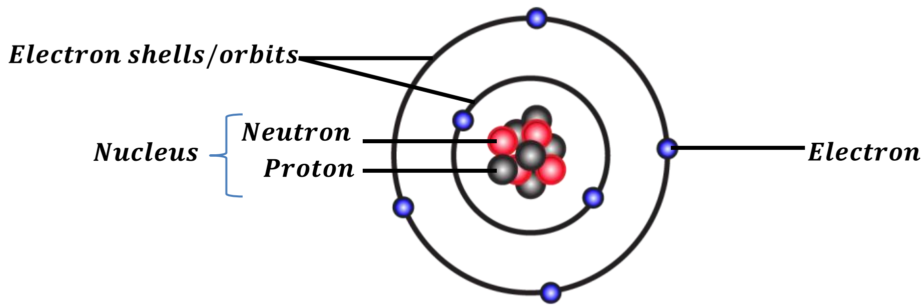
MODERN PHYSICS

The structure 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 particles namely;

- Electrons
- Neutrons
- Protons

An atom is made of a central part called the nucleus around which electrons revolve.
The nucleus is positively charged because it consists of protons which are positively charged and neutrons which have no charge. The properties of the particles of an atom are as shown in the table below.

Name	Symbol	Mass	Charge
Protons	P	1	Positive
Neutrons	n	1	No charge
Electrons	e	0	Negative

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

Likely question: ***Describe the model/structure of an atom***

Atomic number, Z:
This is the number of protons in the nucleus of an atom.

$$Atomic\ number, Z = Number\ of\ protons$$

Mass number [atomic mass], A: (nucleon number):
This is the total number of protons and neutrons in the nucleus of an atom.

$$Mass\ number = Number\ of\ protons + Number\ of\ neutrons$$
$$A = Z + n$$

If an atom of an element X is represented as

$\boldsymbol{{}^{A}_{Z}X}$ where **A** is the mass number and **Z** is the atomic number

Examples:

1. Given a chloride atom $^{35}_{17}\boldsymbol{Cl}$. Find the number of electrons in the atom.

$$A = Z + n \quad where\ A = 35, Z = 17$$
$$n = 35 - 17$$
$$n = \mathbf{18\ neutrons}$$
$$Number\ of\ electrons = Number\ of\ protons = Atomic\ number\ Z = \mathbf{17\ electrons}$$

2. State the composition of the atom $^{235}_{92}U$

$Atomic\ number = 92$
$Mass\ number = 235$
$Number\ of\ neutrons = 235 - 92 = 143$
$Number\ of\ electrons = 92$
$Number\ of\ protons = 92$

<u>ISOTOPES</u>:

These are atoms of the same element with the same atomic number but different mass numbers. Therefore, isotopes of an element have the same number of protons and electrons and different number of neutrons

<u>Examples of isotopes are</u>:

Chlorine; $^{35}_{17}Cl, ^{36}_{17}Cl, ^{37}_{17}Cl$
Carbon; $^{12}_{6}C, ^{13}_{6}C, ^{14}_{6}C$
Hydrogen; $^{1}_{1}H, ^{2}_{1}H, ^{3}_{1}H$

RADIOACTIVITY:

This is the spontaneous disintegration of unstable nucleus of an atom to form a stable nucleus with emission of radiations.
There are three radiations emitted by radioactive nucleus namely:

- Alpha particles, α.
- Beta particles, β.
- Gamma rays, γ.

Elements that undergo radioactivity are called **<u>radioactive elements/nuclides.</u>**
Heavy nuclides are generally unstable hence radioactivity ensures that they reach a stable state.

<u>Examples of radioactive elements are</u>:

- Uranium (U)
- Radium (Ra)
- Polonium (Po),
- Protactinium (Pa)
- Etc.

<u>Radioisotopes</u>:

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

TYPES OF RADIATIONS

Alpha particle, α:

Alpha particle is a high speed helium nucleus $\left({}^{4}_{2}\boldsymbol{He}\right)$

Alpha particles have a mass number of 4 and atomic number of 2 i.e. two protons and two neutrons and they carry a positive charge. They have no electrons to balance the two positively charged protons.

Properties of alpha particles:

- They are helium nuclei
- They are slightly deflected by both magnetic and electric fields because of their large mass.
- They are positively charged.
- They have the greatest ionizing power.
- They have the least penetrating power.
- They are stopped by a thick sheet of paper.
- They have a very short range in air.
- They affect the photographic films.
- They have speed less than the speed of light.
- They cause fluorescence when incident on fluorescent substance.

Alpha decay:

When a nuclide undergoes an alpha decay, it loses two protons and two neutrons.
Therefore its mass number reduces by four and its atomic number reduces by two and the daughter nuclide is two steps to the left in the periodic table.

Given that a radioactive element, ${}^{A}_{Z}\boldsymbol{X}$ undergoes an alpha decay to form element **Y**. Then the nuclear reaction equation is given by;

$$\underset{\text{(Parent)}}{{}^{A}_{Z}\boldsymbol{X}} \longrightarrow \underset{\text{(Daughter)}}{{}^{A-4}_{Z-2}\boldsymbol{Y}} + \underset{\text{(Alpha particle)}}{{}^{4}_{2}\boldsymbol{He}} + \text{energy}$$

Examples:

1. Radium (**Ra**) decays to become radon (**Rn**) according to the equation
$${}^{226}_{88}Ra \longrightarrow {}^{222}_{86}Rn + {}^{4}_{2}He$$

2. Uranium (**U**) decays to become thorium (**Th**) according to the equation
$${}^{238}_{92}U \longrightarrow {}^{234}_{90}Th + {}^{4}_{2}He$$

Question 1:

A radioactive substance ${}^{22}_{6}X$ undergoes decay and emits an alpha particle to form nuclide Y. Write an equation for the process.

$${}^{22}_{6}\boldsymbol{X} \longrightarrow {}^{18}_{4}\boldsymbol{Y} + {}^{4}_{2}\boldsymbol{He}$$

Beta particle, β:

A beta particle is a high-speed electron emitted from the nucleus of a radioactive element.
Beta particles have no mass number and carry a negative charge ($_{-1}^{0}e$).
A beta particle is produced as a result of one of the neutrons changing to a proton.

$$_{0}^{1}n \longrightarrow {}_{1}^{1}P + {}_{-1}^{0}e$$

Properties of beta particles:

- They are negatively charged.
- They are lighter since they have negligible mass
- They are easily deflected by both magnetic and electric fields
- They have greater penetrating power than alpha particles because of their high speed.
- They have less ionizing power than alpha particle.
- They can be stopped by a thin sheet of aluminium.
- They have a greater range in air than alpha particles.
- They cause fluorescence when incident on fluorescent substance.
- They are electrons.

Beta decay:

When a nuclide undergoes beta decay its mass number does not change but its atomic number increases by one. The daughter nuclide is one step to the right in the periodic table.

Given that a radioactive element, $_{Z}^{A}X$ undergoes a beta decay to form element **Y**. Then the nuclear reaction equation is given by:

$$\underset{\text{(Parent)}}{_{Z}^{A}X} \longrightarrow \underset{\text{(Daughter)}}{_{Z+1}^{A}Y} + \underset{\text{(Beta particle)}}{_{-1}^{0}e} + \text{energy}$$

Examples:

1. Carbon-14 decays to Nitrogen according to the equation
   $$_{6}^{14}C \longrightarrow {}_{7}^{14}N + {}_{-1}^{0}e$$

2. $_{92}^{235}U$ decays by emitting 3 beta particles to form a daughter nuclide P. Find the atomic and mass nummber of P.
   $$_{92}^{235}U \longrightarrow {}_{95}^{235}P + 3\,{}_{-1}^{0}e$$
   $Mass\ number = 235, \quad Atomic\ number = 95$

Gamma rays, γ:

Gamma ray is an electromagnetic radiation with a very short-wave length.
Gamma rays have no mass number and carry no charge.
Gamma rays are produced when an excited atomic nucleus loses energy and the energy is given out as gamma rays.

Properties of gamma rays:

- They are not charged.
- They travel at a speed of light since they are electromagnetic radiations.
- They are not deflected by both magnetic and electric fields since they are not charged.
- They have the least ionizing power.
- They have the greatest penetrating power.
- They undergo interference and diffraction.
- They cause fluorescence when incident on fluorescence substances.
- They have the greatest range in air.
- They are stopped by thick block of lead.

Gamma decay:

Gamma rays are not particles, therefore when nuclide emits gamma rays its atomic number and its mass number do not change but the nucleus becomes more stable.

Given that a radioactive element, ${}^{A}_{Z}\boldsymbol{X}$ undergoes a gamma decay to form a stable element **X**. Then the nuclear reaction equation is given by:

$$\underset{\text{(Parent)}}{{}^{A}_{Z}\boldsymbol{X}} \longrightarrow \underset{\text{(Daughter)}}{{}^{A}_{Z}\boldsymbol{Y}} + \underset{\text{(Beta particle)}}{\gamma} + \text{energy}$$

Note:

The change of an element to another element is called **Transmutation**.

Examples:

1. Radium ${}^{226}_{88}\boldsymbol{Ra}$ loses 5 alpha particles and 4 beta particles and is converted into a new stable element, an isotope of lead Pb. Find the mass number and atomic number of this isotope.

$${}^{226}_{88}Ra \longrightarrow {}^{A}_{Z}Pb + 5({}^{4}_{2}He) + 4({}^{0}_{-1}e)$$

$$226 = A + (5 \times 4) + (4 \times 0) = A + 20$$

$$\boldsymbol{A = 206}$$

$$Also,\ 88 = Z + (5 \times 2) + (4 \times -1) = Z + 10 - 4$$

$$\boldsymbol{Z = 82}$$

2. Thorium ${}^{232}_{90}Th$ is converted into Radium ${}^{224}_{88}Ra$ by radioactivity transformation below. How many α and β emissions have taken place?

$${}^{232}_{90}\text{Th} \longrightarrow {}^{224}_{88}\text{Ra} + \text{x}({}^{4}_{2}\text{He}) + \text{y}({}^{0}_{-1}\text{e})$$

$$90 = 88 + 2\text{x} - \text{y}$$

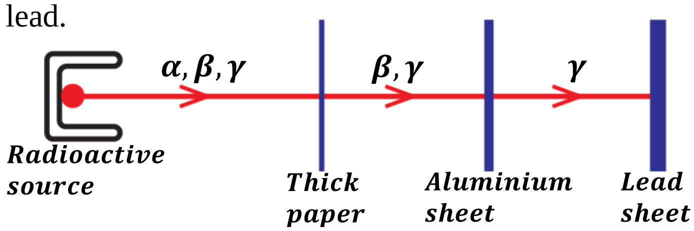
$\text{y} - 2\text{x} = 2$ ……………………………………..(eqn 1)

$$232 = 224 + 4\text{x}$$

$\boldsymbol{x} = \mathbf{2}$, therefore, $\boldsymbol{y} = \mathbf{2}$.

