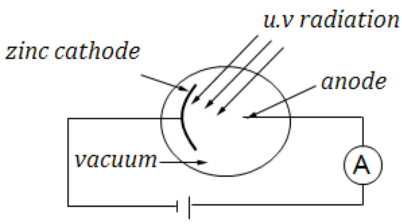
S.4 ATOMIC PHYSICS

PRODUCTION OF ELECTRONS

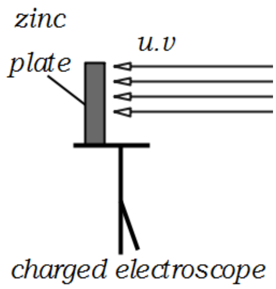
Metals contain loosely attached electrons to their atoms. These electrons can easily escape/be emitted when they gain sufficient energy.
Methods of electron production include photo electric emission and thermionic emission.

1. Photo electric emission: this is the production of electrons when suitable radiation such as ultraviolet (u.v) falls on metal surfaces.



As electrons are produced when u.v falls on cathode, they are attracted to the anode and current flows through the circuit.
Note:
(a) A bright/intense/strong radiation produces more electrons and thus more current flows.
(b) A small node is used to produce a stronger electric field around it.
(c) A beam of longer wavelength such as radio waves has less energy hence no electrons are emitted.
(d) A photocell is used in burglar alarms which are operated by infra-red radiations.

Question:
Explain what is observed on the leaf of a electroscope if
(i) electroscope is positively charged
(ii) electroscope is negatively charged
(iii) a beam of radio waves is used instead.



(i) No effect on the leaf. Photoelectrons from zinc are attracted back on the zinc by strong attraction force and neutralize the positive ions on the zinc, without causing a change on charges on the leaf.
(ii) Leaf collapses. Photoelectrons from zinc are repelled and positive ions on the zinc neutralize some negative charges on the leaf.
(iii) No effect on the leaf. Radio waves have higher wavelength hence low energy. This energy is insufficient to cause emission of electrons.

2. Thermionic emission is the production of electrons from metal surfaces when they are heated at higher temperatures.

CATHODE RAYS

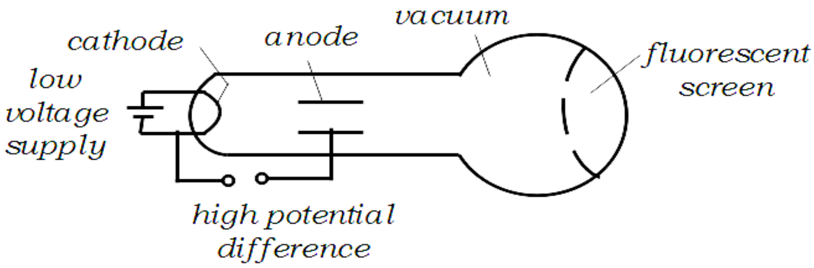
These are streams of fast moving electrons.

Properties of cathode rays

- They are negatively charged
- They are deflected by both electric and magnetic fields
- They travel in straight lines
- They cause fluorescence with some metals
- They have low penetrating power and low ionising power

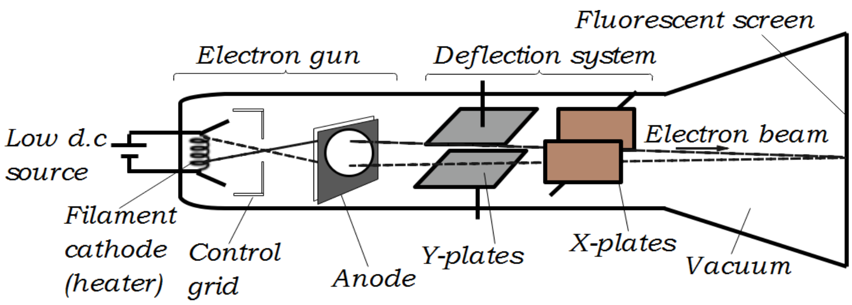
Production of cathode rays in a cathode ray tube

They are produced when a metal is electrically heated at low voltage and a high p.d applied between the electrodes.



