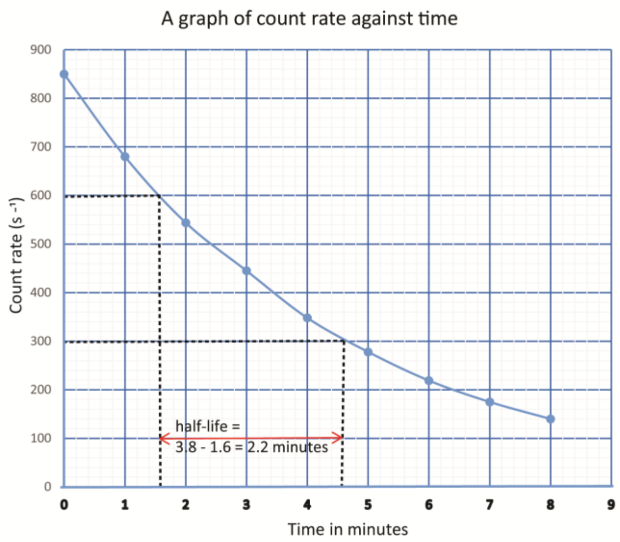
### Example 4

The table below shows the count rate of a radiaoactive element with time

| Time (minutes) | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| Count rate ($s^{-1}$) | 850 | 680 | 544 | 445 | 348 | 278 | 219 | 175 | 140 |

Plot a graph of count rate against time. From the graph, find the value of half-lifeof the radioactive element.

Solution




Half-life = 2.2minutes

**Health hazard of radioactive radiations**

They

- Destroy living cells of the body
- Cause sterility (inability to produce children)
- Cause leukemia (cancer of blood)
- Cause abnormalities in unborn children)

**Safety precautions**

When dealing with radioactive materials

- Use a pair of forceps not bare hands to hold the material
- Keep a radioactive source in lead boxes
- Wear jackets with a layer of lead
- Avoid places where radioactive materials are kept

**Uses of radioactive materials**

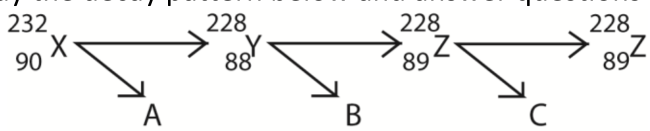
1. Industrial use
   - To estimate thickness of pare
   - Detect leaks in underground pipes
2. Medical use
   Diagnosis of diseases
   Treatment of cancer
   Sterilizing equipment and materials
3. Finding age of a rock through carbon dating
4. Production of electricity by nuclear reactions

**Detection of radiation**

It is done by the Geiger Muller tube and cloud chamber

**Trial 3**

1. (a) Name the precautions taken by people handling radioactive substances
   (b) Give one use in each of the following
      (i) Industry
      (ii) Biological and
      (iii) agriculture
   (c) A radioactive material of mass 12g has a half-life of 15 days. How much of it will decay after 60days? [0.75g]
2. Thorium has a half-life of 24 days. How many days would it take 8g of thorium to disintegrate to 1g?
   A. 3
   B. 24
   C. 72
   D. 96 [C]
3. (a) Define the statement ‘half-life of a radioactive substance’.
   (b) A radioactive substance decays to 1/16 of its original mass in 16 days. What is
      (i) Half-life
      (ii) The fraction of the original mass that will not have decayed after 20 days
   (c) Study the decay pattern below and answer questions that follow.




      (i) Identify the particles or radiations A, B and C emitted in the decay process shown above
      (ii) State two differences between radiations A and B.
      (iii) Give three hazards of radioactivity
      (iv) What is the difference between nuclear fusion and nuclear fission?
   (b) Give 4 properties of X-ray
4. (a) What is radioactivity?
   (b) A radioactive material takes 50hours for 93.755% of its mass to decay. Find its half life [12.5h]

**Nuclear energy**

Nuclear energy is the energy released from the nucleus of an atom, typically through two main processes: **fission** and **fusion**.

**Nuclear fission**

This is the splitting of a heavy nucleus into two or more light nuclei accompanied by the release of energy.

Sufficient excitation energy for the nucleus to split may be provided by particle bombardment of the nucleus with protons, neutrons or electrons. E.g.

$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{95}_{57}Mo + ^{139}_{57}La\ 2^{1}_{0}n + 7^{0}_{-1}e$ + energy

Neutrons are preferred as bombarding particles because they do not carry charge and therefore can penetrate deeper into the nucleus.

**Uses of nuclear fission**

1. To provide electricity
2. To manufacture atomic bombs.

**Nuclear fusion**

It is the union of two lighter nuclei to produce heavier nucleus of higher binding energy per nucleon accompanied by release of energy, e.g.

$^{2}_{1}H + ^{2}_{1}H \rightarrow ^{3}_{2}He + ^{1}_{0}n + Energy$

Nuclear fusion takes place at high temperature because the nuclei need a lot of kinetic energy to overcome their electrostatic repulsion.

**Nuclear reactors**

Nuclear reactors are devices in which controlled nuclear reactions are generated to release huge amounts of energy that can be used for electricity generation

**Advantages of nuclear energy**

- Produces massive energy with a small amount of fuel
- Low greenhouse gas emissions
- Reliable and efficient electricity generation

**Disadvantages of nuclear energy**

- Produces radioactive waste that must be managed
- Risk of nuclear accidents (like Chernobyl or Fukushima)
- Production of atomic bombs is a big threat to world peace and survival of human race.
- High costs and complex infrastructure

**International Atomic Energy Agency (IAEA)**

The **International Atomic Energy Agency (IAEA)** is a global organization that promotes the *peaceful, safe, and secure use of nuclear technology*. Established in 1957 and headquartered in Vienna, Austria, it operates as an autonomous body within the United Nations system.

**The role of the IAEA**

- **Promotes Peaceful Use of Nuclear Energy**: Encourages the use of nuclear science for medicine, agriculture, energy, and industry.

- **Ensures Nuclear Safety and Security**: Sets international safety standards and helps countries implement them to protect people and the environment.
- **Implements Safeguards**: Verifies that nuclear materials are not diverted to weapons programs, especially under the Nuclear Non-Proliferation Treaty (NPT).
- **Supports Scientific Research**: Provides training, technical cooperation, and research support, especially to developing countries.

**Please obtain free notes, exams and marking guides of Physics, chemistry, biology, history, from digitalteachers.co.ug website.**

Thanks

Dr. Bbosa Science