There are $2\alpha - particles$ and $2\beta - particles$.

Penetrating power of the radiations:
Alpha particles have the least penetrating power and can be stopped by a thick sheet of paper. Beta particles have a greater penetrating power than alpha particles and can be stopped by a thin sheet of aluminium while gamma rays have the greatest penetrating power and can be stopped by thick block of lead.

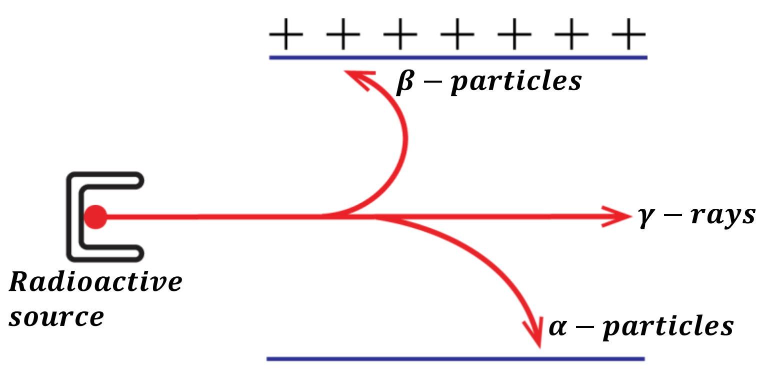


Ionizing power of the radiations:
Alpha particles produce straight traces because they are heavy and they cause greater ionization of the air through which they pass.
Beta particles produce irregular and light traces.
Gamma rays do not traces but leave hairy traces after colliding with the air molecules since they have a least ionization power.

(Alpha particle) (Beta particle) (Gamma ray)

Deflection of the radiations in an electric field:
When the radiations from a radioactive nucleus are passed through a strong electric field;

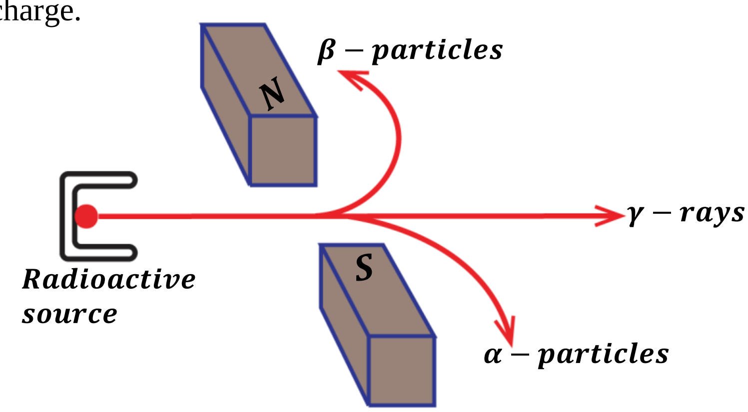
- The beta particles are deflected towards a positive plate showing that they carry a negative charge.
- Alpha particles are deflected towards a negative plate in the direction opposite to that of beta particles showing that alpha particles carry a positive plate.
- The gamma rays are not deflected at all showing that they carry no charge.

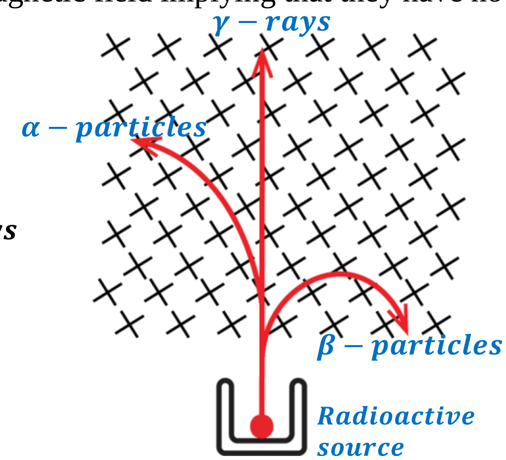


<u>Deflection of the radiations in a magnetic field</u>:

Alpha particles are deflected in a direction towards the South Pole while beta particles are deflected towards the North Pole.

Alpha particles are less deflected than beta particles implying that alpha articles are heavier than beta particles. The gamma rays are not deflected in the magnetic field implying that they have no charge.





<u>Differences between alpha and beta particles</u>

ALPHA PARTICLES	BETA PARTICLES
▪ Are helium atoms. ▪ They are positively charged. ▪ Deflected towards the negative plate in electric field. ▪ Deflected towards south pole in magnetic field. ▪ Stopped by thick sheet of paper. ▪ They are heavier.	▪ Are electrons. ▪ They are negatively charged. ▪ Deflected towards positive plate in an electric field. ▪ Deflected towards the north pole in a magnetic field. ▪ Stopped by thin sheet of aluminium. ▪ They are lighter.

<u>Similarities between Alpha and Beta particles</u>

- Both cause ionization of gases
- Both have charges.
- Both are deflected by electric field.
- Both are deflected by magnetic field.
- Both penetrate matter.

<u>Uses of radioactivity</u>:

a) <u>Medical uses</u>:

- ✓ Detection of broken bones.
- ✓ Detection of cancer cells and treating them.
- ✓ Used for sterilization of medical instruments
- ✓ Detection of brain tumors
- ✓ Detecting amount of blood in a patient

b) Industrial uses:

- ✓ Used to measure fluid flow in pipes in industries.
- ✓ Used to provide source of energy [electricity].
- ✓ Used in hardening polythene and petroleum.
- ✓ Used in food preservation.
- ✓ Used in detecting oil leakages in oil pipes.
- ✓ Used to measure the thickness of the metal sheet.

c) Agricultural uses:

- ✓ Used to produce new varieties of plants with new characteristics.
- ✓ Used to study the rate of uptake of fertilizers by plants.
- ✓ Used in pest control.

d) Archeological uses

- ✓ Used in determining the age of fossils (carbon-dating)
- ❖ ***Every living thing (plant or animal) has a certain constant quantity of carbon -14 elements (isotope). When the plant or animal dies this isotope begins decaying and the rate of disintegration decreases with time. So, when a fossil is obtained the rate of disintegration is determined, and this is used to calculate the age of the fossil. i.e. when the plant or animal died, which would show when that type of plant or animal existed.***

HEALTH HAZARDS / DANGERS OF RADIOACTIVITY:

- Radiations cause skin burns.
- Radiations cause blood cancer.
- Radiations cause sterility [inability to produce].
- Radiations cause low body resistance to normal diseases.
- Radiations cause genetic changes [mutation].
- Radiations destroy body cells.
- Radiations damage eye sight and body tissues.

Safety precautions when handling radioactive elements:

- They should be handled using long pair of tongs.
- They should be transported in thick lead containers.
- You should avoid unnecessary exposure to the radiations.
- You should wear protective clothing when handling radioactive elements.
- You should not eat or drink where radioactive sources are in use.
- You should cover any wound before using radioactive source.

Background radiations:

These are ionizing radiations from a variety of natural and artificial sources that are always present in the environment.

Natural sources of background radiations:

Natural sources of background radiation include the following:

Cosmic Radiation:

These are radiations that reach the Earth from space.
The sun is a major source of cosmic rays. Cosmic rays originating from the sun, stars and other major events in outer space are continuously striking the Earth. The majority of these cosmic rays are absorbed by the Earth atmosphere but the more energetic radiations interact with the atoms in the atmosphere creating energetic neutrons.

Terrestrial Radiation:

These are radiations from radioactive materials that exist naturally in soil and rock.
E.g. radiations from uranium, thorium, and radium. Some rocks are radioactive and give off radioactive radon gas. Essentially all air contains radon. In addition, water contains small amounts of dissolved uranium and thorium, and all organic matter (both plant and animal) contains radioactive carbon and potassium. Some of these materials are ingested with food and water, while others (such as radon) are taken in.

Internal Radiation:

These are radiations from radioactive materials which are present in the human body. These come from natural radioactive sources such as Carbon-14 in the air we breathe. Fruits and crops take in radioactive materials from the soil as well as Carbon-14 from the air.

Artificial sources of background radiations:

These are mainly from human activities. They include:

Nuclear power stations:

Major incidents from nuclear power stations have released radiations into the environment. Nuclear waste from power station also accounts for a proportion of artificial background radiation.

Nuclear weapons:

Nuclear weapon testing resulted in an increase of radiation in the environment because of **radioactive fallout** from nuclear weapons testing.

Medical sources:

Humans are exposed to radiations by medical procedures such as x-rays and radiotherapy. Nearly all artificial background radiation comes from medical procedures such as receiving X-rays for X-ray photographs.

Detecting the radiation:

The following can be used to detect radiations;

Photographic film:

Photographic film goes darker when it absorbs radiations. The more radiation the film absorbs, the darker it becomes. People, who work with radiation, wear film badges which are checked regularly to monitor the levels of radiation absorbed.

Geiger-Muller tube and Cloud Chamber:

The Geiger-Muller tube or cloud chamber detects radiation and each time it absorbs radiation, it transmits an electrical pulse to a counting machine. This makes a clicking sound or displays the count rate. The greater the frequency of clicks, the higher the count rate and the more radiation the Geiger-Muller tube or cloud chamber is absorbing.

NUCLEAR REACTIONS:

This is a process in which energy is produced. A nuclear reaction takes place in a nuclear reactor. There are two types of nuclear reactions and these are

- Nuclear fusion.
- Nuclear fission.

Nuclear fusion:

This is a process by which two light nuclei combine to form a heavy nucleus with release of energy.
It takes place at the sun, stars and in the hydrogen bomb.
The process results into three products i.e. one heavy atom, neutron and energy.

Example:

Two Deuterium nuclei (heavy hydrogen) combine to form Helium -3 and a neutron with release of energy

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

Conditions for nuclear fusion to occur:

- It occurs at very high temperature
- The light nuclei should be moving at a very high speed

Nuclear fission:

This is the splitting of a heavy nucleus into two lighter nuclei with release of energy.
This process is started by bombardment of a heavy nucleus with a slow-moving neutron.
The four products of the process are two light atom and more neutrons which can make the process continue and energy.