Explanation: *Low voltage supply heats the cathode and electrons are thermionically emitted. The high potential difference (p.d) between cathode and anode accelerates electrons to high speeds to the fluorescent screen. These electrons are called cathode rays.*

The cathode ray oscilloscope (C.R.O)



Functions of the parts

1. Grid: this controls brightness of the spot on the screen by controlling the number of electrons reaching the screen.
2. Anode: this accelerates and focuses the electrons on the screen
3. Deflecting system: this deflects the beam either vertically or horizontally when a p.d is applied across it.
4. Y – Plates: these deflect the electron beam vertically on the screen. Any signal to be studied is connected to these plates
5. X – Plates: these deflect the electron beam horizontally on the screen when the time-base is switched on.

   The time – base circuit automatically applies a p.d across x – plates so that the spot moves across and back on the screen.
6. Fluorescent screen: this provides a background where patterns to be studied are formed.

Note: The C.R.O is evacuated since air molecules which are massive compared to electrons would obstruct motion of electrons to the anode if not removed.

Question: Explain what happens to the brightness of the spot when

(i) filament current is increased

(ii) anode current is reduced

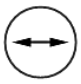
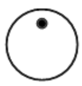
Increasing filament current increases the temperature hence number of electrons emitted from the filament. The brightness of the spot increases when more electrons reach the screen.

Reducing anode current reduces the p.d between anode and cathode hence reducing velocity of emitted electrons. The brightness of the spot decreases when few electrons reach the screen.

Uses of C.R.O

- It is used as a voltmeter to measure voltage
- It is used to determine the frequency of an alternating current (a.c)
- It is used to study wave patterns
- It is used as a timing device in radar system at airports and navigation ships.

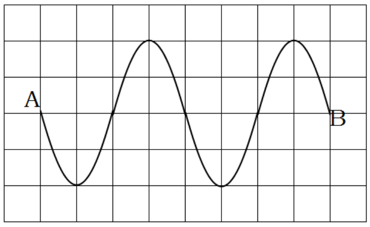
Wave pattern formed in a CRT

 *both X and Y plates off*	A spot is formed when no p.d is applied to both x – plates and y – plates (i.e. when they are switched off)
 *X plates on, Y plates off*	A horizontal line is obtained when y – plates are off and the time– base is applied on x – plates are switched on.
 *a.c on Y plates, X plates off*	A vertical line is obtained when a.c is applied to y – plates and time - base is switched off.
 *d.c on Y plates, X plates off*	A vertical spot is obtained when a d.c is applied on y – plates with a positive terminal connected on plate Y_1.
 *a.c on Y plates, X plates on*	A wave pattern is obtained when a.c voltage is connected to y – plates and time – base is switched on.

The CRO is applied in T – V tubes, Monitors of computers e.t.c. **2002/2 no.8**

Calculation of voltage, time and frequency

1. A cathode ray oscilloscope with time-base switched on is connected across a power supply. The waveform shown in the figure below is obtained.



Distance between each line is 1 cm.

(i) Identify the type of the voltage generated by the power supply.

(ii) Find the amplitude of the voltage generated if the voltage gain is $5\ Vm^{-1}$.

(iii) Calculate the peak to peak voltage.

(iv) Calculate the frequency of the power source if the time-base setting on the CRO is $5 \times 10^{-3}\ s\ cm^{-1}$

(i) It is an alternating current voltage

(ii) $Amplitude = 2 \times 1\ cm = 2\ cm = 0.02\ m,$

$But\ for\ 1\ m \rightarrow 5\ V\ \ thus\ \ 0.02\ m \rightarrow 5 \times 0.02 = 0.1\ V$

$Amplitude\ of\ the\ voltage = 0.1\ V$

(iii) $Peak\ to\ peak\ distance = 4 \times 1\ cm = 4\ cm = 0.04\ m$

$Peak\ to\ peak\ voltage = 0.04 \times 5\ V = 0.2\ V$

(iv) $In\ 1\ cycle\ distance\ covered = (4 \times 1\ cm) = 4\ cm$

$But\ 1\ cm \rightarrow 5 \times 10^{-3}\ s\ \ thus\ 4\ cm \rightarrow 4 \times 5 \times 10^{-3} = 0.02\ s,$

$Period\ T = 0.02\ s \qquad thus\ Frequency\ f = \frac{1}{T} = \frac{1}{0.02} = 50\ Hz$

2015/2 no.8(c)