Example:

Splitting of uranium-236 $\boldsymbol{{}^{236}_{92}U}$ to form Barium (Ba) and Krypton (Kr) with release of energy.

$${}^{236}_{92}U + {}^{1}_{0}n \longrightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3{}^{1}_{0}n + Energy$$

Conditions for nuclear fission:

- It occurs at very low temperature.
- It requires a slow moving neutron.
- Presence of a heavy nucleus.

Uses of nuclear fusion and nuclear fission

- Used to produce hydrogen.
- Nuclear fusion is used to make hydrogen bombs.
- Used to produce electricity.
- Used to produce heat energy on large scale.
- Nuclear fission is used to make atomic bombs.

Differences between nuclear fusion and nuclear fission

Nuclear fission	Nuclear fusion
▪ Is the splitting of a heavy nucleus into two lighter nuclei. ▪ Requires a low temperature. ▪ Requires neutrons for bombardment. ▪ Results into four products. ▪ Energy released is high.	▪ Is the combining of two lighter nuclei to form a heavy nucleus. ▪ Requires a high temperature. ▪ Neutrons are not required. ▪ Results into three products. ▪ Energy released is low.

Example:

$$\boldsymbol{{}^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{236}_{92}U \longrightarrow {}^{144}_{x}Ba + {}^{y}_{36}Kr + 2{}^{1}_{0}n}$$

Find the values of x and y in the above nuclear fission reaction.

$236 = 144 + y + 2$	$92 = x + 36 + 0$
$236 = 146 + y$	$92 = x + 36$
$\boldsymbol{y = 90}$	$\boldsymbol{x = 56}$

HALF LIFE:

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

Half-life is measured in seconds, minutes, hours, days, weeks, months and years.

Half-life is not affected by physical factors like temperature and pressure and half-life is different for different radioactive nuclides.

If M_o is the original mass of a radioactive element and M_T is the mass of a radioactive element at any time, t, then

$$\boxed{\frac{M_o}{M_T} = 2^{\frac{t}{T_{½}}}}$$

Where $T_{½}$ is the half-life of a radioactive element.

Examples:

1. If a radioactive element of mass $32g$ decays to $2g$ in 96 days. Calculate the half-life.

Method 1:

$$32g \xrightarrow{\boldsymbol{T_{½}}} 16g \xrightarrow{\boldsymbol{T_{½}}} 8g \xrightarrow{\boldsymbol{T_{½}}} 4g \xrightarrow{\boldsymbol{T_{½}}} 2g$$

$$\boldsymbol{4T_{½} = 96}$$

$$\boldsymbol{T_{½} = \frac{96}{4}}$$

$$\boldsymbol{T_{½} = 24\ days}$$

Method 2:

$M_o = 32g,$
$M_T = 2g,$
$t = 96days,$
$T_{½} = ?$

$$\frac{M_o}{M_T} = 2^{\frac{t}{T_{½}}}$$

$$\frac{32}{2} = 2^{\frac{96}{T_{½}}}$$

$$16 = 2^{\frac{96}{T_{½}}}$$

$$2^4 = 2^{\frac{96}{T_{½}}}$$

$$4 = \frac{96}{T_{½}}$$

$$\boldsymbol{T_{½} = 24\ days}$$

2. A radioactive element of mass $9.6g$ has a mass of $0.15g$ after 24hours.

Method 1:

$$9.6g \xrightarrow{\boldsymbol{T_{½}}} 4.8g \xrightarrow{\boldsymbol{T_{½}}} 2.4g \xrightarrow{\boldsymbol{T_{½}}} 1.2g \xrightarrow{\boldsymbol{T_{½}}} 0.6g \xrightarrow{\boldsymbol{T_{½}}} 0.3g \xrightarrow{\boldsymbol{T_{½}}} 0.15g$$

$$\boldsymbol{6T_{½} = 24}$$

$$\boldsymbol{T_{½} = \frac{24}{6}}$$

$$\boldsymbol{T_{½} = 4\ hours}$$

Method 2:

$M_o = 9.6g,$
$M_T = 0.15g,$
$t = 24hours,$
$T_{½} = ?$

$$\frac{M_o}{M_T} = 2^{\frac{t}{T_{½}}}$$

$$\frac{9.6}{0.15} = 2^{\frac{24}{T_{½}}}$$

$$64 = 2^{\frac{24}{T_{½}}}$$

$$2^6 = 2^{\frac{24}{T_{½}}}$$

$$6 = \frac{24}{T_{½}}$$

$$\boldsymbol{T_{½} = 4\ hours}$$

3. A radioactive element of mass $12g$ has a half-life of 7years. Find the time taken for the element to decay to $0.75g$.

Method 1:

$$12g \xrightarrow{T_{½}} 6g \xrightarrow{T_{½}} 3g \xrightarrow{T_{½}} 1.5g \xrightarrow{T_{½}} 0.75g$$

$$\boldsymbol{4T_{½} = t}$$
$$\boldsymbol{4 \times 7 = t}$$
$$\boldsymbol{t = 28\ years}$$

Method 2:

$M_o = 12g,$
$M_T = 0.75g,$
$t = ?,$
$T_{½} = 7years$

$$\frac{M_o}{M_T} = 2^{\frac{t}{T_{½}}}$$

$$\frac{12}{0.75} = 2^{\frac{t}{7}}$$
$$16 = 2^{\frac{t}{7}}$$
$$2^4 = 2^{\frac{t}{7}}$$
$$4 = \frac{t}{7}$$
$$\boldsymbol{t = 28\ years}$$

4. A certain mass of a radioactive material contains 2.7×10^{24} atoms, how many atoms decayed after 3200 years if the half-life of material is 1600 years.

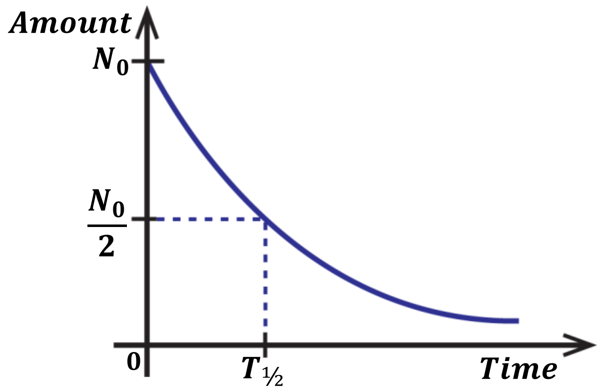
$$\boldsymbol{M_O = 2.7 \times 10^{24}, T_{½} = 1600years, t = 3200years}$$
$$\boldsymbol{Mass\ decayed = original\ mass - mass\ remaining}$$
$$\boldsymbol{M_D = M_O - M_T}$$

$$\boldsymbol{\frac{M_o}{M_T} = 2^{\frac{t}{T_{½}}}}$$
$$\boldsymbol{\frac{2.7 \times 10^{24}}{M_T} = 2^{\frac{3200}{1600}}}$$
$$\boldsymbol{\frac{2.7 \times 10^{24}}{M_T} = 2^2}$$
$$\boldsymbol{2.7 \times 10^{24} = 4M_T}$$
$$\boldsymbol{\frac{2.7 \times 10^{24}}{4} = M_T}$$
$$\boldsymbol{M_T = 6.75 \times 10^{23}g}$$

$$\boldsymbol{M_D = 2.7 \times 10^{24} - 6.75 \times 10^{23}}$$
$$\boldsymbol{= 2.025 \times 10^{24}}$$
$$\textbf{Mass decayed} = \boldsymbol{2.025 \times 10^{24}g}$$

Half-life from the graph:

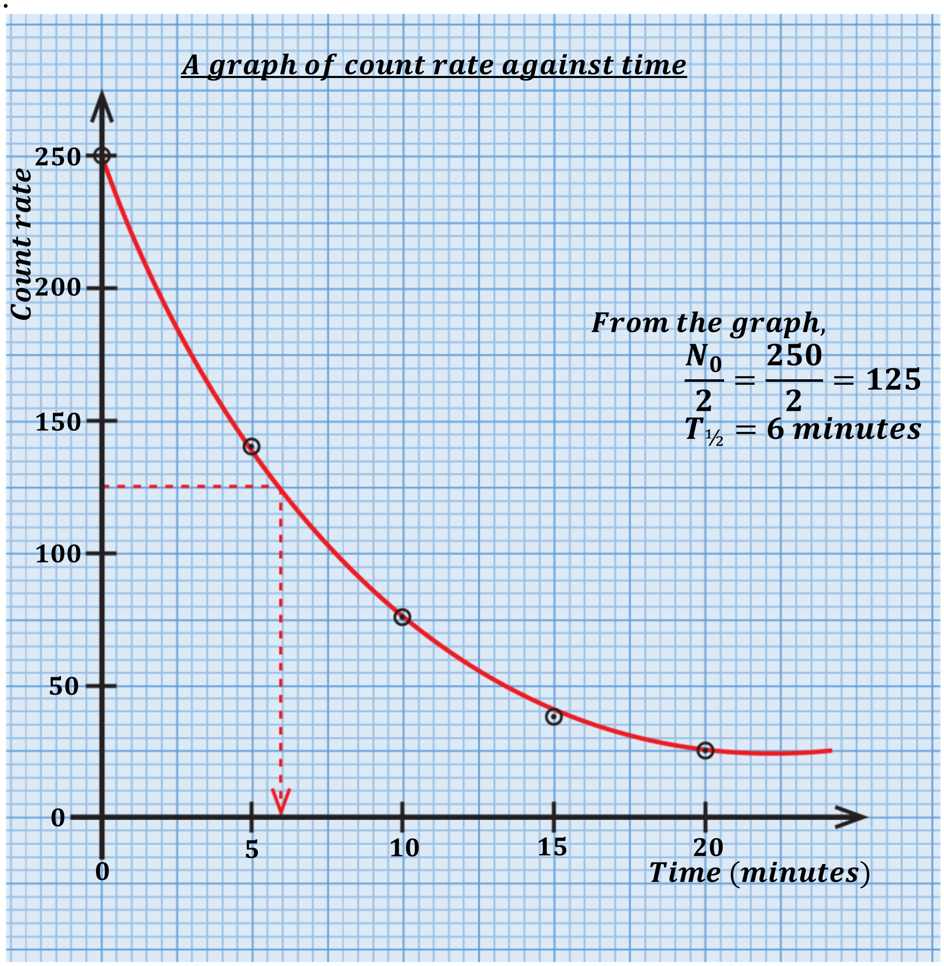
- The graph of amount of an element, **N** against time, $\boldsymbol{t}$ is plotted.
- Draw a horizontal line from half of the original amount to meet the curve.
- Draw a vertical line from the point on the curve to meet the time axis.
- Read the half-life from where the vertical line meets the time axis.



Example:
The table below shows results obtained in an experiment to determine the half-life of a radioactive substance.

Count rate	250	140	76	38	25
Time (min.)	0	5	10	15	20

Draw a graph of count rate against time and use it to determine the half-life of the radioactive substance.



Exercise:
The following values obtained from the readings of a rate meter from a radioactive isotope of iodine.

Time (min)	0	5	10	15	20
Count rate (min^{-1})	295	158	86	47	25

Plot a suitable graph and find the half-life of the radioactive iodine.

EXERCISE:
1. a) Define the following terms
   (i) Atomic number
   (ii) Mass number
   b) State the composition of elements $^{222}_{86}X$ and $^{224}_{86}Y$
   c) i) What is meant by the term radioactivity
   ii) Name the radiations emitted by radioactive materials
   iii)State the properties of the radiations named in (b) (ii) above
   d) What dangers may arise when one is exposed to radioactive materials?
2. a) What is a radioactive nuclide
   b) State the changes that take place in the nucleus of an atom if it emits
   i) Alpha particle ii) Beta particle iii) Gamma ray
   c) Explain the origin of beta particles and gamma rays.
   d) Explain why
   (i) Alpha particles are more ionizing than beta particles
   (ii) Alpha particles have a short range in air than beta particles
   (iii) Beta particles are deflected more than alpha particles by the same magnetic field
3. a) The nuclide $^{226}_{86}X$ decays to nuclide Y by emission of alpha particle.
   (i) Write the equation for the decay.
   (ii) State the atomic number and mass number of Y.
   Ans: [$\boldsymbol{Mass\ Number\ =\ 222, Atomic\ Number\ =\ 87}$]
   b) The nuclide $^{24}_{11}A$ decays to nuclide P by emission of beta particle.
   (i) Write the equation for the decay.
   (ii) State the atomic number and mass number of P.
   Ans: [$\boldsymbol{Mass\ Number\ =\ 24, Atomic\ Number\ =\ 12}$]
   c) The nuclide $^{214}_{82}X$ decays to nuclide M by emission of beta particle and gamma ray.
   (i) Write the equation for the decay.
   (ii) State the atomic number and mass number of M.
   Ans: [$\boldsymbol{Mass\ Number\ =\ 214, Atomic\ Number\ =\ 83}$]
   d) The nuclide $^{226}_{88}Ra$ decays to nuclide Y by emission of two alpha particles and one beta particle.
   (i) Write the equation for the decay.
   (ii) State the atomic number and mass number of Y.

4. Given that R and H decay as shown below

   (i) $^{232}_{92}R \longrightarrow {}^{224}_{91}Y + m\alpha + n\beta$

   (ii) $^{222}_{86}H \longrightarrow {}^{218}_{84}P + D$

   Find m, n and identify particle D

   Ans: $[m = 2, n = 3]$

5. Given that Ra decays to Y according to the equation

   $^{226}_{88}Ra \longrightarrow {}^{A}_{Z}Y + 2\alpha + \beta$

   Find the values of A and Z.

   Ans: $[A = 218, Z = 85]$

6. a) Define the term half-life.

   b) A radioactive sample of mass $60g$ has half-life of 8 minutes. Determine how much of it remains after 40 minutes.

   Ans: $[1.875g]$

   c) An element X of mass $64g$ decays to $4g$ in 96 days. Calculate

   (i) The half-life of X.

   (ii) The mass that decays in 120 days.

   (iii) How long does it take for $\frac{3}{4}$ of the sample to decay?

   Ans: i) $[24\ days]$ **ii)** $[2g]$ **iii)** $[48\ days]$

7. a) Define the terms

   (i) Nuclear fusion

   (ii) Nuclear fission

   b) i) State the conditions necessary for each to take place

   ii) Give two examples where each takes place

   c) i) $^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{x}_{56}Ba + {}^{92}_{y}Kr + 3{}^{1}_{0}n$

   Find the values of x and y

   ii) $^{2}_{1}H + {}^{3}_{1}H \longrightarrow Q + {}^{1}_{0}n$

   Find the atomic number and mass number of Q

   Ans: i) $[x = 141, y = 36]$ **ii)** $[Mass\ Number = 4, Atomic\ Number = 2]$

8. a) What is background radiation.

   b) i) Describe the structure and action of Geiger-Muller tube.

   ii) Describe the structure and action of diffusion cloud chamber.

   c) Draw diagrams to show tracks of each of the radioactive radiations appear in the Geiger-Muller tube.

THERMIONIC EMISSION:

This is the process by which electrons are emitted from a hot metal surface.

Production of electrons

Electrons can be produced by;

- Thermionic emission
- Photo electric emission

Kinetic theory explanation of thermionic emission:

When a metal surface is heated to a certain temperature, the free electrons at the surface gain kinetic energy and they overcome the forces of attraction by the nucleus hence escaping from the metal surface.

Applications of thermionic emission:

Thermionic emission can be applied in the following devices;

- Diode valves.
- Cathode ray tube.
- Cathode ray oscilloscope.
- X-ray tube.

PHOTO ELECTRIC EMISSION:

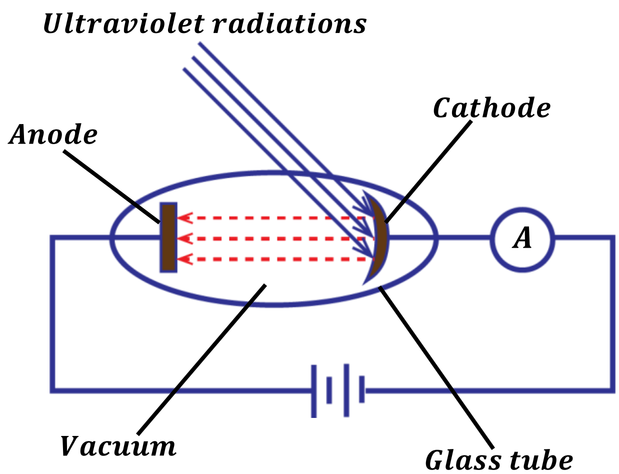
This is the process by which electrons are emitted from the metal surface when exposed to electromagnetic waves of sufficient frequency.

Photo electric emission occurs in phototubes [photoelectric cells].

The electrons emitted are referred to as photoelectrons and the electromagnetic waves used are called ultra violet radiations.

Photoelectric cell:

- Photoelectric cell is composed of the cathode coated with a photo-sensitive material and the anode enclosed in a vacuum tube.
- The glass tube is evacuated in order to avoid collision of cathode rays with air molecules which may lead to low current flowing due to loss in kinetic energy of cathode rays.



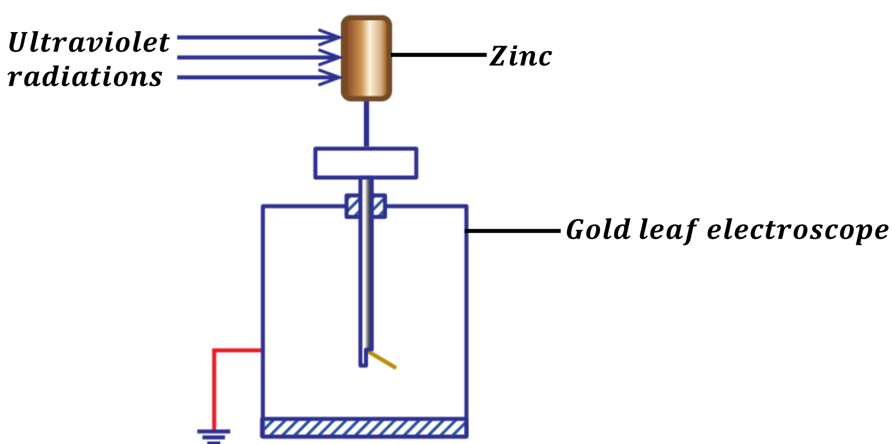
Mechanism of a photoelectric cell:

- Electromagnetic radiation is directed onto the cathode and supplies sufficient energy that causes the liberation of electrons.
- The electrons emitted are then attracted to the anode and the flow of electrons generates a current around the circuit and the ammeter deflects.
- The amount of the current produced is proportional to the intensity of the radiation.
- The stream of electrons flowing from the cathode to the anode is referred to as cathode rays.

NOTE:

If a gas is introduced into the tube, the current decreases slowly because the gas particles collide with the electrons, hence reducing the number of electrons reaching the anode.

EXPERIMENT TO DEMONSTRATE PHOTOELECTRIC EFFECT



When Ultra violet light is incident on a clean zinc plate placed on the cap of a gold leaf electroscope:

- If the ***electroscope is negatively charged***, the leaf divergence slowly decreases indicating that it is losing charge. This is because since radiations fall on a zinc plate, electrons are emitted from leaving it with no electrons. So this makes the electrons to move from the leaf and gold plate to the zinc to replace the lost electrons.
- If the ***electroscope is positively charged***, there is no change in divergence of the leaf. This is because the emitted electrons after ionization in air are attracted back by the positively charged zinc hence no loss of charge.

Conclusion:

The Zinc plate emits photoelectrons when ultra violet radiation falls on it.

Note: Radio waves can't be used because they don't have sufficient energy to emit electrons from zinc.

Applications of photoelectric effect:

Photoelectric effect is applied in:

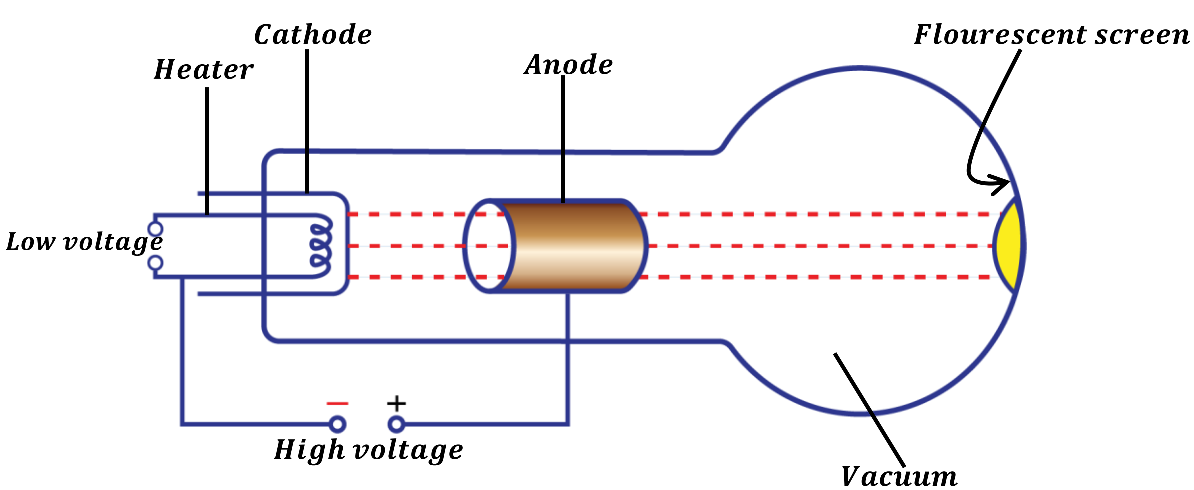
1) Burglar alarms.
2) Automatic lighting systems
3) In solar calculators.
4) Television cameras.
5) Automatic door system.
6) Sound track on a film.