X – RAYS

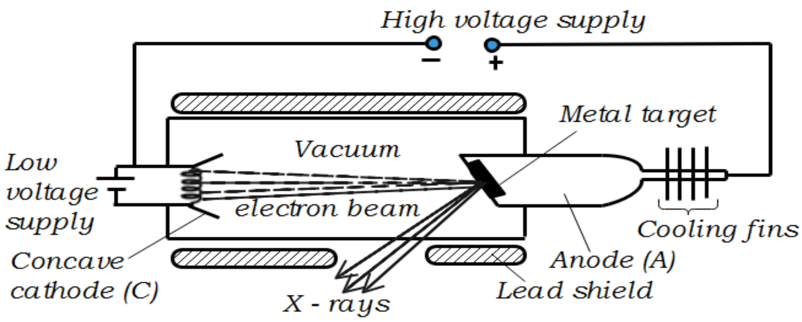
These are electromagnetic waves of short wavelength. They are produced when cathode rays collide with atoms of a metal target and electron transition takes place.

Properties of x – rays

They

- carry no charge
- high penetrating power than gamma rays
- highly affect a photographic paper
- are not deflected by both magnetic and electric fields
- travel in straight lines
- cause fluorescence with some metals
- have low ionising power
- have energy

The x –ray tube



Functions of the parts

1. Low voltage heats up the cathode to emit electrons.
2. Cathode; produces electrons when heated.
3. High voltage: this accelerates cathode rays to the target due to high p.d between the cathode and the anode.
4. Metal target: it is here that there are atoms with in which transitions occur, leading to production of x – rays.
5. Copper anode: too much heat produced at the target would ruin the machine. Copper being a good conductor of heat conducts heat quickly away to the fins.
6. Cooling fins: these conduct away the generated heat from the anode to the surroundings.

The X-ray machine is evacuated since air molecules which are massive compared to electrons would obstruct motion of electrons to the anode if not removed.
The few electrons that would reach the anode would be too weak to produce X-rays.

Note: The target is usually made of a metal such as tungsten with high melting point.

Energy changes in x – ray tube

Electrical energy → heat energy → kinetic energy → x – ray heat
Question: Describe briefly how x – rays are produced.
Cathode rays on collision with the metal target transfer their K.E to electrons in the atoms of the target. Atoms become excited electron transitions occur leading to production of x – rays.

Intensity of X-rays (quantity)

The intensity of X- rays in an X – ray tube is proportional to the number of electrons colliding with the target. The greater the heating current, the greater the number of electrons produced and hence more X – rays produced.

Penetration of X – rays (quality)

Penetration power of X – rays depends on the kinetic energy of the electrons striking the target. The higher the accelerating voltage, the faster the electrons produced. Faster electrons possess higher kinetic energy and shorter wavelength X – rays of greater penetration power are produced. Hence penetrating power of X – rays is determined by the accelerating Voltage across the tube.

Hard and soft X – rays

Hard X – rays have a high penetrating power. This is because they have very short wavelengths. They are produced when a high p.d is applied across the tube.
Soft X – rays are produced by electrons moving at relatively lower velocities than those produced by hard X – rays. They have less energy, longer wavelengths, hence less penetration power compared to hard X – rays.
Hard X – rays can penetrate flesh but are absorbed by bones. Soft X – rays are used to show malignant growths since they only penetrate soft flesh.
They are absorbed by such growths.

Differences between hard and soft x – rays

- Hard x – rays are produced when a high p.d is applied between anode and cathode while soft x – rays are produced when a low p.d is applied between anode and cathode
- Hard x – rays have short wavelength while soft x – rays have longer wavelength
- Hard x – rays have high penetrating power while soft x – rays have low penetrating power

Uses of x – rays

1. Medical:
- soft x – rays are used in taking pictures of fractured bones
- soft x – rays are used in destroying cancer cells
2. Industrial: They are used in locating faults in welded joints
3. They are used in studying molecular arrangements in crystalline materials i.e x – ray crystallography

Health hazards of x – rays

- They destroy living cells and stops them from multiplication
- They lead to hereditary defects and even death in children

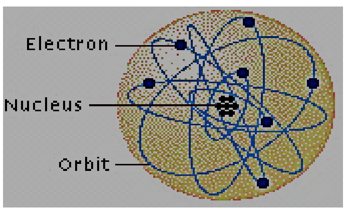
Safety precautions when in working with x – rays