CATHODE RAYS:

These are streams of fast-moving electrons.

They are produced from the cathode by thermionic emission. Cathode rays carry energy since they possess speed.

Production of cathode rays:



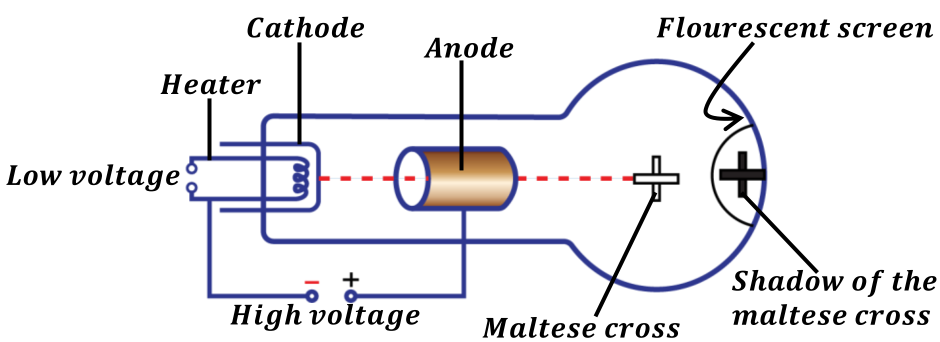
- The cathode is heated by a low voltage applied across the heater.
- The cathode then emits electrons by thermionic emission.
- The emitted electrons are then accelerated by a high voltage applied between the heater and the anode so that they move with a very high speed hence forming <u>cathode rays</u>.
- Some of the electrons (cathode rays) pass through the anode and a parallel beam of electrons is obtained which is received as spot on the fluorescent screen.

Note: The tube is evacuated to prevent cathode rays from colliding with air particles hence free movement of cathode rays.

<u>Properties of cathode rays</u>:

- They travel in straight lines.
- They are negatively charged since they are electrons.
- They produce X-rays when stopped by a heavy metal.
- They are deflected by magnetic fields i.e. towards the north pole.
- They are deflected by electric fields i.e. towards positive plate.
- They possess momentum and kinetic energy.
- They cause fluorescence when they strike matter i.e. they cause other materials to give off light.
- They ionize air and gas molecules.

<u>Experiment to show that cathode rays travel in straight line (Thermionic tube).</u>



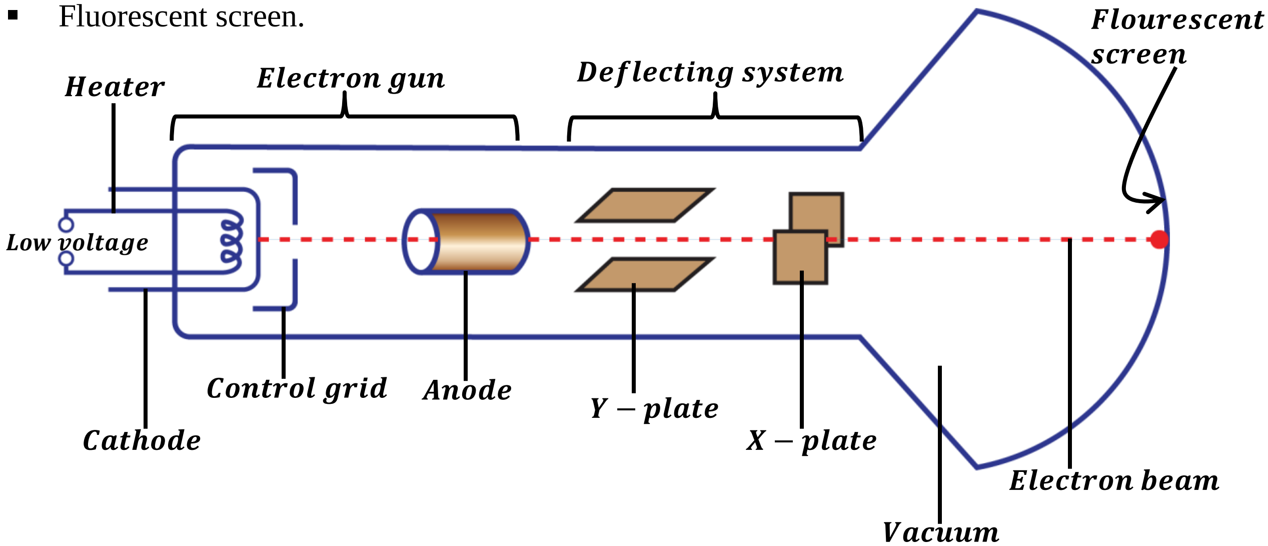
When cathode rays are directed towards the Maltese cross in a cathode ray tube.
A shadow of the cross is formed on the fluorescent screen. The formation of the shadow verifies that cathode rays travels in a straight line.

<u>Applications of cathode rays</u>:

Cathode rays are applied in the following devices;

- Cathode ray oscilloscope.
- X – ray tube.
- Diode.

Cathode Ray Oscilloscope [C.R.O]:
It is an instrument used to study current and voltage wave forms.
It has three main parts and these are
- Electron gun.
- Deflecting system.
- Fluorescent screen.



Functions of the parts:

(a) Electron gun:
It consists of a heater, cathode, grid and Anode.
(i) The heater: This heats the cathode electrically.
(ii) The cathode: It emits electrons by thermionic emission i.e. when heated electrically by the heater.
(iii) The control grid: It controls the brightness of the spot on the screen by controlling the number of electrons reaching the anode and screen.
(iv) The anode: It is used to accelerate the electrons produced by the cathode.

(b) Deflecting system:
It consists of the X – plates and Y – plates.
The Y – plates deflect the beam of electrons vertically.
The X – plates deflect the beam of electrons horizontally.

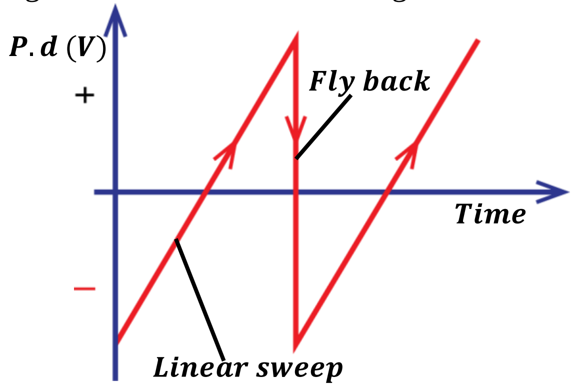
(c) Fluorescent screen:
This is where the bright spot of electrons is formed.

NOTE:
- The inner walls of the cathode ray oscilloscope are coated with graphite to trap stray electrons emitted from the screen.
- The cathode ray oscilloscope is evacuated to minimize loss of energy of electrons due to collision with air molecules.

(d) Time base:

This is a special circuit that generates p.d which rises steadily to a certain value and falls rapidly to zero. It is connected across the X-plates.

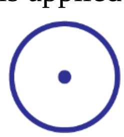
The time base is used to generate a saw-toothed voltage.



<u>Note</u>:

The time base is connected to the X – plates and causes the spot to move from left to right which is called **<u>linear sweep</u>** and the spot returns to the left before it starts the next sweep which is called **<u>fly back</u>**.

<u>Wave forms on C.R.O screen.</u>

(i) No A.C voltage on the Y-plates and time base on 	(ii) A.C voltage on the Y-plates and time base off 
(iii) A.C voltage on the Y-plates and time base on 	(iv) D.C voltage on the Y-plates only and time base off 
(v) No D.C voltage on the Y-plates and time base on 	(vi) D.C voltage on the Y-plates and time base on 
(vii) No potential difference is applied to the Y-plates and time base off 	

USES OF C.R.O:

- It is used to measure potential difference.
- It is used to study wave forms.
- It is used to measure the frequency of the wave.
- It is used to measure the wave length of the wave.
- It is used to measure phase difference between two voltages.
- It is used as a timing device.
- It is used to measure the peak value of alternating and direct current.
- It is used to display pictures in TV sets.

Advantages of C.R.O over ordinary ammeter or voltmeter:

- It has infinite resistance therefore draws no current from the circuit.
- It is not affected by high voltages/currents.
- It measures both alternating and direct voltages.
- It is very accurate.
- It has no coil to burn out.
- It responds very fast.

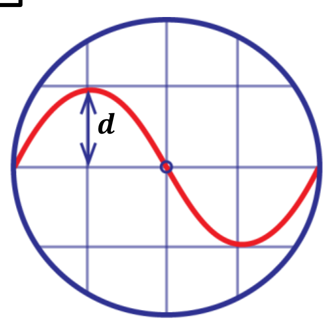
Disadvantages of C.R.O over ordinary ammeter or voltmeter:

- It is not portable.
- It requires skilled personnel.
- It is expensive.
- It takes a lot of time to measure voltages.
- It does not give direct readings.

MEASURING VOLTAGE ON A C.R.O SCREEN

$$Voltage = [voltage\ gain/cm] \times [amplitude(vertical\ deflection)]$$

$$\boxed{\boldsymbol{V = V_g d}}$$



Also, root mean square voltage is given by;

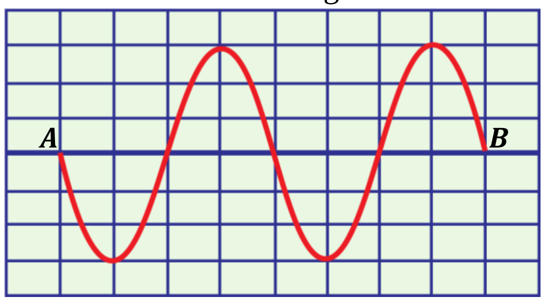
$$\boldsymbol{V_{r.m.s} = \frac{V}{\sqrt{2}}}$$

Also, period;

$$\boldsymbol{T = [time\ base\ setting/frequency\ gain] \times [wavelengthlength\ \ for\ cycle]}$$

Examples:

1. A cathode oscilloscope CRO with time base switched on is connected across a power supply. The wave form shown in figure below is obtained. Length between each line is $1cm$.



a) Identify the type of voltage generated by the power supply.
b) Find the maximum voltage (amplitude of voltage) generated if the voltage gain is $5Vcm^{-1}$.
c) Calculate the frequency of the power source, If the time base setting on the C.R.O is $5 \times 10^{-3} scm^{-1}$.

Solutions:

(a) *Alternating current voltage*

(b)

$From\ the\ graph, amplitude = 3cm$

$V = voltage\ gain \times amplitude$

$V = 5 \times 3$

$\boldsymbol{V = 15V}$

(c)

$\boldsymbol{Period, T = \underset{setting}{Time\ base} \times wavelength}$

$wavelength = 4cm$

$time\ base\ setting = 5 \times 10^{-3} scm^{-1}$

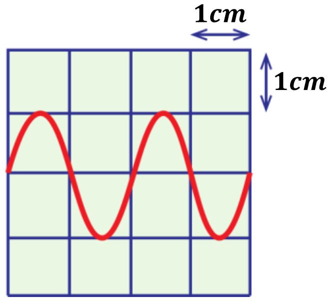
$T = 5 \times 10^{-3} \times 4$

$T = 0.02s$

$f = \frac{1}{T} \quad \Rightarrow f = \frac{1}{0.02}$

$\boldsymbol{f = 50Hz}$

2. A CRO with the time base switched on is connected across a power supply. The wave form shown below is obtained. Distance between each line is $1cm$.



a) Identify the type of voltage generated by the power supply.
An alternating current voltage

b) Find the maximum value of the voltage generated if he voltage gain is $10Vcm^{-1}$.

$\boldsymbol{Amplitude\ or\ vertical\ deflection, d = 1\ cm}$

$\boldsymbol{V_{max} = Voltage\ gain/cm \times amplitude}$

$\boldsymbol{V = V_g d}$

$\boldsymbol{V = 10\ Vcm^{-1} \times 1\ cm = 10\ V}$

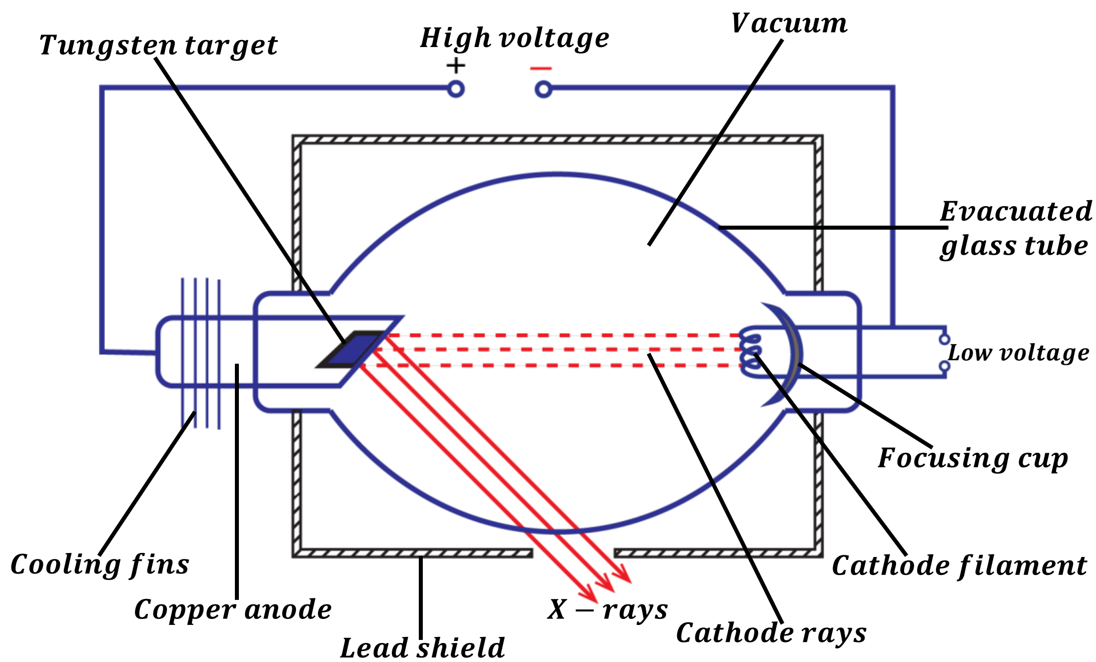
c) Calculate the frequency of the power source if the time base setting on the CRO is $10.0 \times 10^{-3} scm^{-1}$.

$$\boldsymbol{Period, T = time\ base\ setting \times wavelength}$$
$$\boldsymbol{T = 10.0 \times 10^{-3} \times 1.5}$$
$$\boldsymbol{T = 0.015s}$$
$$\boldsymbol{f = \frac{1}{T}, \quad f = \frac{1}{0.015}}$$
$$\boldsymbol{f = 66.7Hz}$$

X-RAYS:

These are electromagnetic waves of short wavelength which are produced when cathode rays are stopped by a metal surface.

Production of X-Rays (X-Ray Tube):



Mode of operation:

- The cathode is heated by a low voltage and electrons are emitted from it by thermionic emission.
- The electrons are accelerated to the anode by the high voltage supply connected across the cathode and anode.
- And on reaching the metal target, 99% of the kinetic energy of electrons is converted into heat and 1% of kinetic energy of elections is converted into X-rays.
- The heat generated at the target is cooled down by means of cooling fins and then conducted.
- The X – ray tube is evacuated to prevent cathode rays from colliding with air molecules hence allowing free movement of electrons in the tube.

NOTE:
- ✓ The tungsten is used because it has a high melting point that can withstand the heat generated when electrons hit the target.
- ✓ The curvature of the cathode helps to focus emitted electrons onto the anode.
- ✓ The cooling fins are painted black to radiate the heat quickly.
- ✓ The lead shield absorbs stray X-rays

In the X – ray tube the following energy changes take place;
Electrical energy → **Heat energy** → **Kinetic energy** → **Electromagnetic energy**

PROPERTIES OF X – RAYS:
- They carry no charge.
- They are not deflected by both magnetic and electric fields.
- They readily penetrate matter. Penetration is least with materials of high density.
- They cause ionization of gases.
- They affect photographic films.
- They travel in a straight line.
- They travel at a speed of light.
- They undergo reflection, refraction and diffraction by atoms.
- They are electromagnetic waves of very short wave length.
- They cause fluorescence when they strike matter.
- They can produce photoelectric emission

Intensity of X- Rays (Quantity):
Intensity is the strength or power of X-rays.
The intensity of X-rays in an X-ray tube is proportional to the number of electrons reaching the target. The number of electrons produced is determined by the filament current. Therefore, the higher the filament current the higher the intensity of the X-rays since more electrons are emitted with high filament current.

Question: Describe how the intensity of X-rays can be improved/increased.
This is done by increasing the filament current which increase the temperature of the filament cathode thus increasing the number of electrons emitted thermionically. Hence the number of electrons hitting the target will increase.

Penetration power of X-Rays (Quality):
Penetration power is the ability of X-rays to enter matter.
The penetration power of X-rays depends on the kinetic energy of electrons reaching the target.
The penetration power of X-rays is determined by the high potential difference across the X-ray tube.
The higher the accelerating voltage the faster the electrons produced and the greater the kinetic energy of electrons hence the higher the penetration power of X-rays produced.

Question: Describe how the penetrating power of X-rays is increased.
This is done by increasing the accelerating voltage between the anode and cathode which makes electrons to move with a faster speed hence increasing the kinetic energy. This increases the penetrating power of X-rays.

TYPES OF X-RAYS

There are two types namely;

- Hard X-rays
- Soft X-rays.

SOFT X-RAYS:

These are X-rays of low penetrating power.

Properties of soft X-rays:

- They produced by low accelerating voltages.
- They have a low penetration power.
- They have low kinetic energy.
- They have a long wave length.
- They have a low frequency

HARD X-RAYS:

These are X-rays of high penetrating power.

Properties of hard X-rays:

- They produced by high accelerating voltages
- They have a high penetration power.
- They have high kinetic energy.
- They have a short wave length.

Differences between soft X-rays and hard X-rays

HARD X-RAYS	SOFT X-RAYS
• Produced by a high voltage. • They have a shorter wavelength. • They are more penetrative. • They have a high frequency. • They have high kinetic energy.	• Produced by low voltage. • They have a longer wavelength. • They are less penetrative. • They have a low frequency. • They have low kinetic energy.

SIMILARITIES BETWEEN X-RAYS AND GAMMA RAYS

- They are both electromagnetic waves.
- They both pass through a vacuum.
- Both are not deflected in both electric and magnetic fields.
- They both have no charge.
- They both travel with a speed of light.
- They are both transverse waves.

USES OF X-RAYS:

Medical uses:

- They are used to investigate the broken bones in X – ray photography.
- They are used to treat cancer cells.
- They used to detect the complicated organs of the body.
- They are used to detect tuberculosis of the lungs.

- They are used to diagnose stomach ulcers.

How x-rays are used to locate broken parts of a bone.

❖ ***When X-rays are passed through the body onto the photographic plate or film,***
The bones which are composed of a much denser material than the flesh absorb most of the X-rays and appear white on the photographic plate or film.
The flesh which is composed of less dense material allows most of the X-rays to pass through it hence darkening the photographic film or plate.
These shadows are studied in order to locate the broken part.

Industrial uses:

- They are used to detect cracks in metal castings and welded joints.
- They are used to study the structure of crystals [crystallography].
- They are used to detect faults in motor tyres.
- They are used to detect defects in paints.

Dangers of X-rays:

- They destroy living cells in the body.
- They damage blood cells and eye sight.
- They cause genetic changes [mutation].
- They skin burns due to their greater penetration power.
- They cause cancer after excessive exposure.