- Avoid unnecessary exposure to x – rays
- Wear coats coated with lead
- Expose x – rays to only the affected parts
- Avoid exposure of x – rays to unborn babies and children
- Shorten the exposure time
- X – ray machines be kept in buildings with concrete walls

SIMPLE ATOMIC MODEL

An atom consists of

- central nucleus which contains neutrons and protons. The protons are positively charged and the neutrons have no charge.
- negatively charged electrons revolving round the nucleus in certain allowed orbitals/shells



The number of protons is always equal to the number of electrons and the atom is electrically neutral.

Note: Protons and neutrons are called nucleons

Definitions

1. Atomic number Z is the number of protons in the nucleus of an atom.
2. Mass number A is the number of nucleons in the nucleus of an atom $A = Z + N$ where N is the number of neutrons.

The nucleus of an atom is represented as ${}^{A}_{Z}X$ where X is the chemical symbol of an element.

Example: ${}^{4}_{2}He, {}^{23}_{11}Na$ and ${}^{24}_{12}Mg$. For each of these elements find the atomic mass, atomic number and the number of protons.

Particles in an atom of an element

Particle	*Symbol*	*Charge*
Proton	${}^{1}_{1}H$	Positive
Electron	${}^{0}_{-1}e$	Negative
Neutron	${}^{1}_{0}n$	Nil

An atom is electrically neutral since the charge of electrons is equal and opposite to that of the protons.

3. Isotopes are atoms of same element with the same atomic number and different mass numbers.

   Examples: ${}^{37}_{17}Cl$, ${}^{35}_{17}Cl$ are isotopes of chlorine, ${}^{1}_{1}H$, ${}^{2}_{1}H$ and ${}^{3}_{1}H$ are isotopes of hydrogen, and ${}^{24}_{12}Mg, {}^{26}_{12}Mg$ are isotopes of magnesium.

   Isotopes have the same number of electrons and same chemical properties thus can't be separated by chemical methods.

RADIOACTIVITY

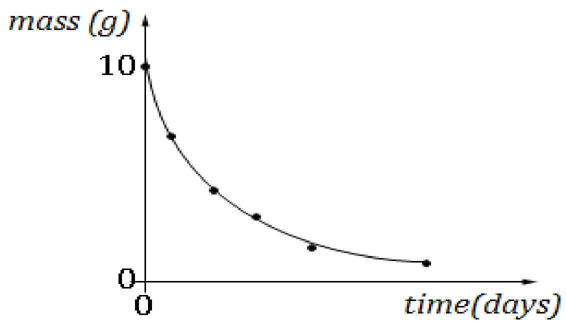
Mass of unstable some elements (their atomic number is greater than 83) decrease with increase in time. Such materials are called radioactive materials and the whole process is called *disintegration/decay/breaking up*. This process occurs naturally without any foreign agent i.e. it occurs spontaneously.

During the decay process, some particles; alpha, α, beta, β and gamma, γ are emitted.

Radioactivity is a spontaneous disintegration of radioactive elements emitting alpha, beta particles and gamma rays.

Alpha and Beta radiation are particles because they have mass, protons, neutrons and electrons. Gamma radiation consists of photons which have no mass and they are electro-magnetic waves.

Since the process involves decrease in mass with time, a decay graph is drawn.



Properties of alpha particles

They are

- helium nuclide in nature (^4_2He)
- positively charged (with charge of 2)
- more ionising than beta particles and gamma rays.
- less penetrating than beta particles and gamma rays (are stopped by thin sheets of papers, cardboards)
- least deflected by both electric and magnetic fields since they are massive

Properties of beta particles

- They are electrons in nature ($^{0}_{-1}e$)
- They are negatively charged
- They are less ionising than alpha particles and gamma rays
- They are more penetrating than alpha particles (are stopped by aluminium and lead sheets)
- They are more deflected by both electric and magnetic fields since they are less massive compared to alpha particles.

Properties of gamma rays

- They are electromagnetic radiations in nature
- They carry no charge
- They are less ionising than alpha and beta particles
- They are more penetrating than alpha and beta particles (are stopped by lead sheets)
- They pass through by both electric and magnetic fields without being deflected.

Summary

Property	**Alpha particle**	**Beta particle**	**Gamma ray**
Nature	Helium nuclide	Electron	Electromagnetic radiation
Charge	Positive	Negative	No charge
Ionizing	More beta and gamma	more than gamma	Less
Deflection by electric and magnetic fields	Least	More	Not deflected
Penetration	Stopped by thin sheets of papers	Stopped by Aluminum and Lead sheets	Stopped by Lead sheets

Similarity:

- They all cause fluorescence with some metals.

- They affect a photographic paper when exposed to it
- They are all produced when nucleus of un stable element decays

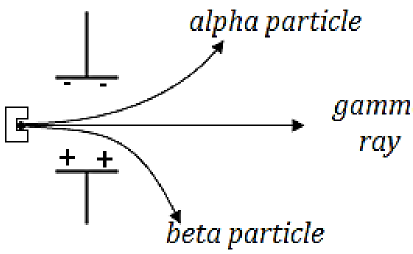
  2001/1 no.4a,b and c

Differences between x – rays and gamma rays

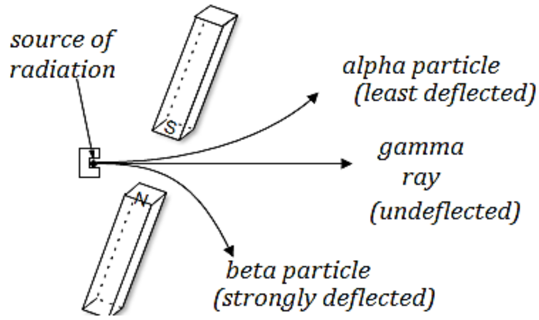
- X – rays are produced when cathode rays hit a metal target while gamma rays are only produced when the nucleus of a radioactive element decays.
- X – rays have longer wavelength than gamma rays
- Production of x-rays is controlled by changing the temperature of the cathode while production of gamma rays is natural and can't be controlled.

Effect of alpha, beta particles and gamma rays on

(i) electric field



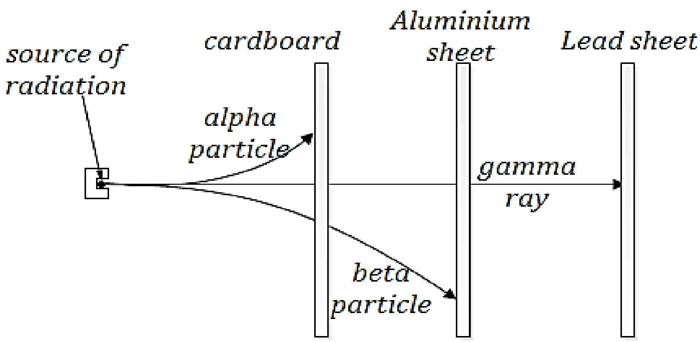
(ii) magnetic field



Note:

conventionally, current flows in the direction opposite to the flow of electrons. According to Fleming's left hand rule – with **F**irst finger in the direction of the field, se**C**ond finger in the direction of current (opposite to electron flow), the thu**M**b points in the direction of motion. Thus electrons (beta particles) pass downwards in the direction perpendicular to the magnetic field. **2013/2 no.8d(i)**

Absorption of alpha, beta particles and gamma rays by obstacles



Atomic disintegrations

a) When a nucleus of an element decays with emission of an alpha particle its atomic number decreases by 2 and atomic mass decreases by 4.

   A new element called a *daughter nuclide* is formed.

$$\underbrace{{}^{A}_{Z}X}_{parent\ nuclide} \longrightarrow \underbrace{{}^{A-4}_{Z-2}Y}_{daughter\ nuclide} + \underbrace{{}^{4}_{2}He}_{alpha\ particle}$$

b) When a nucleus of an element decays with emission of a beta particle, its atomic number increases by 1 and atomic mass does not change.

$$\underbrace{{}^{A}_{Z}X}_{parent\ nuclide} \longrightarrow \underbrace{{}^{A}_{Z+1}Y}_{daughter\ nuclide} + \underbrace{{}^{0}_{-1}e}_{alpha\ particle}$$

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

Exercise

1. $^{232}_{90}X \xrightarrow{A} {}^{228}_{88}Y \xrightarrow{B} {}^{228}_{89}T \xrightarrow{C} {}^{228}_{89}Z$