Safety precautions taken when using X-rays:

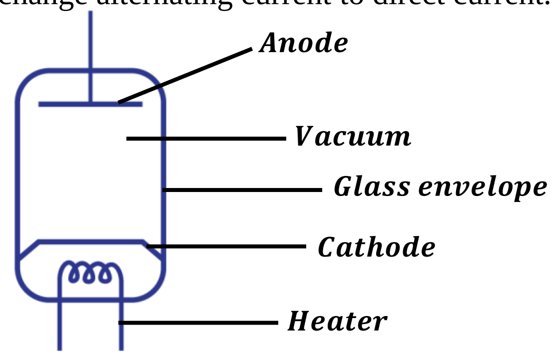
- Avoid unnecessary exposure to X-rays.
- The X-ray apparatus should be shielded using thick lead.
- The person should wear protective clothing made of thick lead.
- Keep large distance between X-ray source and people.
- Soft X-rays should always be used on human tissues

THE DIODE:

This is an electrical device that conducts electricity in one direction only.
There are two types of diodes and these are

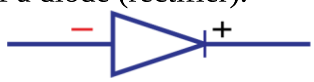
- Semi-conductor diode.
- Vacuum diode.

Thermionic diode (vacuum diode):
This is a device used to change alternating current to direct current.



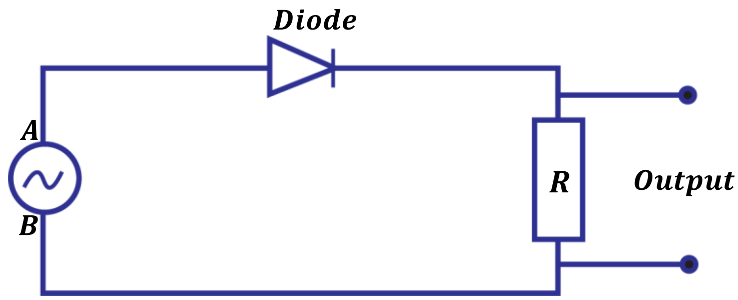
It consists of the following;
- The heater which heats the cathode electrically.
- The cathode which emits electrons thermionically.
- The anode which accelerates electrons emitted from the heated cathode.
- Evacuated glass envelope helps to prevent electrons from colliding with air molecules.

RECTIFICATION:
This is a process of changing alternating current to direct current.
This is done by use of a diode (rectifier).



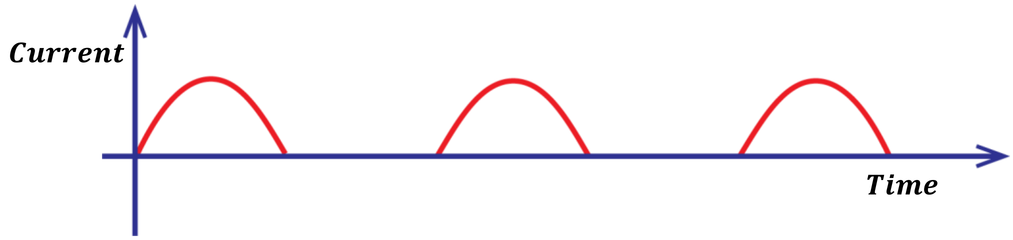
The arrow head in the diode or rectifier shows the direction of flow of current.
There are two types of rectification and these are;
- Half wave rectification
- Full wave rectification

Half wave rectification:

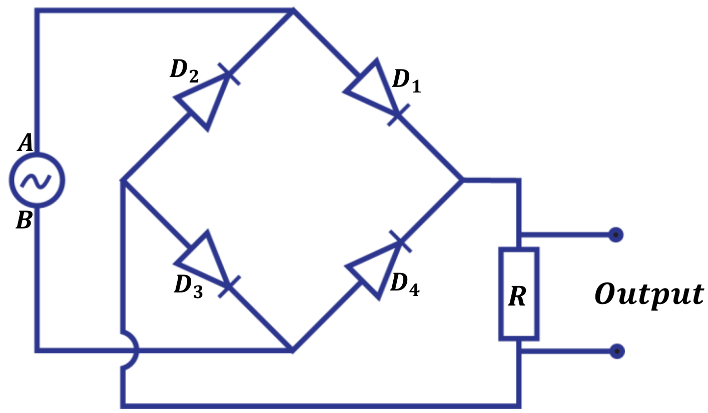


- During the first half of the cycle when A is positive and B is negative, the diode conducts current and it flows through the resistor R.
- During the next half cycle when B is positive and A is negative, the diode doesn't conduct current to flow through the resistor R.
- Hence current flows through R during only one half of the cycle when A is positive with respect to B.

The graph of current/voltage against time for half wave is as shown below.

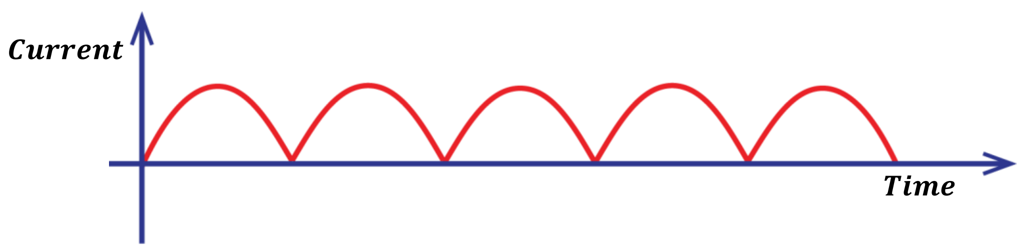


Full wave rectification:



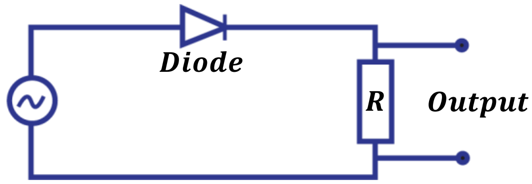
- During the first half cycle when A is positive and B is negative, diodes $D_1$and D_3 conduct current and it flows though the resistor R. Diode D_3 takes back current to the source. Diodes D_2 and D_4 do not conduct current.
- During the next half cycle when B is positive and A is negative, diodes D_2 and D_4 conduct current and it flows through the resistor R. Diode D_4 takes back current to the source. Diodes D_1 and D_3 do not conduct current.
- Hence current flows through R during both cycles and therefore both cycles are rectified giving a full wave rectification.

The graph of current/voltage against time for full wave rectification is as shown below.



EXERCISE:

1. a) What is a diode?
   (i) Draw a graph of current against p.d across the diode and explain the features of your graph.
   (ii) What is rectification?



   b) The diagram above shows a diode in a circuit that can be used to change a.c to d.c. Draw a graph for the variation of voltage against time.
   c) What is meant by the term photo electric emission?
   d) Give applications of photo cells
2. a) What are cathode rays
   b) Give the properties of cathode rays
   c) Draw a well labeled diagram of cathode ray oscilloscope (C.R.O) and give the function of each part.
3. a) i) Draw a well labeled diagram of an X-ray tube and describe how X-rays are produced.
   b) State the effect on X-rays produce when
   i) The filament current is increased   ii) The anode is made more positive
   c) Explain how the intensity and penetrating power of X-rays in an X-ray tube may be varied.
4. a) i) State and explain what happens when X-rays are passed above the cap of a positively charged gold leaf electroscope.
   b) Would your observation and explanation in (a) (i) above be different if the gold leaf electroscope is negatively charged.
   c) Briefly explain how X-rays may be used to locate the broken part of a bone.
   d) State and explain what happens when X-rays are directed into a metal block like that of lead.

EXAMINATION QUESTIONS:

1. a) What is meant by the following;
   (i) Radioactivity
   (ii) Half-life

   b) The following figures were obtained from the reading of a rate metre for the alpha particle emission from Thoron – 220.

Time(s)	0	20	40	60	80	100	120	140
Average Counts	96	72	55	45	36	26	20	15

   Plot a suitable graph from the readings and obtain the half-life of Thoron – 220
   Ans: [52 $\boldsymbol{seconds}$]

   c) i) Distinguish between soft x-rays and hard x-rays
   ii) Mention two uses of x-rays and briefly describe how they are applied.

2. a) Define the following terms
   i) Atomic number
   ii) Mass number

   b) When lithium is bombarded by Neutrons, a nuclear reaction occurs which is represented by the following reaction.

$$^{6}_{3}Li + ^{1}_{0}n \longrightarrow ^{3}_{1}H + P$$

   Complete the equation and name P

   c) i) Describe the application of radioactivity in determining the age of foils.
   (ii) Give two harmful effects of radioactivity.

   d) The half-life of Uranium is 24 $days$. Calculate the mass of Uranium which remains after 120 $days$ if the initial mass is 64g
   Ans: [2$\boldsymbol{g}$]

   e) State three differences between alpha particles and gamma rays

3. a) Draw a labeled diagram of x-ray tube.

   b) i) Using the diagram in (a) above, explain how x-rays are produced
   ii) What adjustments will you make while using the x-ray tube to obtain hard x-rays instead of soft x-rays?

   c) i) Explain the use of a cooling system in an x-ray tube
   ii) What special property has a metal target in the x-ray tube and why
   iii) Why are x-rays used in study of crystals?
   iv) If x-rays have wave lengths ranging from $10^{-8}m$ and $10^{-10}m$. What is the frequency of the hardest x-rays that can be obtained?
   Ans: [$\boldsymbol{3 \times 10^{18} Hz}$]

4. a) Give two methods of producing electrons from the metal surface.

   b) State the effect of each of the following on a fine beam of electrons
   i) Electric field
   ii) Magnetic field

   c) i) Explain briefly how x-rays are produced (diagram not necessary)
   ii) Distinguish between soft x-rays and hard x-rays
   iii) What precaution should be taken in order to minimize x-rays health hazards

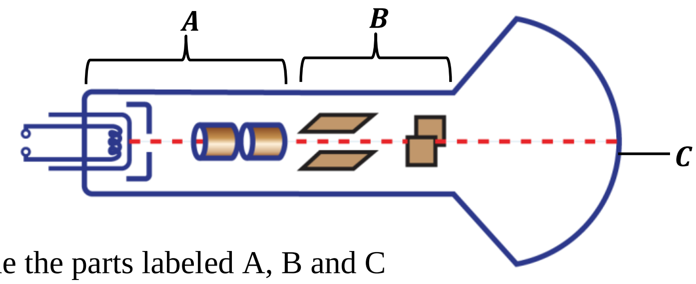
5. a) Define radioactivity
   b) i) Name any two particles emitted by radioactive nuclides
   ii) State the three differences between the two particles named in (b) (i) above
   c) The table below gives the count produced by a radioactive isotope at different times during an experiment

Time ($hour$)	0.0	1.0	1.8	2.5	3.0	3.8	4.5	5.5
Counts rate (min^{-1})	1816	1376	1096	896	776	616	516	416

   i) Given that a back-ground count of 16 counts per minute was recorded throughout the experiment, plot a suitable graph and use it to determine the half-life of the isotope
   ii) What is the count rate after 9.6 hours?