   Identify the particles or radiations A, B and C emitted in the decay process above.
   Atomic mass decreased by 4 and atomic number decreased by 2 therefore, A is alpha particle.
   No change in atomic mass and atomic number increased by 1 therefore B is beta particle. No change in atomic mass and atomic number thus C is the gamma ray.
2. A radioactive nuclide 88226Ra decays by emission of two alpha particles and two beta particles to a nuclide Y. State the atomic number and mass number of Y
   $^{226}_{88}Ra \longrightarrow 2{}^{4}_{2}He + {}^{218}_{84}P$
   $Then\ {}^{218}_{84}P \longrightarrow 2{}_{-1}^{0}e + {}^{218}_{86}Y$
   Atomic number of Y is 86 and its mass number is 218.

   Alternatively
   $^{226}_{88}Ra \longrightarrow {}^{x}_{y}Y + 2{}^{4}_{2}He + 2{}_{-1}^{0}e$
   $226 = x + 2 \times 4 + 0 \quad \Rightarrow x = 218$
   $88 = y + 2 \times 2 - 2 \quad \Rightarrow y = 86$
   Atomic number of Y is 86 and mass number is 218
3. In the reaction equation, find the values of x and y
   $^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{y}_{56}Ba + {}^{92}_{x}Kr + 3{}^{1}_{0}n$
   $235 + 1 = y + 92 + 3 \times 1 \quad \Rightarrow y = 141$
   $92 = 56 + x + 3 \times 0 \quad \Rightarrow x = 36$ **2013/2 no.8d(ii), 2012/1 no.47**

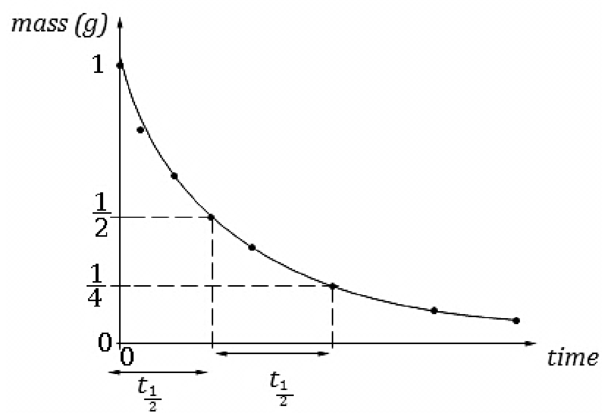
HALF LIFE

This is the time taken for half the number of a radioactive nuclide to decay.

Example $1g \xrightarrow[t_{\frac{1}{2}}]{} \frac{1}{2}g \xrightarrow[t_{\frac{1}{2}}]{} \frac{1}{4}g \xrightarrow[t_{\frac{1}{2}}]{} \frac{1}{8}g$

Determination of half-life from a graph

Consider 1g of a radioactive element decaying. A decay graph below is drawn.



The average time interval $t_{\frac{1}{2}}$ is half-life of the radioactive nuclide.

Example

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

T(minutes)	0	1	2	3	4	5	6	7	8
Count rate(cs^{-1})	850	680	544	345	348	278	219	175	140

Plot a graph of count rate against time.

From the graph, find the value of half-life of the radioactive element.

Calculations of half-life

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

   After 20 days half of the mass of the material decays

   Method 1

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

   $Mass\ remained\ (un\ decayed)\ after\ 60\ days\ decayed = 1g\ and$

   $Mass\ decayed\ after\ 60\ days\ decayed = 8 - 1 = 7g$

   Method 2

   If M_o *is the original mass of the element, mass remained* $M = \frac{M_o}{2^n}$

   Where $n = \frac{t}{t_{\frac{1}{2}}}$ *is the number of half-lives*

   t *is the time taken and* $t_{\frac{1}{2}}$ *is the half-life.*

   $t = 60days,\ \ t_{\frac{1}{2}} = 20days\ \ \Rightarrow n = \frac{60}{20} = 3\ \ \Rightarrow M = \frac{8}{2^3} = \frac{8}{8} = 1g$

   $Thus\ mass\ decayed\ after\ 60\ days\ decayed = 8 - 1 = 7g$

2. x grams of a radioactive material of half-life 3 weeks decayed and 5.12g remained after 15weeks. What is the value of x ?

   $M = 5.12g, t_{\frac{1}{2}} = 3\,weeks, t = 15\,weeks\ \ n = \frac{15}{3} = 5$

   $M = \frac{M_o}{2^n} \Rightarrow 5.12 = \frac{M_o}{2^5} = \frac{M_o}{32}\ \Rightarrow M_o = 32 \times 5.12 = 163.84g$

   $Mass\ decayed,\ x = M_o - M = 163.84 - 5.12 = 158.72g$

3. 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) the fraction of the original mass will have decayed after 20 days?

   (i) Let M_o *be the original mass of the element, undecayed mass* $M = \frac{1}{16}M_o$

   From $M = \frac{M_o}{2^n} \Rightarrow \frac{1}{16}M_o = \frac{M_o}{2^n}\ \ \Rightarrow 2^n = 16\ \Rightarrow n = 4.$

   If $t = 16\ days,\ number\ of\ half\ lives\ \ n = 4 = \frac{16}{t_{\frac{1}{2}}}\ \ \Rightarrow t_{\frac{1}{2}} = \frac{16}{4} = 4\ days$

   (ii) $t = 20\ days,\ t_{\frac{1}{2}} = 4\ days\ \Rightarrow n = \frac{20}{4} = 5.\ \ \ M = \frac{M_o}{2^n} = \frac{M_o}{2^5} = \frac{1}{32}M_o$

   $Mass\ decayed = M_o - M = M_o - \frac{1}{32}M_o = \frac{31}{32}M_o$

   Therefore $\frac{31}{32}$ *is the fraction of the original mass that decayed*

Questions

1. The half-life of Uranium is 24 days. Calculate the mass of Uranium which remains after 120 days if its original mass is 64 g. [2g]
2. A radioactive sample has a half-life of 3.0×10^3years. How long does it take for three – quarters of the sample to decay? [6.0×10^3 years]
3. The half-life of a radioactive substance is 12 days. After 36 days, what fraction of the original activity
   (i) will remain
   (ii) will have decayed?

Health hazards of radioactive radiations

- They destroy living cells of a body
- They cause sterility (inability to produce children)
- They cause leukemia (cancer of blood)
- They cause serious abnormalities to unborn children.

Safety precautions

When dealing with radioactive materials,

- use a pair of forceps not bare hands to hold the materials
- keep a radioactive source in lead boxes
- wear jackets with a layer of lead
- avoid places where radioactive materials are kept
- avoid eating when working with radioactive substances
- keep a reasonable distance from the source of radiation.

Uses of radioactivity

1. Industrial use:
- Beta particles are used to estimate thickness of papers, plastic materials and metal sheets
- Beta particle when dissolved in flowing liquids is used to detect leaks in underground pipes.
2. Medical use:
- Radioactive iodine is used in the treatment and diagnosis of goiter
- Radioactive cobalt is used in the treatment of cancer
- Plastic syringes are sterilized by gamma radiation, after being manufactured.
3. Carbon dating: The age of fossils (remains of dead materials) can be obtained.

NUCLEAR FUSION AND FISSION

(a) Nuclear fusion is the joining of two or more smaller nuclides to form a fairly heavy nuclide with release of energy.

Nuclear fusion occurs when there are

- two light and unstable nuclides
- extremely high temperature

Nuclear fusion reactions occur in the sun.

(b) Nuclear fission is the splitting of a heavy nuclide to form slightly smaller nuclides with the release of energy.

Nuclear fission occurs when there is

- an unstable nucleus
- a neutron directed to the nucleus of a radioactive substance such as uranium.

Nuclear fission reactions occur in

- nuclear reactors to produce electricity
- nuclear bombs.

In a nuclear reactor intense heat energy from fission reactions heats water and the produced steam is used to turn the turbines of generators hence producing electricity.