Ans: i) [$2.6\ hours$] **ii) [$125\ per\ minute$]**

6. The diagram in the figure below shows the main parts of a cathode ray oscilloscope (C.R.O)



   a) i) Name the parts labeled A, B and C
   ii) Why is a C.R.O evacuated?
   b) i) Describe briefly the principle of operation of C.R.O
   ii) How is the bright spot formed on the screen of a C.R.O?
   c) Use diagrams to show what is observed on the screen of a C.R.O when
   i) The C.R.O is switched on and no signal is applied on the Y-plates
   ii) The time base is switched on and no signal is applied to the Y-plates
   iii) An alternating signal is applied to the Y-plates while the time base is switched off
   d) Give two uses of C.R.O
7. a) i) State the necessary conditions for production of x-rays
   ii) Distinguish between hard x-rays and soft x-rays
   b) i) Draw a labeled diagram of an x-ray tube
   ii) Describe how the penetration power of the x-rays produced by the tube may be adjusted
   iii) Mention two applications of x-rays
   c) What is meant by the following?
   i) Radioactivity
   ii) Half-life
   d) A radioactive substance is found to have a half-life of 5 days. If after 15 days, 125g of it is remaining, what amount was present at the beginning?

Ans: [$1000g$]

8. a) What are x-rays
   b) With the aid of a labeled diagram, describe the structure and operation of x-ray tube
   c) Explain briefly how each of the following can be increased in an x-ray tube
   i) Intensity of x-rays
   ii) Penetrating power of x-rays

d) State four ways in which x-rays are similar to gamma rays
e) Give two biological uses of x-rays

9. a) i) Distinguish between nuclear fission and nuclear fusion
ii) State one example where nuclear fusion occurs naturally
b) State one use of nuclear fission
c) The following nuclear reaction takes place when a neutron bombards a sulphur atom

$$^{34}_{6}S + ^{1}_{0}n \longrightarrow ^{a}_{b}Y$$

i) Describe the composition of the nuclide, Y formed
ii) The nuclide, Y decays by emission of an $\alpha - particle$ and a $\gamma - ray$. Find the changes in mass number and atomic number of the nuclide, Y
iii) State two properties of $\alpha - particles$
d) The half-life of the isotope, Cobalt-60, is 5 years. What fraction of the isotope remains after 15 years?

Ans: [$\frac{1}{8}$]

e) State i) One medical use of radioisotopes
ii) Two ways of minimizing the hazardous effects of radiation from radioactive materials

10. a) Define half-life of a radioactive substance
b) The mass of a radioactive substance decays to $\frac{1}{16}^{th}$ of its original mass after 16 days. What is
i) its half-life
ii) Fraction of the original mass will have decayed after 20 days

Ans: i) **[4 *days*]**

c)

$$^{232}_{90}X \xrightarrow[A]{} ^{228}_{88}Y \xrightarrow[B]{} ^{228}_{89}Z \xrightarrow[C]{} ^{228}_{89}Z$$

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) Name two health hazards of radioactivity
d) What is the difference between nuclear fission and nuclear fusion?

11. a) Define the following terms
i) Atomic number   ii) Mass number   iii) Isotopes
b) A radioactive nucleus decays by emission of alpha particles
i) What is an alpha particle?
ii) What changes occur in mass number and atomic number when an alpha particle is emitted?
iii) State any three differences between alpha particles and beta particles
c) The table shows the count rates of a certain radioactive material

Time ($hour$)	0	1	3	4	7	9
Counts rate (min^{-1})	6400	5380	3810	2700	1910	1350

Plot a suitable graph and use it to find half-life of the material.

Ans: [3.2 *hours*]

12. a) What is meant by the terms;
    i) Isotopes
    ii) Atomic number
  b) i) Name and state the nature of emissions from radioactive nuclides
    ii) What effect does each of the emissions have on the parent nuclide?
  c) A radioactive sample has a half-life of 3×10^3 years
    i) What does the statement half-life of 3×10^3 years mean?
    ii) How long does it take for three-quarters of the sample to decay?

  Ans: ii) $[6.0 \times 10^3 years]$

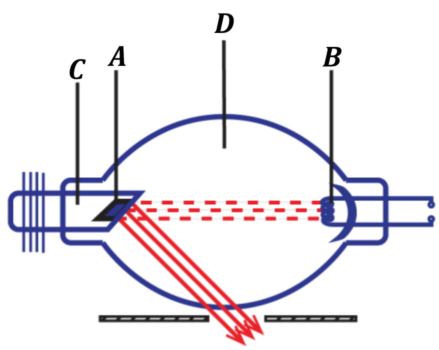
  d) Give two uses of radioactivity.

13. a) A radioactive nuclide decays by emission of two alpha particles and two beta particles to nuclide, Y
    i) What is meant by radioactive nuclide?
    ii) Give three differences between alpha and beta alpha particles
    iii) State atomic number and mass number of Y
  b) What precautions would have to be taken when handling radioactive materials?
  c) A certain radioactive material contains 2.7×10^{24} atoms. How many atoms will have decayed after 32000 years if the half- life of the material is 800years?

  Ans: $[2.53125 \times 10^{24}\ atoms]$

  d) Explain briefly one industrial application of radioactivity.

14. The figure below shows the main parts of an x-ray tube



  a) Name the parts labeled A, B, C and D
  b) List in order the energy changes which occur in the x-ray tube
  c) Describe one industrial use of x-rays
  d) i) What is meant by the half-life of a radioactive material
    ii) The activity of a radioactive source decreases from 4000 counts per minute to 250 counts per minute in 40 minutes. What is the half-life of the source?
    iii) A carbon source of half-life 6 days initially contains 8×10^6 atoms. Calculate the time taken for 7.75×10^6 atoms to decay.

  Ans: ii) $[10\ minutes]$ iii) $[30\ days]$

15. a) Define the following terms as used in nuclear reactions
    i) Fusion
    ii) Fission
    iii) Activity
  b) Describe a simple model of an atom

c) Uranium, U has a mass number of 238 and atomic number of 92. It undergoes radioactive decay by emission of an alpha particle to form element X.
   i) Write down a nuclear equation reaction that takes place
   ii) State the mass number and atomic number of X

Ans: ii) [$\boldsymbol{Mass\ Number\ =\ 234, Atomic\ Number\ =\ 90}$]

d) i) What is meant by half-life of radioactive substance
   ii) The count rate of a radioactive isotope fall from 600 counts per second to 75 counts per second in 75 minutes. Calculate the half-life of the radioactive isotope.

Ans: ii) [$\boldsymbol{25\ minutes}$]

16. a) A radioactive nuclide $^{236}_{92}U$ decays by emission of two alpha particles and two beta particles to a nuclide Y
   i) What is meant by a radioactive nuclide?
   ii) State the mass number and atomic number of Y
   iii) Give four differences between alpha and beta particles

Ans: ii) [$\boldsymbol{Mass\ Number\ =\ 234, Atomic\ Number\ =\ 90}$]

b) State four precautions that would have to be taken when handling radioactive materials

c) A certain mass of radioactive material contains 2.4×10^{12} radioactive atoms. How many atoms will have decayed after 3200 years if the half-life of the material is 800 years?

Ans: [$\boldsymbol{2.25 \times 10^{12}\ atoms}$]

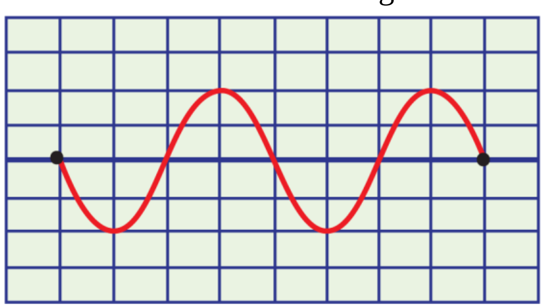
d) Explain briefly one industrial application of radioactivity

e) Briefly describe how full wave rectification can be achieved

17. a) i) What is meant by cathode rays
   ii) With the aid of a labeled diagram, describe how cathode rays are produced by thermionic effect

b) With reference to the cathode ray oscilloscope, describe
   i) The function of the time base
   ii) How the brightness is regulated

c) A cathode ray oscilloscope (C.R.O) with time base switched on is connected across a power supply. The waveform shown in the figure below is obtained



The distance between the lines is 1cm
   i) Identify the voltage generated by the power supply
   ii) Find the amplitude of the voltage generated if the voltage gain is $5Vcm^{-1}$
   iii) Calculate the frequency of the power source if the time base setting on the C.R.O is $5.0 \times 10^{-3} scm^{-1}$

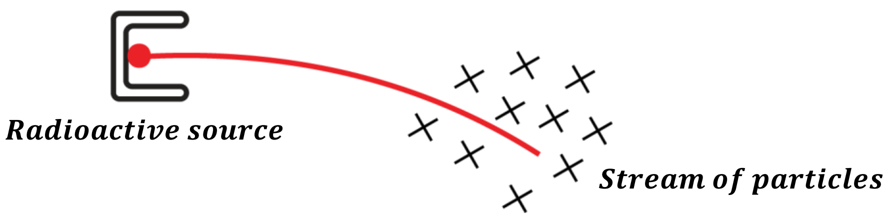
Ans: i) [$\boldsymbol{10V}$] ii) [$\boldsymbol{50Hz}$]

18. a) Describe a simple model of the atom
b) Define the following
i) Isotopes of an element
ii) Atomic number
c) State two differences between an alpha particle and a beta particle
d) i) What is meant by nuclear fission and nuclear fusion
ii) Give one example of where each one occurs
e) The half-life of radioactive substance is 24 days. Calculate the mass of the substance which has decayed after 72 days if the original mass is $0.64g$.

Ans: [$0.56g$]

19. a) Define the following terms
i) Atomic number
ii) Mass number
b) A radioactive nuclide $^{42}_{19}Y$ decays by emission of both alpha & gamma radiations to a nuclide X
i) Write a balanced equation for the nuclear reaction
ii) Give three differences between beta and alpha particles
c) State conditions required for each of the following to occur
i) Fission
ii) Fusion

20. a) i) Name the particles emitted by radioactive nuclides
ii) Give two properties common to the particles named in (i) above
b) A stream of particles from a radioactive source passes through a magnetic field directed into the plane of the paper as show below



i) Identify the particles in the stream
ii) Sketch a diagram to show the path of the particles in an electric field