<u>GENERAL QUESTIONS</u>

<u>Question 1</u>

(a) Describe a simple model of the atom (4 marks)

(b) Define the following;

- atomic number (1 mark)
- nucleon number (1 mark)

(c) What are cathode rays? (1 mark)

(d) Give two properties of cathode rays (2 marks)

(e) State two differences between cathode rays and gamma rays (2 marks)

(f) In the cathode ray oscilloscope (C.R.O), explain the effect of the following on the brightness of the electron spot on the screen

(i) Increasing the filament current (2 marks)

(ii) Decreasing the anode voltage (2 marks)

(g) What is meant by nuclear fission? (1 mark)

(h) Outline the process involved in generation of electricity using uranium – 235 (3marks)

(i) Use diagrams to show what is observed on the screen of a (C.R.O) when

- the C.R.O is switched on and no signal is applied to the Y – plates (1mark)
- the time – base is switched on and no signal is applied to the Y – plates (1mark)
- an alternating signal is applied to the Y – plates while the time – base is switched off. (1mark)

Question 2

(a) Describe how cathode rays are produced in a cathode ray tube (4 marks)

(b) With reference to an X – ray tube, explain

(i) Why the tube has to be evacuated (3 marks)

(ii) Why the tungsten target is embedded in copper block (2 marks)

(iii) How the penetrating power of X – rays can be varied (3marks)

(c) Describe a simple experiment to distinguish the three radiations that are emitted by radioactive materials. (4 marks)

(d) State four ways in which X – rays are similar to gamma rays (2 marks)

(e) Give two biological uses of X – rays (2 marks)

Question 3

a) Draw a labelled diagram to show the main feature of a cathode ray tube (2 marks)

b) Describe briefly how cathode rays are produced in the cathode ray tube (2 marks)

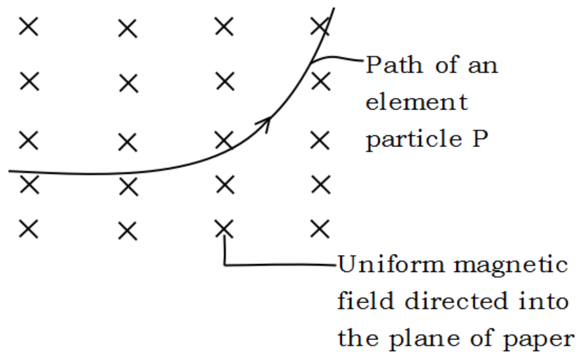
c) State two uses of a cathode ray oscilloscope (1 mark)

d) Define the following terms as applied to radioactivity

(i) Isotope (1 mark)

(ii) Half-life (1 mark)

e) The diagram below shows a path of a particle P, emitted from a radioactive sample of rock, passing through a region of uniform magnetic field directed perpendicular into paper



(i) Identify the particle (1 mark)

(ii) Describe the changes that take place in the nuclear structure of element X with atomic number 88 and mass number 226 when it emits particle P, identified in (i) above (2 marks)

f) The mass of a radioactive substance decays to $\frac{1}{16}$ of its original value after 36 days. Find its half-life. (3 marks)

g) State one medical use and one non-medical use of radioactive tracers (2 marks)

h) Sketch a graph of the number of atoms of a radioactive material present against time to show how the half-life is determined from it. (2 marks)

Question 4

(a) How does the passage of a beta particle through an electric field differ from that of an X – ray? (2 marks)

(b) What is meant by thermionic emission? (1 mark)

(c) Describe the functions of the three main components of a cathode ray oscilloscope (6 marks)

(d) With the aid of a labelled diagram, describe how X – rays are produced in an X – ray tube (5 marks)

(e) Explain why soft X – rays are used instead of hard X – rays to take photographs of internal parts of a patient in hospitals. (3 marks)

Question 5

(a) Distinguish between nuclear fusion and nuclear fission. (2 marks)

(b) State one example where nuclear fusion occurs naturally. (1 mark)

(c) Stat one use of nuclear fission (1 mark)

(d) A nuclear reaction when a neutron bombards a Sulphur atom is

$$^{34}_{16}S + ^{1}_{0}n \longrightarrow ^{a}_{b}Y$$

(i) Describe the composition of nuclide Y formed (2 marks)

(ii) Y decays by emission of an α −particle and a γ −ray. Find the changes in mass number and atomic number of the nuclide. (2 marks)

(iii) State two properties of α −particles. (2 marks)

(e) The half-life of the isotope cobalt-60 is five years. What fraction of the isotope remains after 15 years? (3 marks)

(f) State

(i) one medical use of radioisotopes (1 mark)

(ii) two ways of minimizing the hazardous effects of radiation from radioactive materials. (2 marks)

END